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LLNL-CONF-747781

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

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March 13, 2018

49th Lunar and Planetary Science Conference
The Woodlands, TX, United States
March 19, 2018 through March 23, 2018

Disclaimer

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

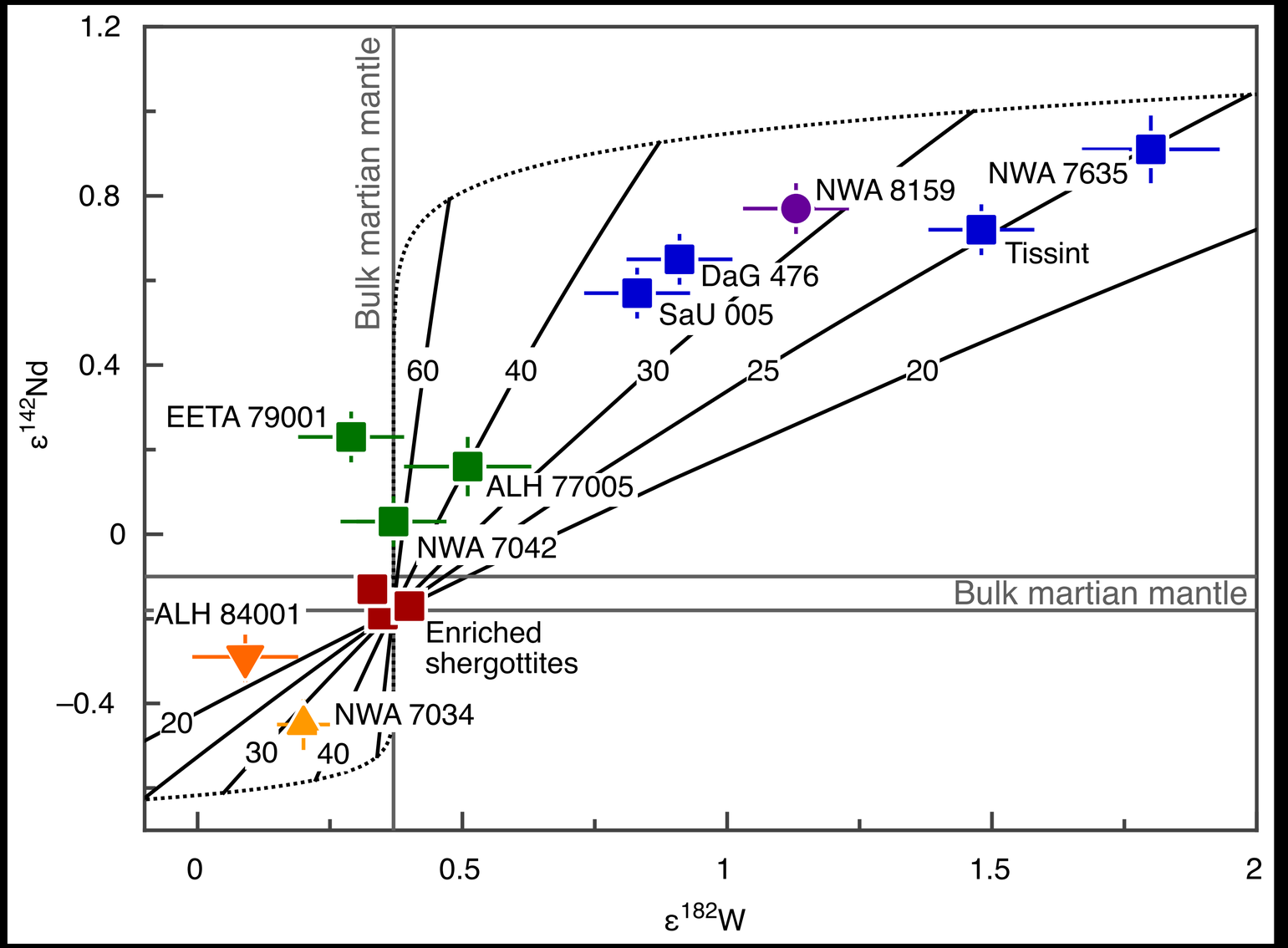
Sm-Nd chronometry: ‘Late’ differentiation at ~60 Ma
Hf-W chronometry: ‘Early’ differentiation at 20-30 Ma

