EGU General Assembly 2020 – D1605 Abstract: EGU2020-10054

Low recycling efficiency of boron into the deep mantle

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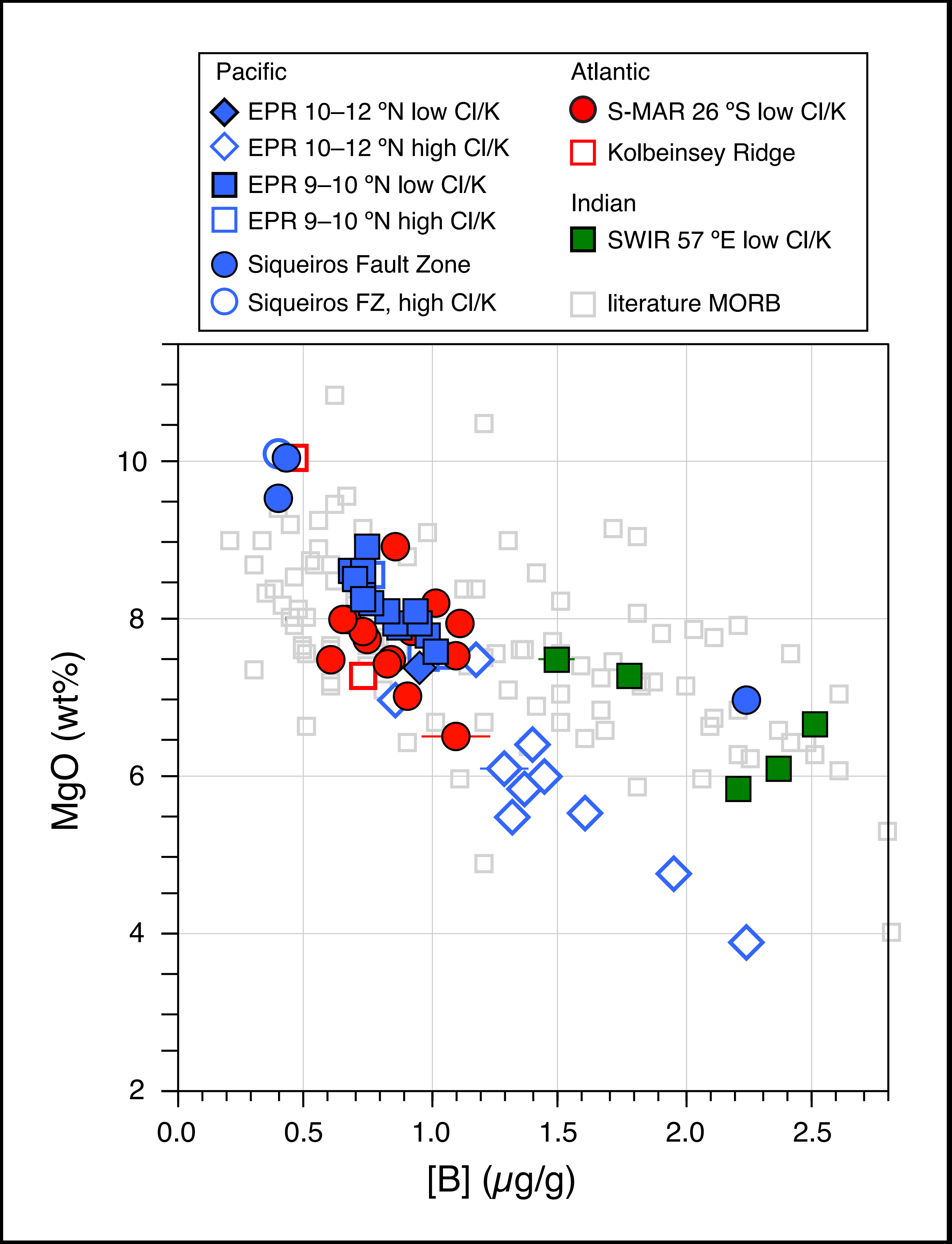
Boron in fresh MORB

Boron is incompatible during mantle melting and basalt differentiation

D_B (melt/solid) similar to Ce, Pr, Pb, P, Be



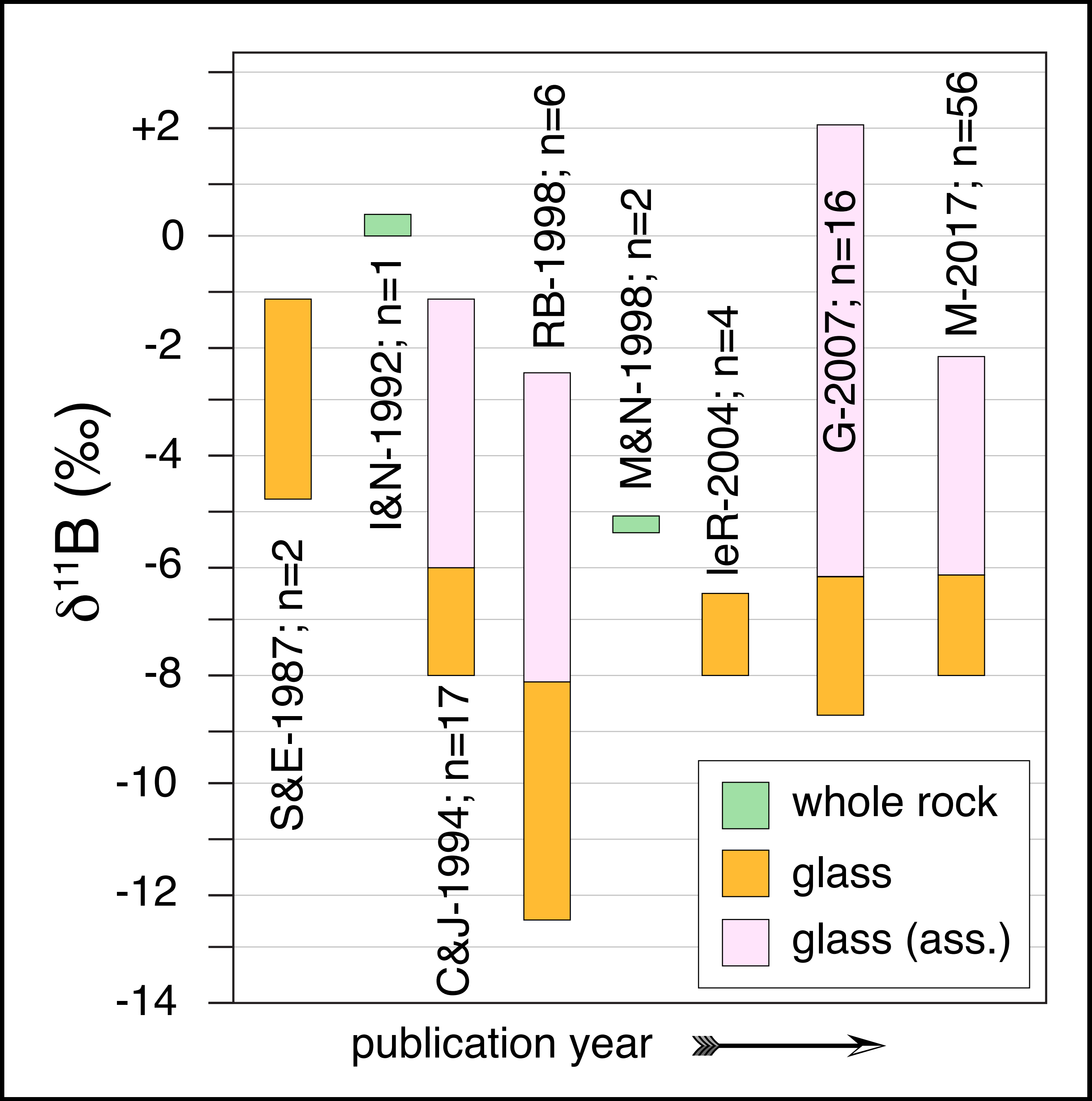
Marschall et al. (2017, GCA)

Boron isotopes in fresh MORB and the mantle

N-MORB
$\delta^{11}B$ = -7.1 ±0.9 ‰
[B] = 1.19 µg/g

Depleted Mantle
$\delta^{11}B$ = -7.1 ±0.9 ‰
[B] = 0.077 ±0.010 µg/g

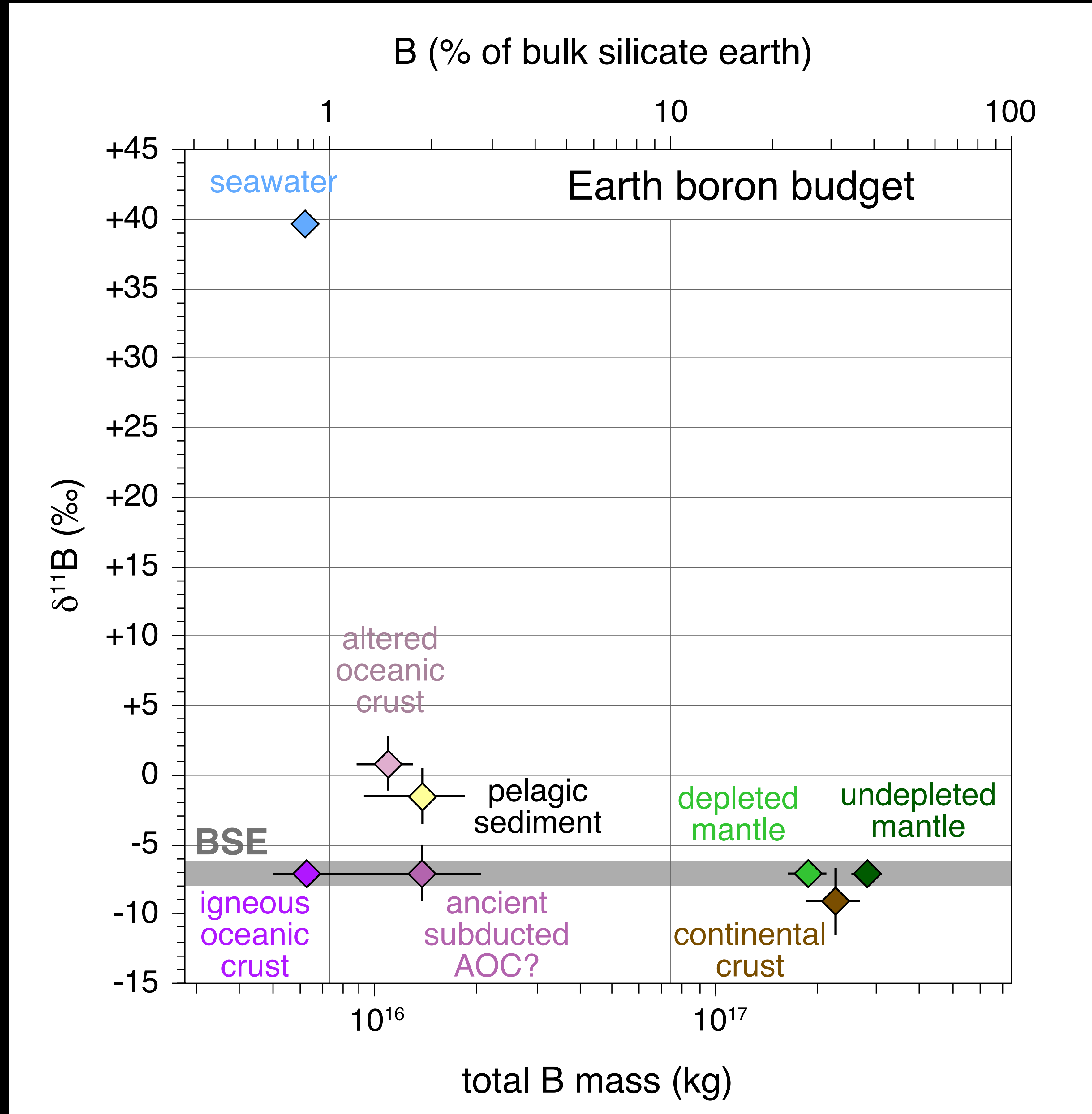
Primitive Mantle
$\delta^{11}B$ = -7.1 ±0.9 ‰
[B] = 0.19 ±0.02 µg/g



