第三届“非传统同位素地球化学”暑期学校

从非传统同位素的角度重新认识地幔端元的属性

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大陆动力学国家重点实验室

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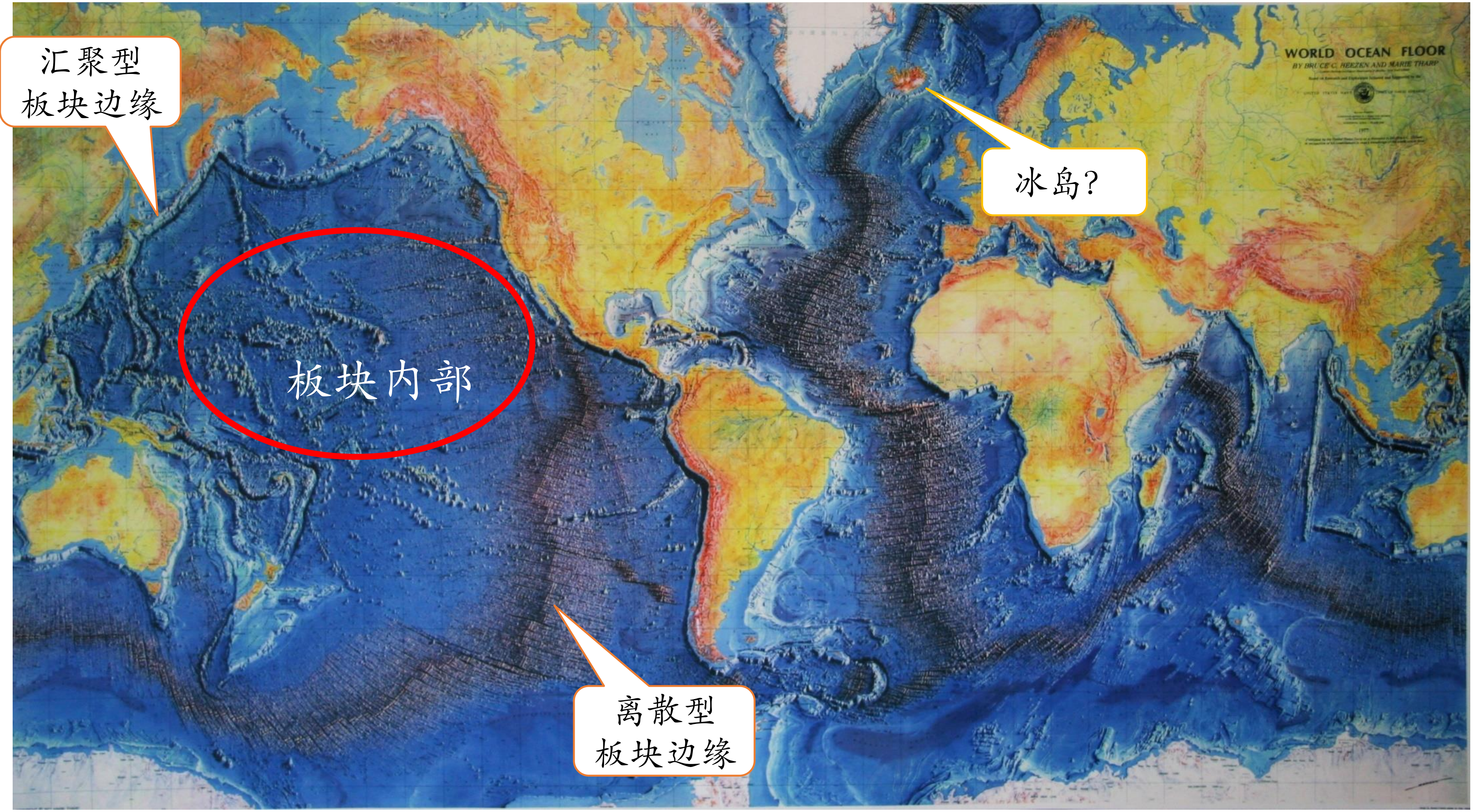
换个‘望远镜’看地幔

一．海洋玄武岩与地幔的化学不均一性

二．地幔端元属性的争议

三．Mg稳定同位素示踪地幔端元EM1的属性

一．海洋玄武岩与地幔的化学不均一性

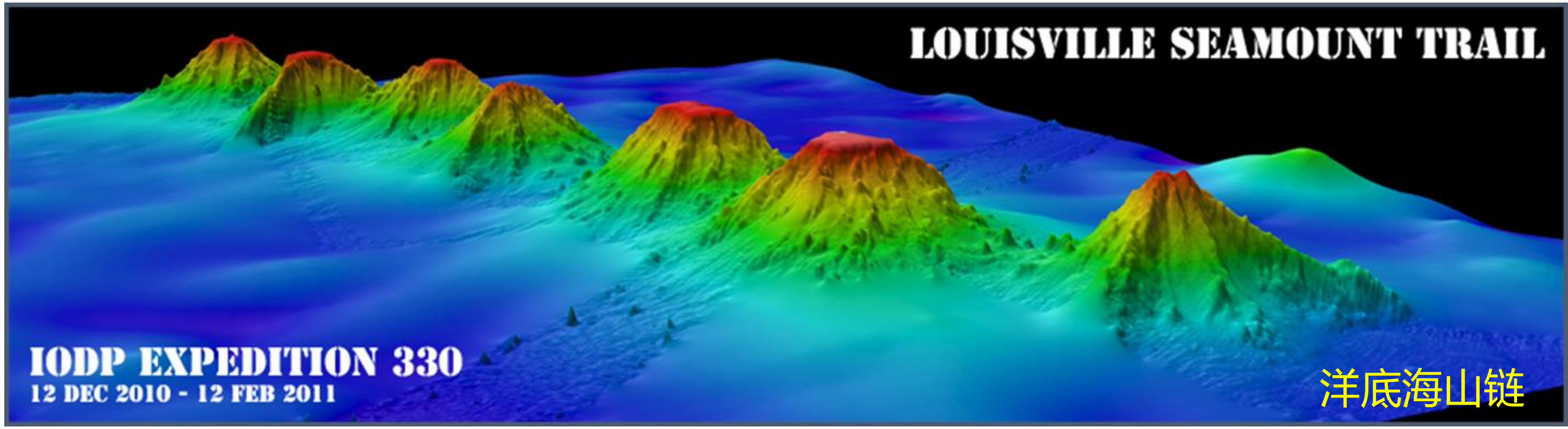


不同构造背景：

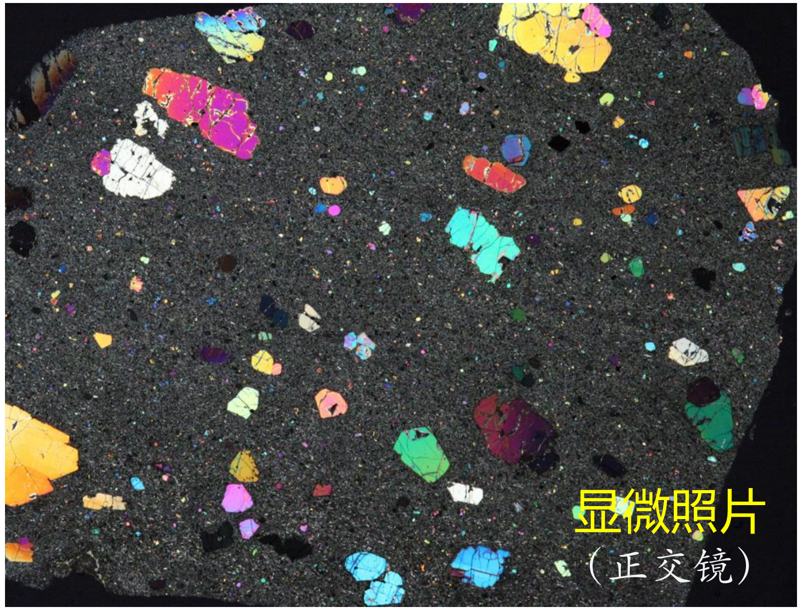
- 洋中脊玄武岩
- 岛弧玄武岩
- 洋岛玄武岩

“玄武岩是了解地幔大尺度化学不均一性的理想研究对象”

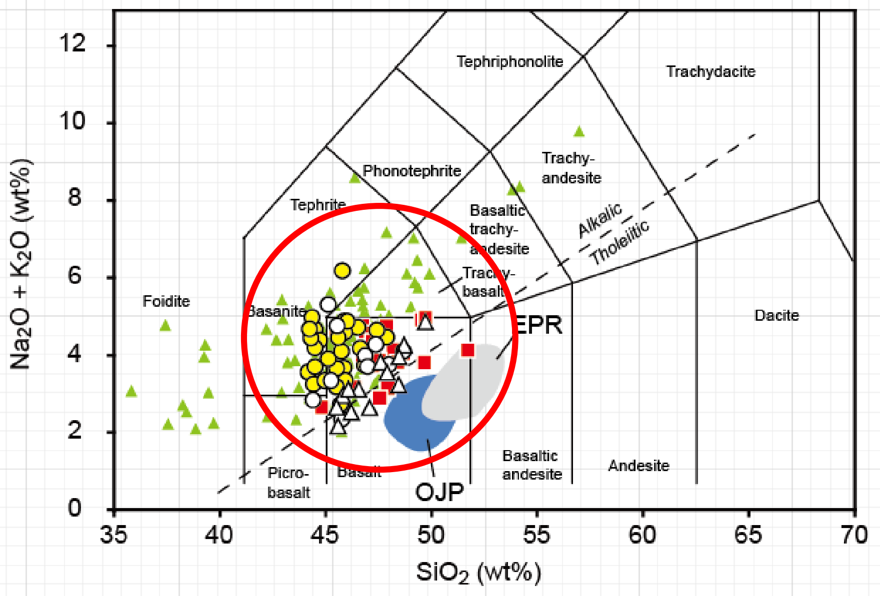
海底火山作用与大洋玄武岩



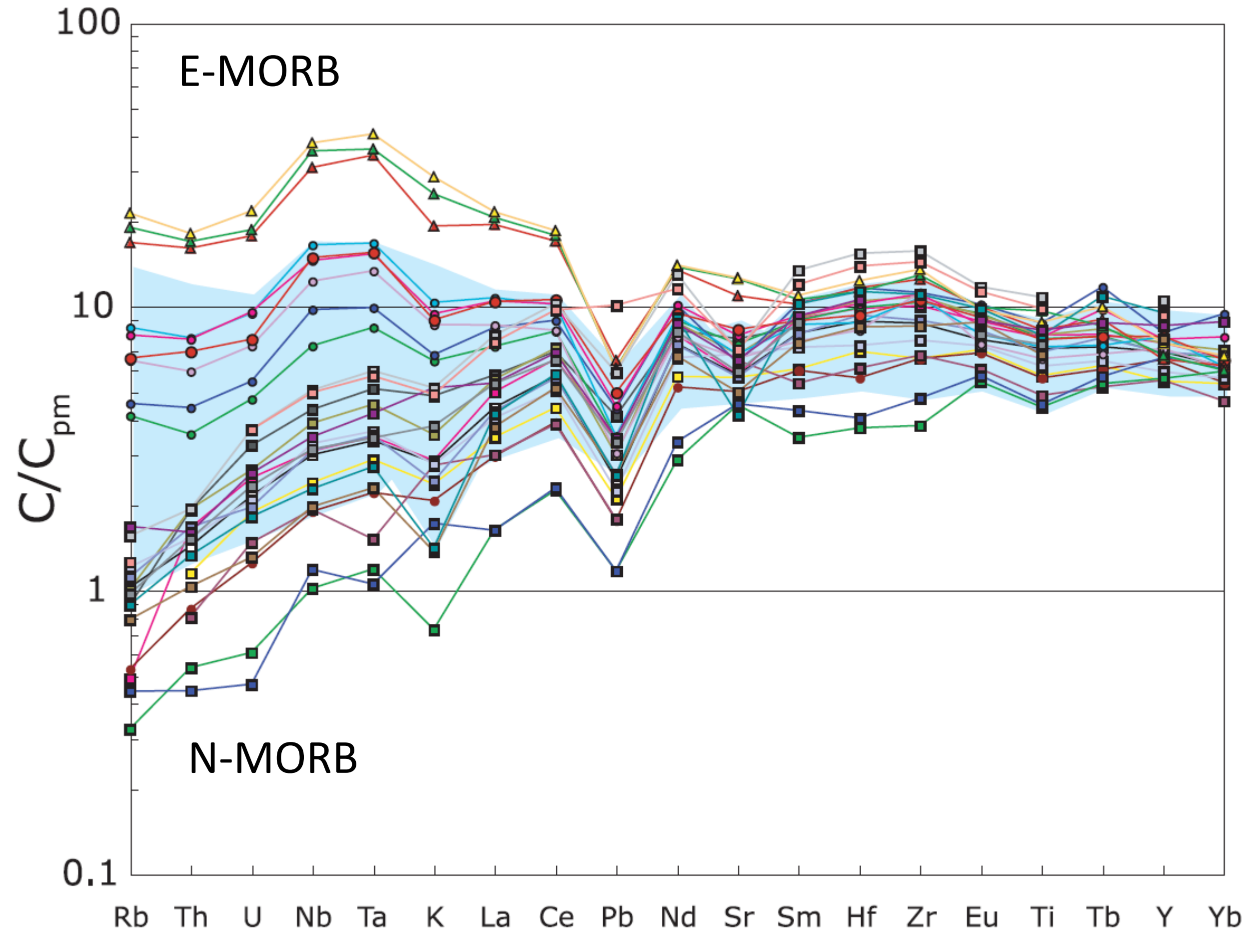
新鲜的玄武岩

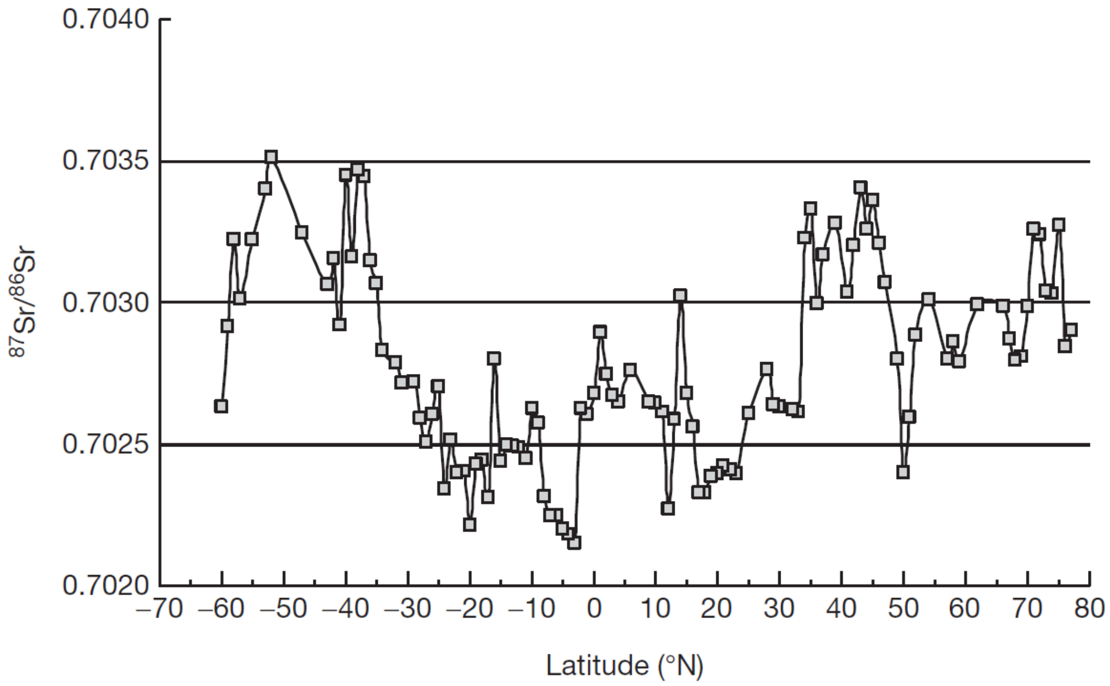


海洋玄武岩的TAS图



大西洋洋中脊玄武岩的化学不均一性





大西洋洋脊玄武岩微量元素和Sr同位素组成的不均一性

Ann. Rev. Earth Planet. Sci. 1986. 14: 493–571

【综述文献，经典版】

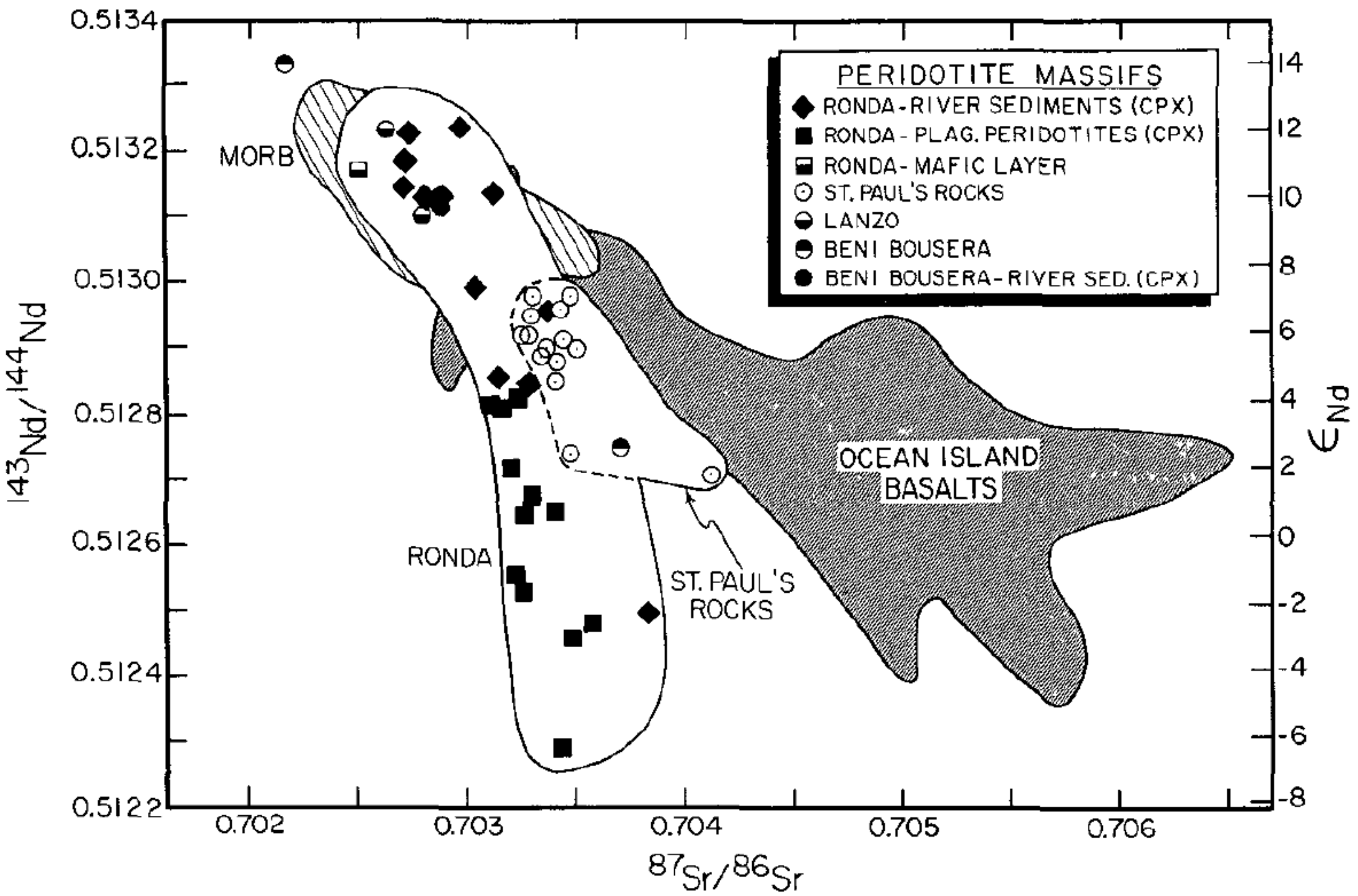
CHEMICAL GEODYNAMICS

Alan Zindler

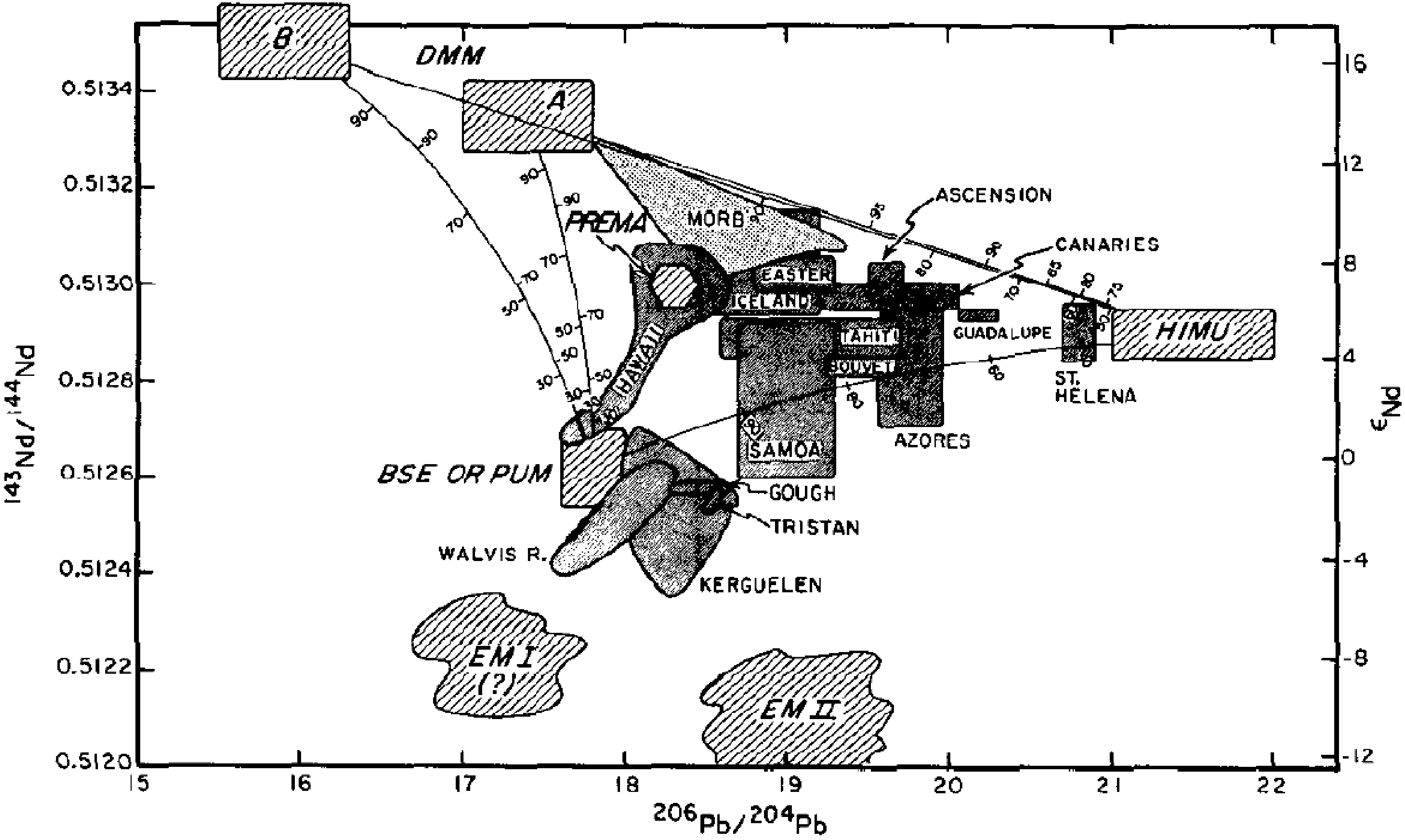
Lamont-Doherty Geological Observatory and Department of Geolo
Sciences, Columbia University, Palisades, New York 10964

