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# Cr isotope systematics of martian meteorites Implications for the early differentiation history of Mars

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# **Cr isotope systematics of martian meteorites**

***Implications for the early differentiation history of Mars***

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**Processes and timescales of martian mantle differentiation remain enigmatic**

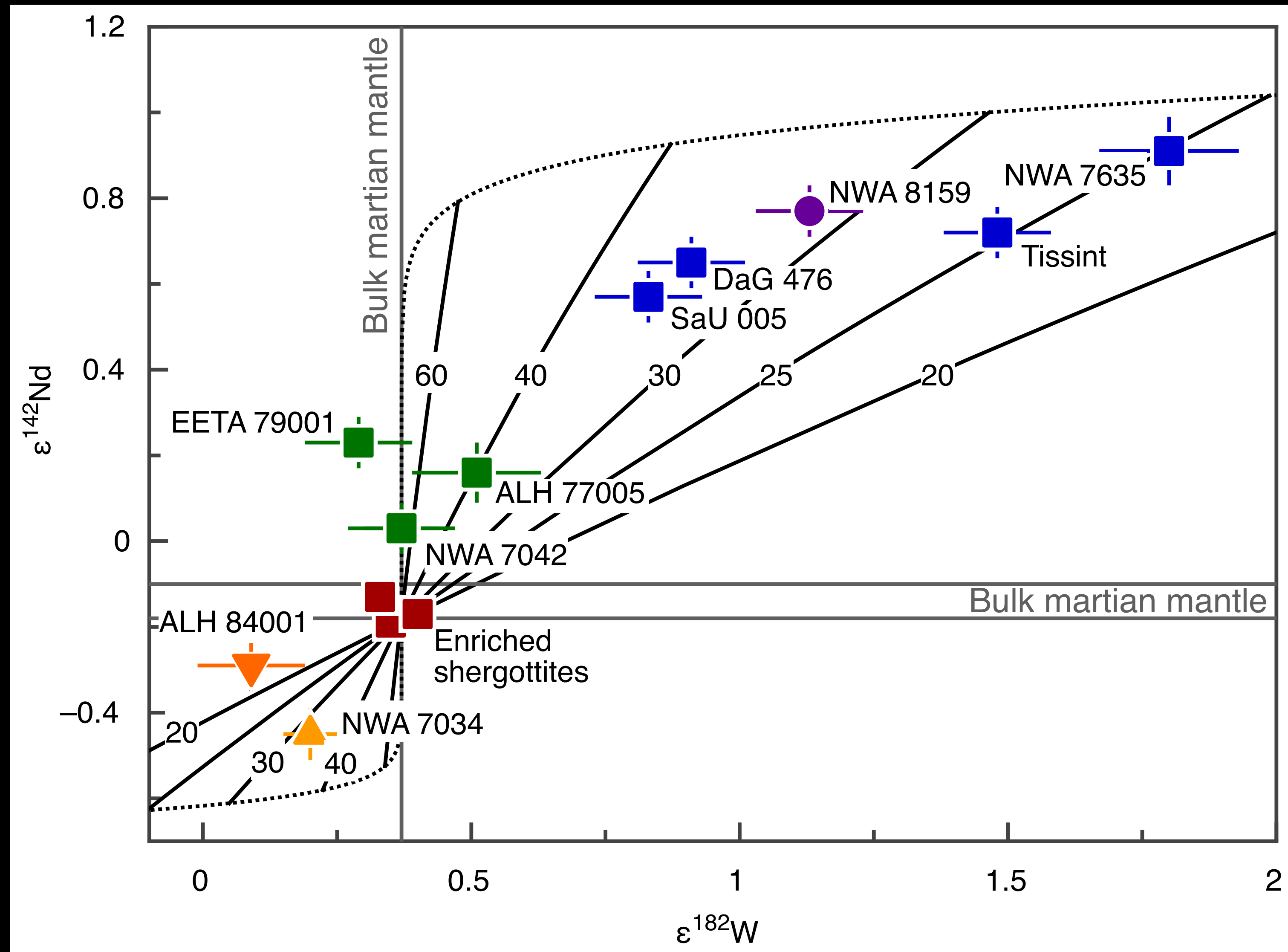
**Sm-Nd chronometry: 'Late' differentiation at ~60 Ma**  
**Hf-W chronometry: 'Early' differentiation at 20-30 Ma**

**Global (e.g. magma ocean) or more localized differentiation processes?**

# $\epsilon^{142}\text{Nd}$ vs. $\epsilon^{182}\text{W}$ data of martian meteorites

Isotopic  
heterogeneities  
preserved over ~4.5  
billion years

Was the martian  
mantle ever  
homogeneous?