Marschall et al. (2017, GCA)

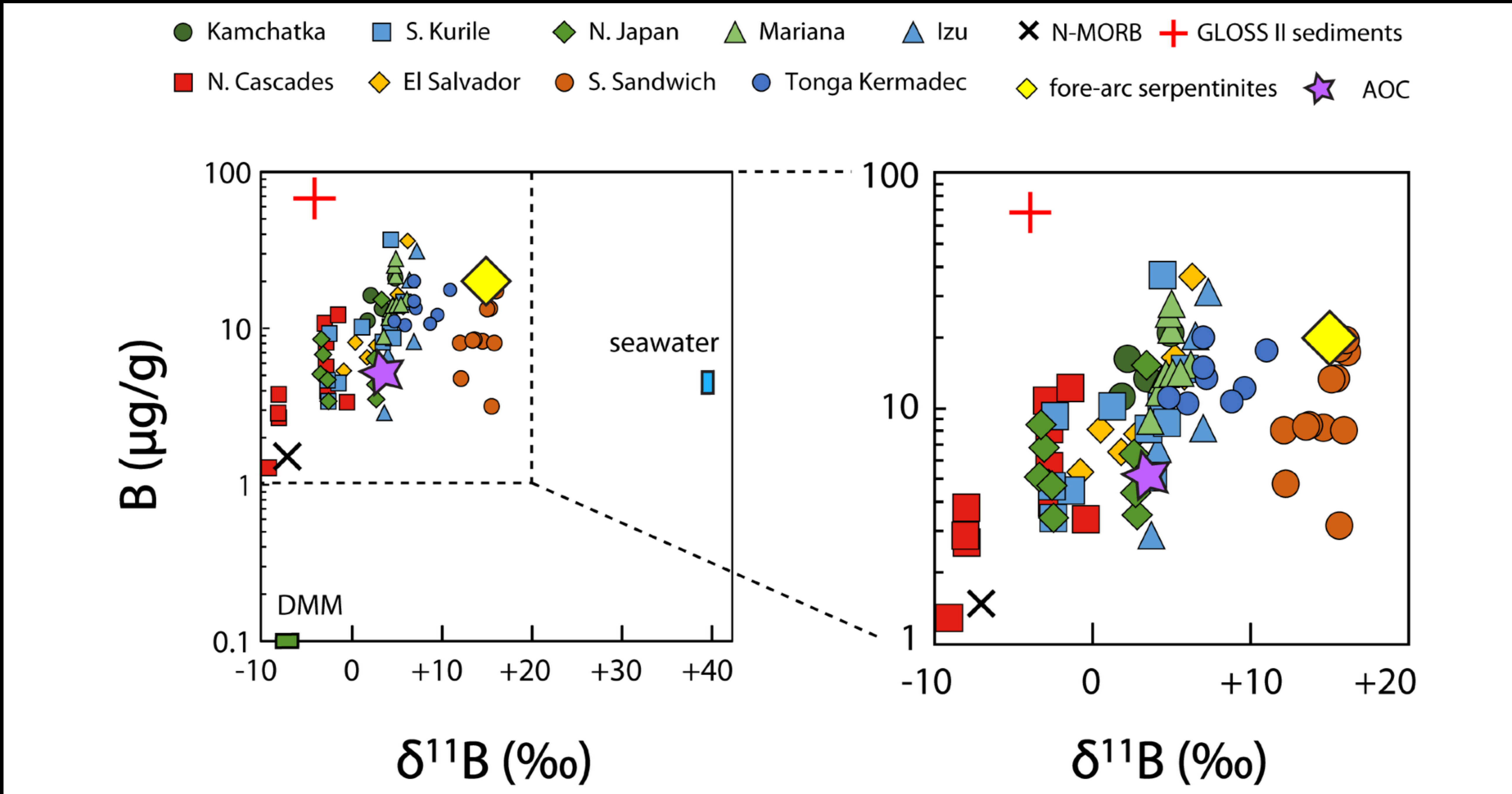
Marschall (2018, Adv. Isotope Geochem.)

Boron budget of the Earth



Marschall (2018, Adv. Isotope Geochem.)
Marschall et al. (2017, GCA.)

Boron isotopes in subduction zones

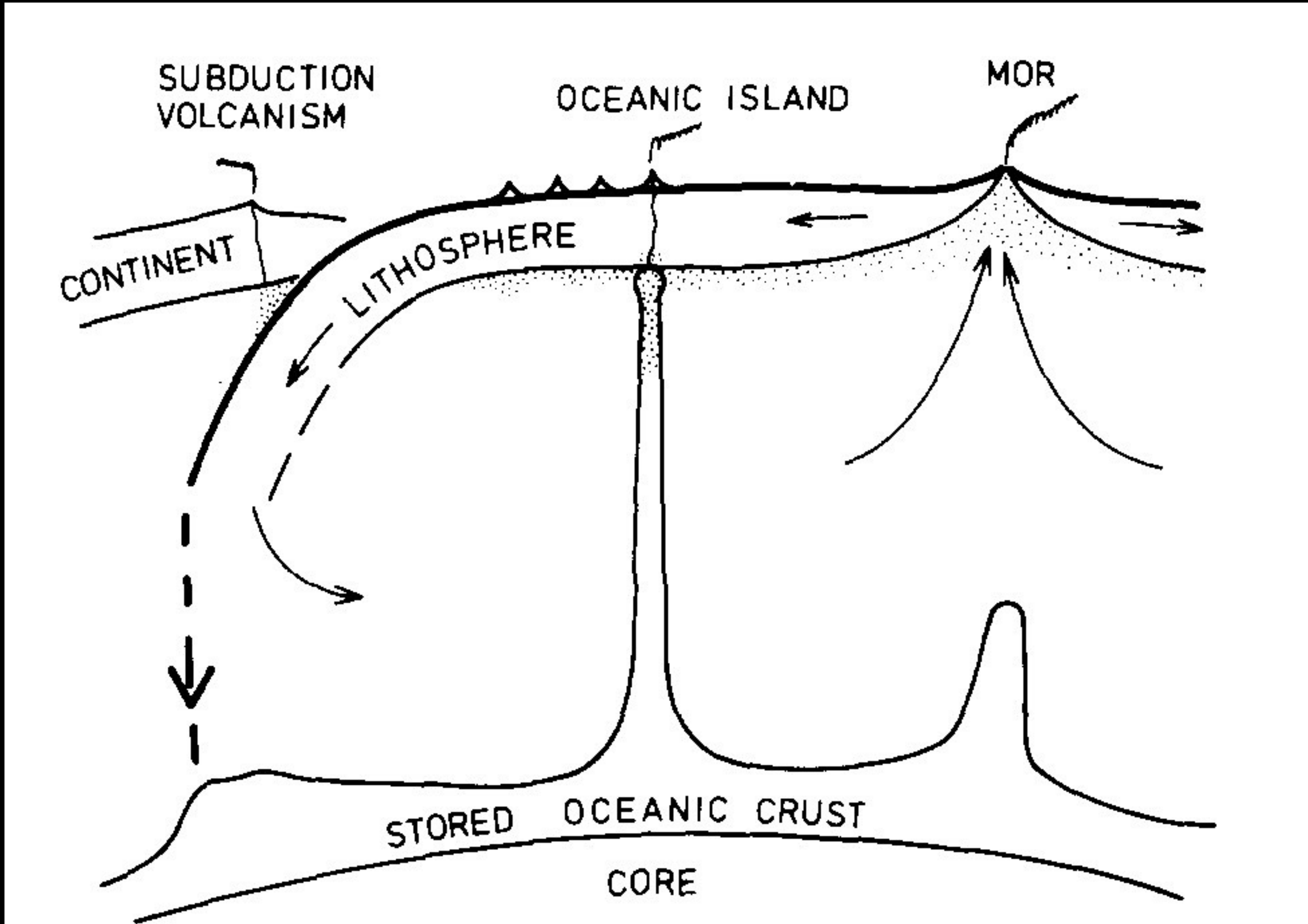


De Hoog & Savov (2018, Adv. Isotope Geochem.)

=> Boron is strongly enriched and isotopically heavy in almost all subduction-related magmas

=> This shows that a lot of isotopically heavy B leaves the slab at an early stage of subduction and is not recycled to the deep mantle