Stan Hart

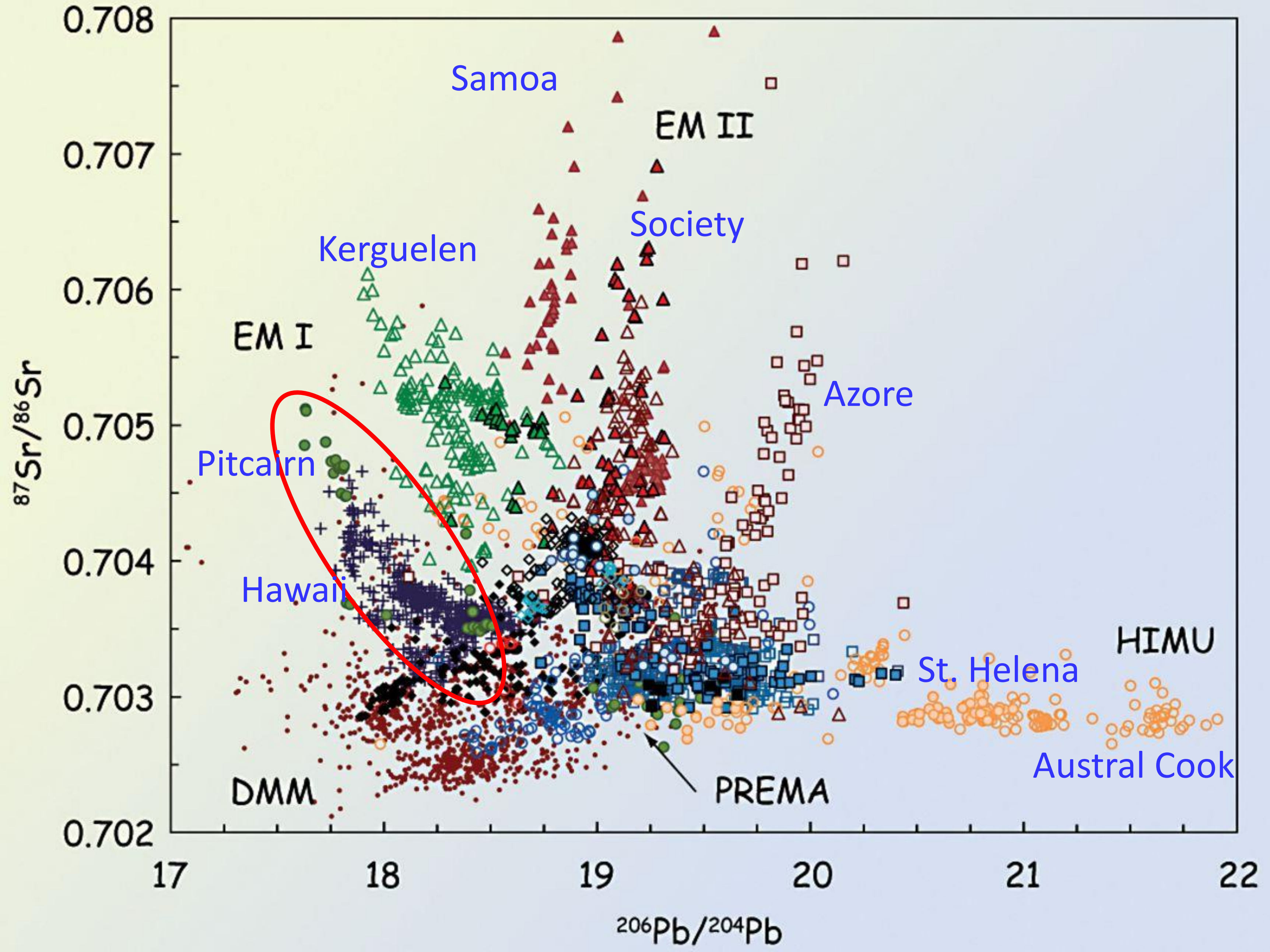
Center for Geoalchemy, Department of Earth, Atmospheric, and Plane
Sciences, Massachusetts Institute of Technology, Cambridge,
Massachusetts 02139



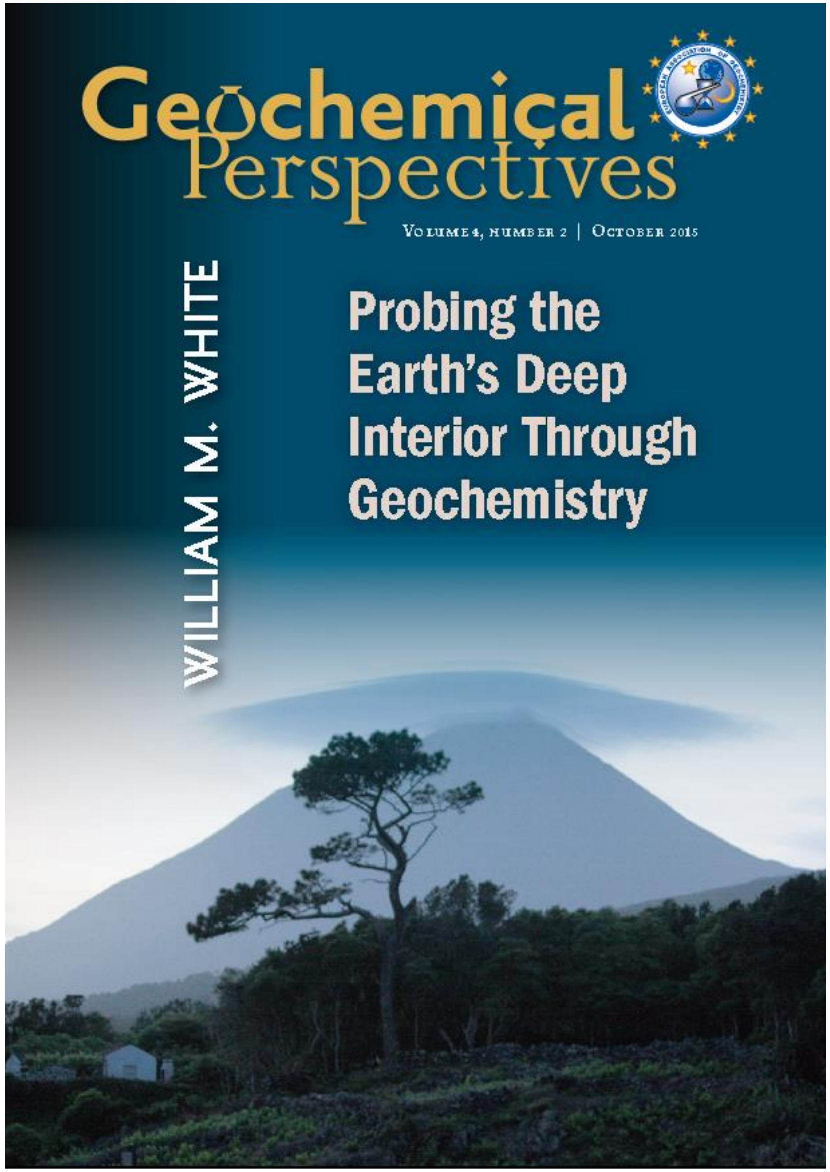
Zindler & Hart, 1986, AREPS



Zindler & Hart, 1986, AREPS



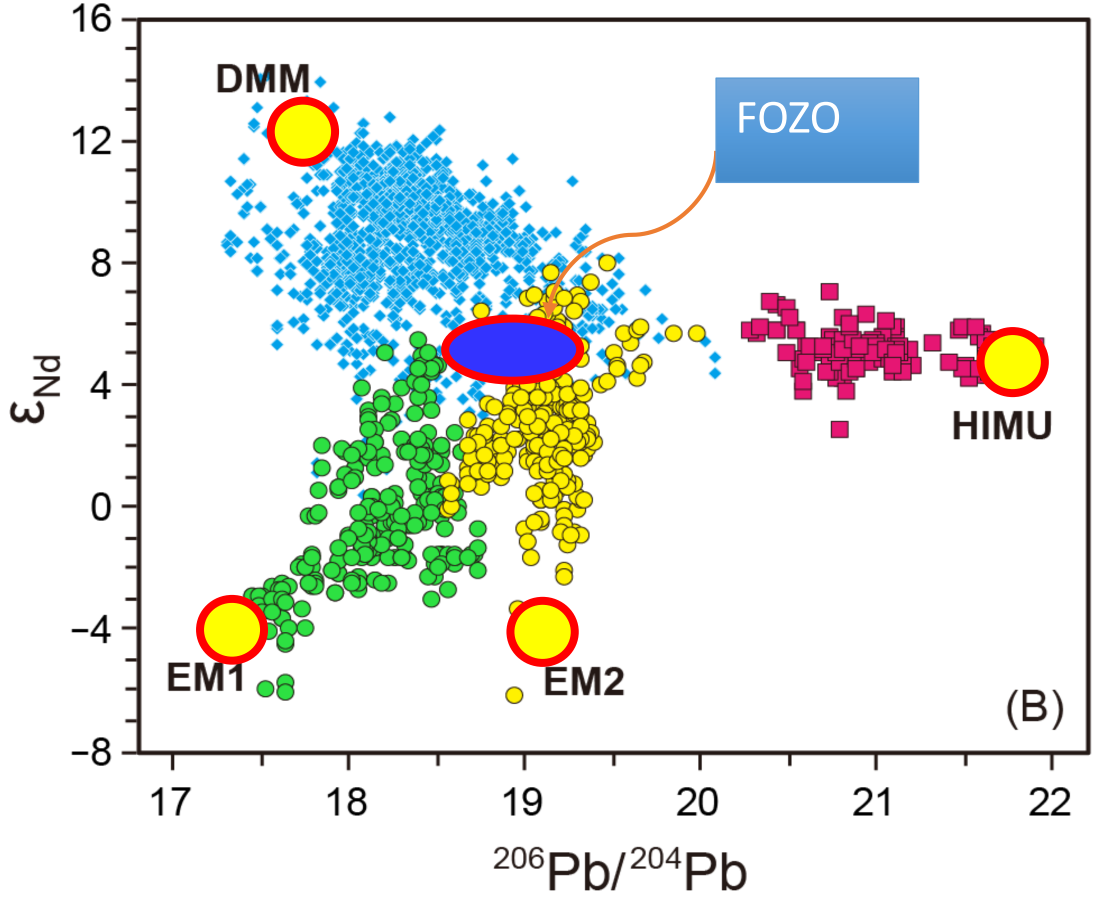
【综述文献，完整版】

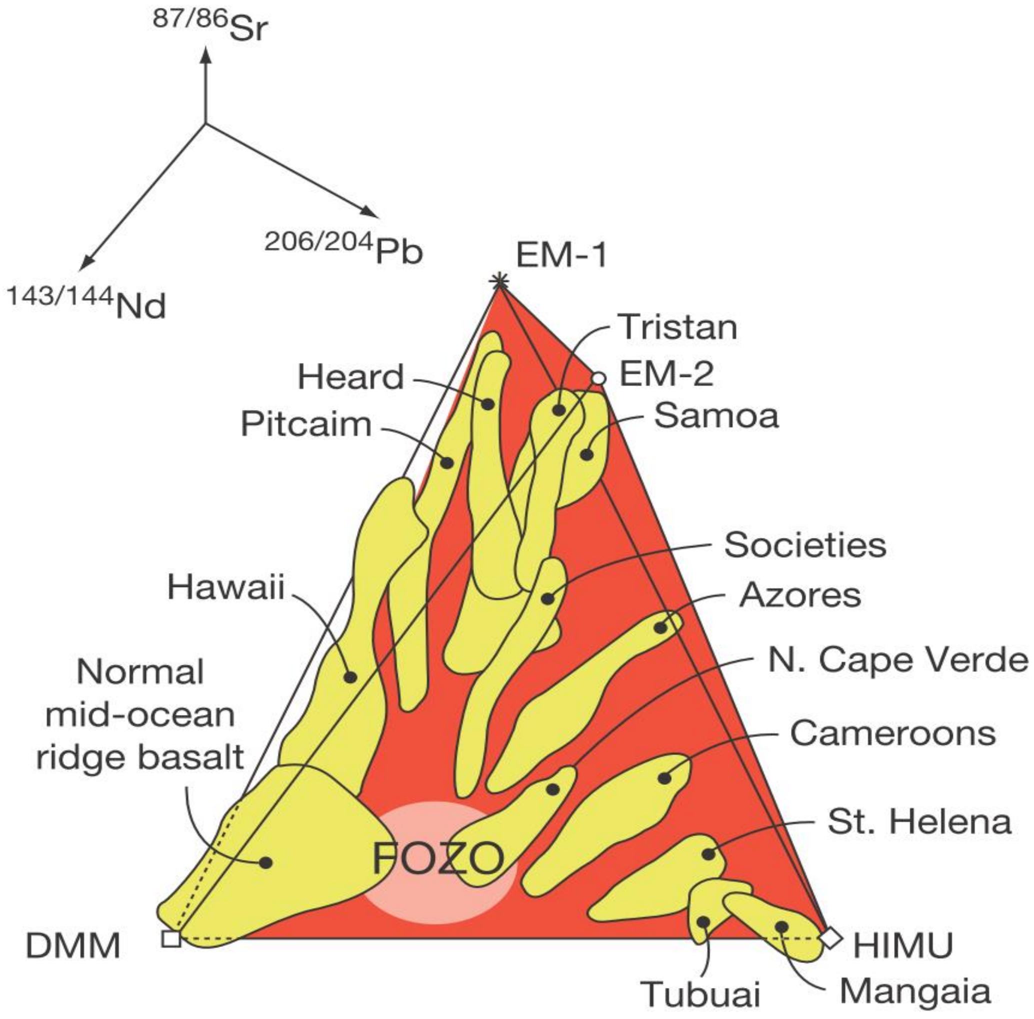


洋岛玄武岩高度不均一的同位素组成

White, 2015, GP

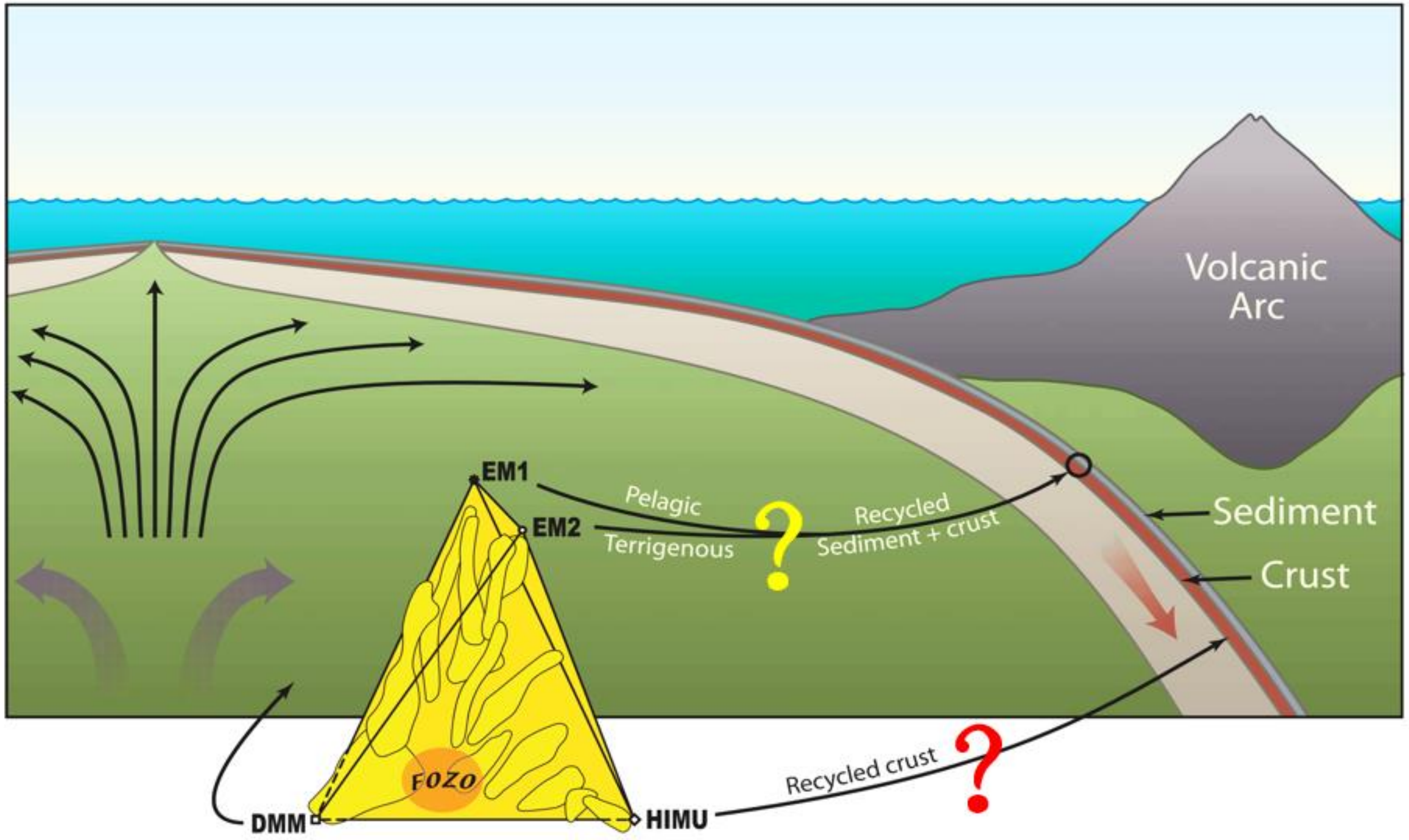
大洋玄武岩同位素组成上的变化：放射成因同位素



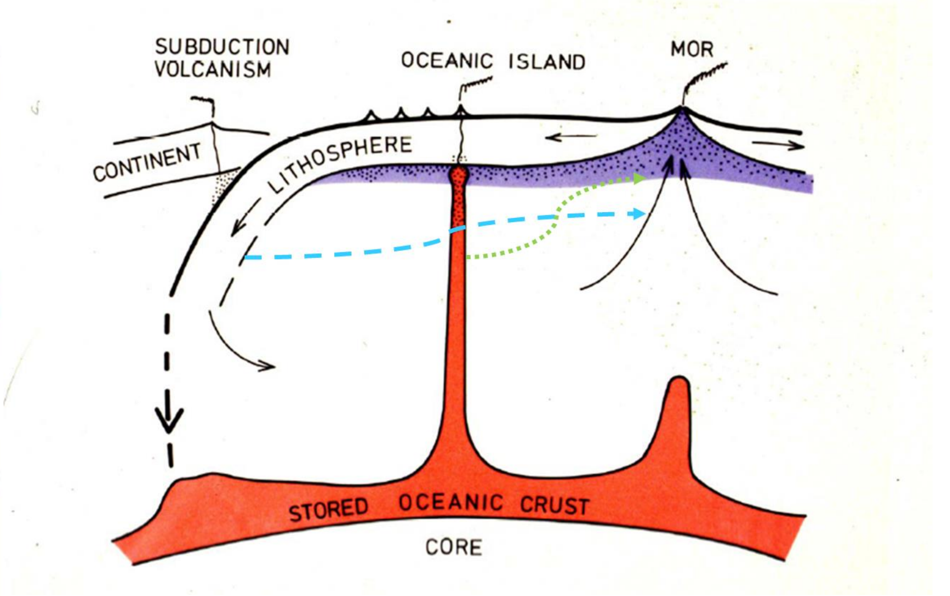


所有洋岛玄武岩的同位素组成可以用各端元不同比例的混合形成

二. 地幔端元属性的争议



Workman et al., 2004

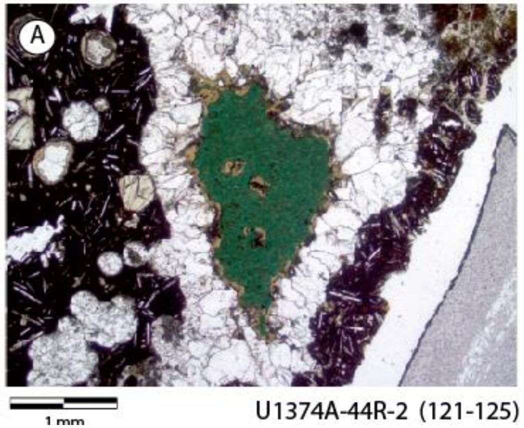


Hofmann & White, 1982, EPSL

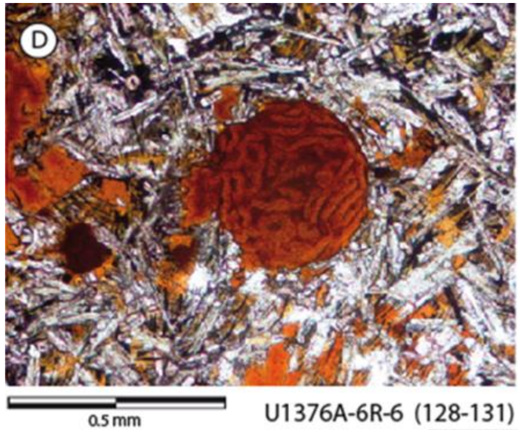
俯冲进入地幔物质的多样性

蚀变的洋壳玄武岩

(IODP 330航次报告)