Kruijer et al. (2017)

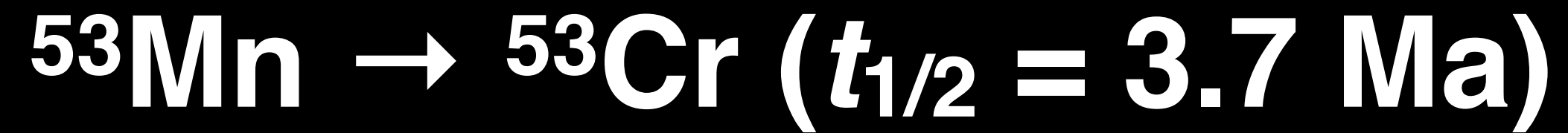
# Questions and approach

**When did large-scale differentiation of the martian mantle commence?**

**Was the martian mantle ever isotopically homogeneous?**

**Here we address these questions using Cr isotopes**

# Cr isotope systematics of martian meteorites

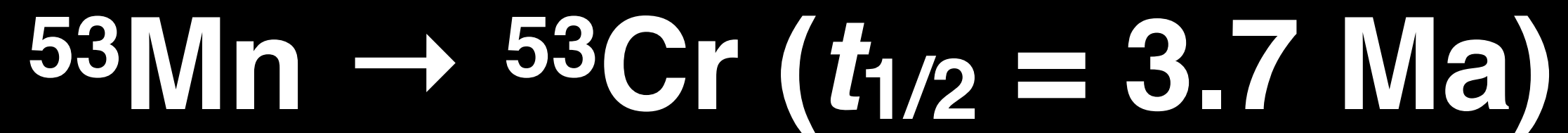


**Mn/Cr fractionation during:**

- **volatility related processes**
- **core formation**
- **silicate differentiation**