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

ε^{142}Nd *vs.* ε^{182}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

$^{53}Mn \rightarrow {}^{53}Cr$ ($t_{1/2}$ = 3.7 Ma)

Mn/Cr fractionation during:
- volatility related processes
- core formation
- silicate differentiation

^{54}Cr is a nucleosynthetic tracer

Cr isotope systematics of martian meteorites

$^{53}Mn \rightarrow {}^{53}Cr$ ($t_{1/2}$ = 3.7 Ma)

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

occur during silicate fractionation

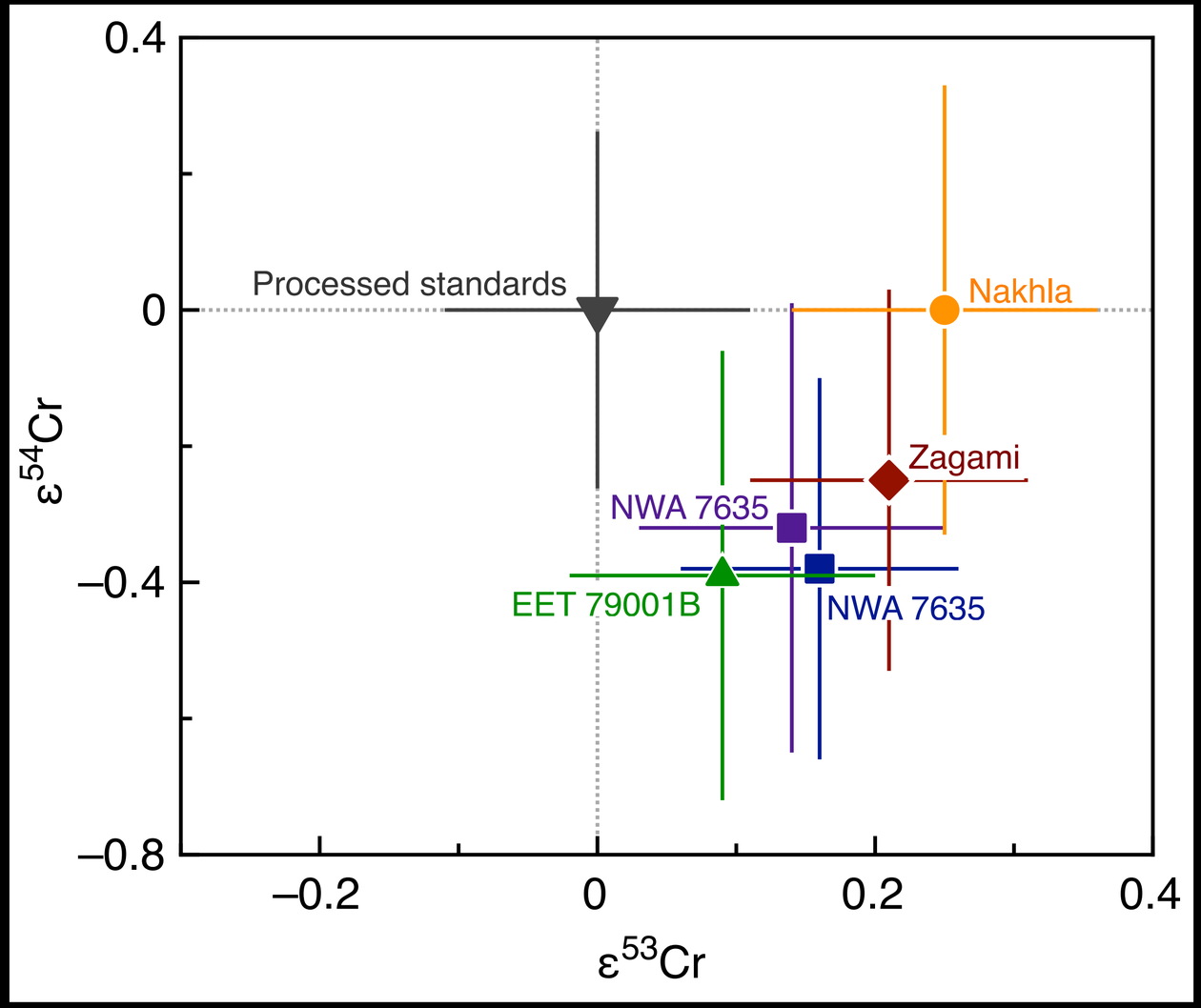
Samples and analytical methods

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

Results: $\varepsilon^{54}Cr$ *vs.* $\varepsilon^{53}Cr$ of martian meteorites

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

Shergottites have uniform deficit in $\varepsilon^{54}Cr$ of *ca.* –0.30



No ^{53}Cr heterogeneity within the martian mantle

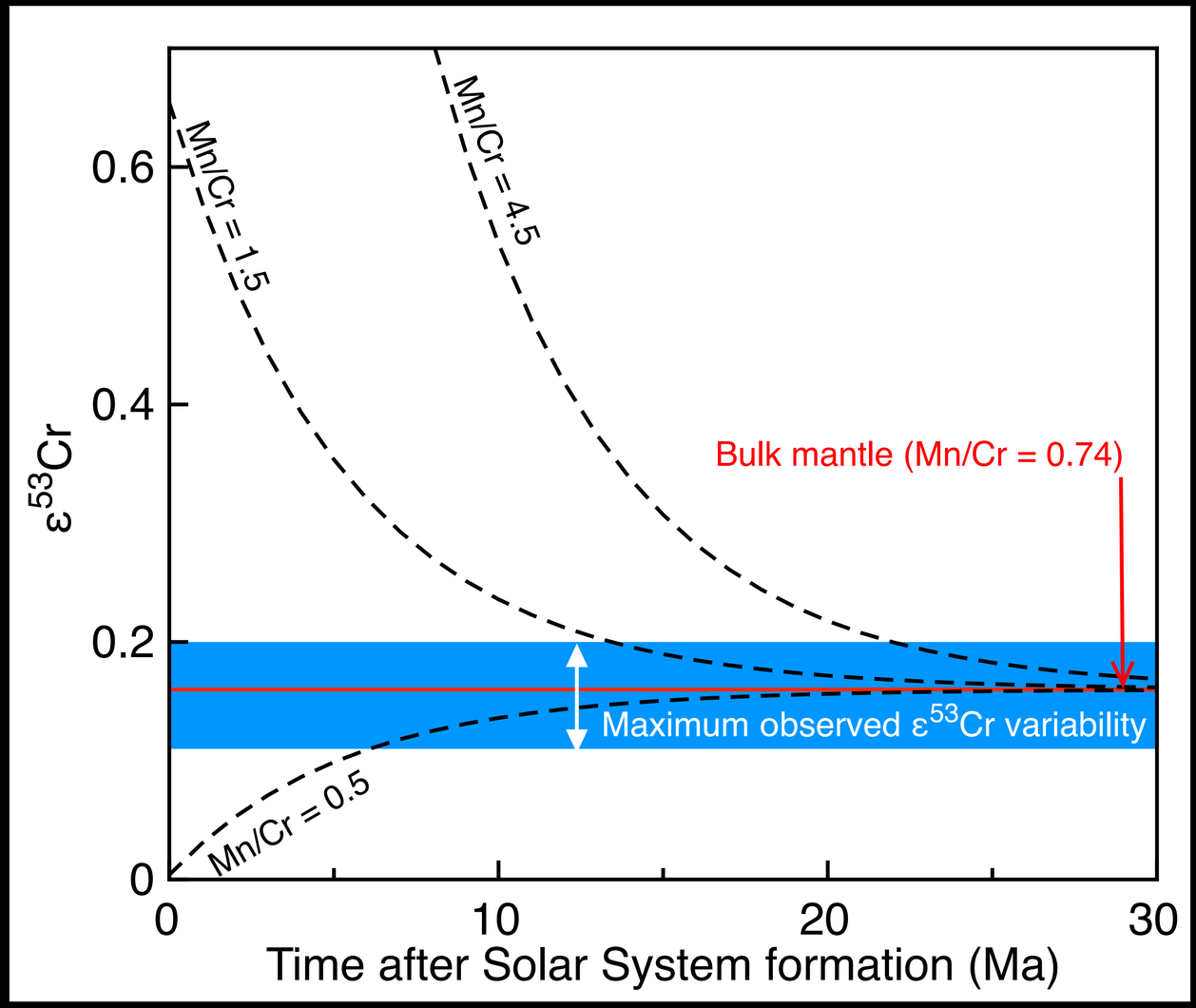
1. Mn/Cr variations in martian mantle too small?