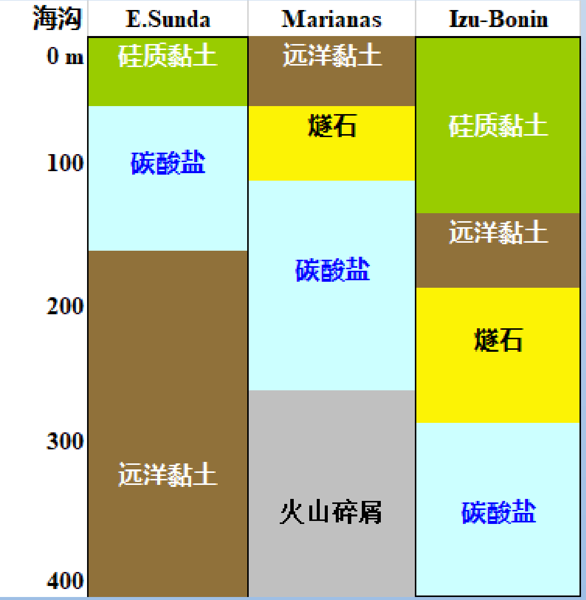
U1374A-44R-2（121-125）

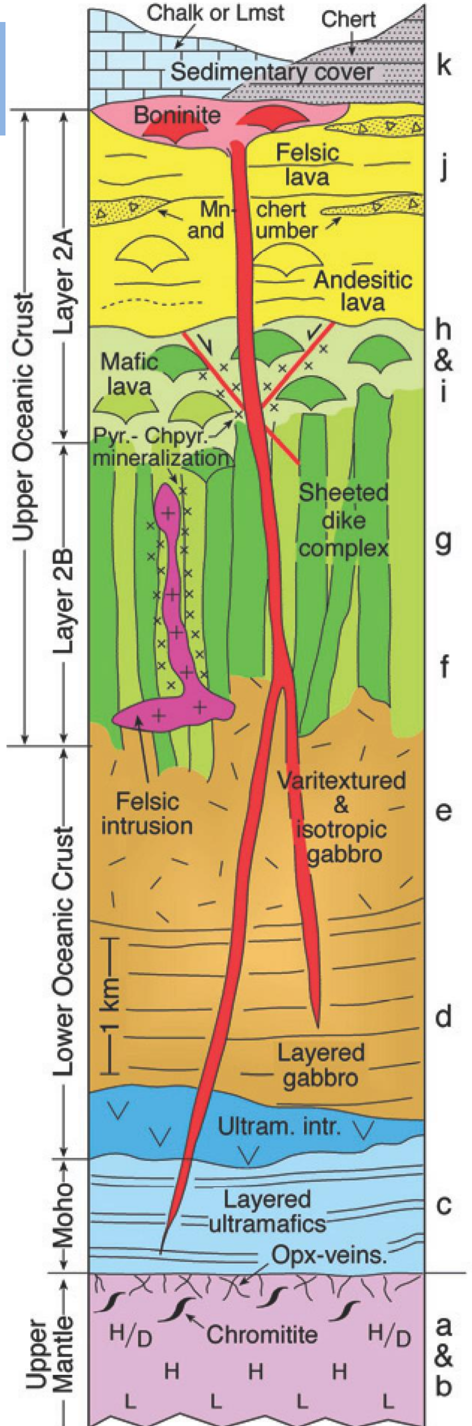


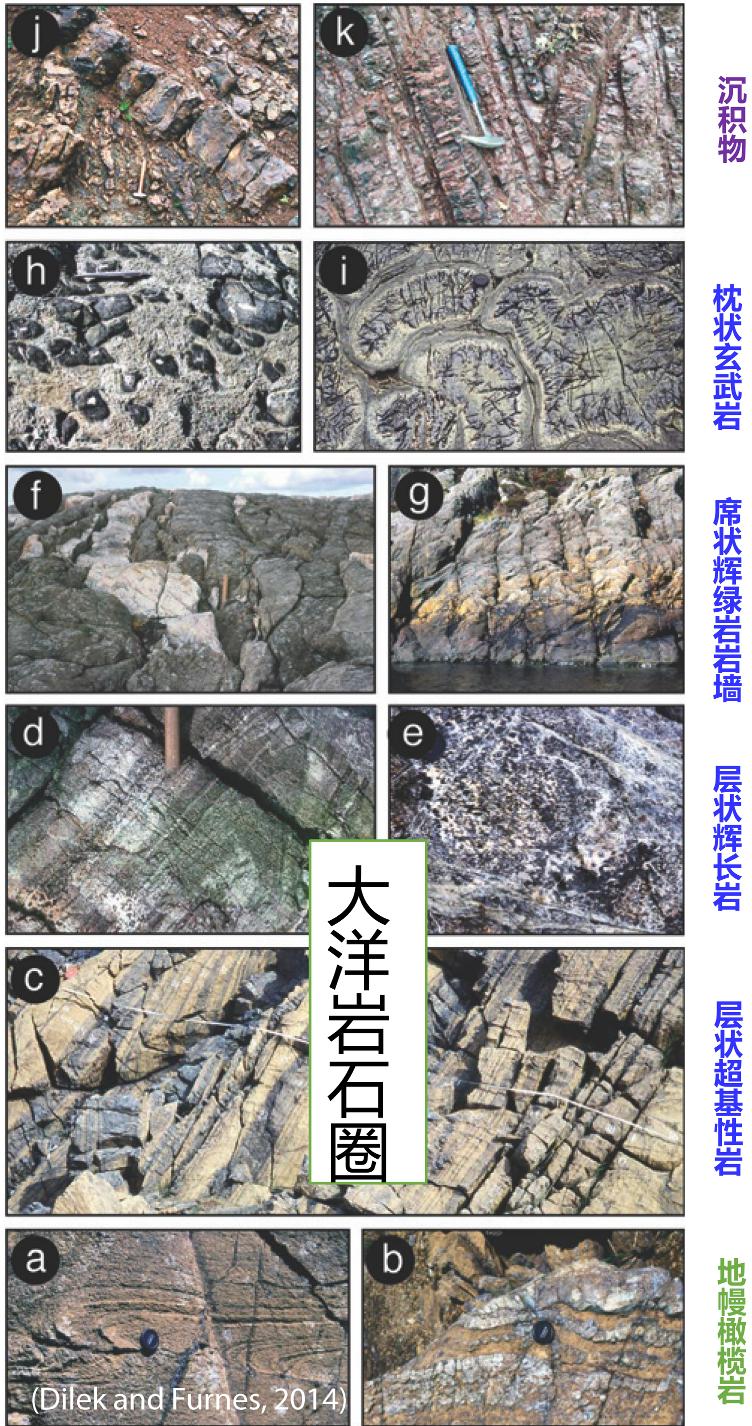
U1376A-6R-6（128-131）

俯冲的沉积物

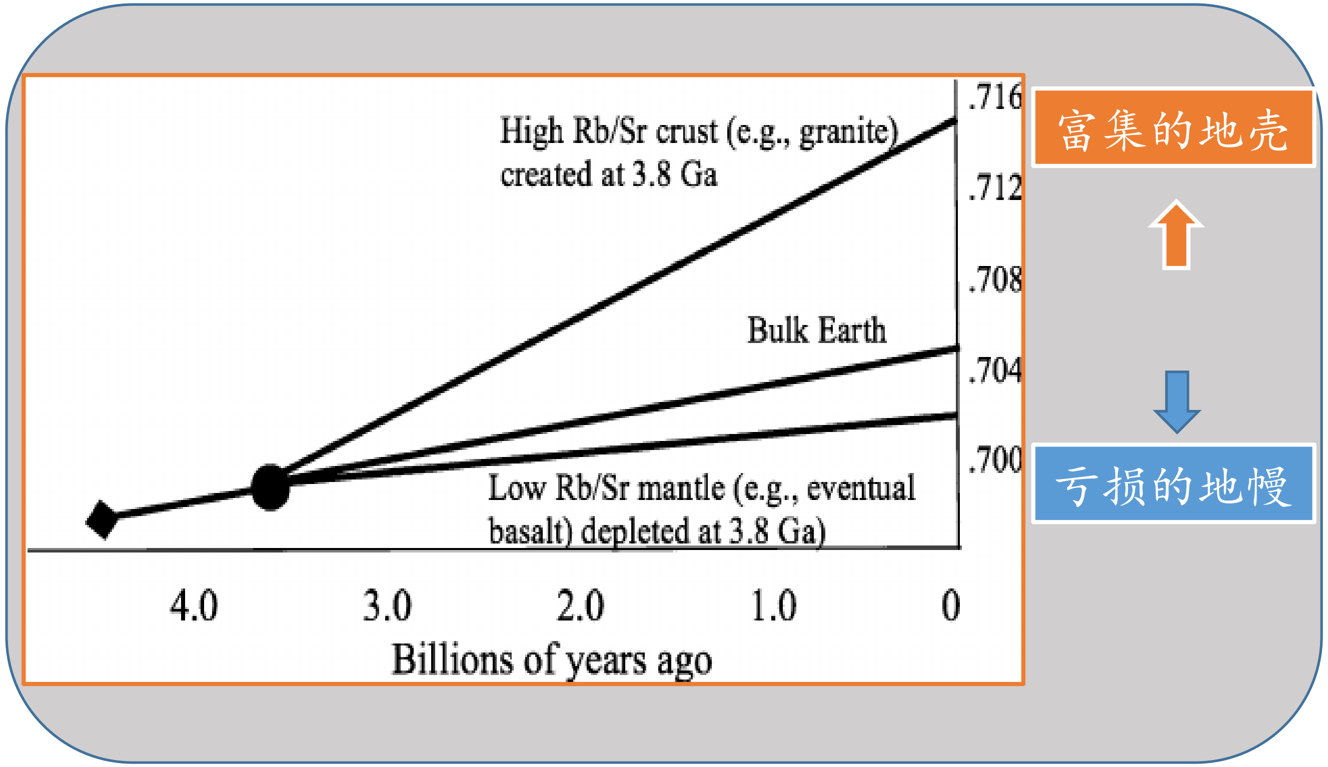
(Plank, 2014)

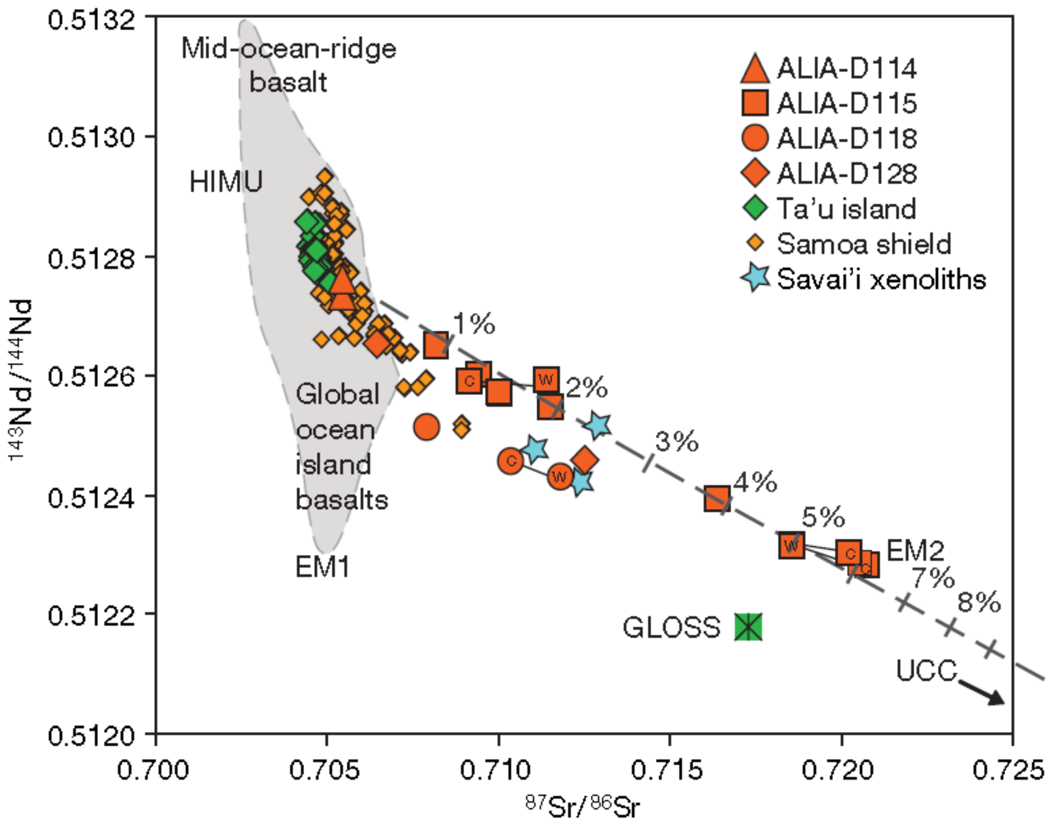






地幔化学不均一性与地幔端元





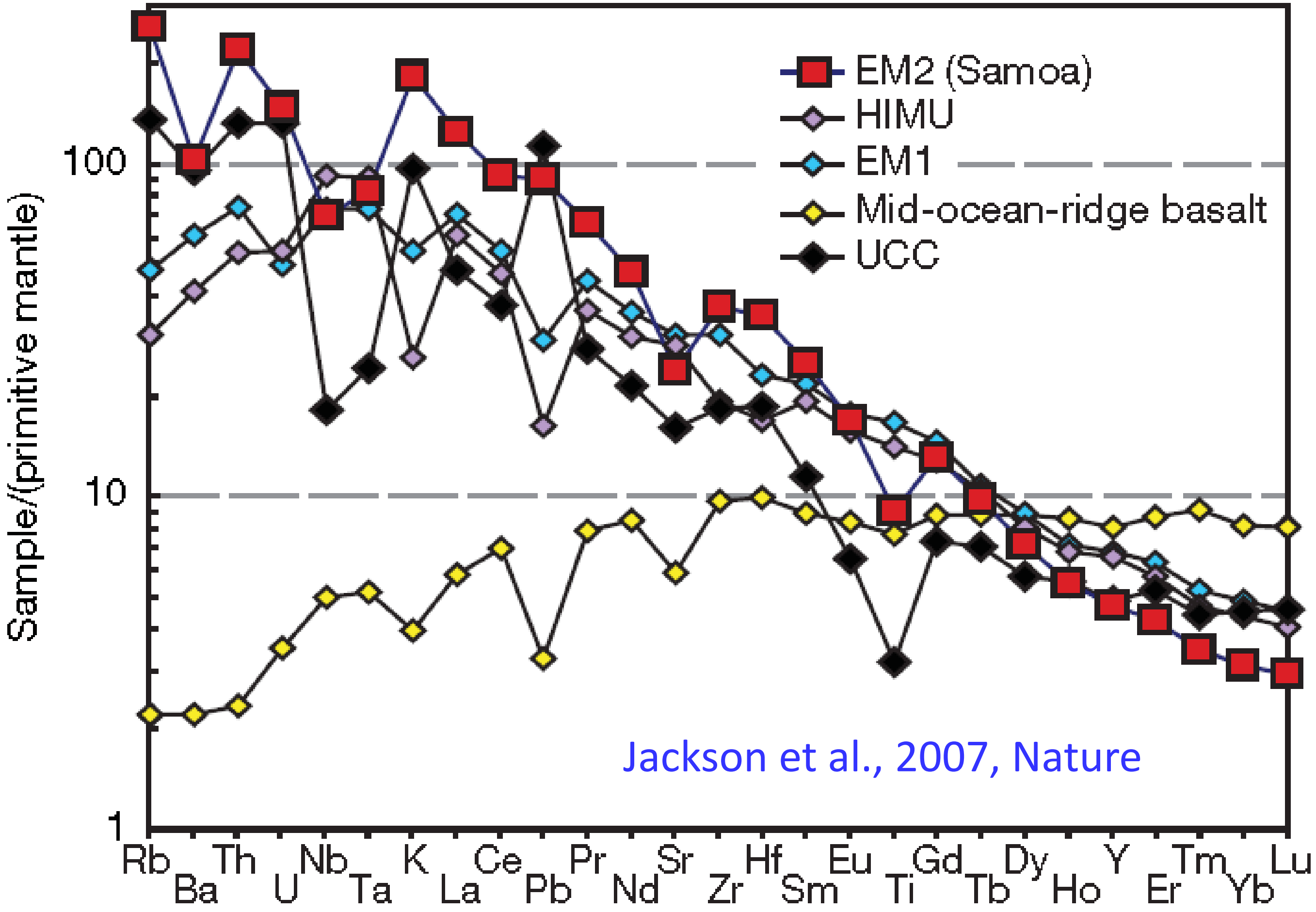
南太平洋萨摩亚群岛

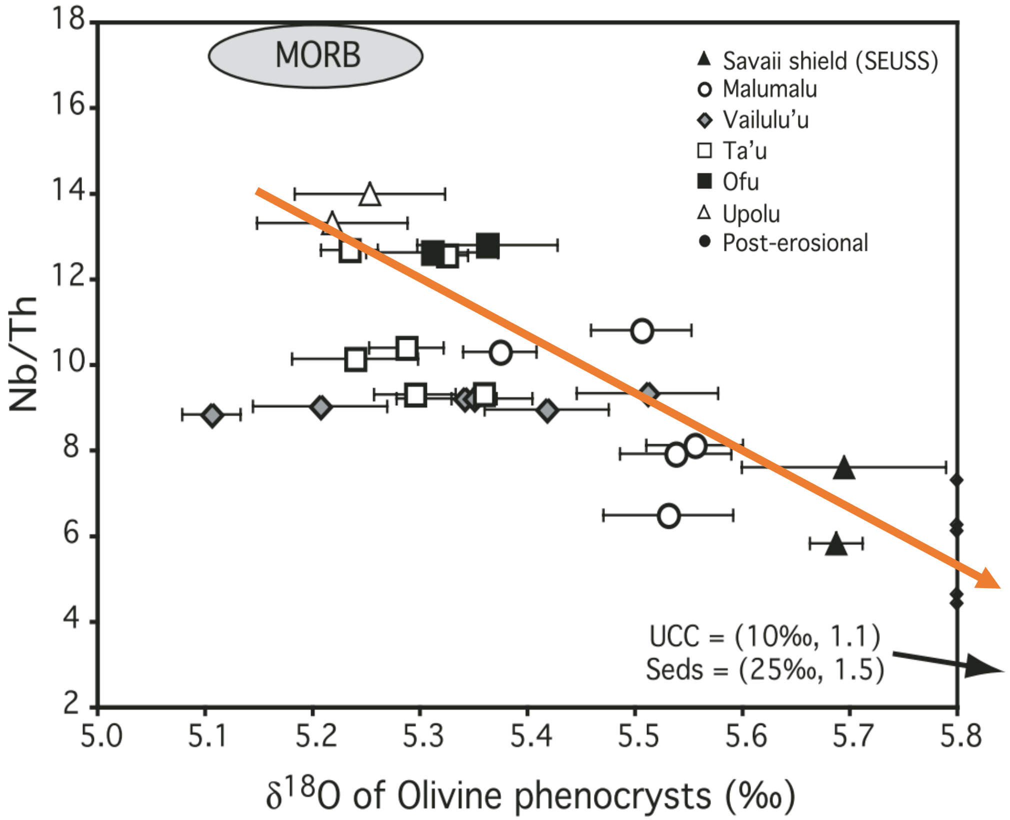
“玄武岩是了解地幔大尺度化学不均一性的理想研究对象”

“富集地幔——地幔中某些位置的同位素组成表现出与大陆地壳相似的特征”