**$^{54}\text{Cr}$  is a nucleosynthetic tracer**

# Cr isotope systematics of martian meteorites



**Finding  $^{53}\text{Cr}$  variations on Mars would provide evidence for differentiation within  $<20 \text{ Ma}$**

**occur during silicate  
fractionation**



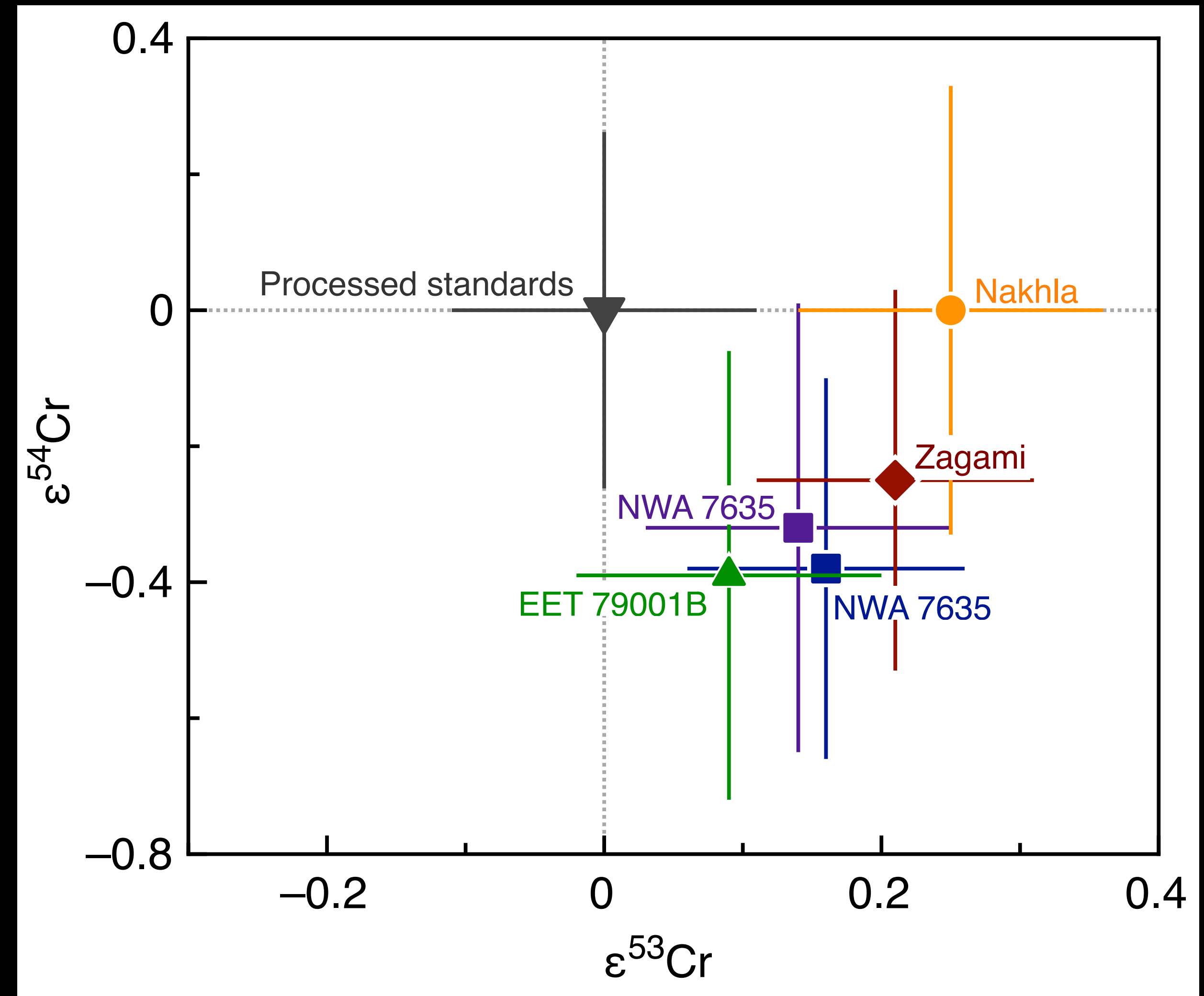
# Samples and analytical methods

- ▶ Shergottites (1 enriched, 1 intermediate, 2 depleted), Nakhla
- ▶ Cr separated by ion exchange chromatography
- ▶  $^{53}\text{Cr}/^{52}\text{Cr}$  and  $^{54}\text{Cr}/^{52}\text{Cr}$  analyzed on Triton TIMS at LLNL
- ▶ Fractionation correction by normalizing to  $^{50}\text{Cr}/^{52}\text{Cr} = 0.00518$
- ▶ Precision:  $\sim 0.1$   $\epsilon$ -units on  $^{53}\text{Cr}/^{52}\text{Cr}$ ;  $\sim 0.3$   $\epsilon$ -units on  $^{54}\text{Cr}/^{52}\text{Cr}$

# Results: $\epsilon^{54}\text{Cr}$ vs. $\epsilon^{53}\text{Cr}$ of martian meteorites

Uniform excess in  $\epsilon^{53}\text{Cr}$  of  $+0.17 \pm 0.04$  (95% conf.)

Shergottites have uniform deficit in  $\epsilon^{54}\text{Cr}$  of *ca.*  $-0.30$