2. Martian mantle differentiation occurred after extinction of ^{53}Mn?

No ^{53}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}Cr excess in martian meteorites

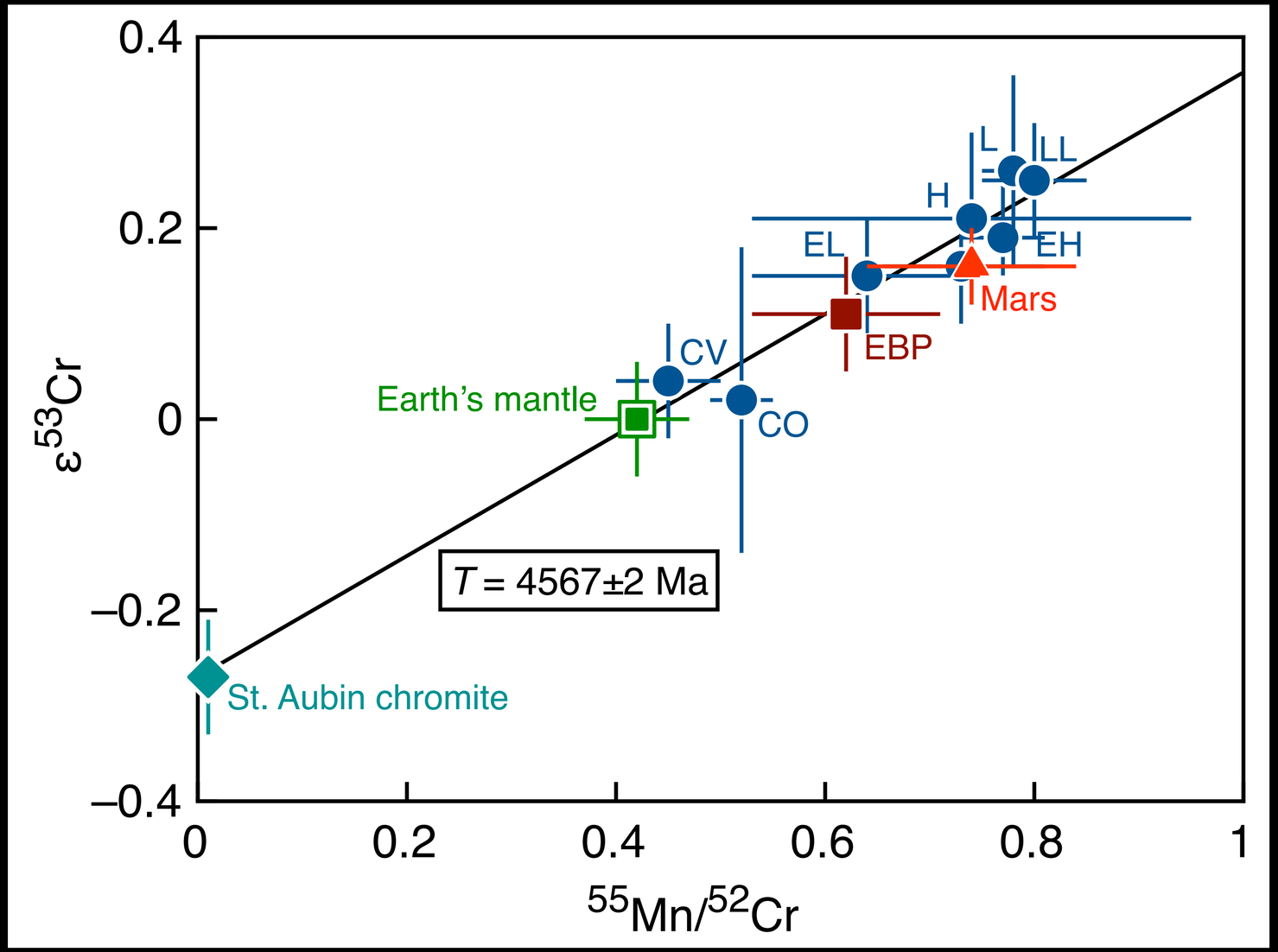
1. Mn/Cr fractionation during core formation?