Jackson et al., 2007, Nature

富集地幔de属性：EM2



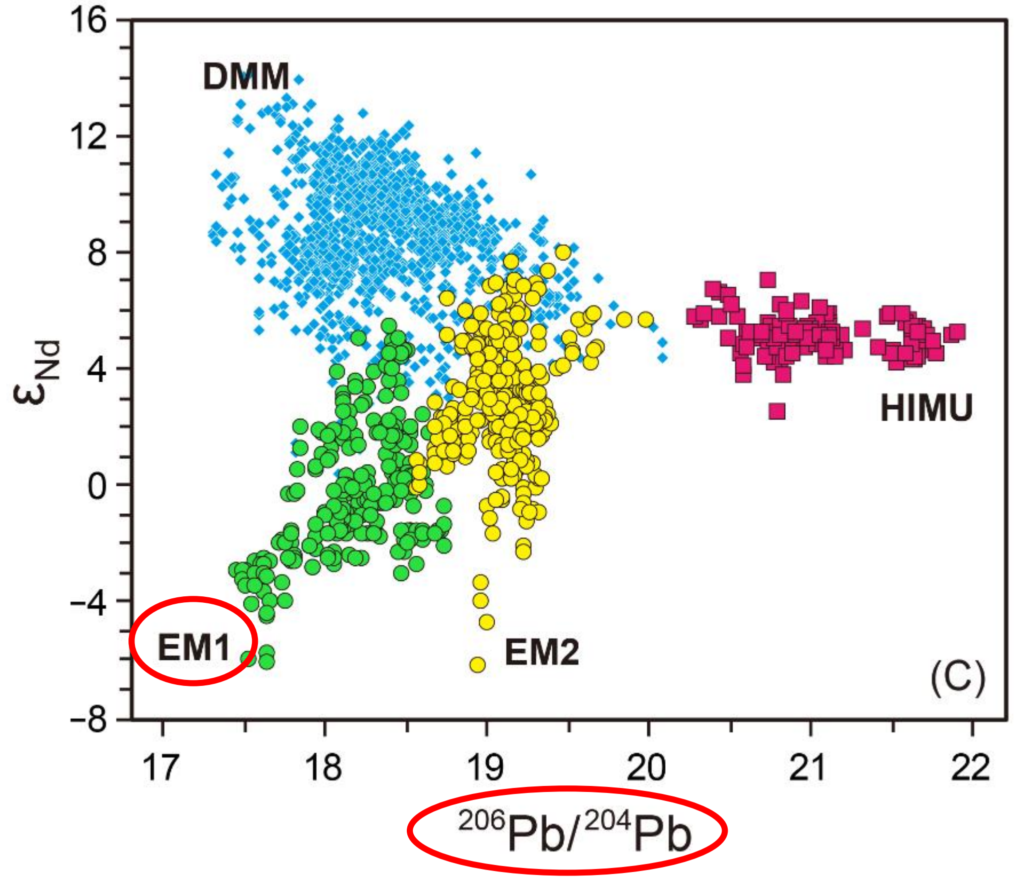


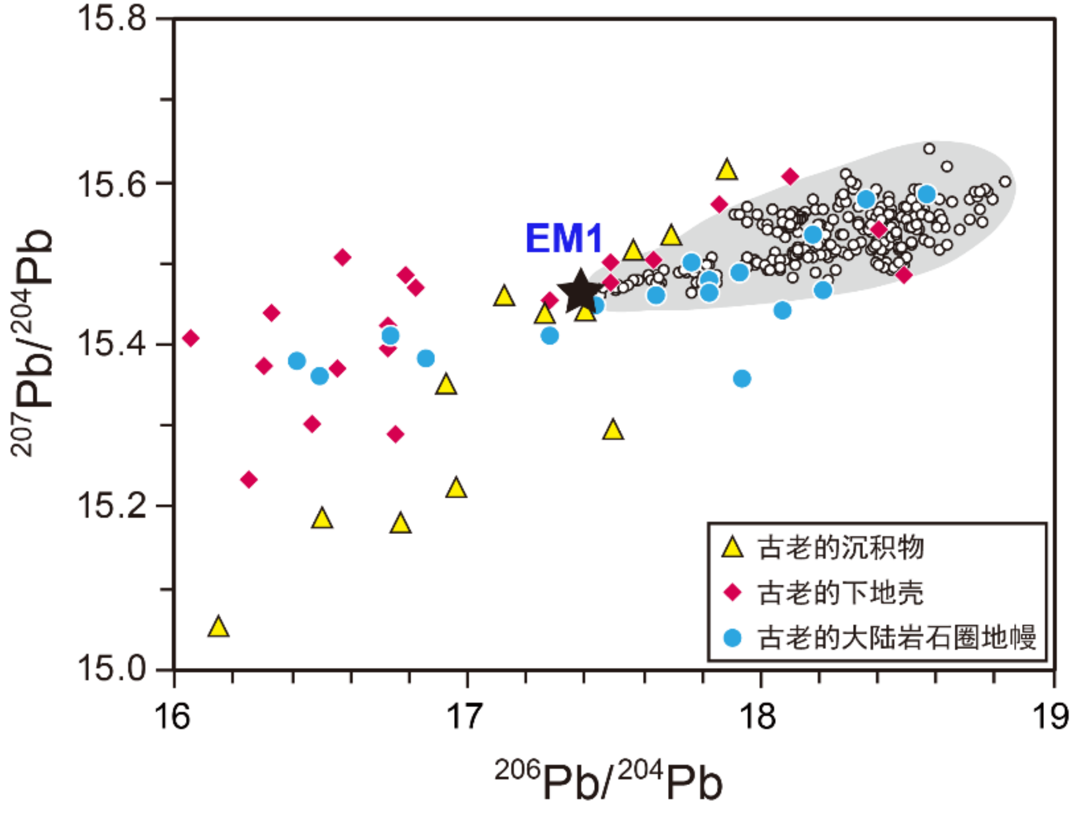
Workman et al., 2008, GGG

EM2的源区为再循环的陆源沉积物！

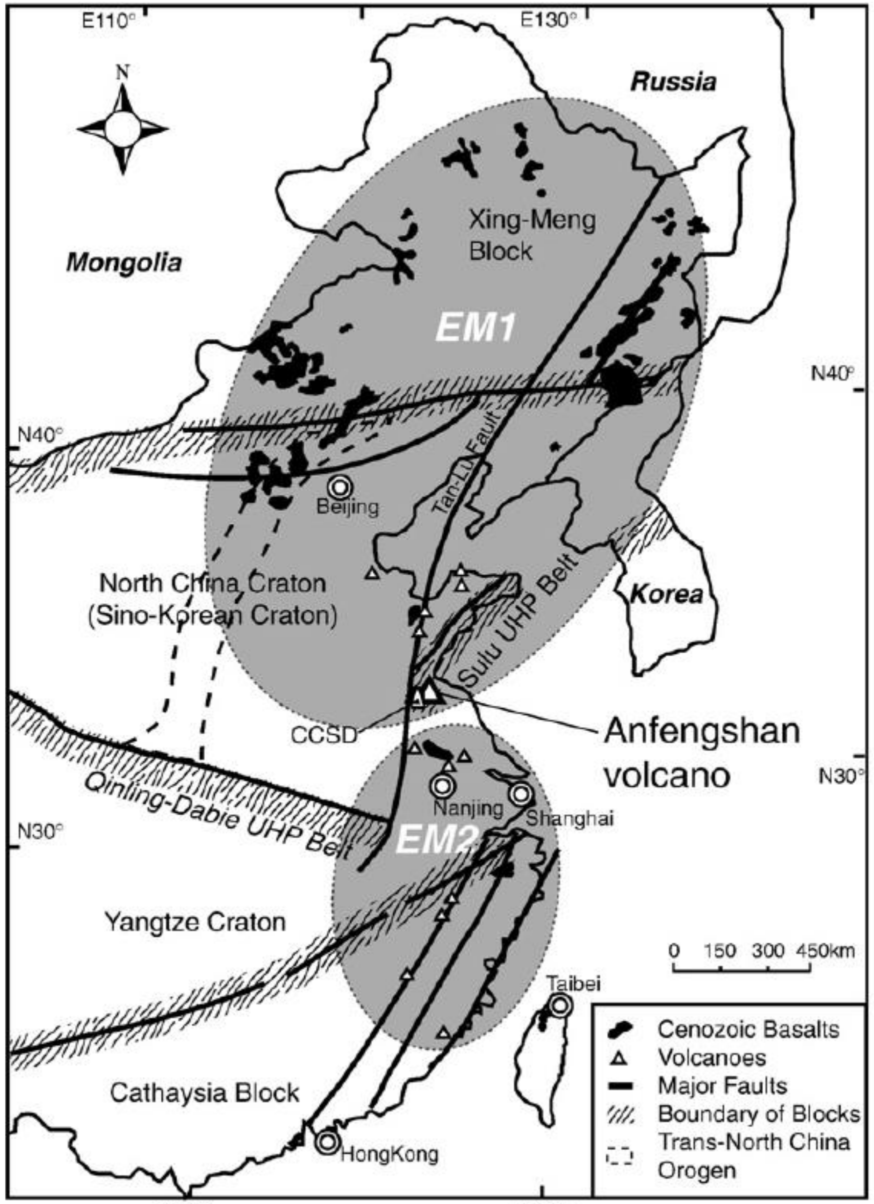
富集地幔de属性：EM1的争议

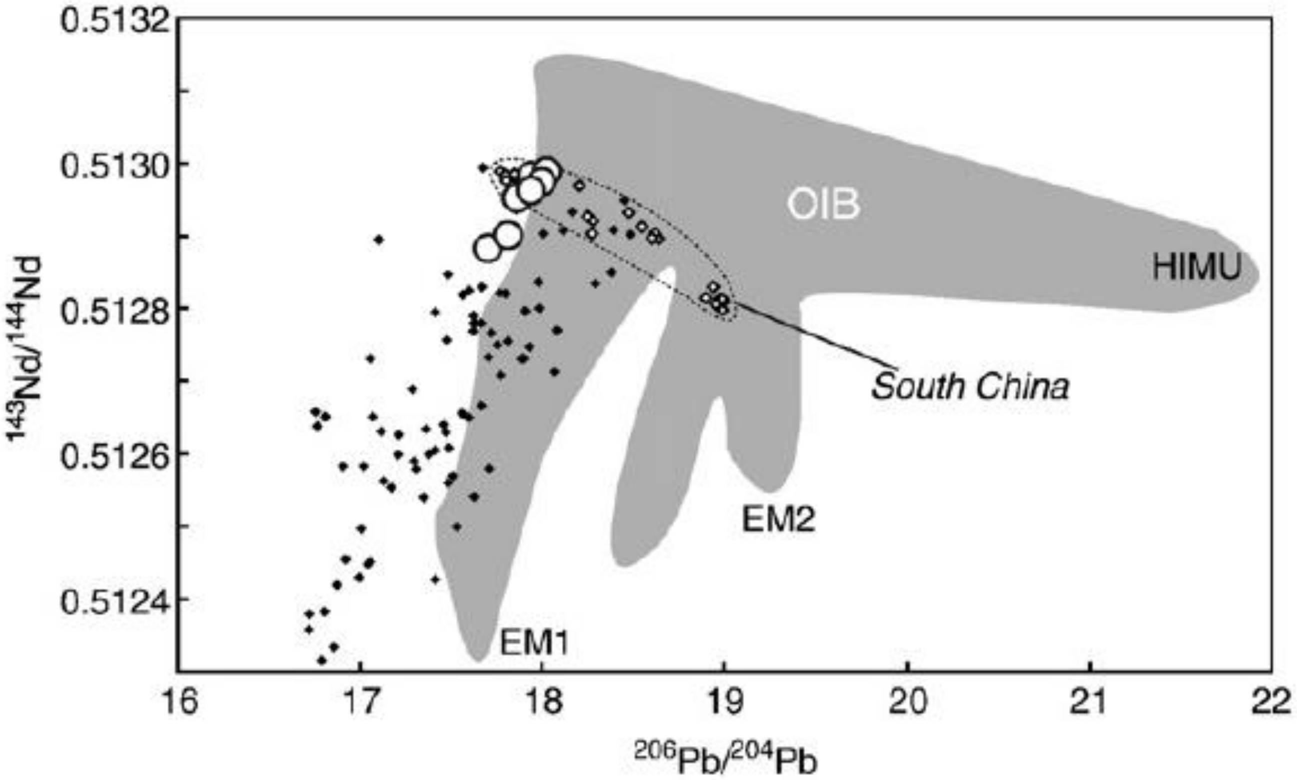
- 再循环古老沉积物? (e.g., Woodhead et al., 1989; Eisele et al., 2002; Delavault et al., 2016)
- 拆沉的古老大陆岩石圈地幔? (e.g., McKenzie and O'Nions, 1983; Gibson et al., 2005)
- 再循环古老大陆下地壳? (e.g., Hanan et al., 2004; Willbold and Stracke, 2006, 2010)



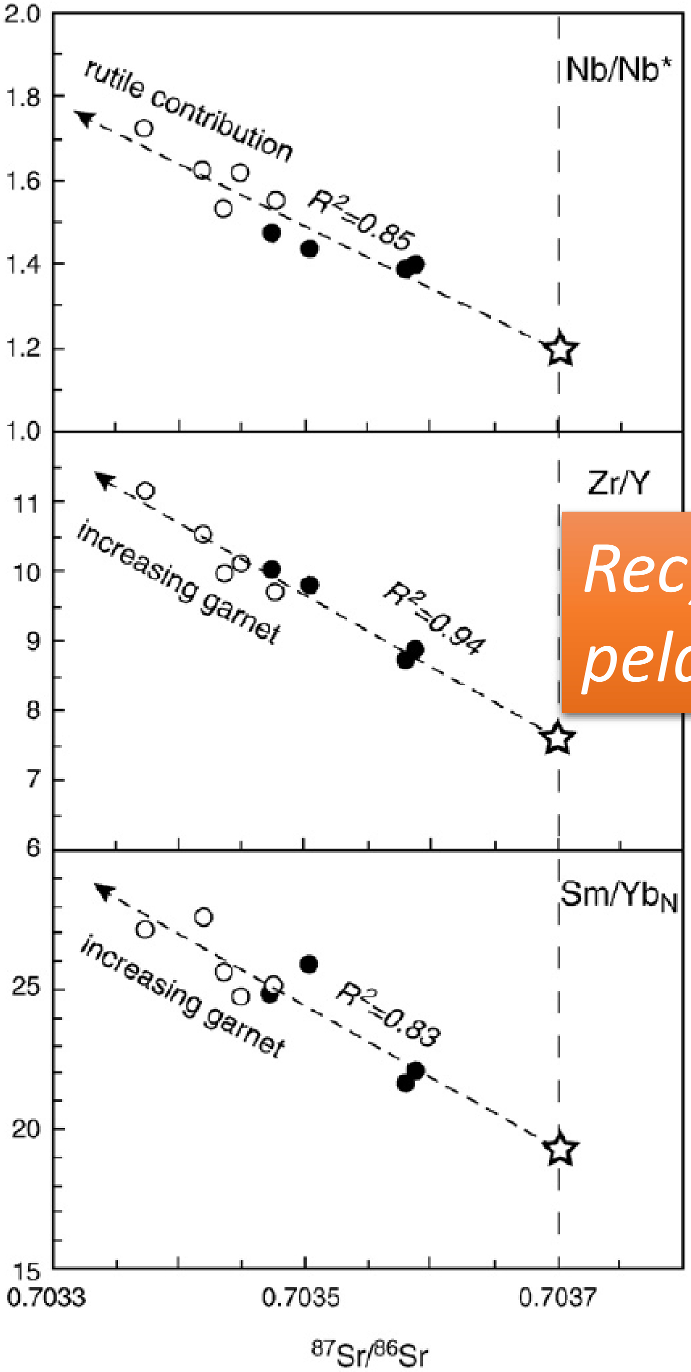


以中国东部新生代玄武岩为例——苏鲁造山带中的安峰山

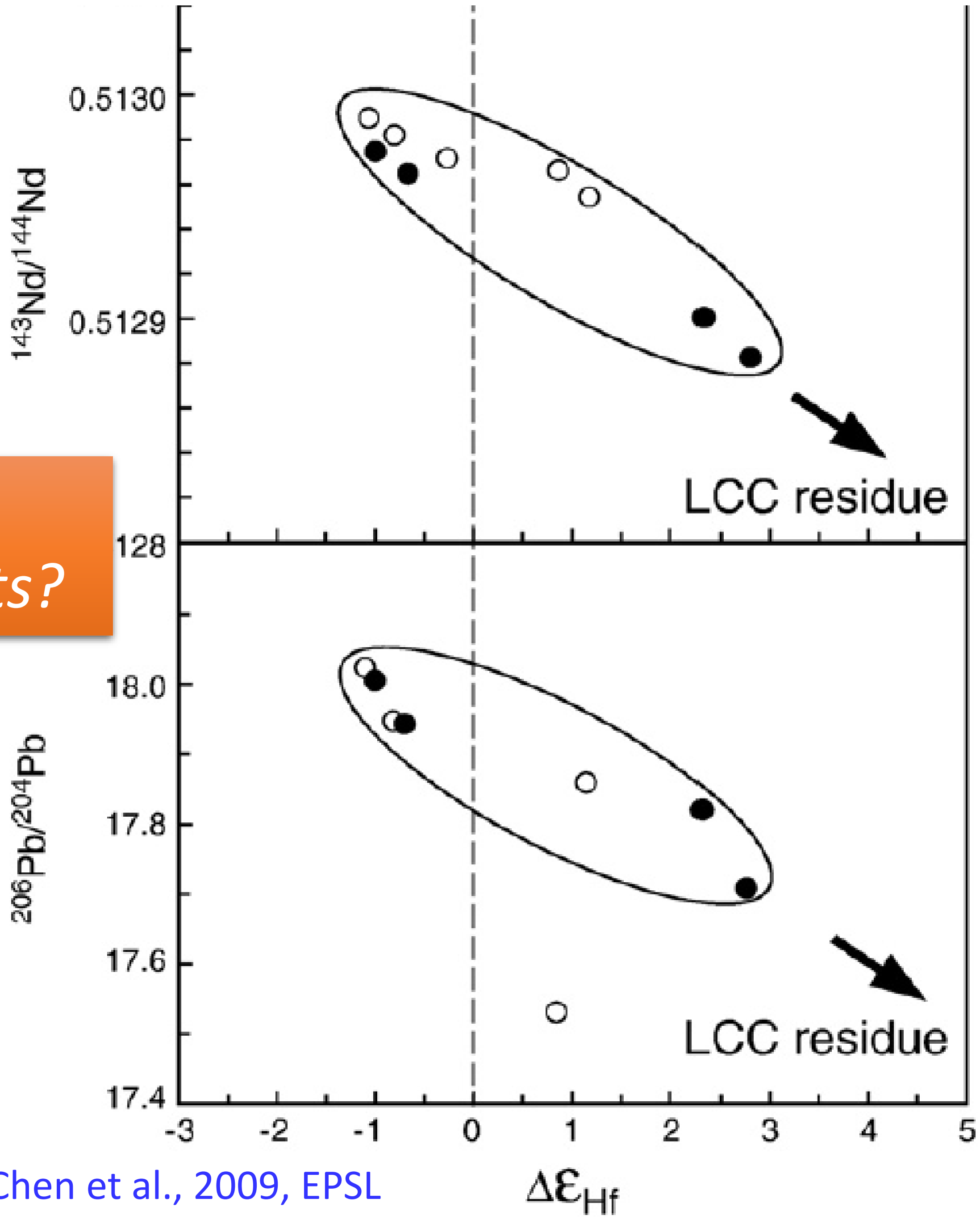




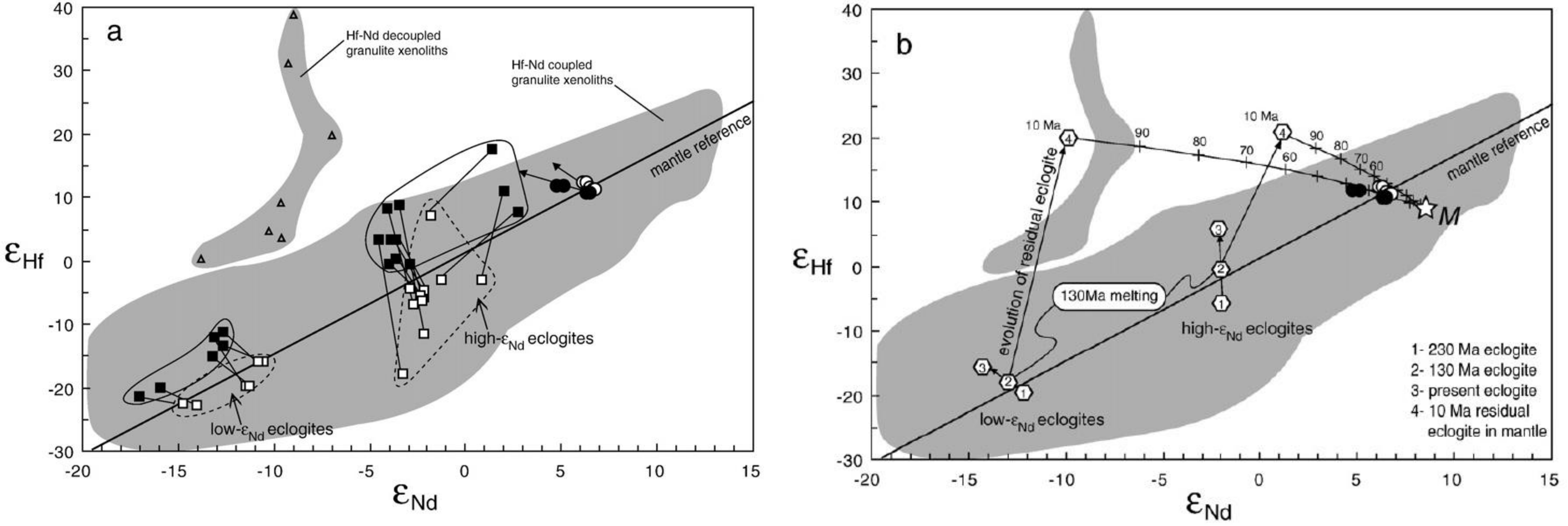
Chen et al., 2009, EPSL



Recycled LCC or pelagic sediments?



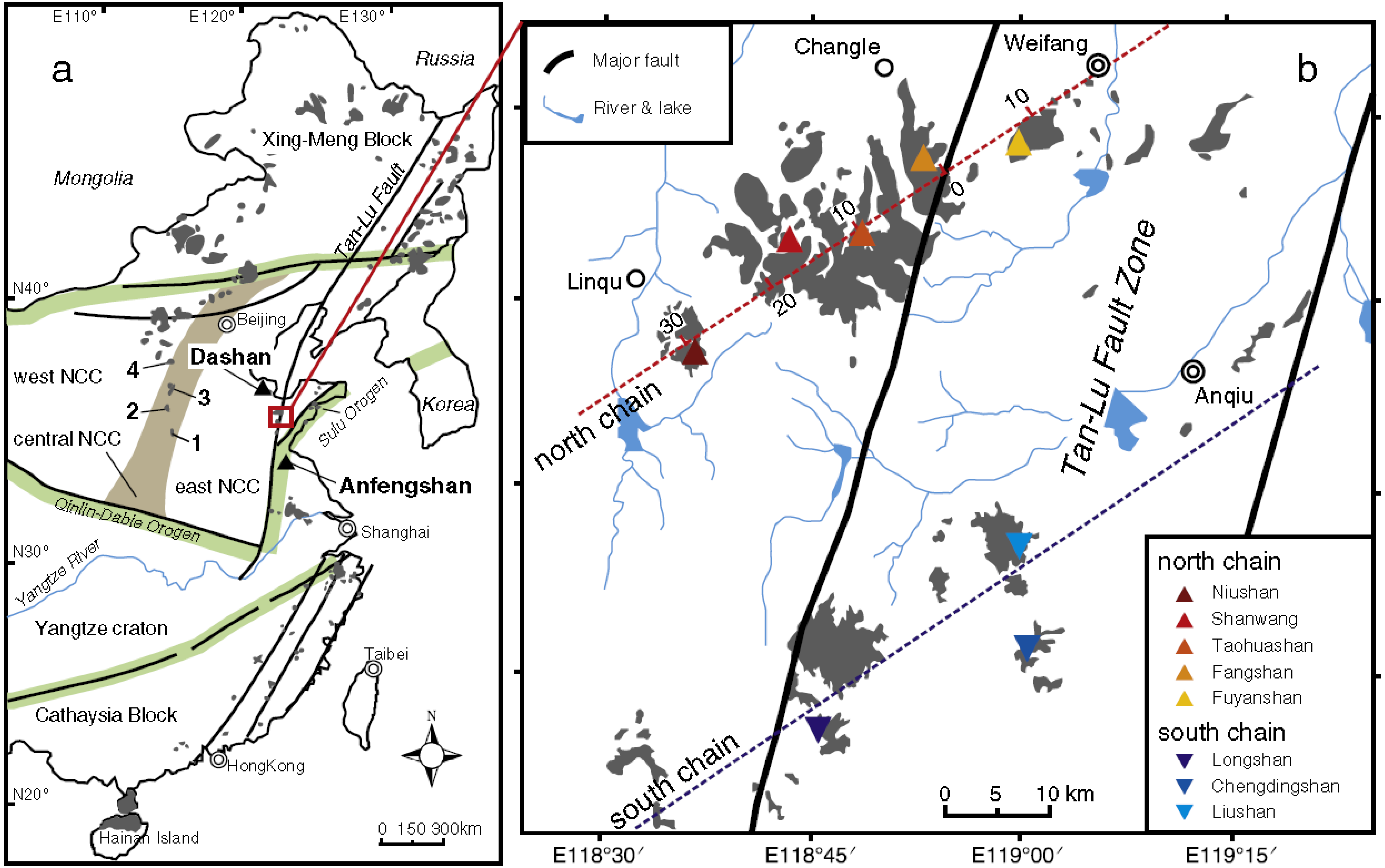
Chen et al., 2009, EPSL

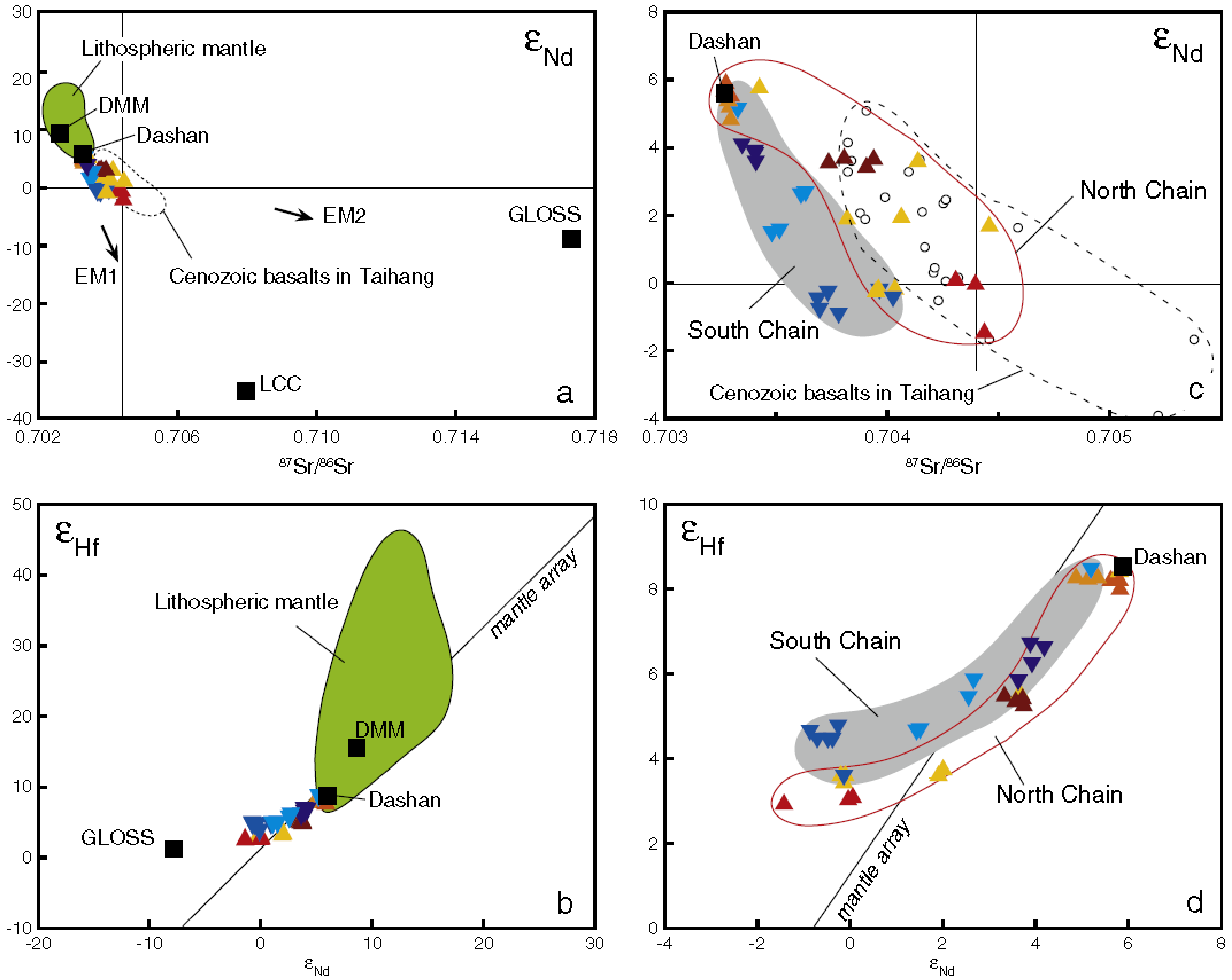


Recycled LCC or pelagic sediments?