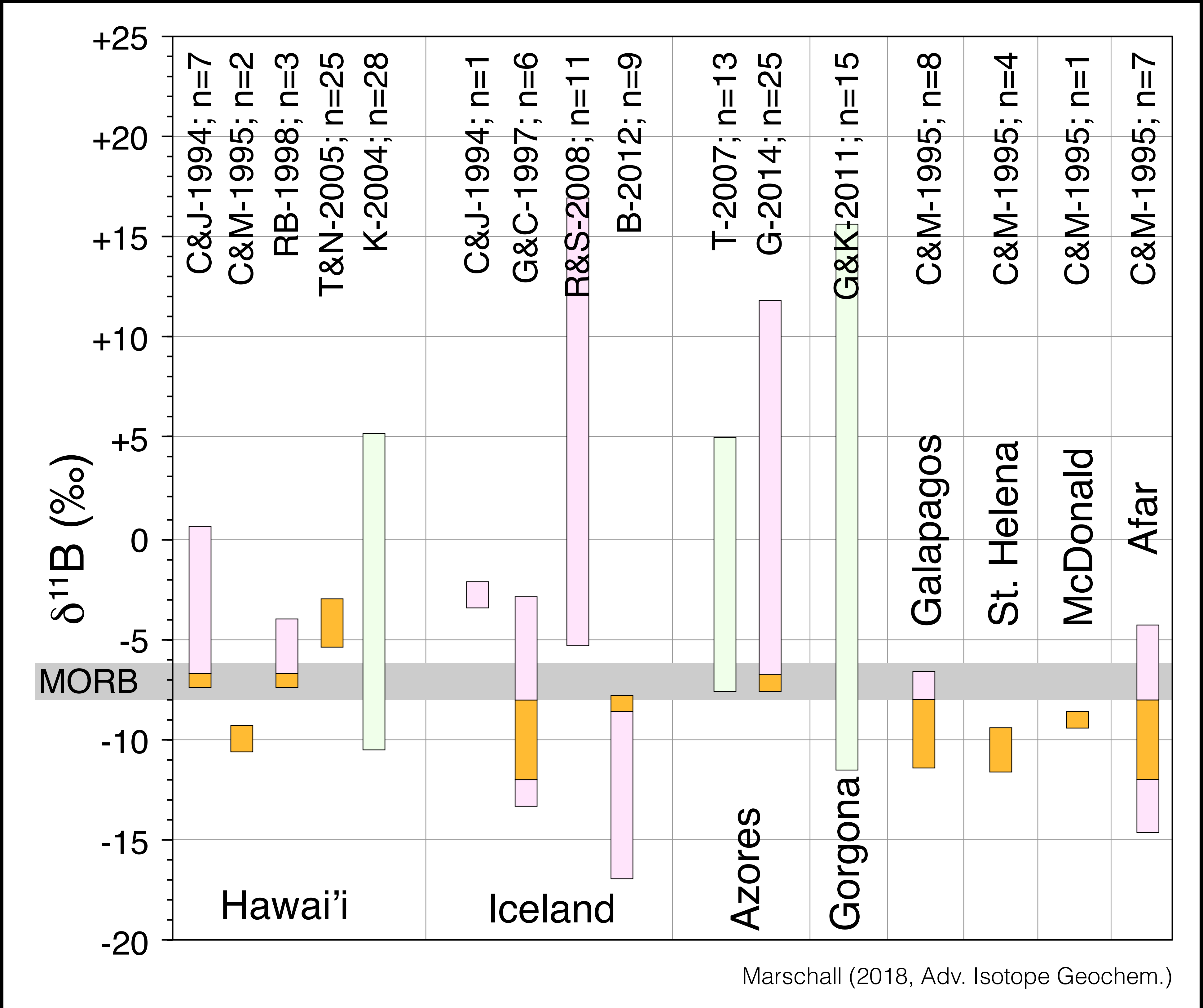
Boron isotopes and global recycling?



Hofmann & White (1982, EPSL)

What is the recycling efficiency of boron?
Can B be used to trace subducted materials in the mantle?

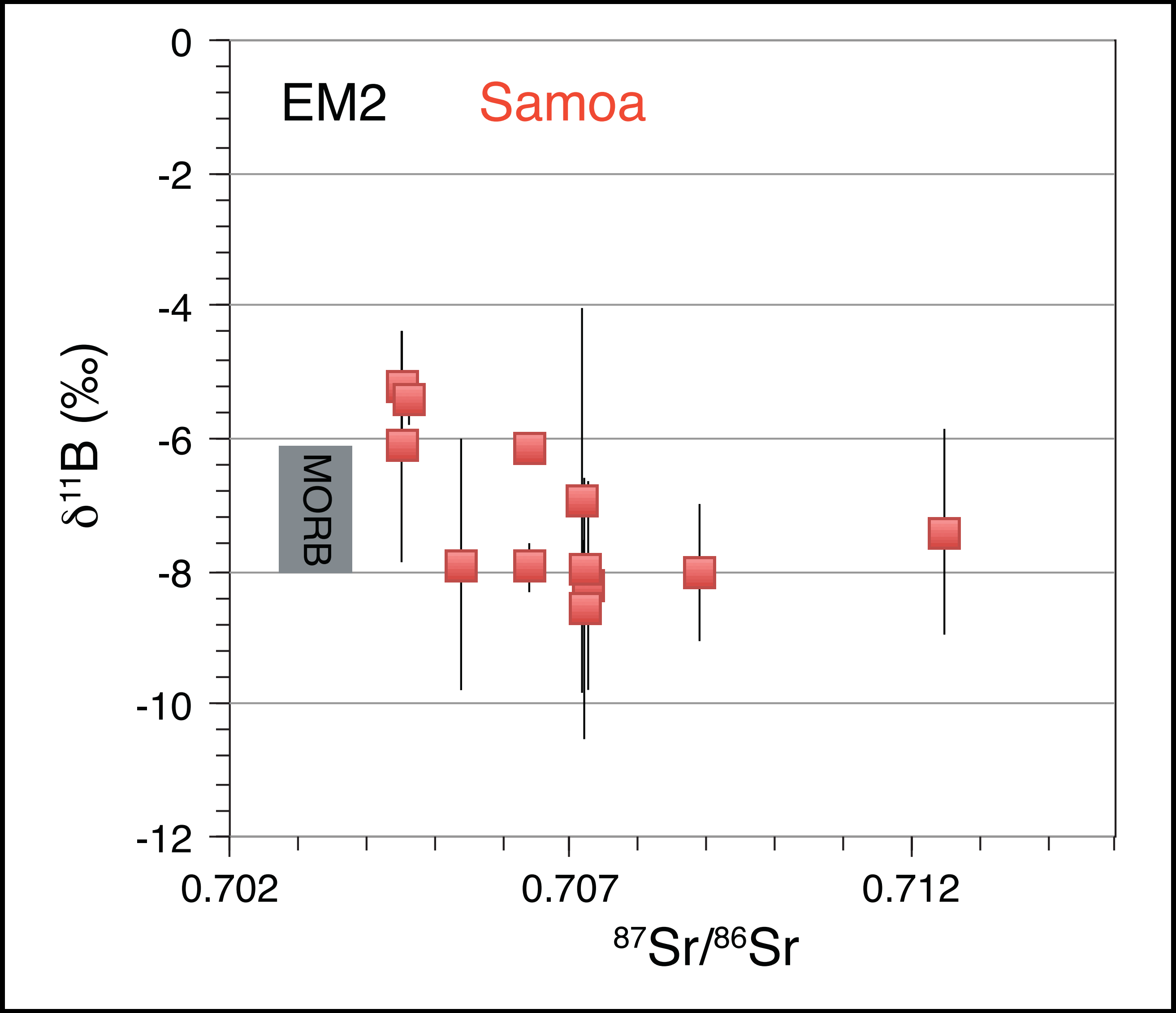
Boron isotopes in Ocean Island Basalts



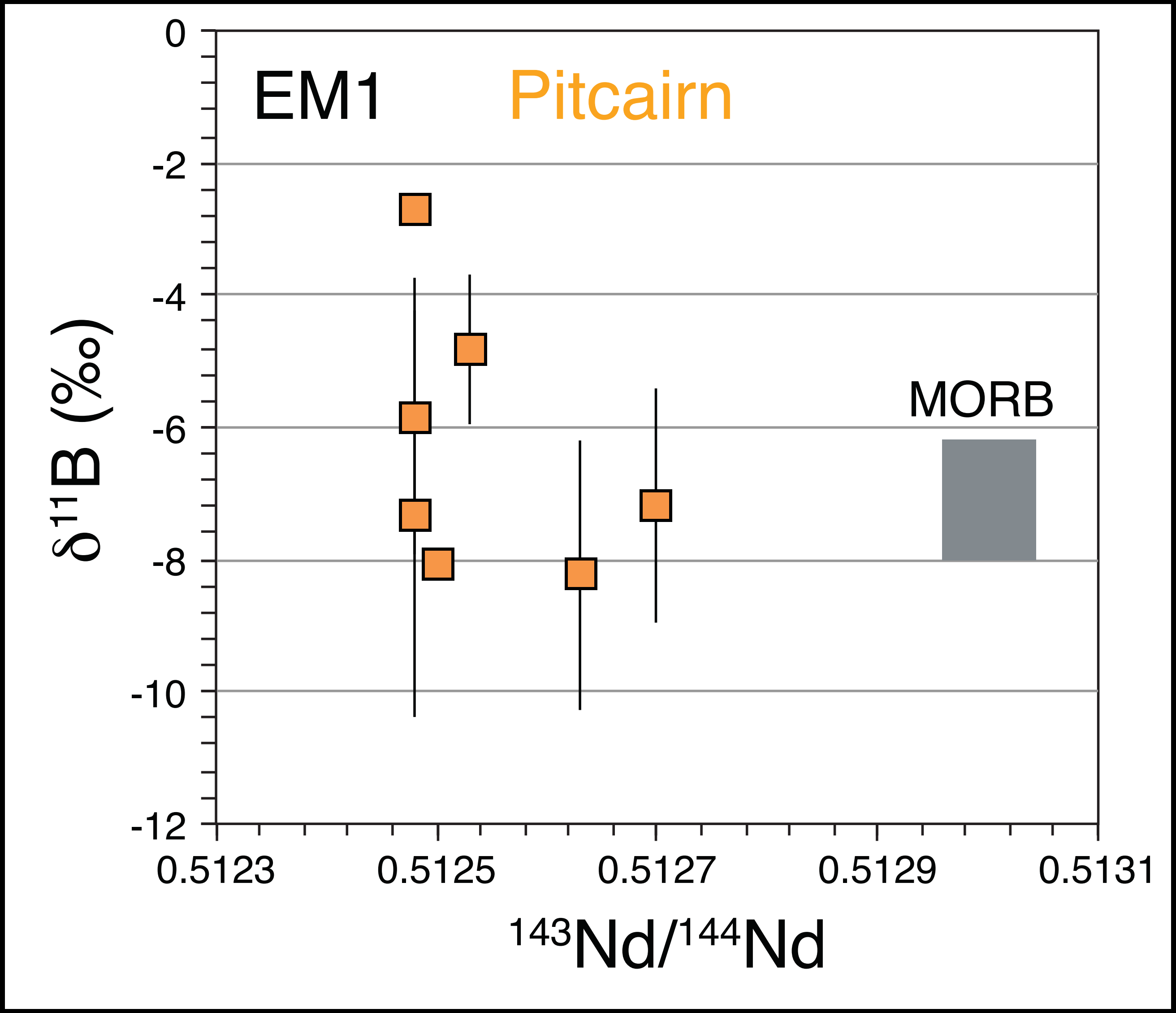
Boron isotopic composition of unaltered OIB samples from various localities published pre-2018. Orange fields depict estimates of B isotopic composition of the OIB mantle source, whereas pink fields display samples with evidence for assimilation of hydrothermally altered crust. The green fields show samples that were interpreted to represent the heterogenous mantle sources of the OIB, but a reconsideration in the light of crustal assimilation has been published or assumed.

This compilations suggests that the mantle sources of OIB vary by less than 9 ‰ around the MORB value (from -12 to -3 ‰).