2. Volatility induced Mn/Cr fractionation?

Origin of ^{53}Cr excess in martian meteorites

Mars plots on bulk Mn-Cr isochron

Volatility induced Mn/Cr fractionation at ~4567 Ma



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

Conclusions

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

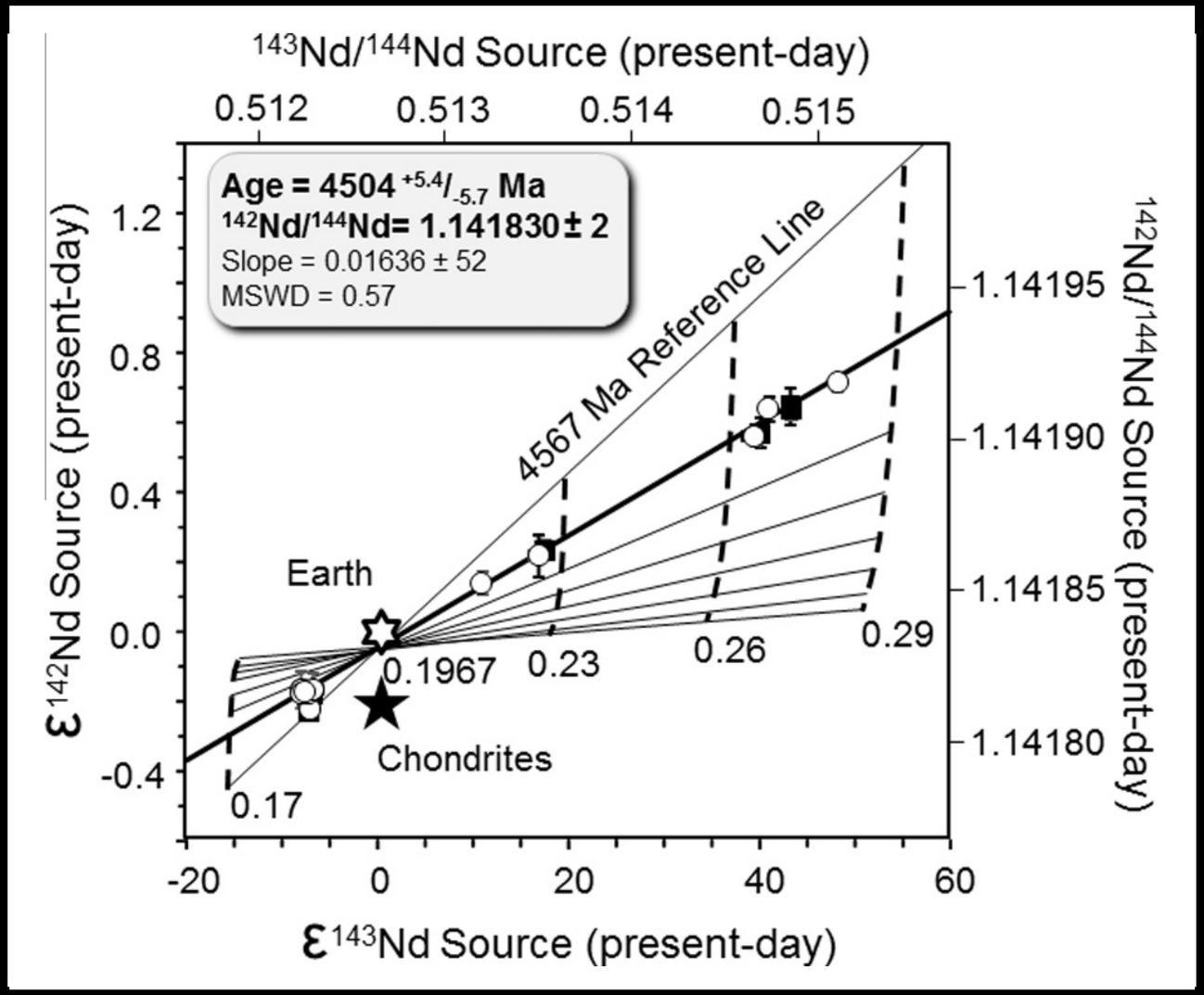
Sm-Nd chronometry of martian meteorites

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