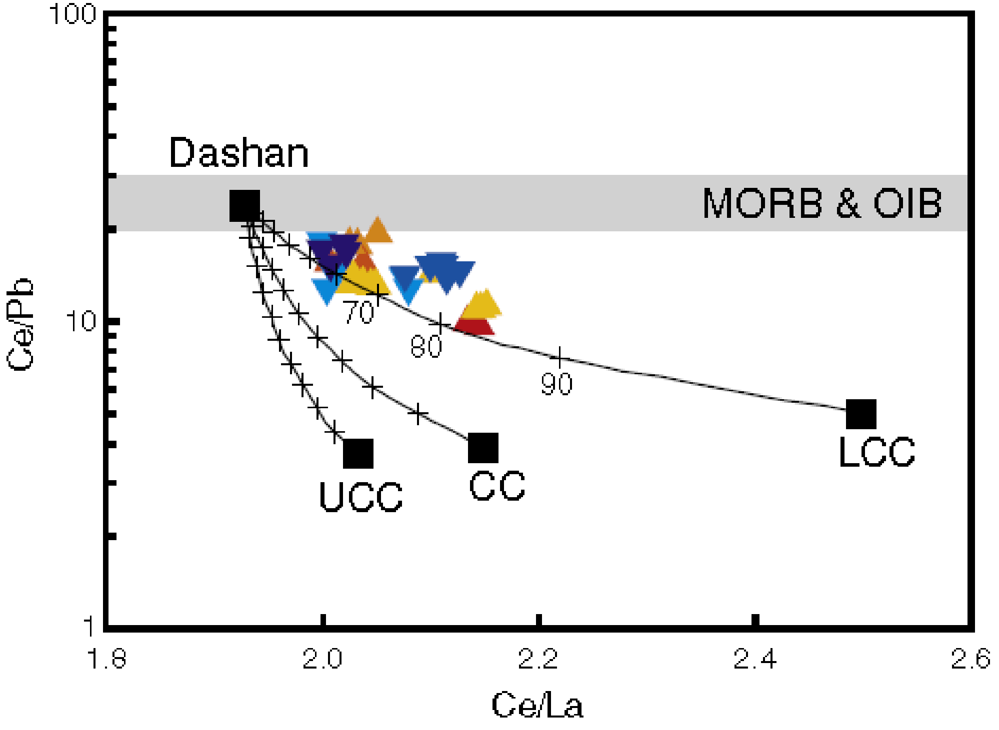
Chen et al., 2009, EPSL

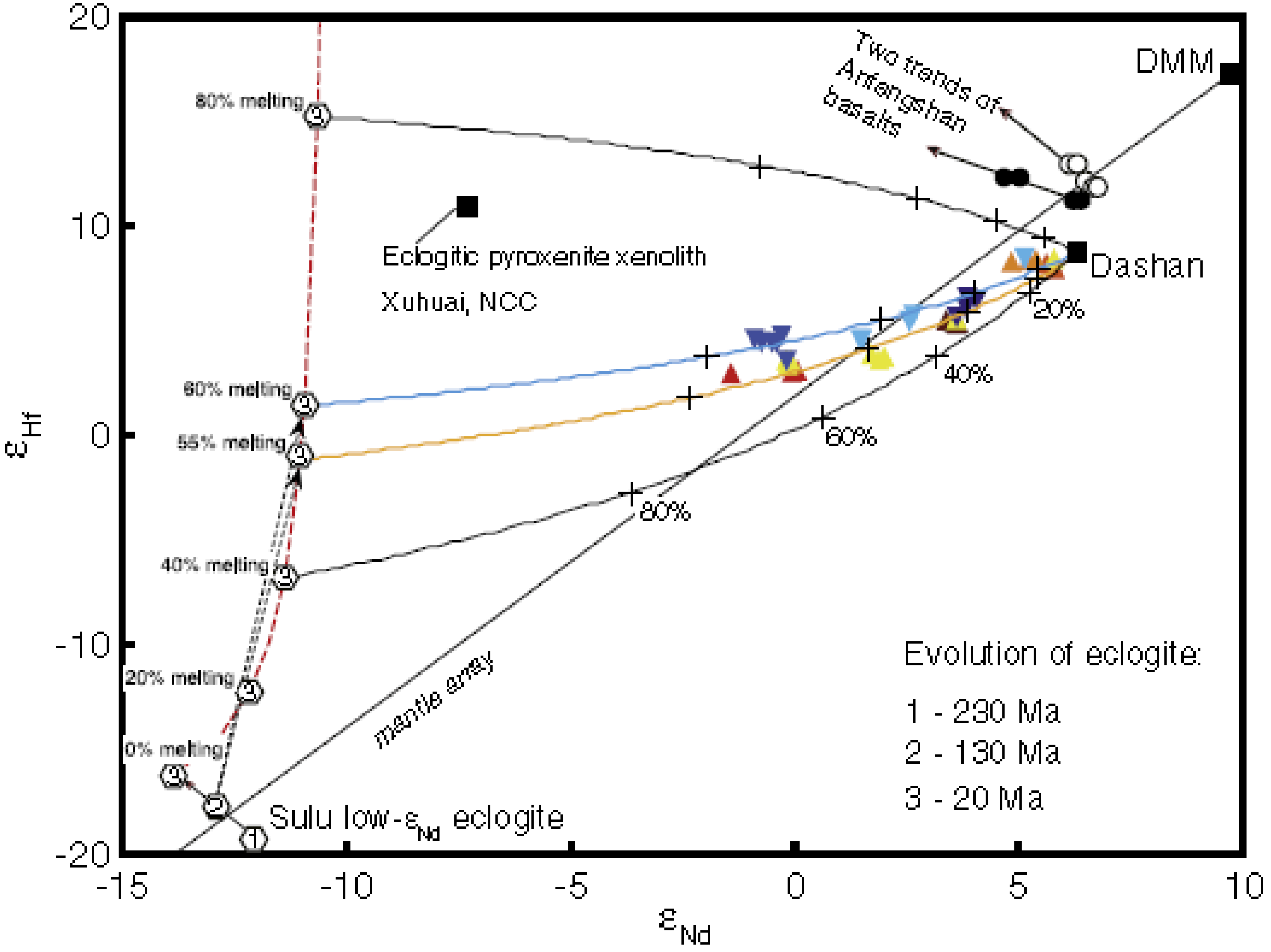
以中国东部新生代玄武岩为例——鲁西的双链





Zeng et al., 2011, EPSL





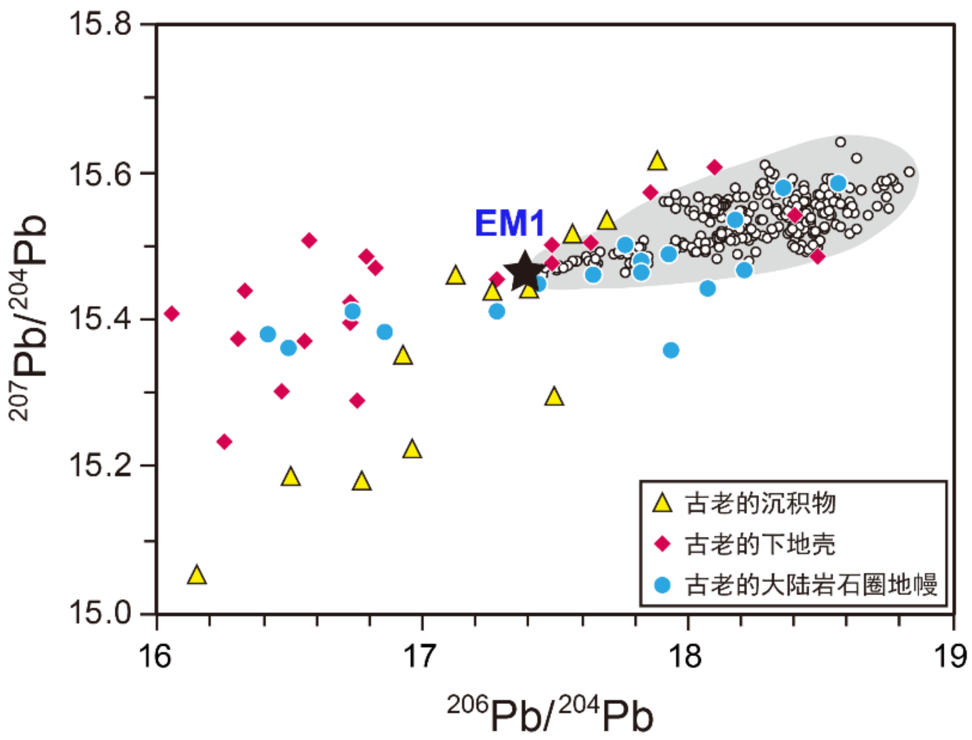
Recycled LCC or pelagic sediments?

Zeng et al., 2011, EPSL

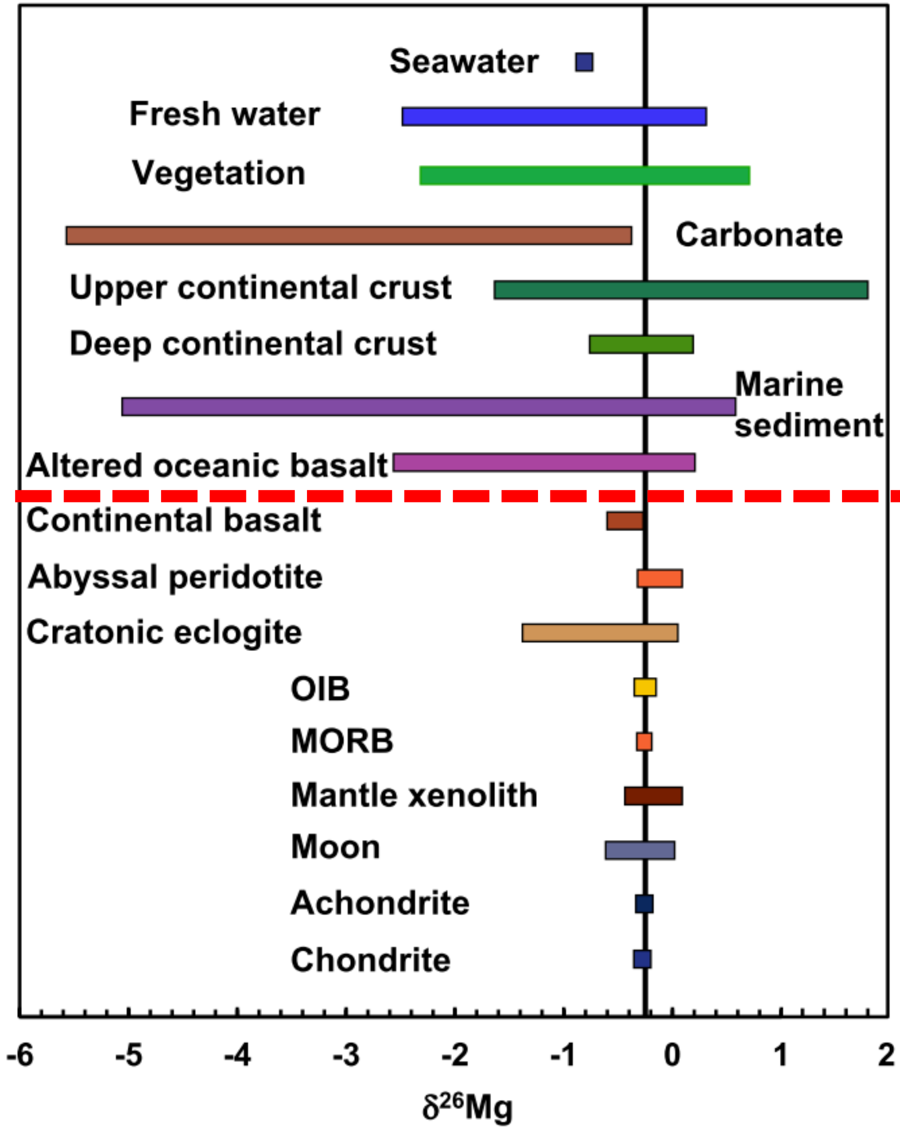
小结

放射成因同位素无法区别Recycled LCC/sediments:

- 两者都具有大陆地壳物质的基本特征；
- 两者都经历了脱水过程。

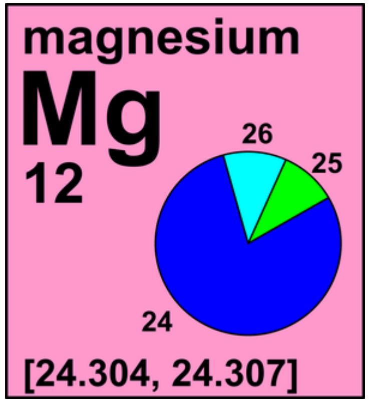


三．Mg稳定同位素示踪地幔端元的属性



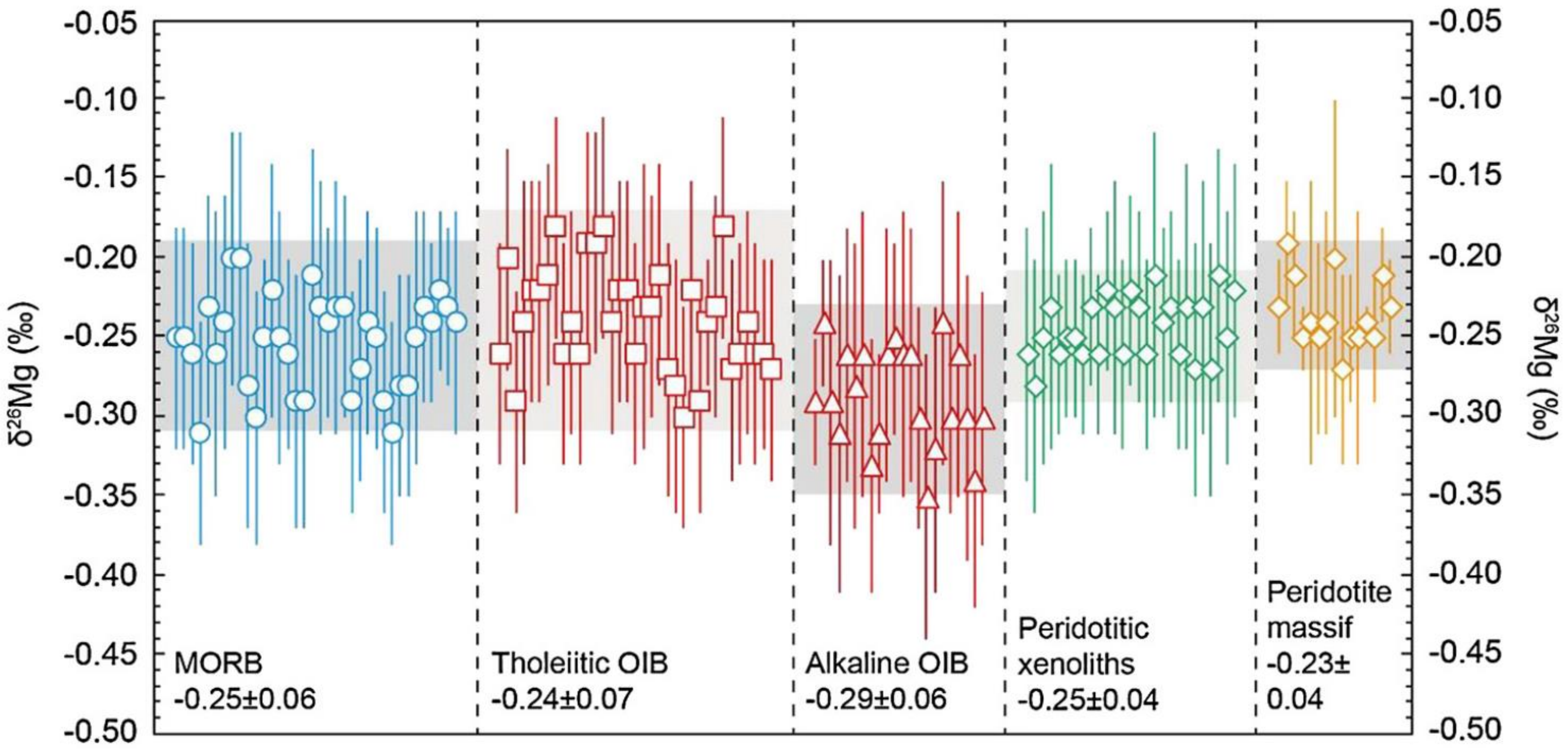
Low temperature

High temperature



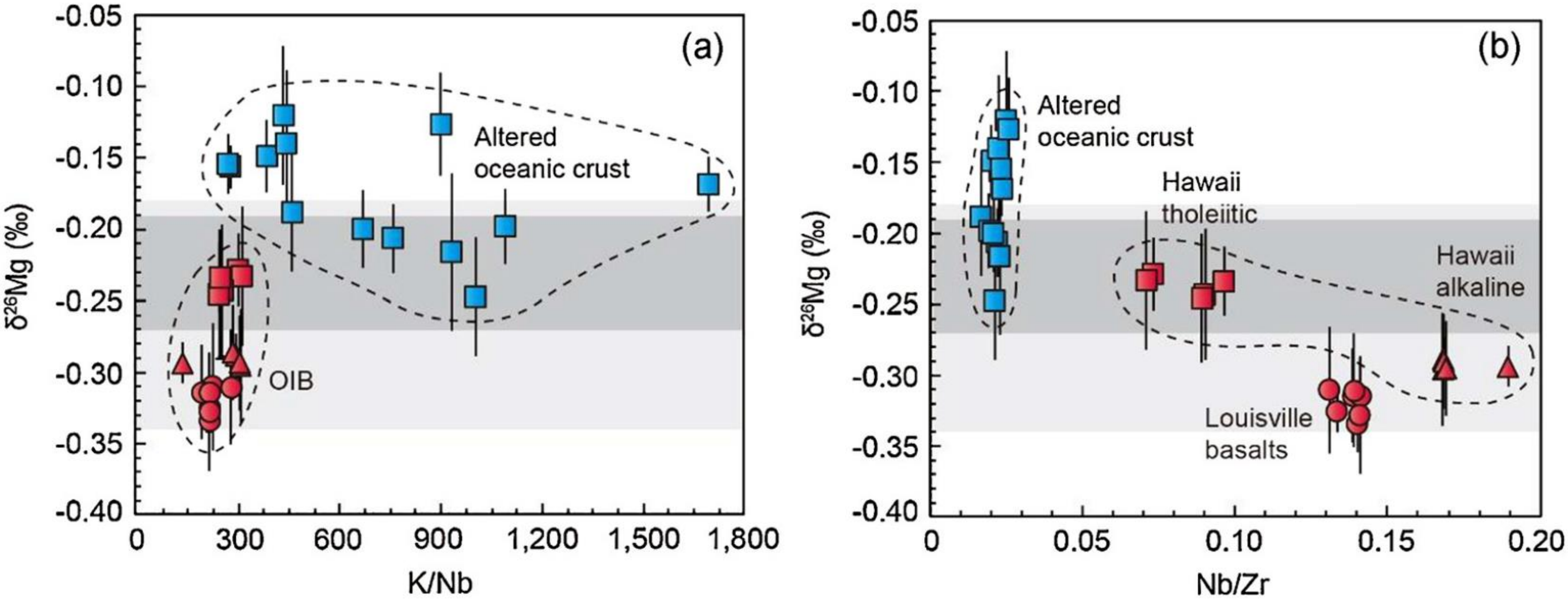
Teng, 2017, RMG

统计意义上OIB里的碱性玄武岩比拉斑玄武岩Mg同位素要轻一点



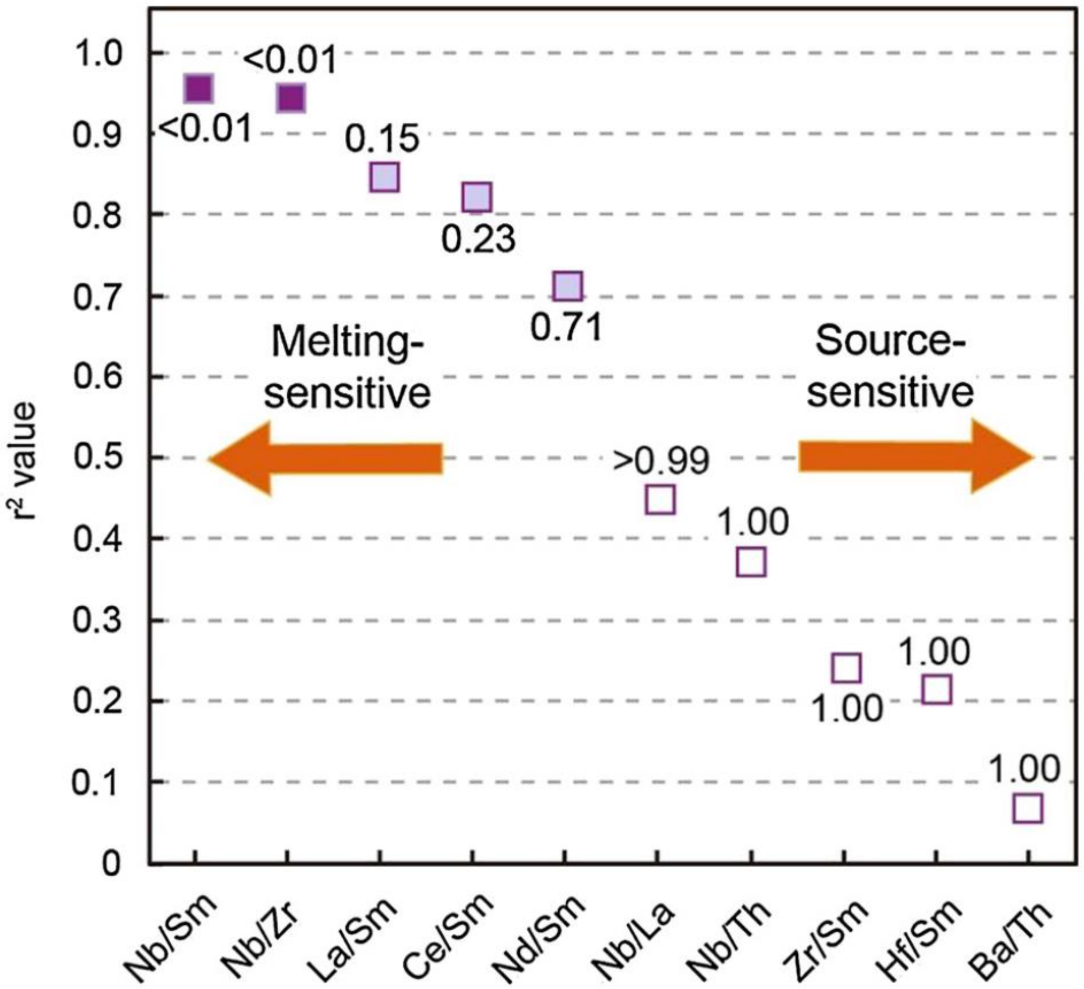
Zhong et al., 2017

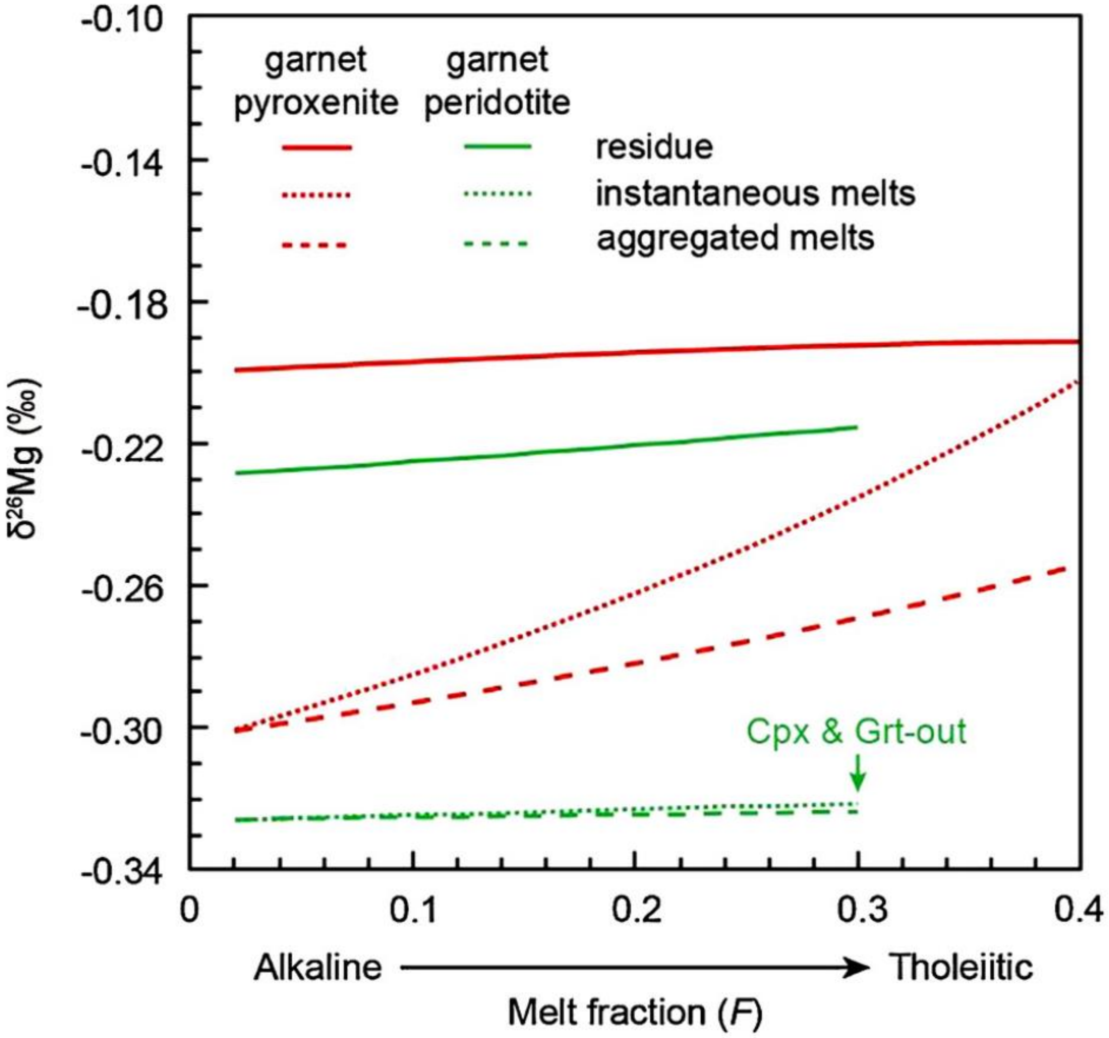
夏威夷的例子



Zhong et al., 2017

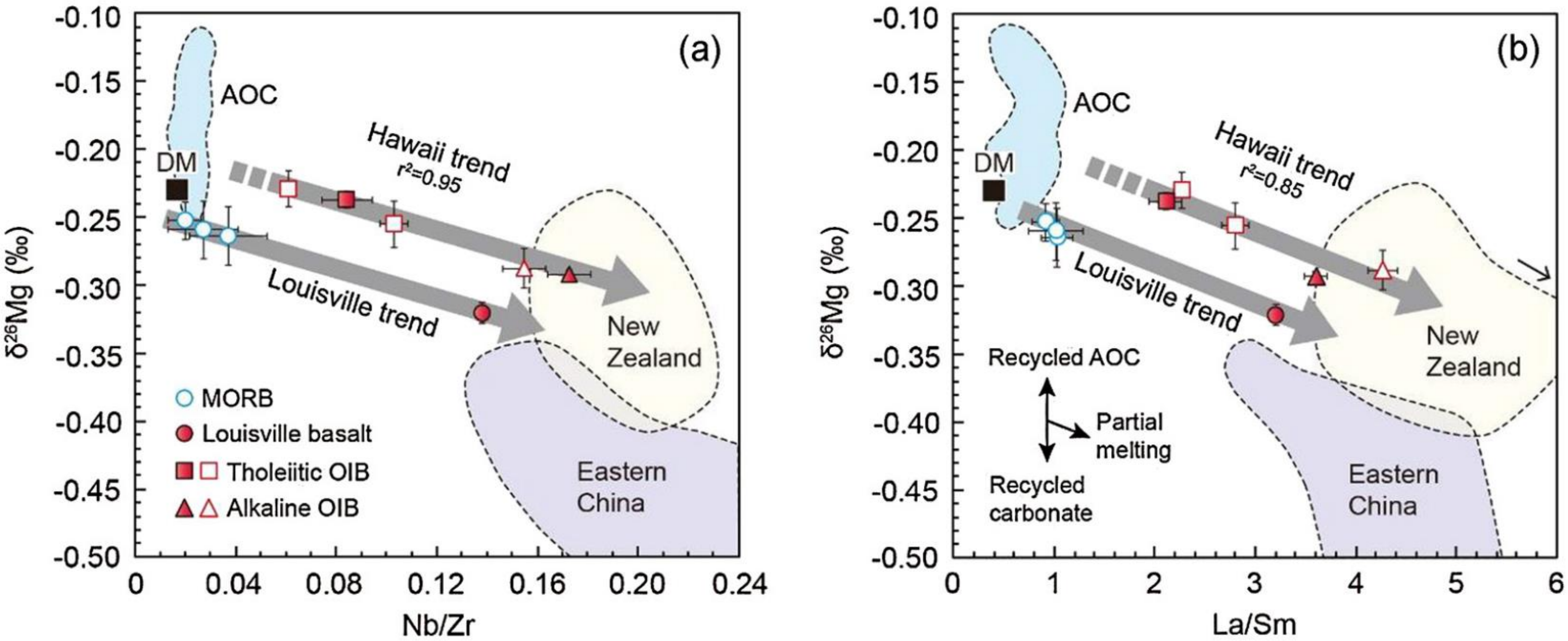
部分熔融的影响





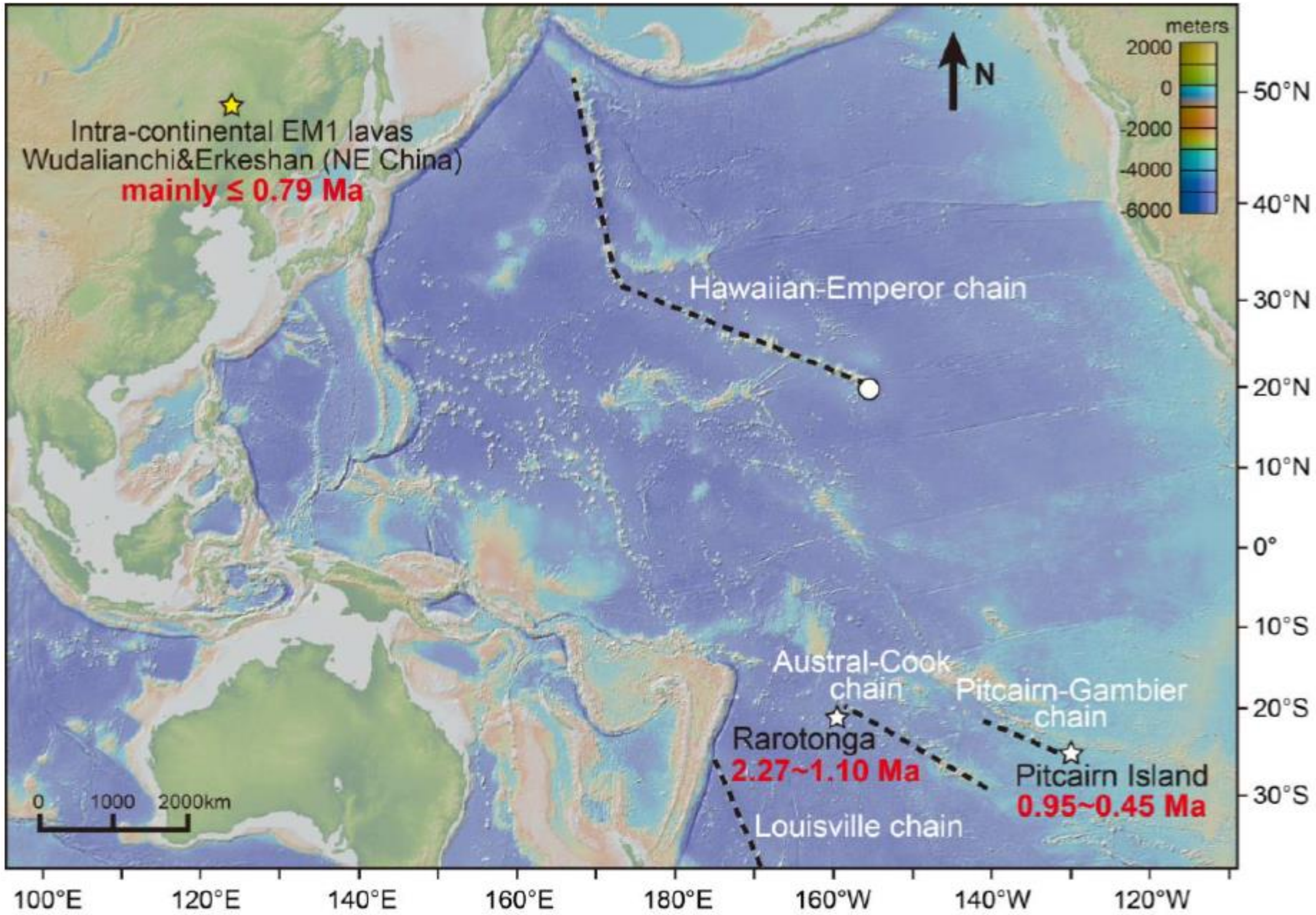
Zhong et al., 2017

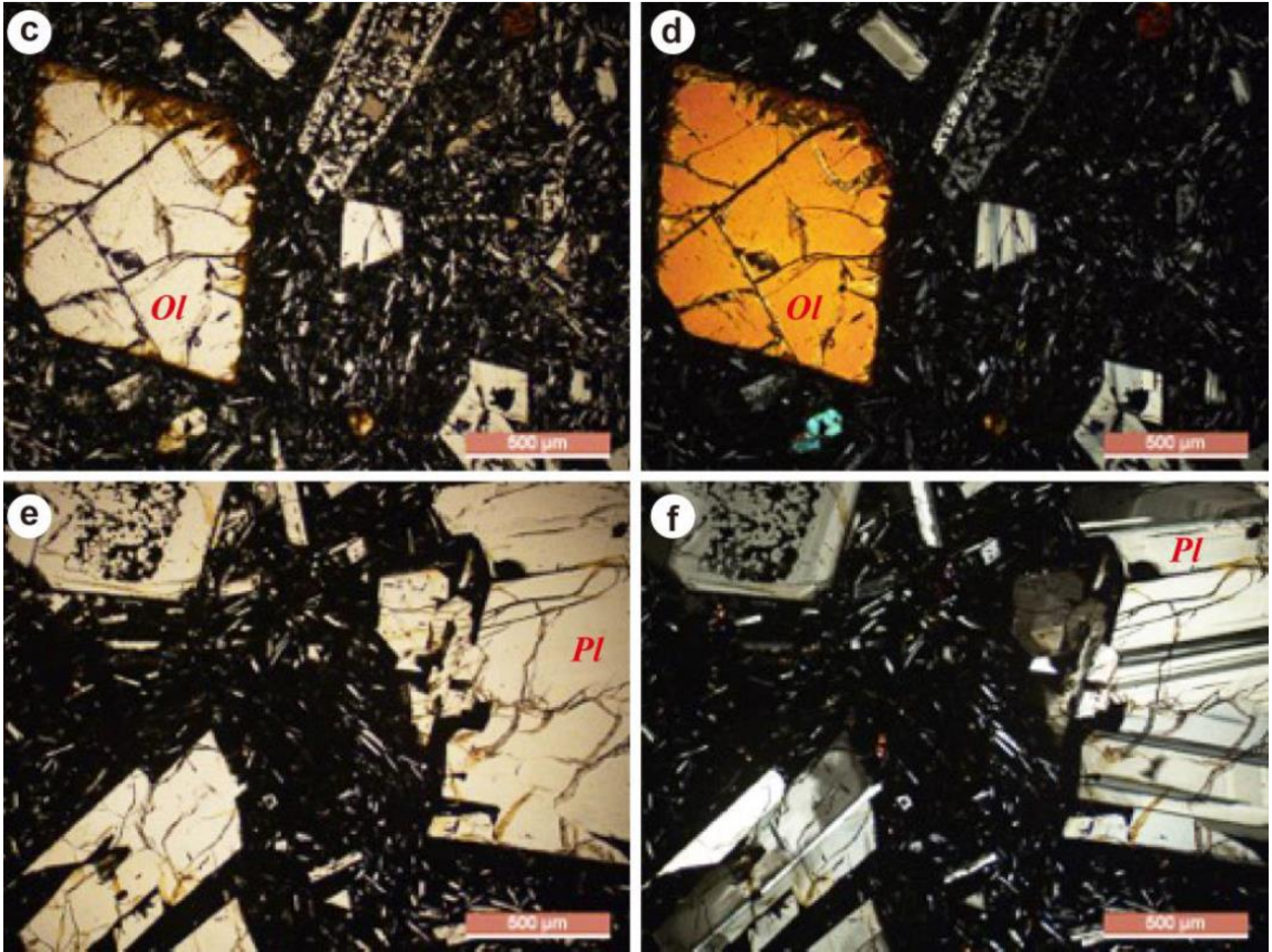
两个平行的趋势

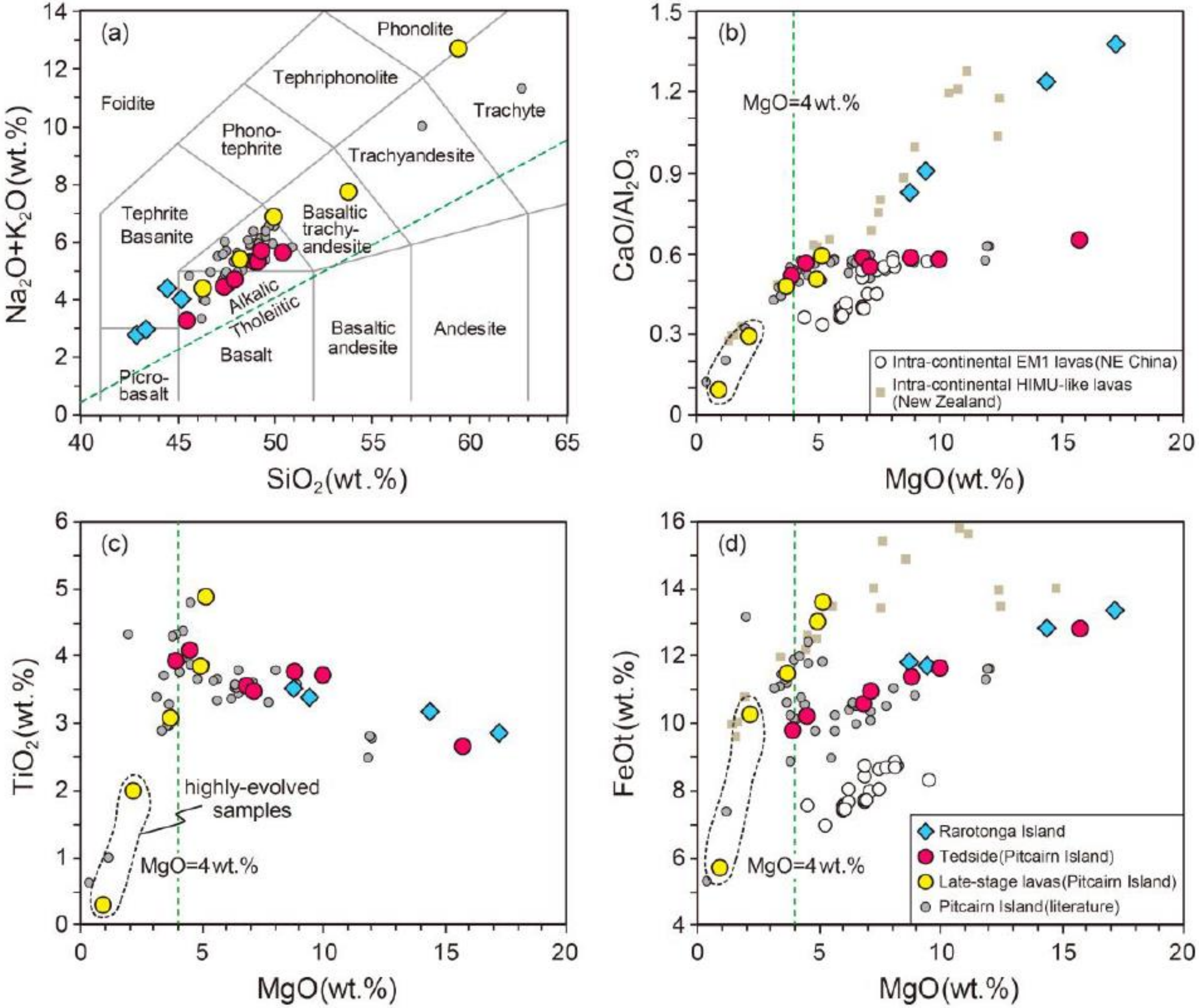


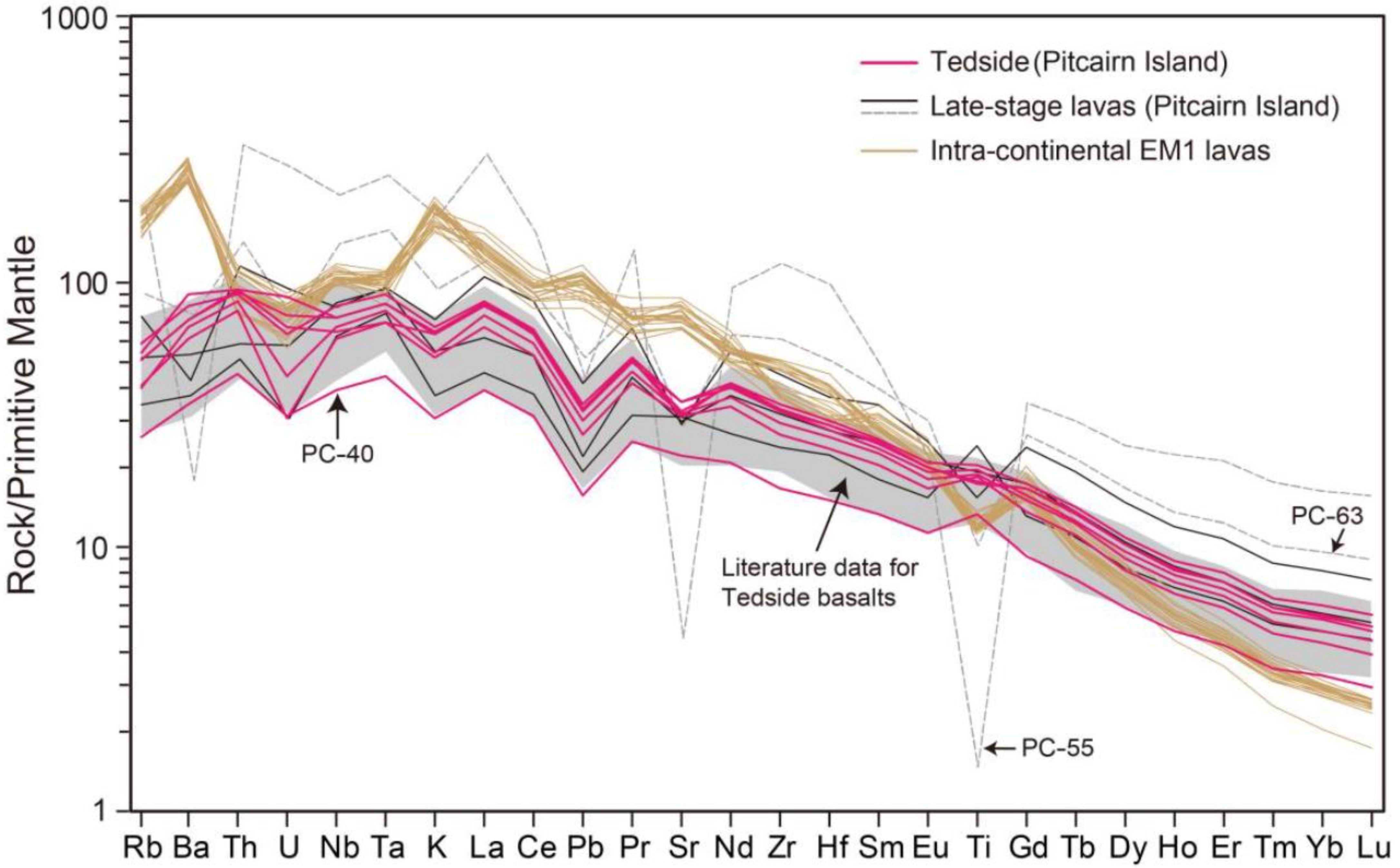
Zhong et al., 2017

大洋视角下的【I型富集地幔】

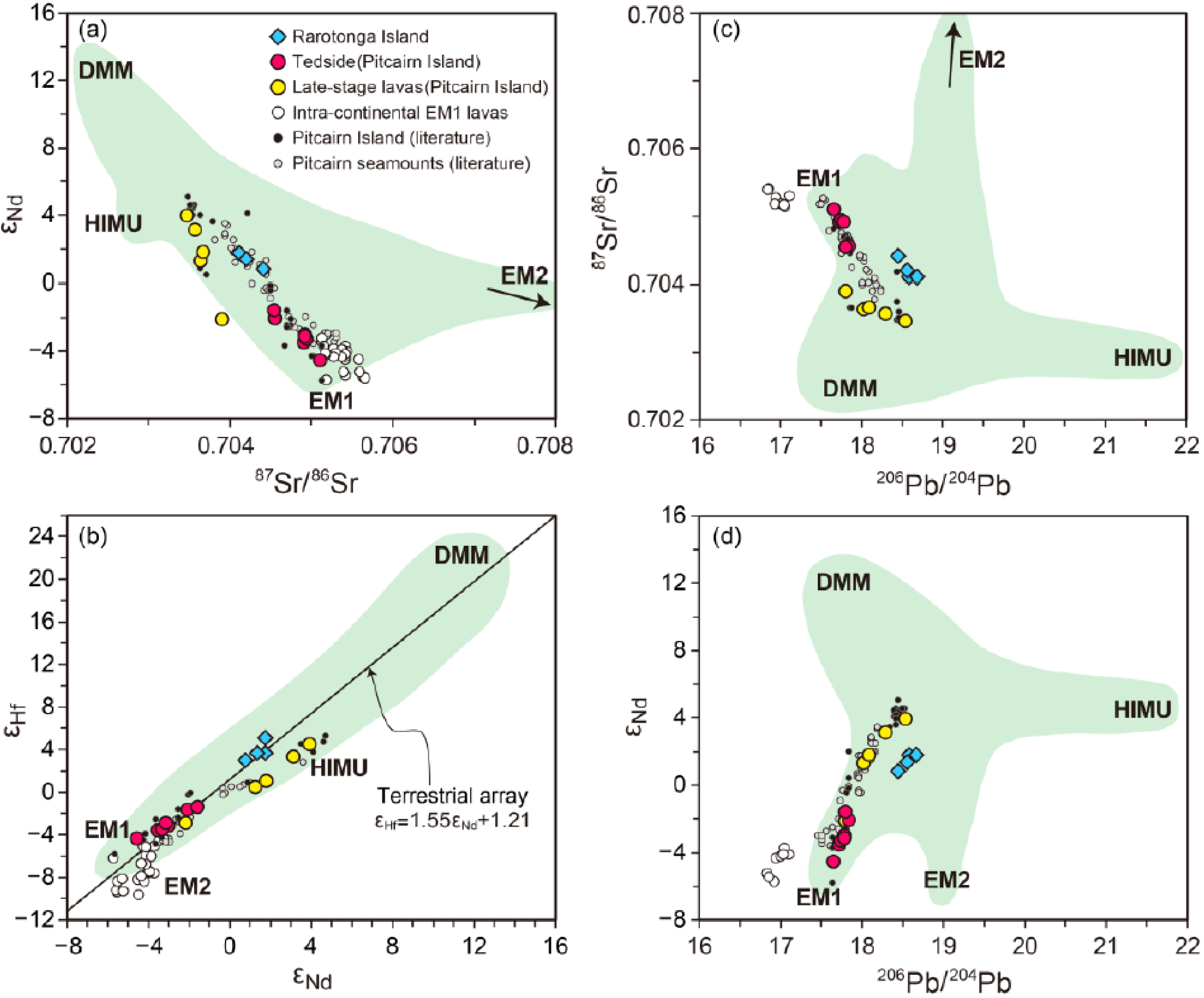


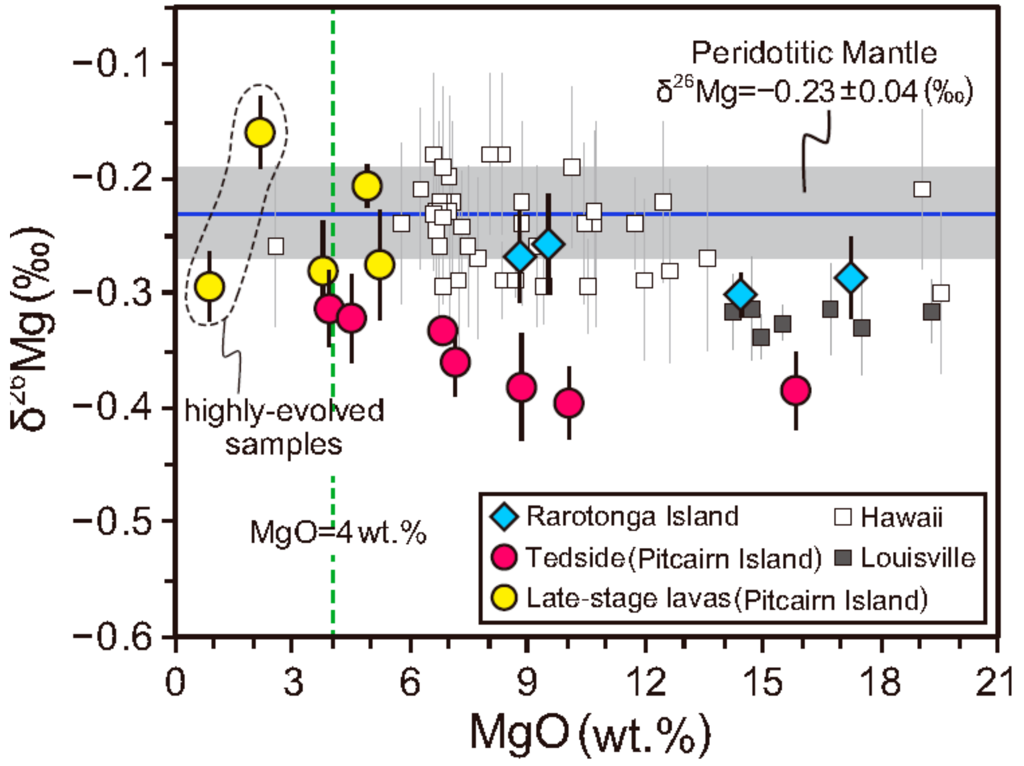

c
Ol
500 µm
d
Ol
500 µm
e
Pl
500 µm
f
Pl
500 µm


(a)
Phonolite