Boron isotopes in EM1 and EM2



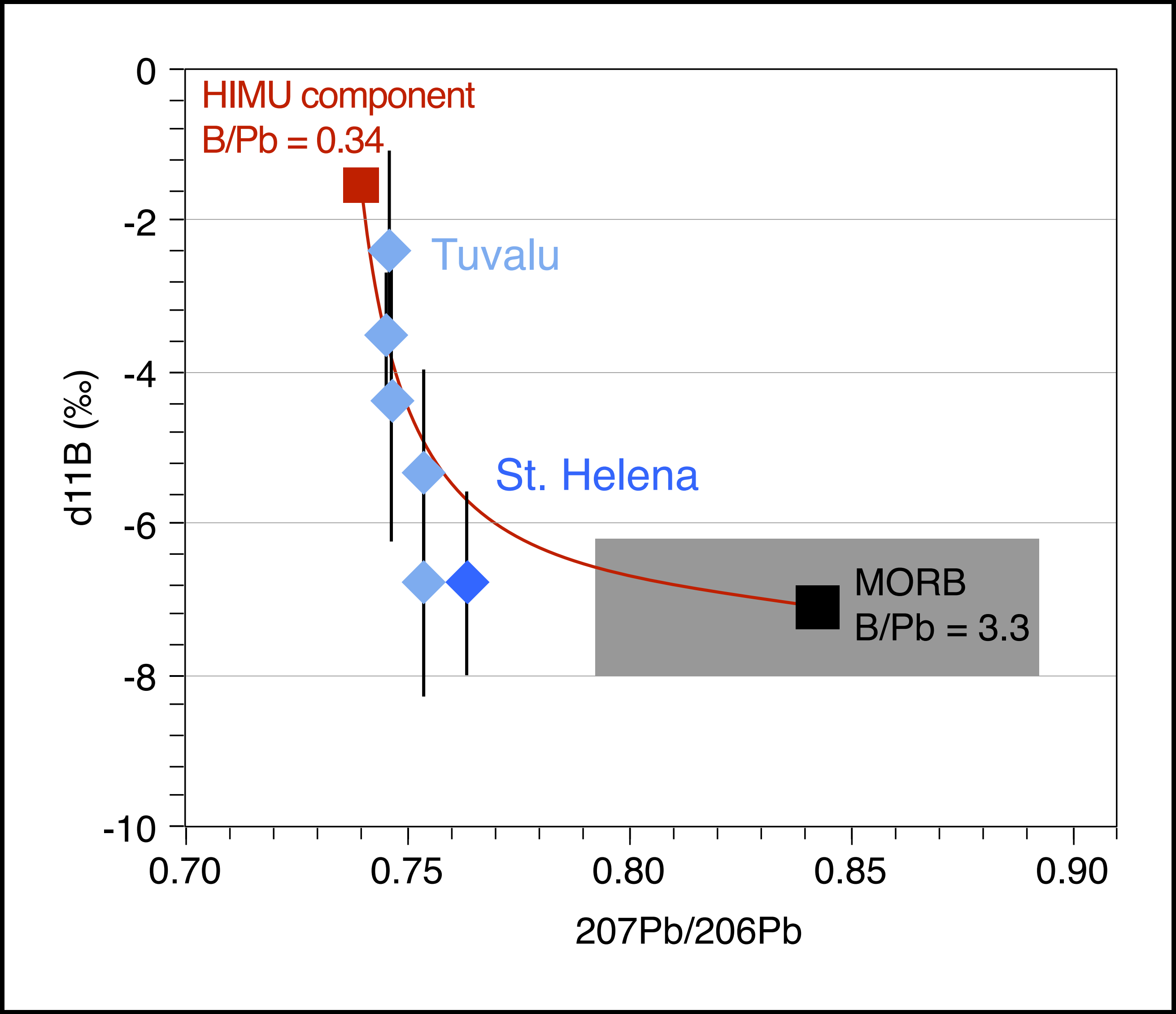
Boron isotopes vs. Sr isotopic composition of analysed EM2 glasses from Samoa. Boron isotope ratios in most samples are indistinguishable from MORB, and even the most radiogenic (enriched) samples (i.e. the EM2 endmember) show MORB-like d11B.



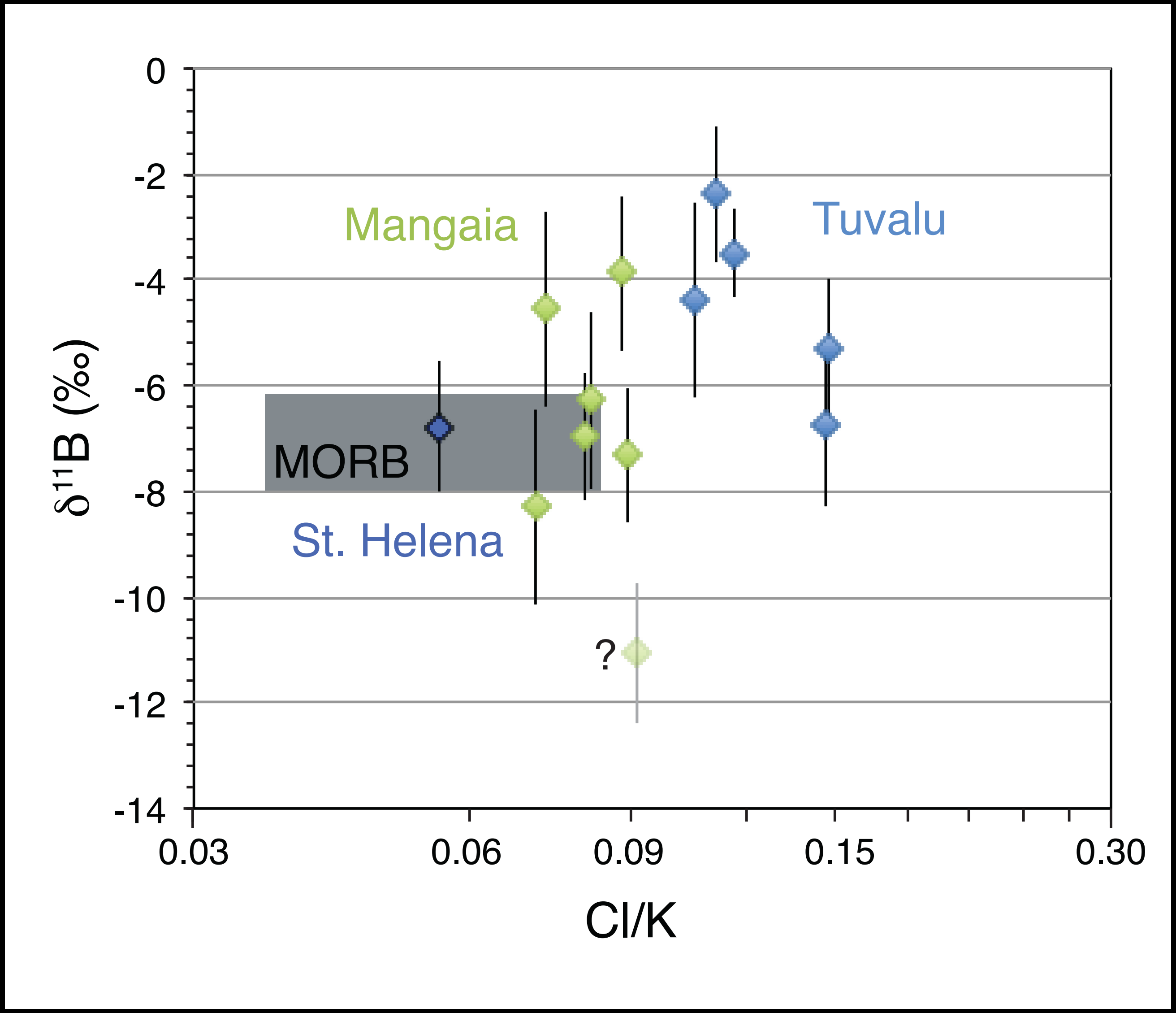
Boron isotopes vs. Nd isotopic composition of analysed EM1 glasses from Pitcairn. Whereas boron isotope ratios in most samples are indistinguishable from MORB, some of the most unradiogenic (enriched) samples from Pitcairn show strongly elevated d11B.

H. Marschall & M. Jackson (unpubl.)

Boron isotopes in HIMU

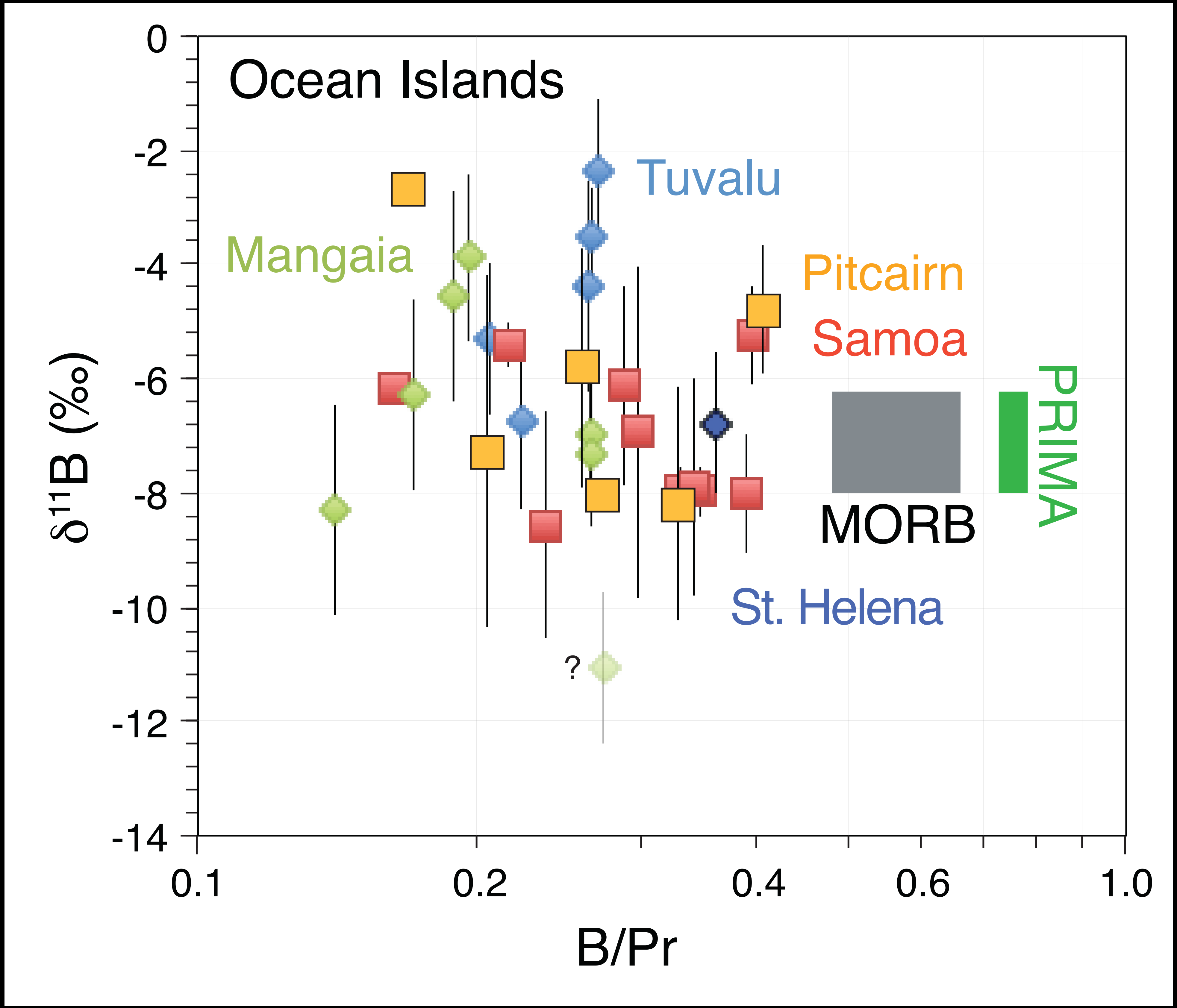


Boron isotopes vs. Pb isotope ratios of analysed HIMU samples from Tuvalu and St. Helena in comparison to MORB ($^{207}Pb/^{206}Pb = 0.86$; $d^{11}B = -7.1$ ‰). The mixing line was calculated by estimating the HIMU recycled component with isotopically heavy B (approx. -1.5 ‰). The elevated B isotopic signal observed in Tuvalu (and Mangaia) is proposed to be related to the mantle source.