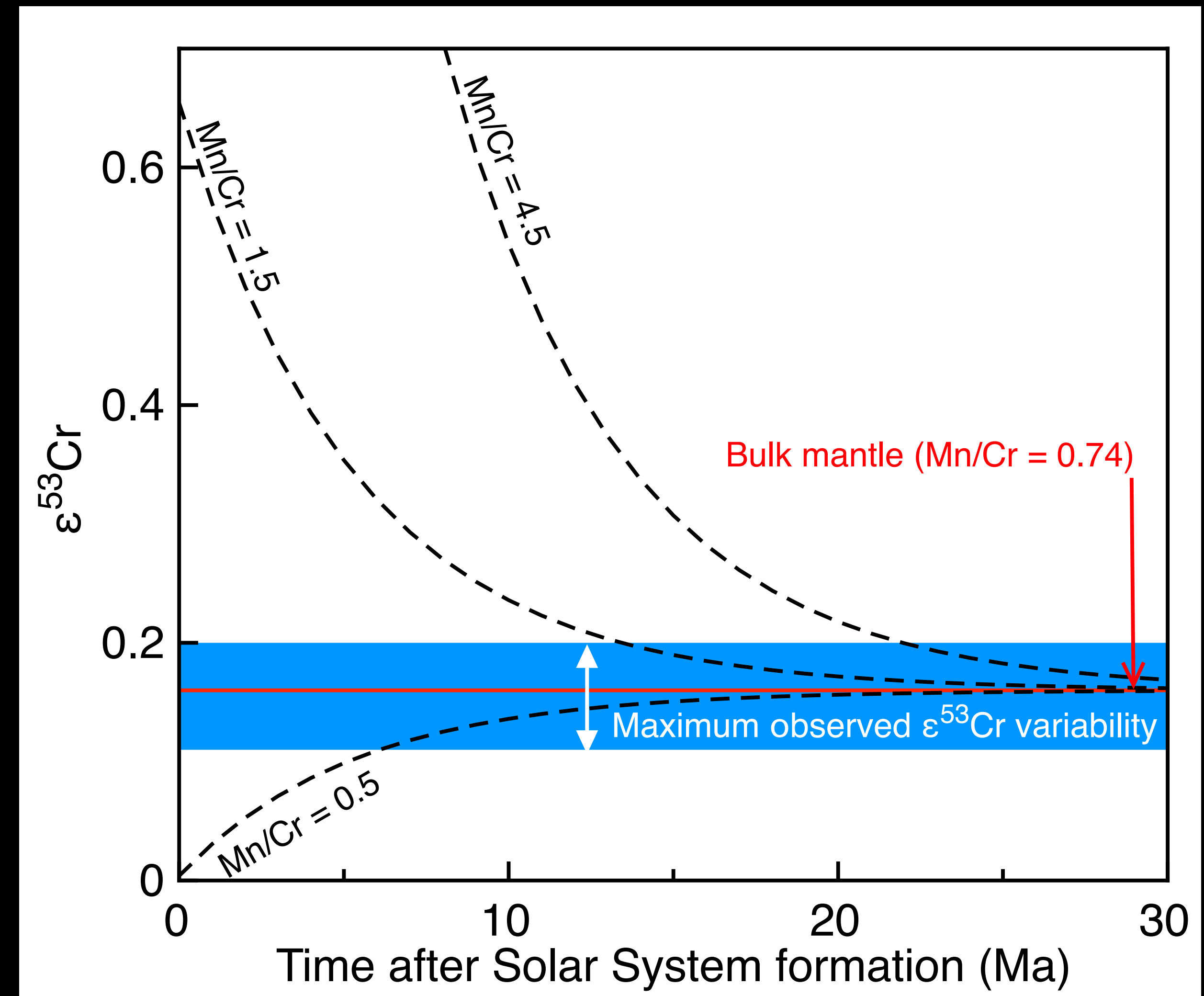
# No $^{53}\text{Cr}$ heterogeneity within the martian mantle

1. Mn/Cr variations in martian mantle too small?
2. Martian mantle differentiation occurred after extinction of  $^{53}\text{Mn}$ ?