Tephriphonolite
Foidite
Trachyte
Phono-tephrite
Trachyandesite
Tephrite Basanite
Basaltic trachy-andesite
Alkalic
Tholeiitic
Basaltic andesite
Andesite
Basalt
Picro-basalt
Na_2O+K_2O(wt.%)
SiO_2(wt.%)
(b)
MgO=4 wt.%
CaO/Al_2O_3
MgO(wt.%)
Intra-continental EM1 lavas (NE China)
Intra-continental HIMU-like lavas (New Zealand)
(c)
highly-evolved samples
MgO=4 wt.%
TiO_2(wt.%)
MgO(wt.%)
(d)
MgO=4 wt.%
FeOt(wt.%)
MgO(wt.%)
Rarotonga Island
Tedside (Pitcairn Island)
Late-stage lavas (Pitcairn Island)
Pitcairn Island (literature)

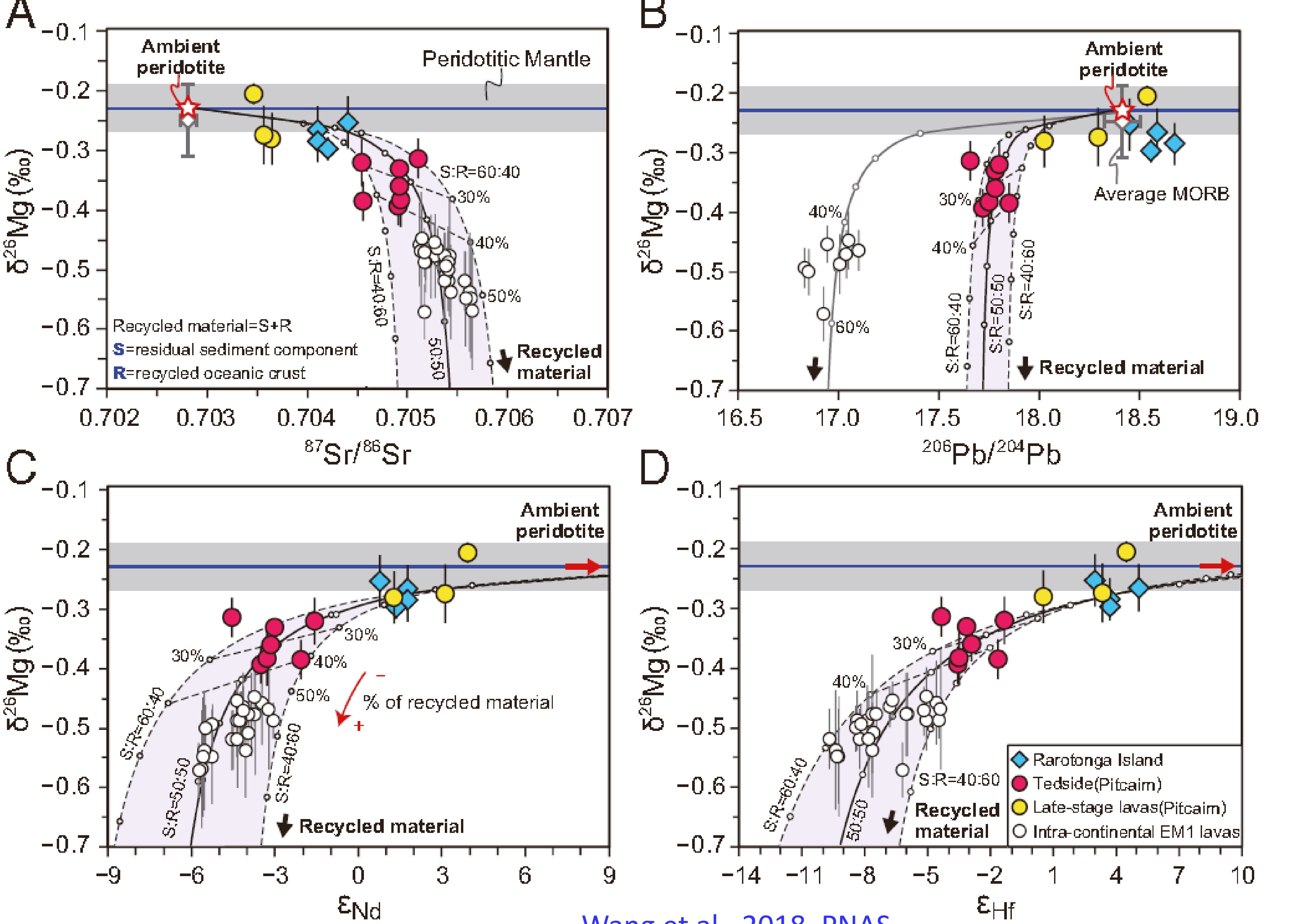


Tedside (Pitcairn Island)
Late-stage lavas (Pitcairn Island)
Intra-continental EM1 lavas
Rock/Primitive Mantle
1000
100
10
1
PC-40
Literature data for Tedside basalts
PC-63
PC-55
Rb Ba Th U Nb Ta K La Ce Pb Pr Sr Nd Zr Hf Sm Eu Ti Gd Tb Dy Ho Er Tm Yb Lu