Boron isotopes vs. Pb isotope ratios of analysed HIMU samples from Mangaia, Tuvalu and St. Helena in comparison to MORB. The absence of Cl enrichment related to isotopically heavy B in any individual sample set suggests that this signal is related to the mantle source and was not caused by crustal assimilation.

H. Marschall & M. Jackson (unpubl.)



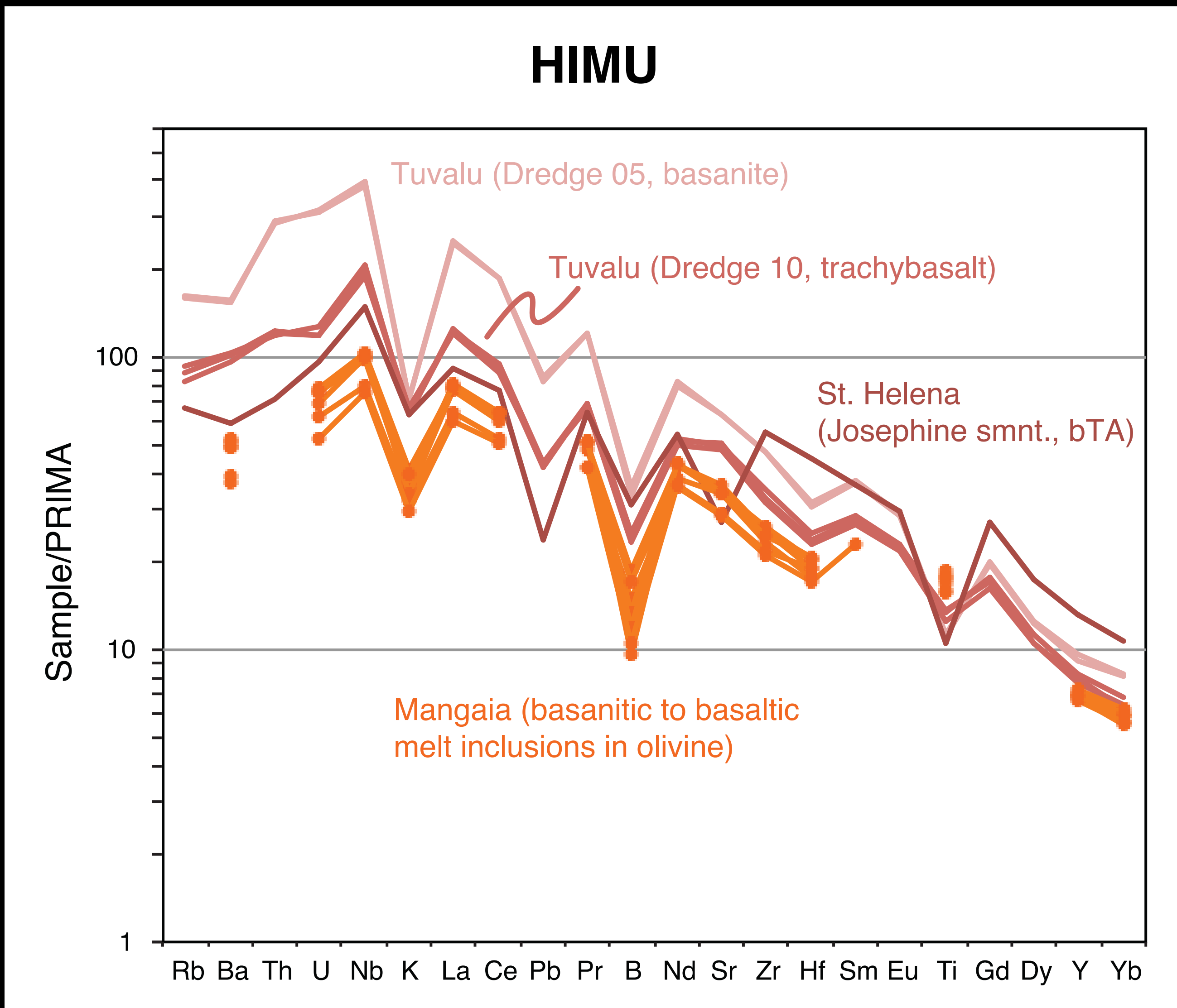
Boron isotopes vs. B/Pr ratios of analysed HIMU, EM1 and EM2 samples in comparison to MORB. Note that all analysed samples show boron depletion relative to MORB. Their boron isotopic compositions are either indistinguishable from MORB (in most samples) or is heavier by up to ~4 ‰. One Mangaia melt inclusion produced an analysis with below-MORB composition (pale green diamond with question mark), but this analysis had a low count rate and could not be reproduced. MORB values and PRIMA estimate are from Marschall et al. (2017, GCA).

H. Marschall & M. Jackson (unpubl.)

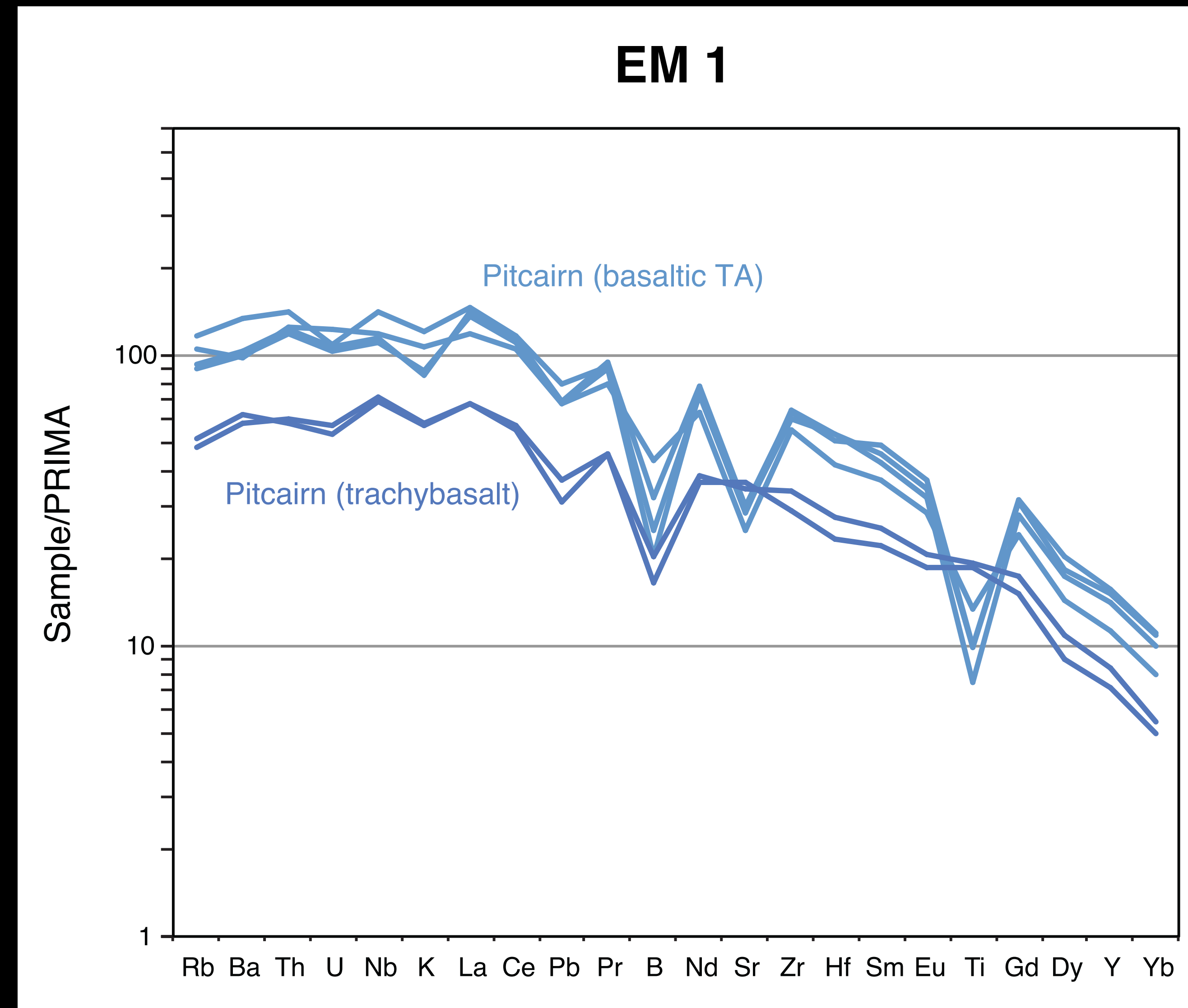
Conclusions (1)

- The HIMU and EM1 sources may comprise a high-$\delta^{11}B$ component, whereas $\delta^{11}B$ in the EM2 source is indistinguishable from MORB
- Recycling of subducted materials may introduce some isotopically heavy B into the mantle
- Non of the 44 samples analysed in this study, including the most extreme members of the 'mantle zoo' show a $\delta^{11}B$ significantly lower than MORB.
- The very large range in $\delta^{11}B$ from oceanic basalts reported in early studies is likely due to shallow (crustal) assimilation of altered materials during magma ascent

OIB trace-element data



Primitive-mantle normalized trace-element patterns of the investigated HIMU samples from Tuvalu, St. Helena and Mangaia. Data except for B from Cabral et al. (2014), Jackson et al. (2015) and Kendrick et al. (2017). Boron data from this study.