# No $^{53}\text{Cr}$ heterogeneity within the martian mantle

**Martian mantle  
differentiation likely  
occurred  $>15$  Ma  
after CAIs**

**Consistent with both  
Sm-Nd and Hf-W  
chronometry**



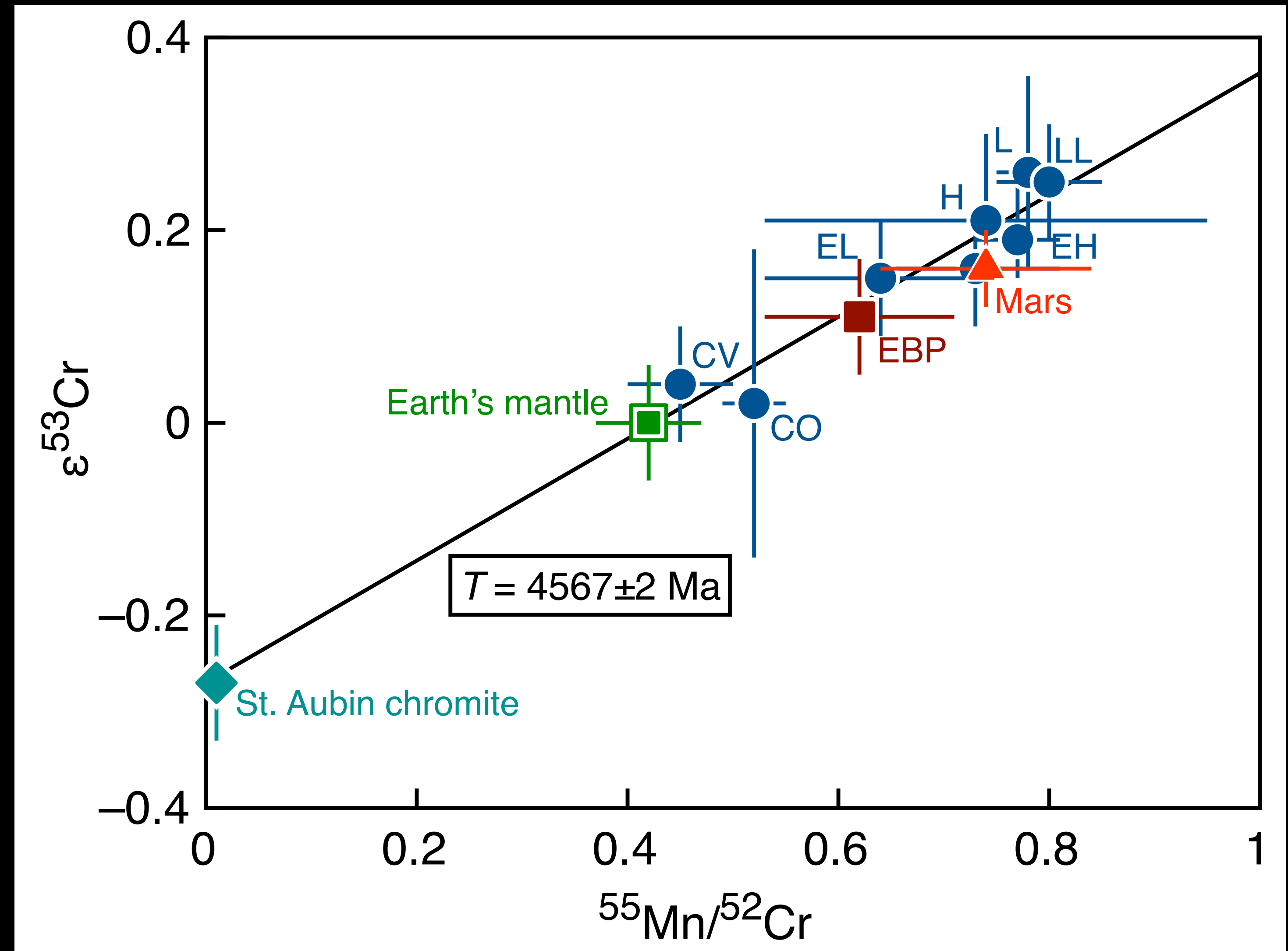
# Origin of $^{53}\text{Cr}$ excess in martian meteorites

1. Mn/Cr fractionation during core formation?
2. Volatility induced Mn/Cr fractionation?

# Origin of $^{53}\text{Cr}$ excess in martian meteorites

Mars plots on bulk  
Mn-Cr isochron

Volatility induced  
Mn/Cr fractionation  
at  $\sim 4567$  Ma



Data sources: This study and Trinquier et al. (2008); Qin et al. (2010); Palme & O'Neill (2014)

# Conclusions

- ▶ No  $^{53}\text{Cr}$  heterogeneities among martian meteorites
- ▶ Consistent with both Sm-Nd and Hf-W chronometry
- ▶ Mars has small excess in  $\epsilon^{53}\text{Cr}$  relative to Earth
- ▶ Reflects inner solar system wide volatility induced Mn/Cr fractionation at *ca.* 4567 Ma
- ▶ Do  $^{54}\text{Cr}$  heterogeneities exist on Mars?