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

Sm/Nd fractionation during silicate differentiation

Sm-Nd isochron age:
~60 Ma after CAIs



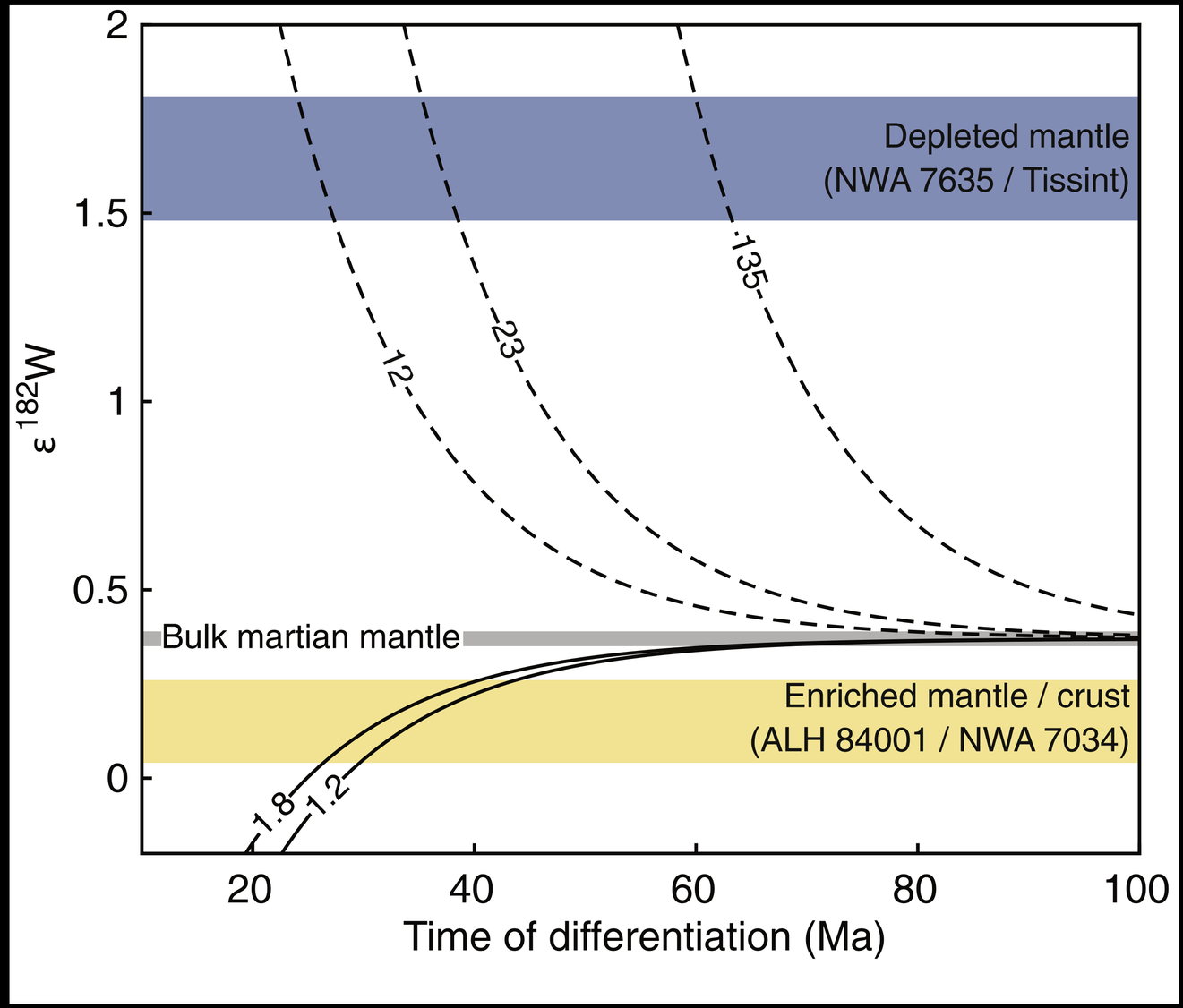
Borg et al. (2016)

Hf-W chronometry of martian meteorites

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

Hf/W fractionation during silicate differentiation

Large ^{182}W variations require differentiation at **~20–30 Ma after CAIs**



Kruijer et al. (2017)

^{54}Cr heterogeneity on Mars?