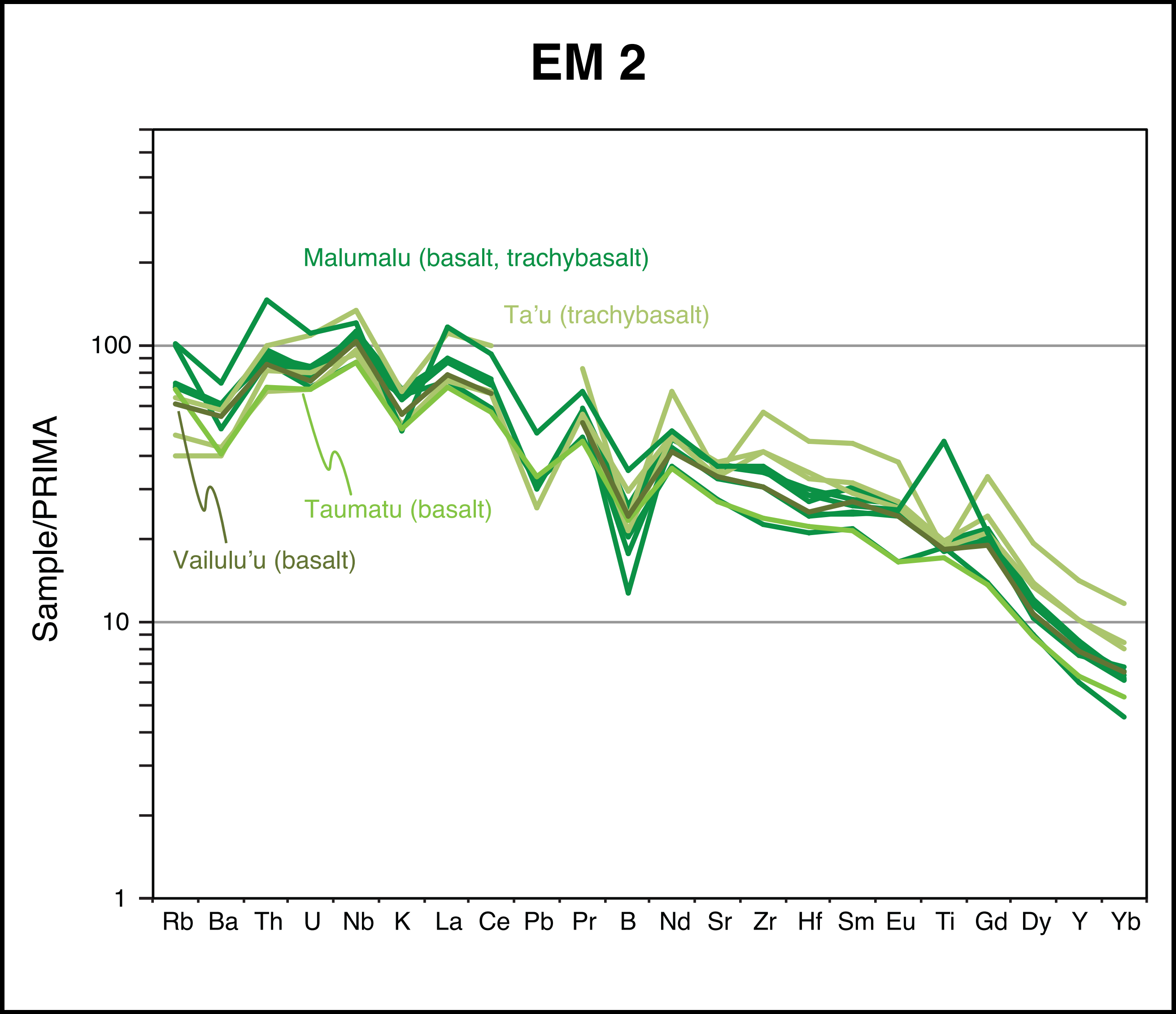


Primitive-mantle normalized trace-element patterns of the investigated EM1 samples from Pitcairn. Data except for B from Kendrick et al. (2017). Boron data from this study. Primitive mantle values are from Mcdonough & Sun (1995, ChemGeol), except for B (Marschall et al., 2017, GCA).

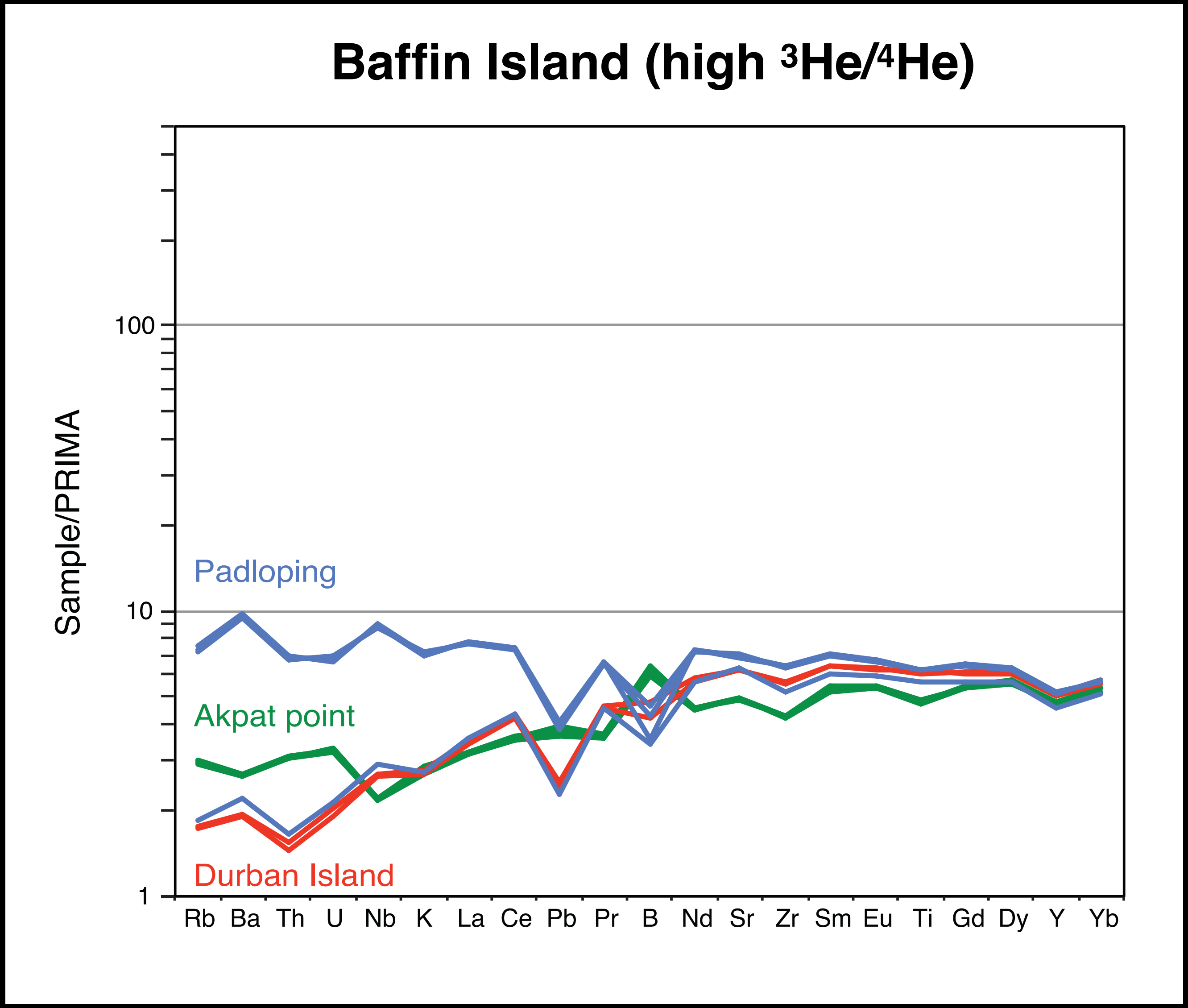
=> all OIB samples show negative B and Pb anomalies

H. Marschall & M. Jackson (unpubl.)

OIB trace-element data



Primitive-mentle normalized trace-element patterns of the investigated EM2 samples from Samoa. Data except for B from Kendrick et al. (2017). Boron data from this study. Primitive mantle values are from Mcdonough & Sun (1995, ChemGeol), except for B (Marschall et al., 2017, GCA).

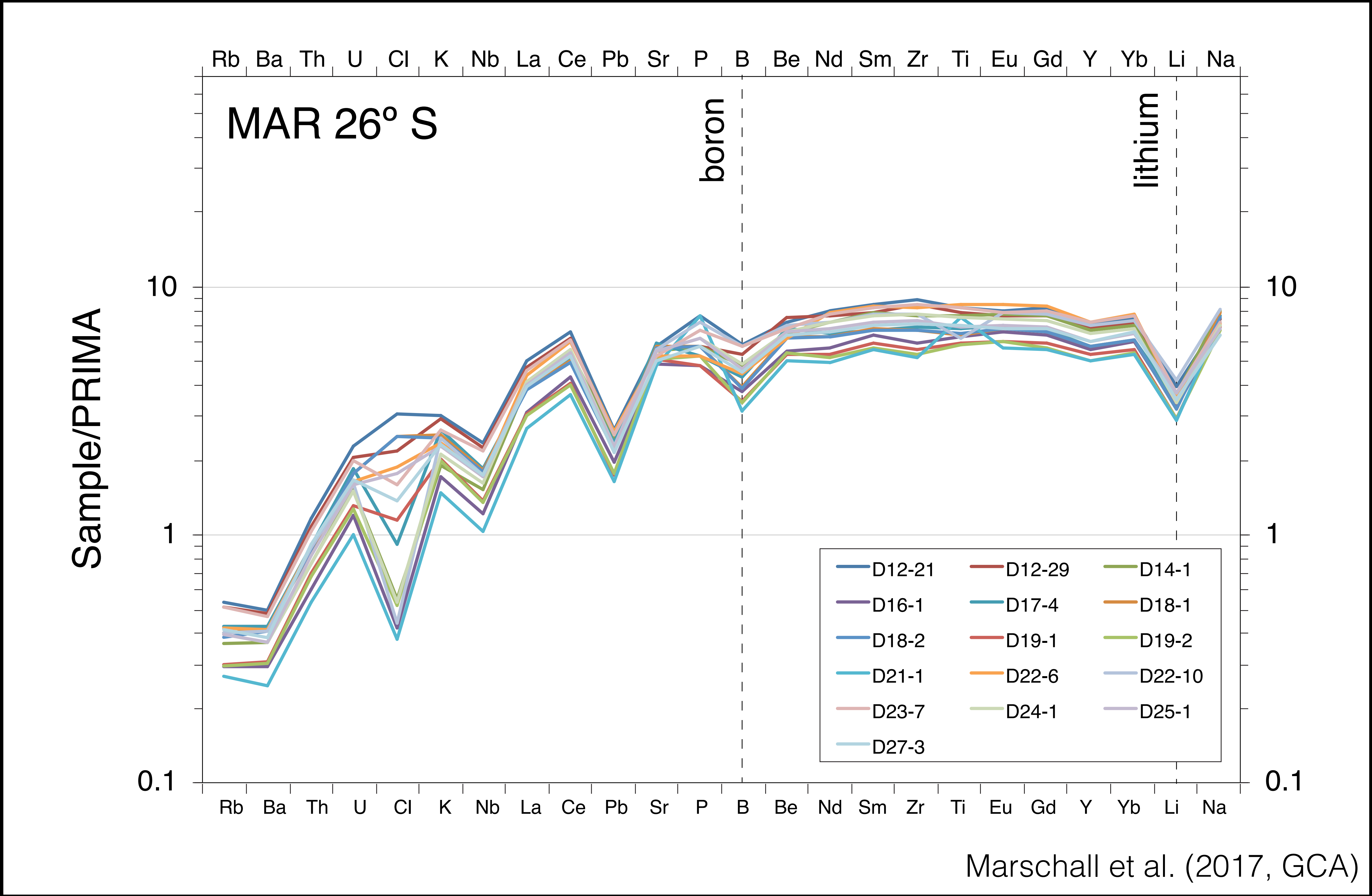


Primitive-mantle normalized trace-element patterns of the investigated glass in samples from three localities around Baffin Bay. Trace-element data are unpublished. Boron data from this study.