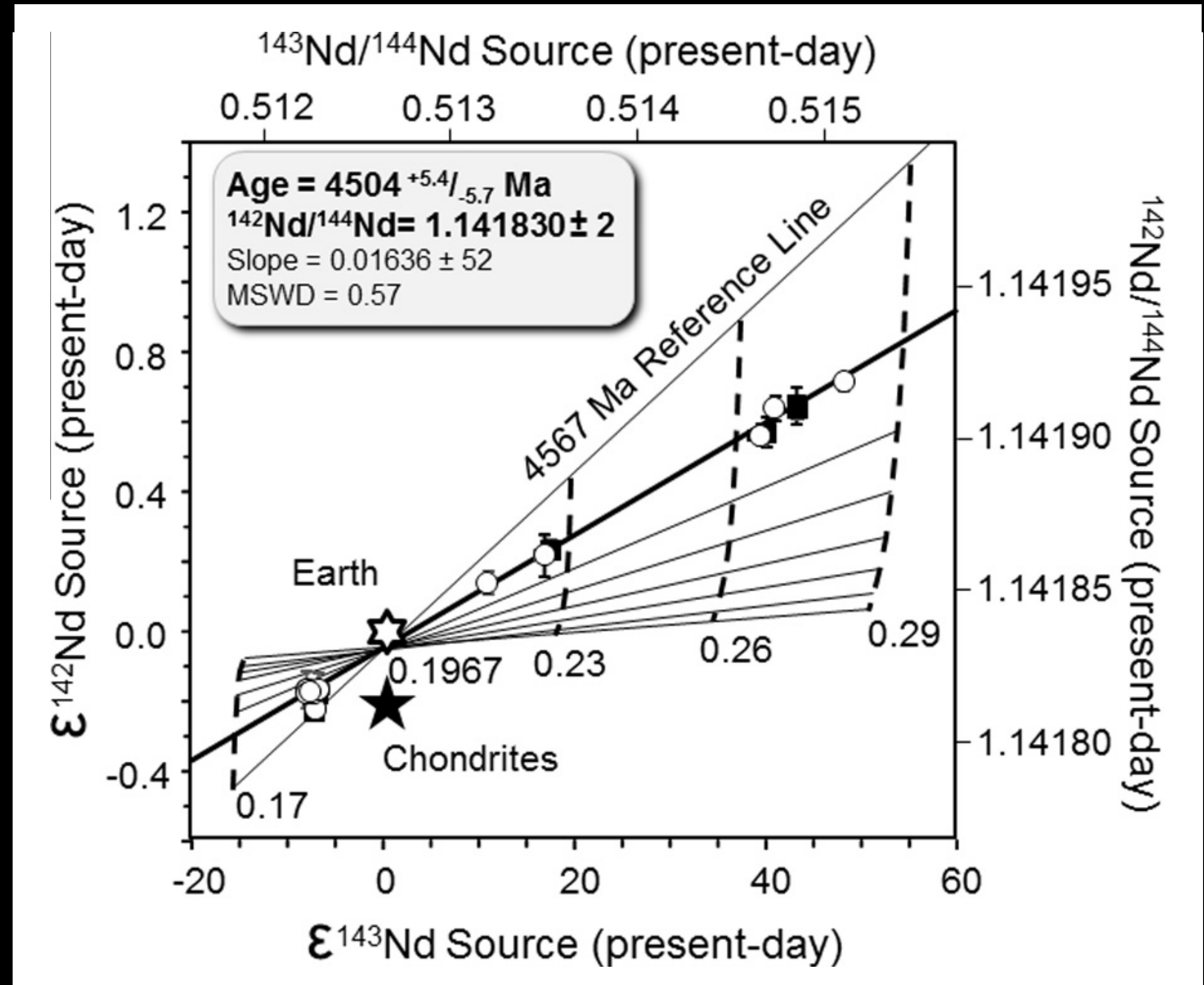
# Sm-Nd chronometry of martian meteorites

$^{146}\text{Sm} \rightarrow ^{142}\text{Nd}$  ( $t_{1/2} \approx 103 \text{ Ma}$ )

$^{147}\text{Sm} \rightarrow ^{143}\text{Nd}$  ( $t_{1/2} \approx 106 \text{ Ga}$ )

Sm/Nd fractionation during  
silicate differentiation

**Sm-Nd isochron age:  
~60 Ma after CAIs**



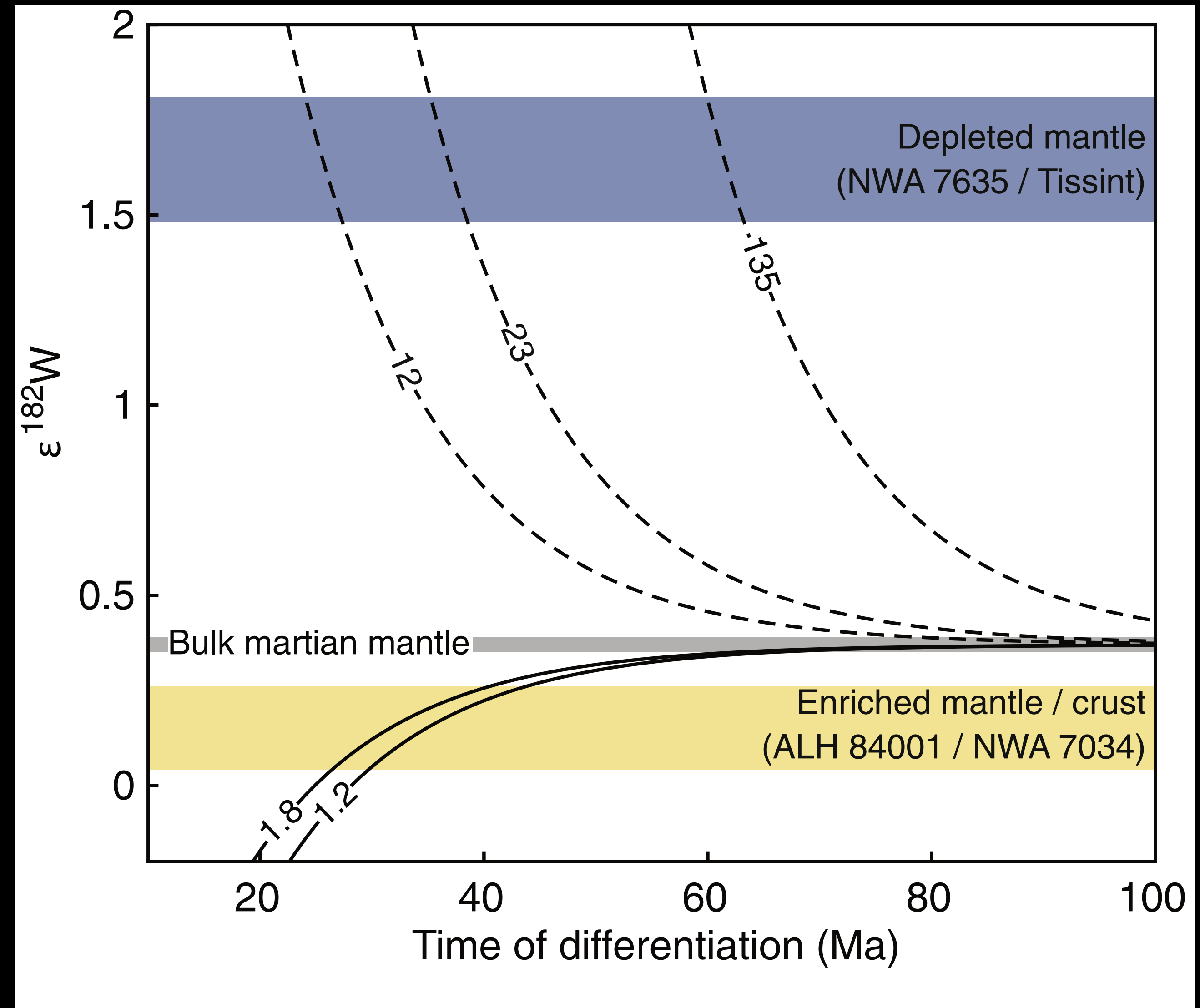


# Hf-W chronometry of martian meteorites

$^{182}\text{Hf} \rightarrow ^{182}\text{W}$  ( $t_{1/2} \approx 9 \text{ Ma}$ )

Hf/W fractionation during  
silicate differentiation

Large  $^{182}\text{W}$  variations  
require differentiation at  
 **$\sim 20\text{--}30 \text{ Ma}$  after CAIs**



# $^{54}\text{Cr}$ heterogeneity on Mars?