=> all mantle-derived samples show negative B and Pb anomalies, with the exception of some Baffin Island samples

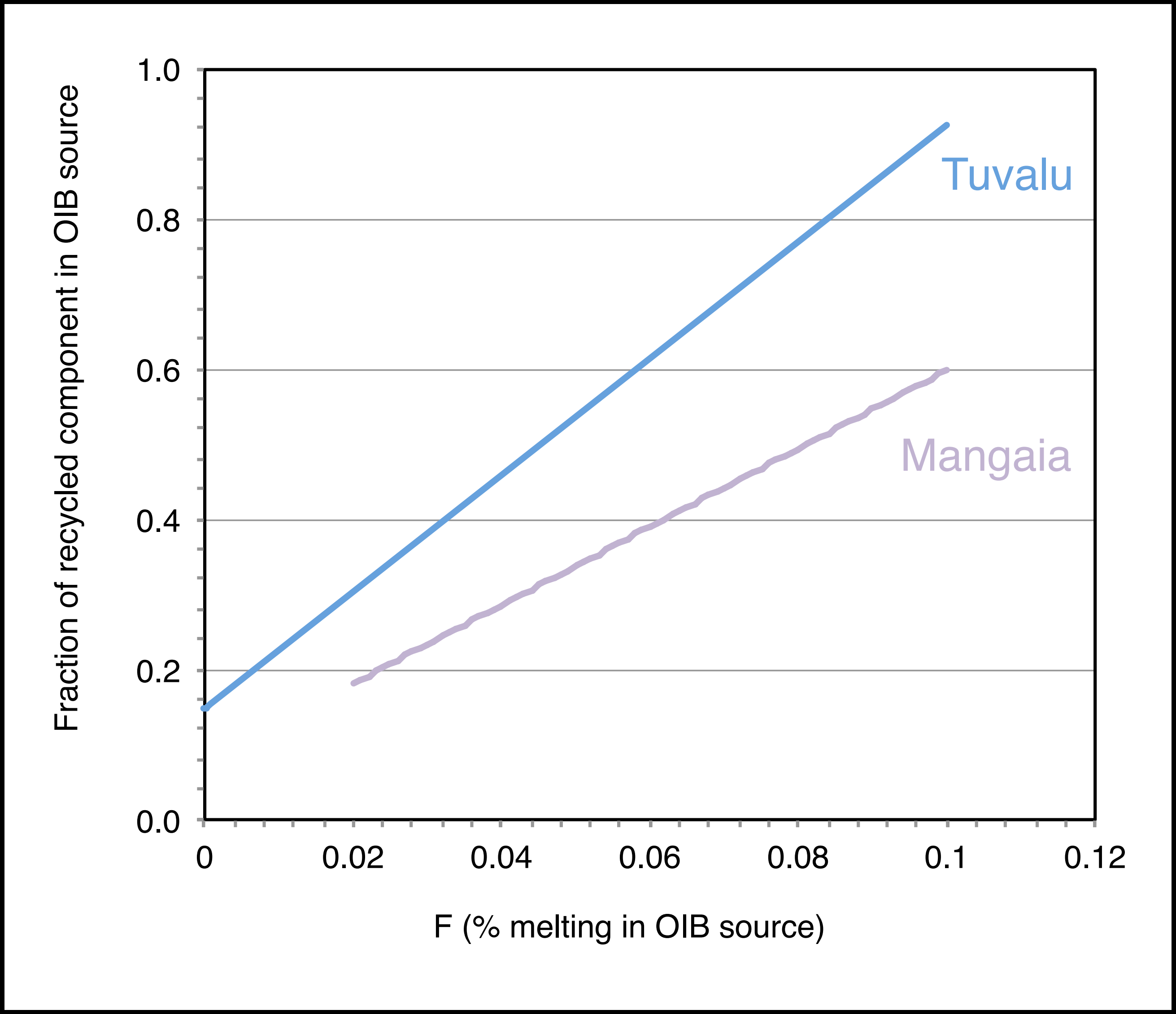
H. Marschall & M. Jackson (unpubl.)

Boron in fresh uncontaminated N-MORB

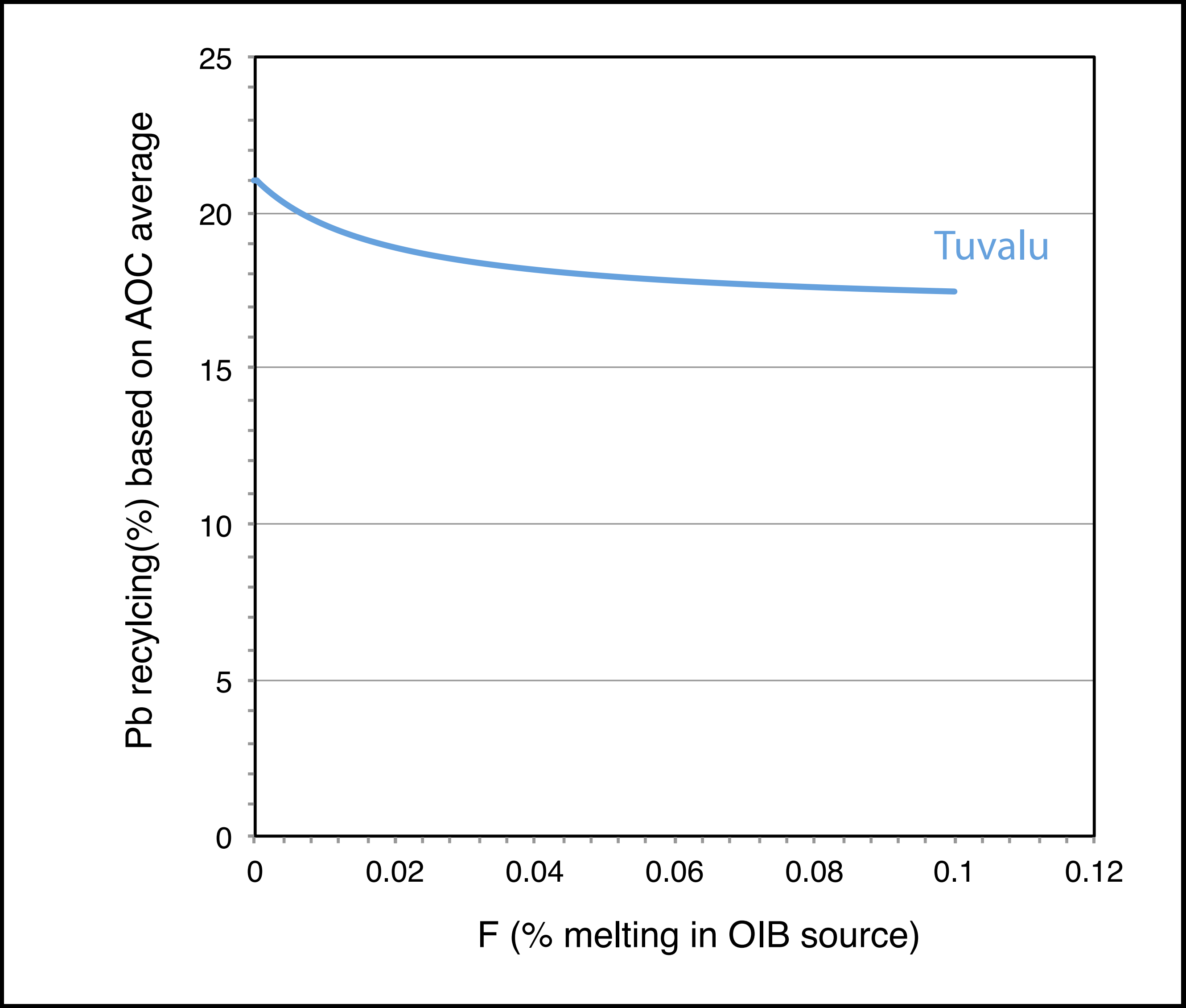


=> N-MORB also shows negative B and Pb anomalies, but not as negative as OIB

OIB source modelling



Fraction of recycled material in HIMU OIB sources as a function of partial melting in the OIB source. The partial melting model is confined by the assumption that Pr is conserved during subduction and remains in the recycled material at the same concentration as in MORB.



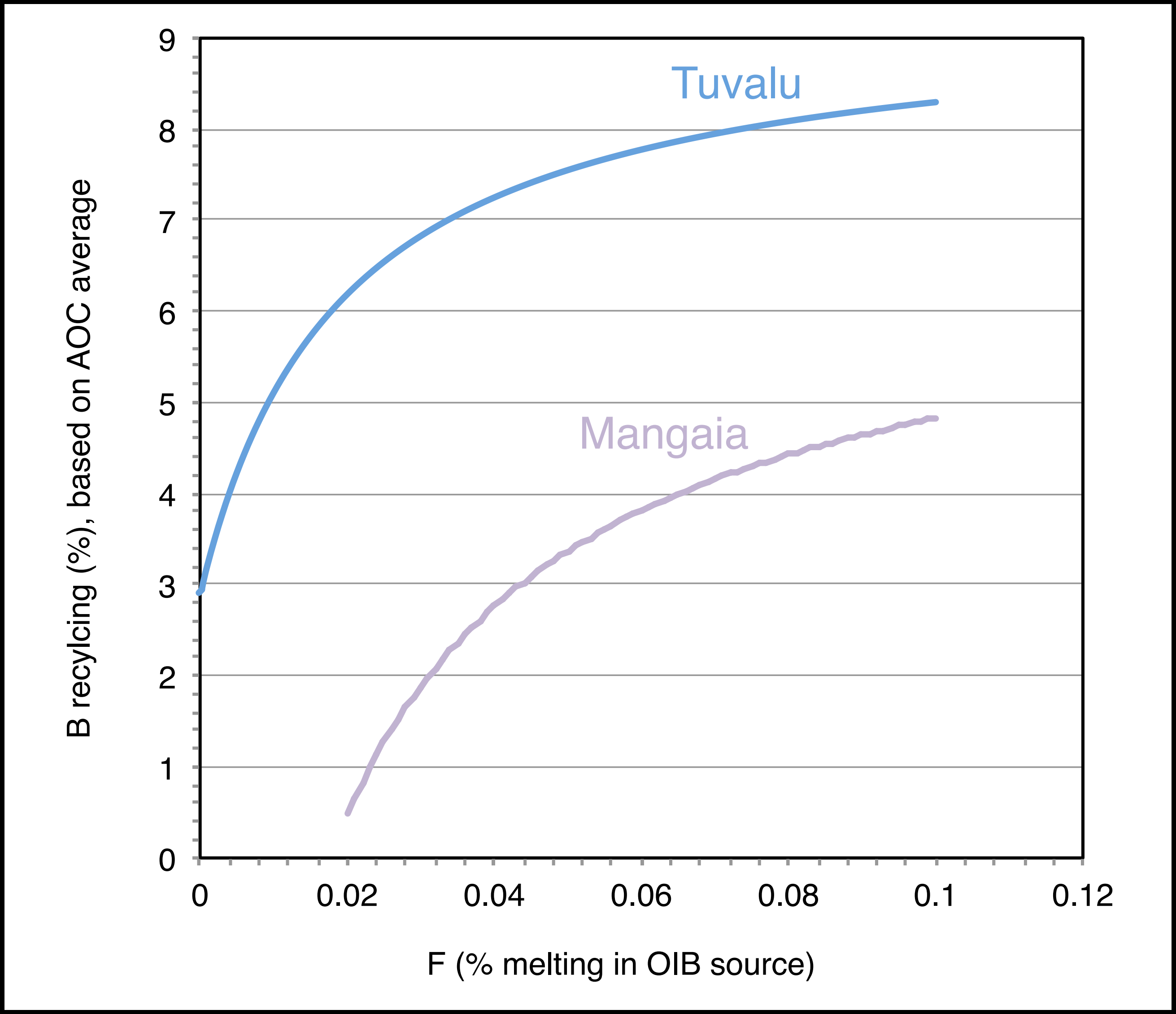
Recycling efficiency of Pb resulting from melting model, based on identical partition coefficients for Pb and Pr and the observed Pr and Pb concentrations in Tuvalu lavas. (Pb concentrations for Mangaia are not available).

=> a fraction of 30–40 % recycled component is consistent with 3 to 5 % partial melting in the source

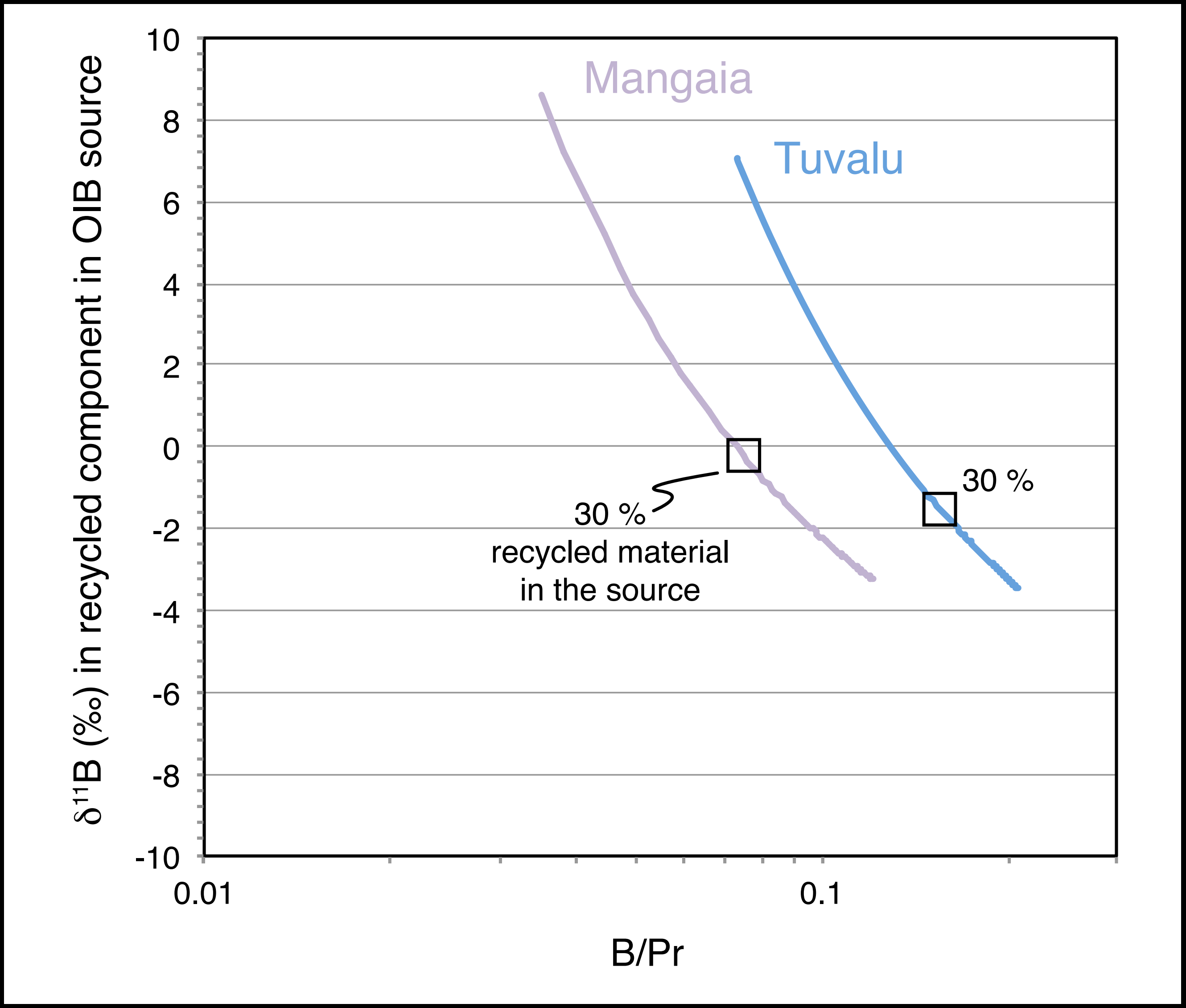
=> Pb recycling efficiency is 15–20 % for the Tuvalu source (≥80 % removal relative to AOC)

H. Marschall & M. Jackson (unpubl.)

OIB source modelling



Recycling efficiency of B resulting from melting model, based on identical partition coefficients for B and Pr and the observed Pr and B concentrations in Tuvalu and Mangaia lavas.



Boron isotopic composition and B/Pr ratios of the recycled components in the source of Tuvalu and Mangaia as a function of mixing proportions. Assuming 30 % recycled component (plus 70 % MORB-source mantle) results in B isotope values between -2 and 0 ‰.

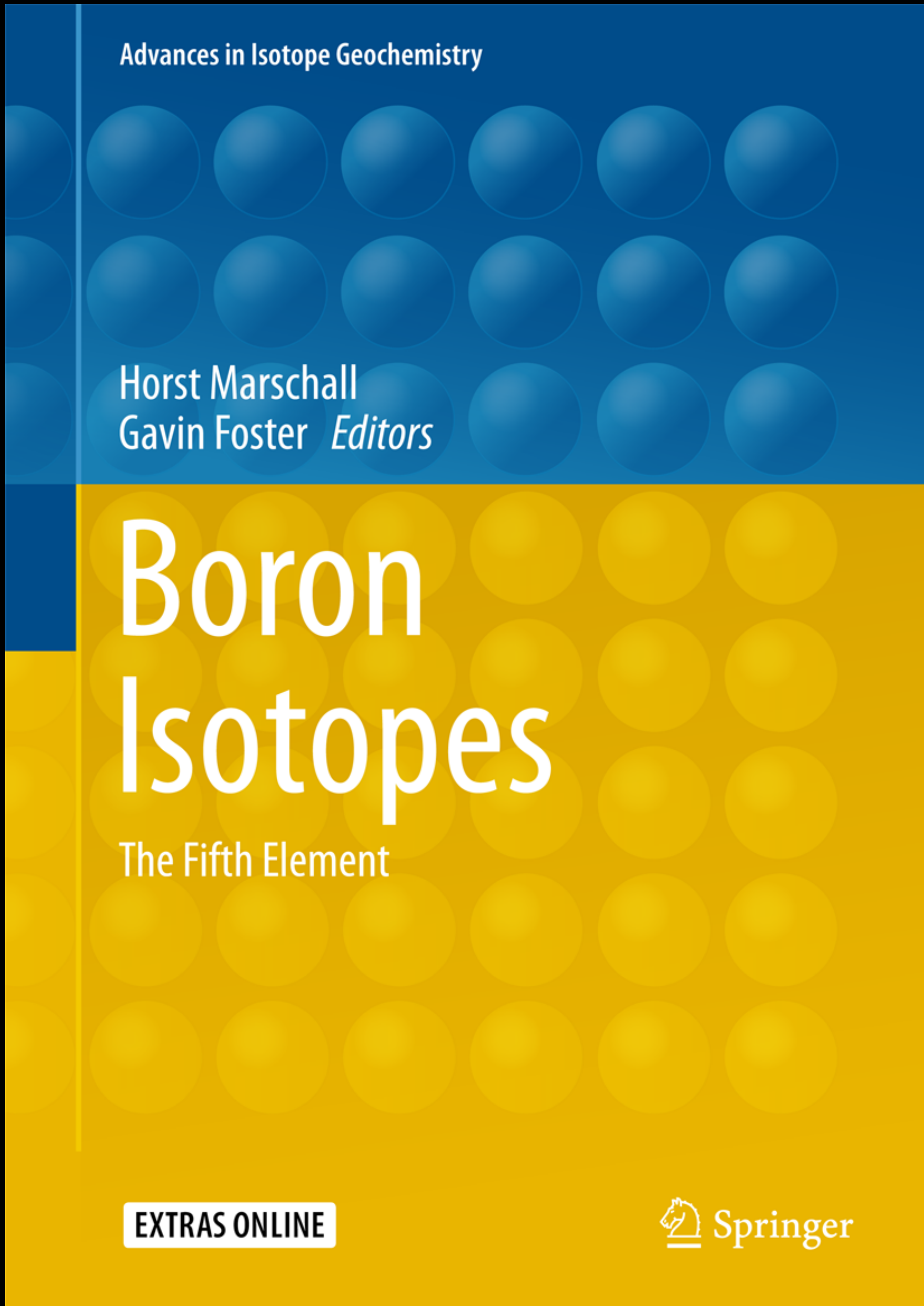
=> Boron recycling efficiency is 2–8 % for the HIMU sources (≥90 % removal relative to AOC)

=> Boron concentrations in the recycled material are still 1 to 5 times that of the depleted mantle

H. Marschall & M. Jackson (unpubl.)

Conclusions (2)

- All OIB samples are depleted in boron relative to MORB as evident from sub-MORB B/Pr
- MORB itself is depleted in boron and has lower B/Pr than the Primitive Mantle
- Recycling of subducted materials may introduce some isotopically heavy B into the mantle, but this B return is much less efficient than the enrichment of most other trace elements (e.g. REE)
- 92–98 % of B and 80–85 % of Pb are extracted from subducting altered oceanic crust during slab devolatilization



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Me fifth element – supreme being. Me protect you.
Leeloo

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- experiments and theory
- marine geochemistry
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