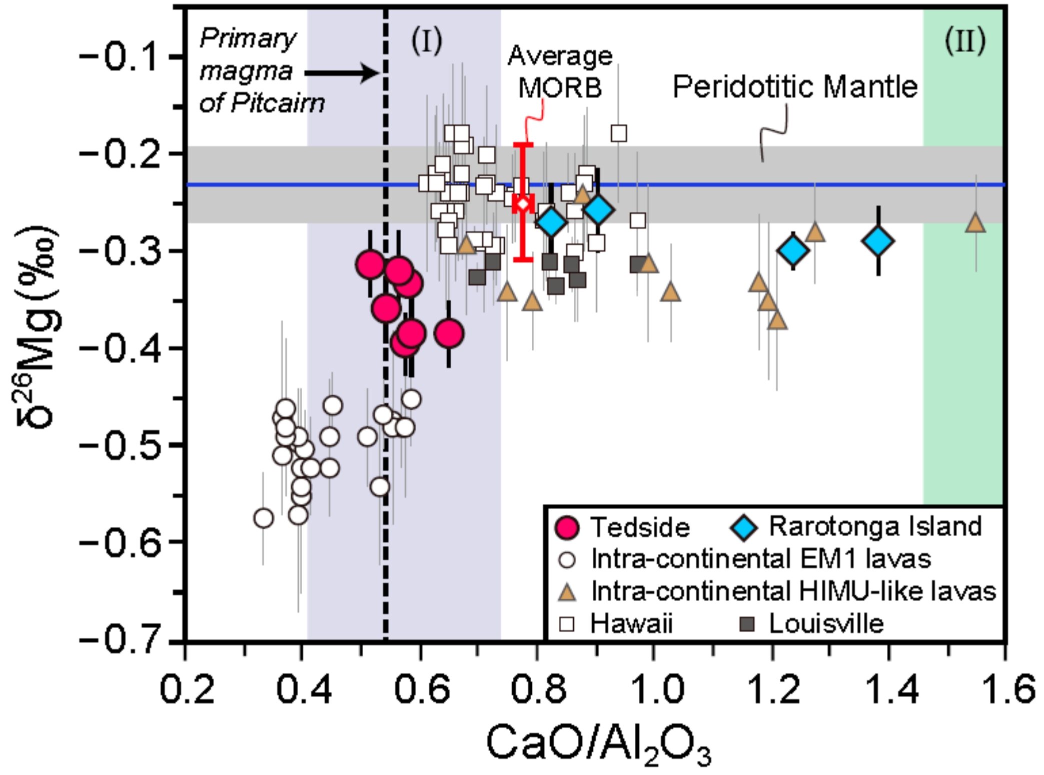


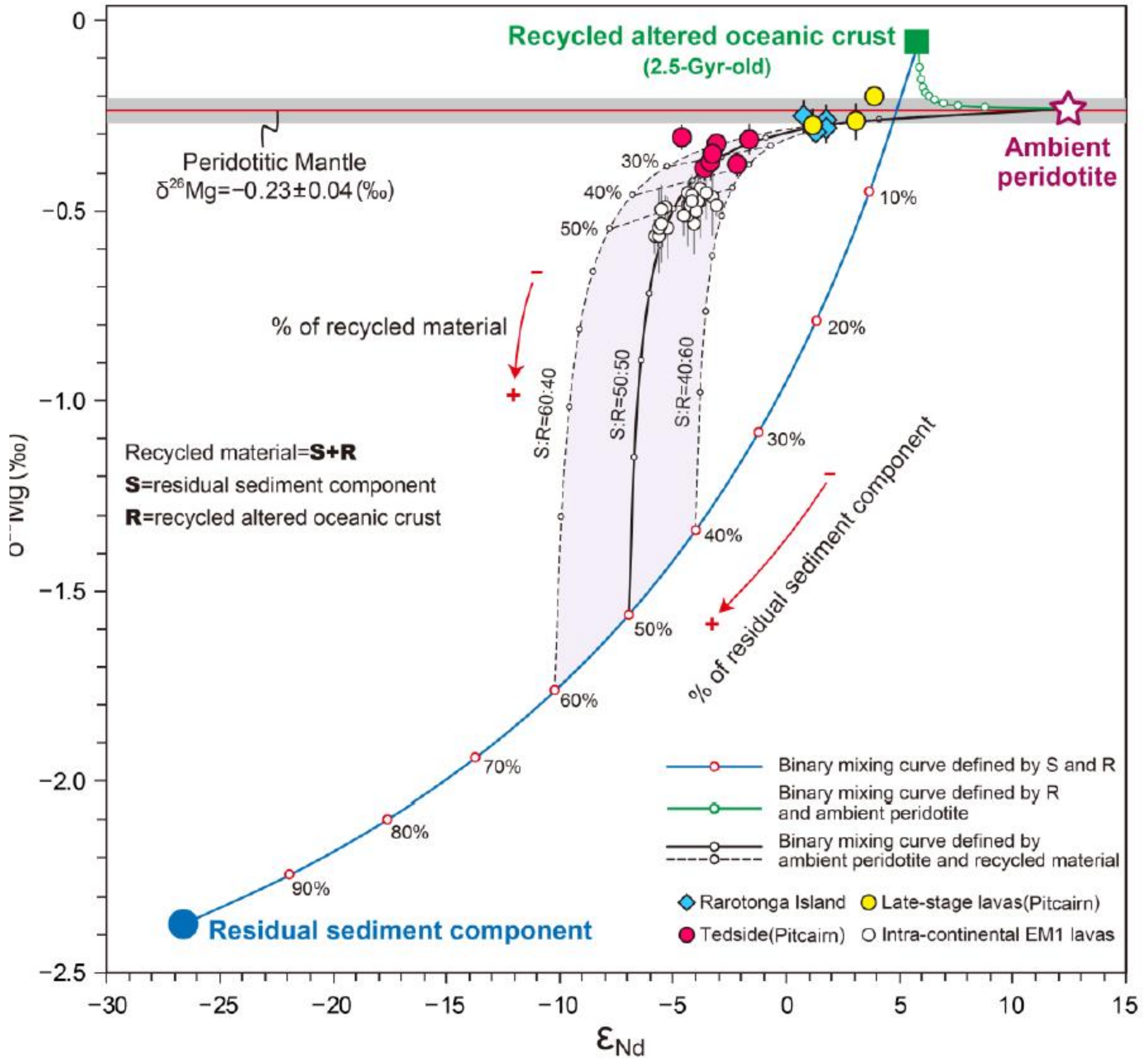


Wang et al., 2018, PNAS



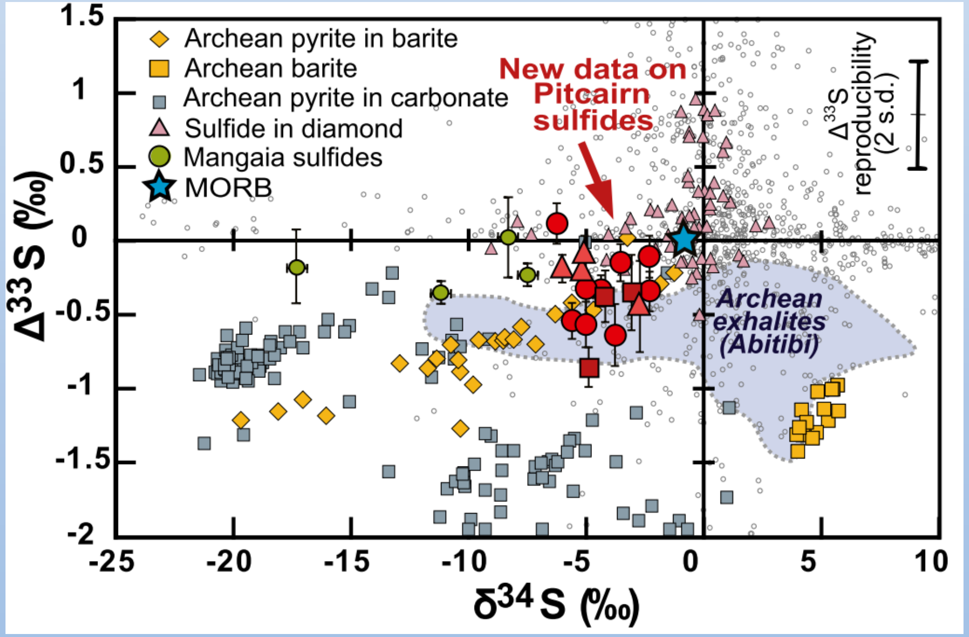
Wang et al., 2018, PNAS





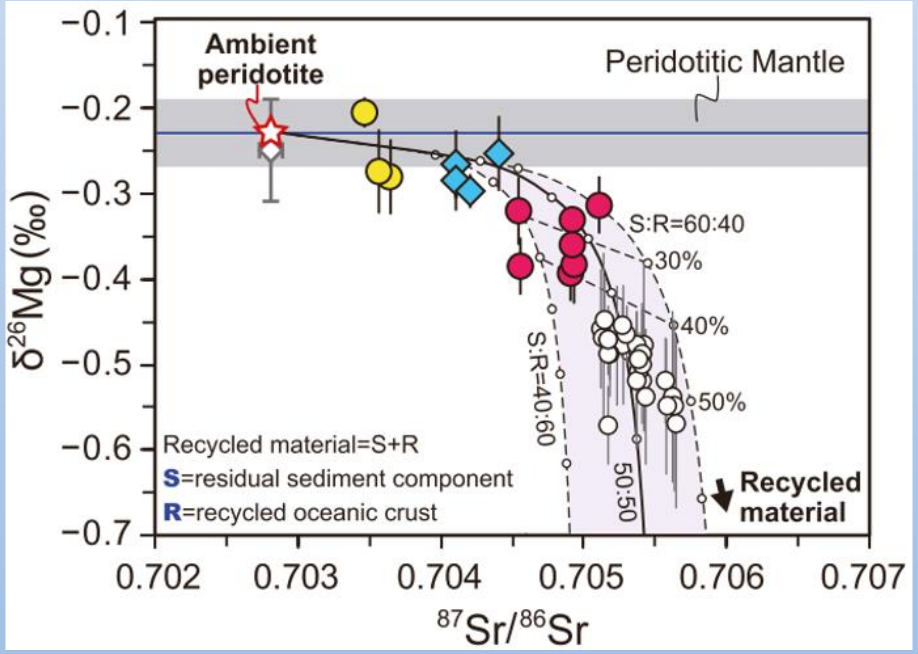
Wang et al., 2018, PNAS

I型富集地幔de属性：来自S和Mg同位素的制约



熔体包裹体硫化物的S同位素非质量分馏现象，记录源区含有老于24.5亿年的沉积物。

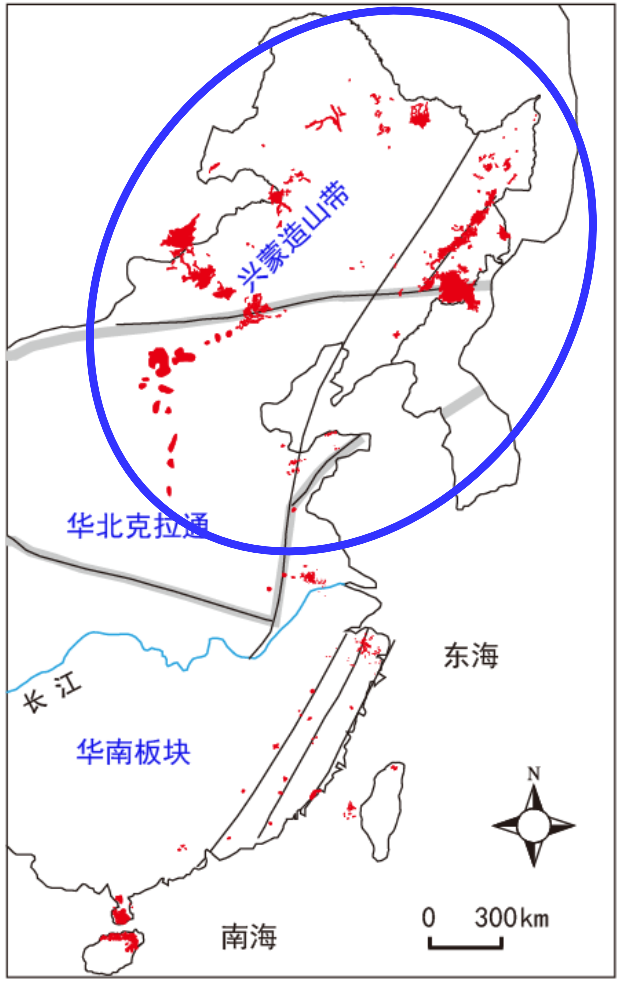
Delavault et al., 2016, PNAS

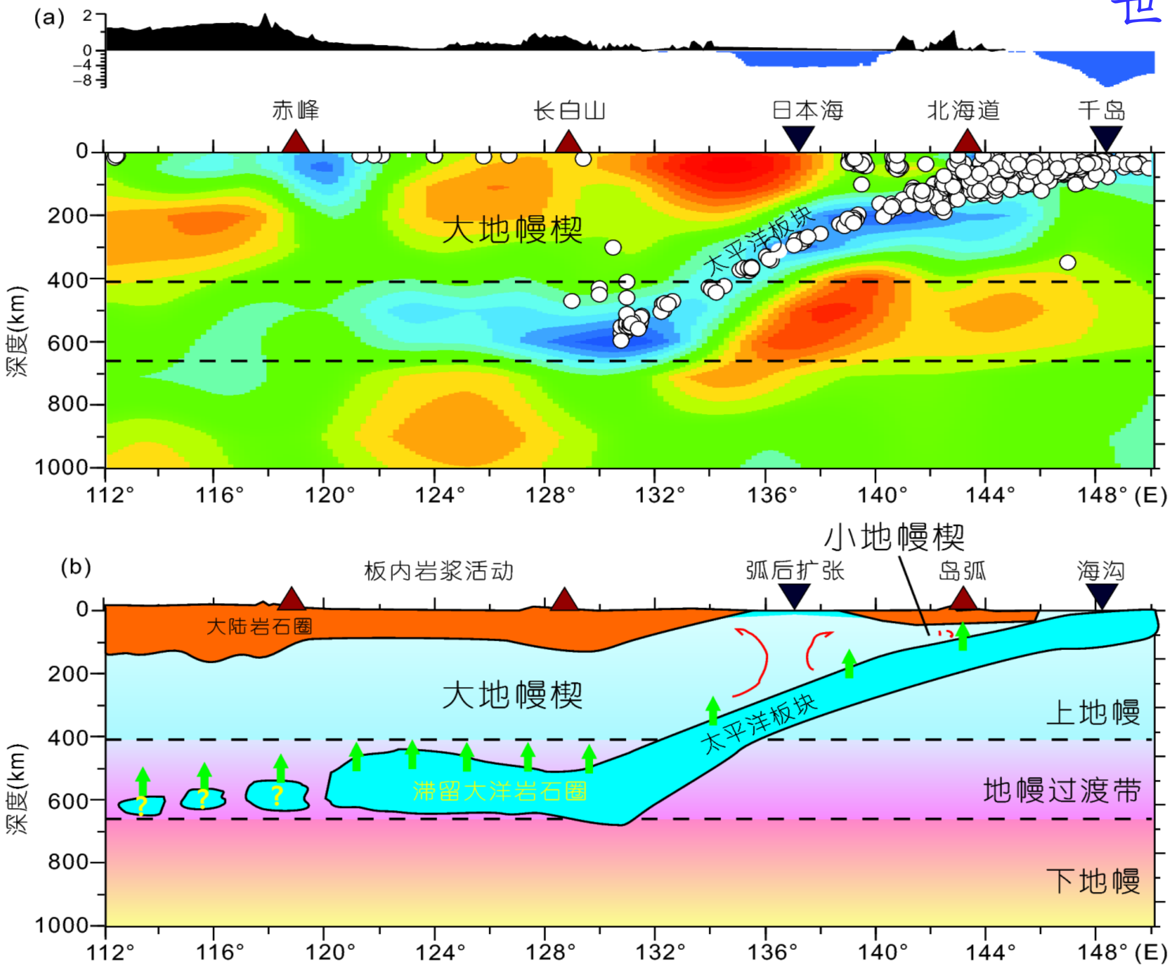


偏轻的Mg同位素以及与其它同位素的耦合关系说明EM1为曾经含碳酸盐的沉积物。

Wang et al., 2018, PNAS

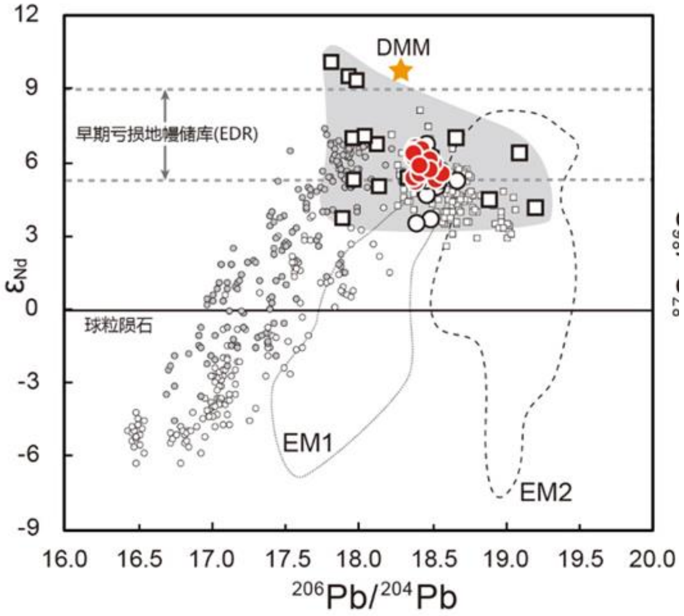
大陆视角下的【I型富集地幔】





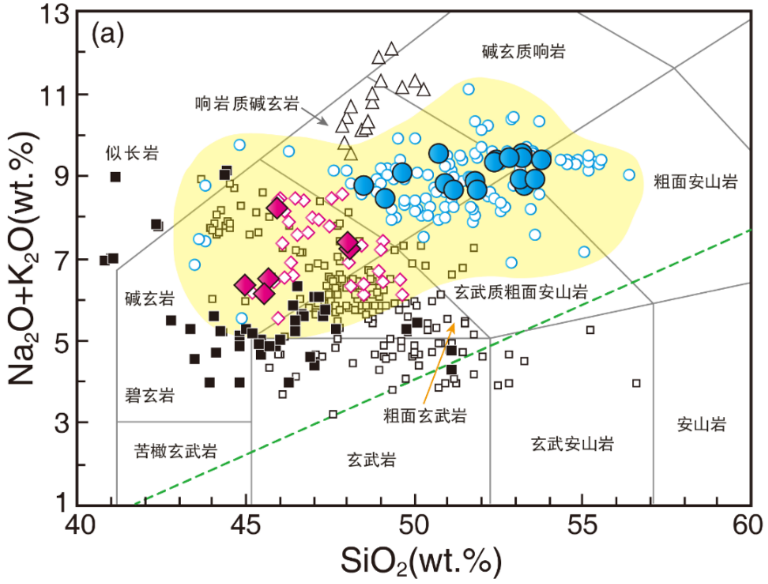
徐义刚 等，2018，中国科学

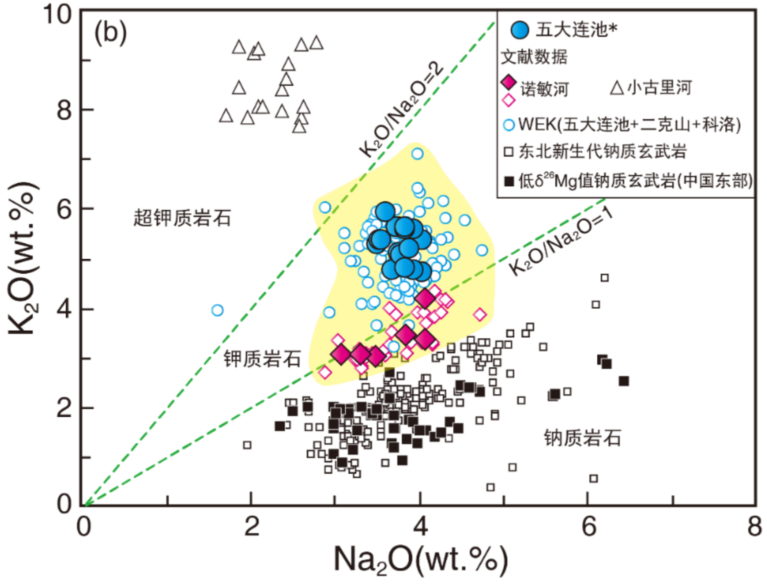
世界地质公园——五大连池

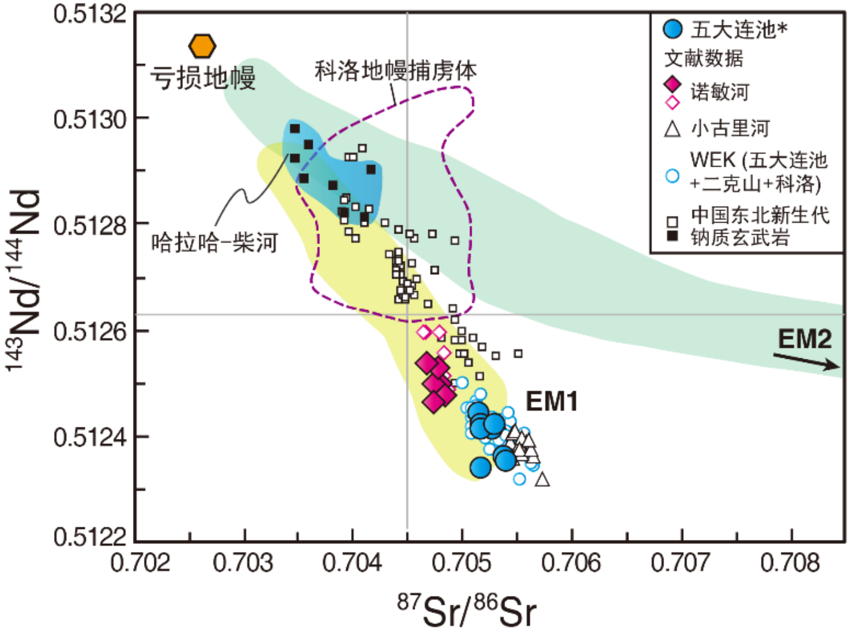


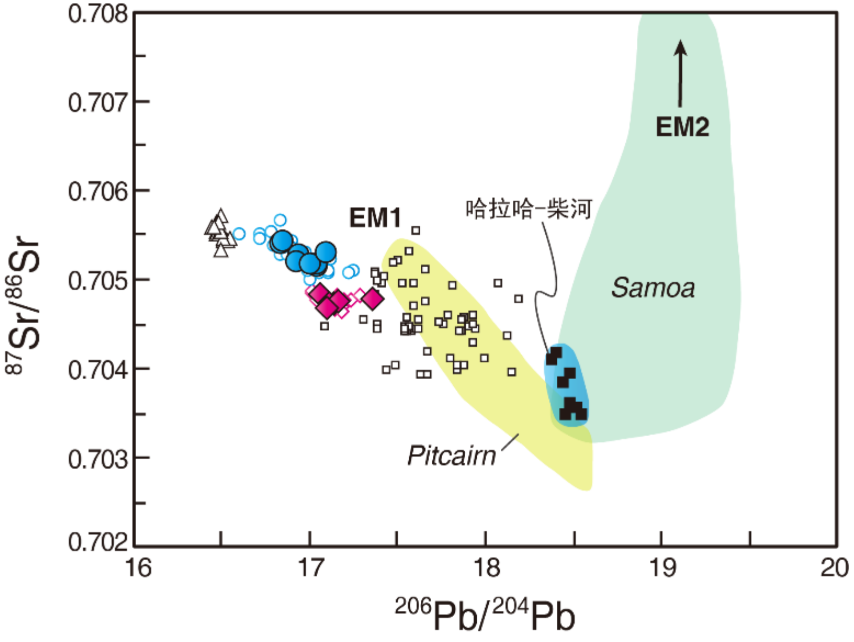
中国东部新生代OIB型玄武岩在空间上与大地幔楔吻合，常见EM1组分

五大连池钾质玄武岩具有极端de同位素特征

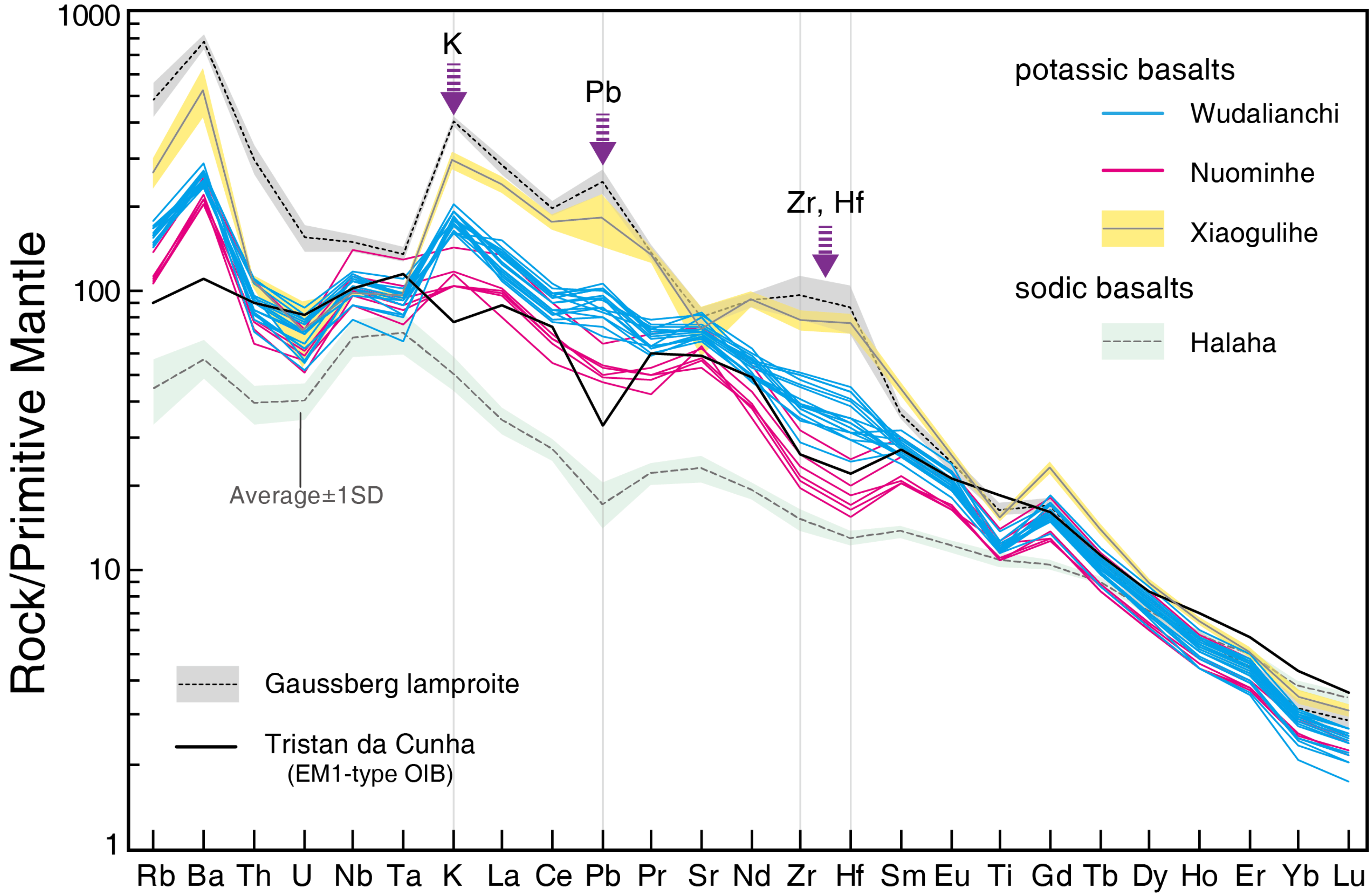




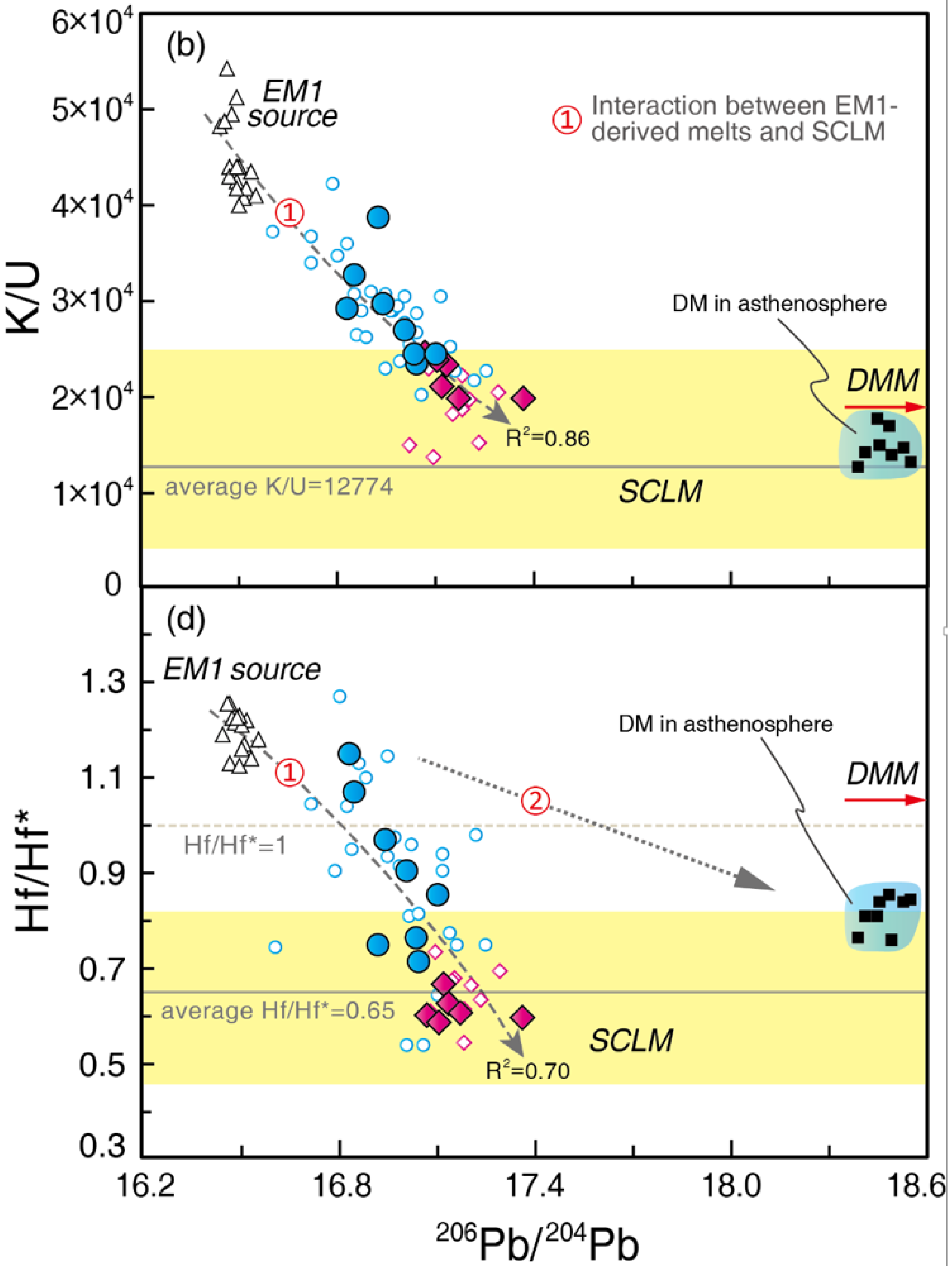


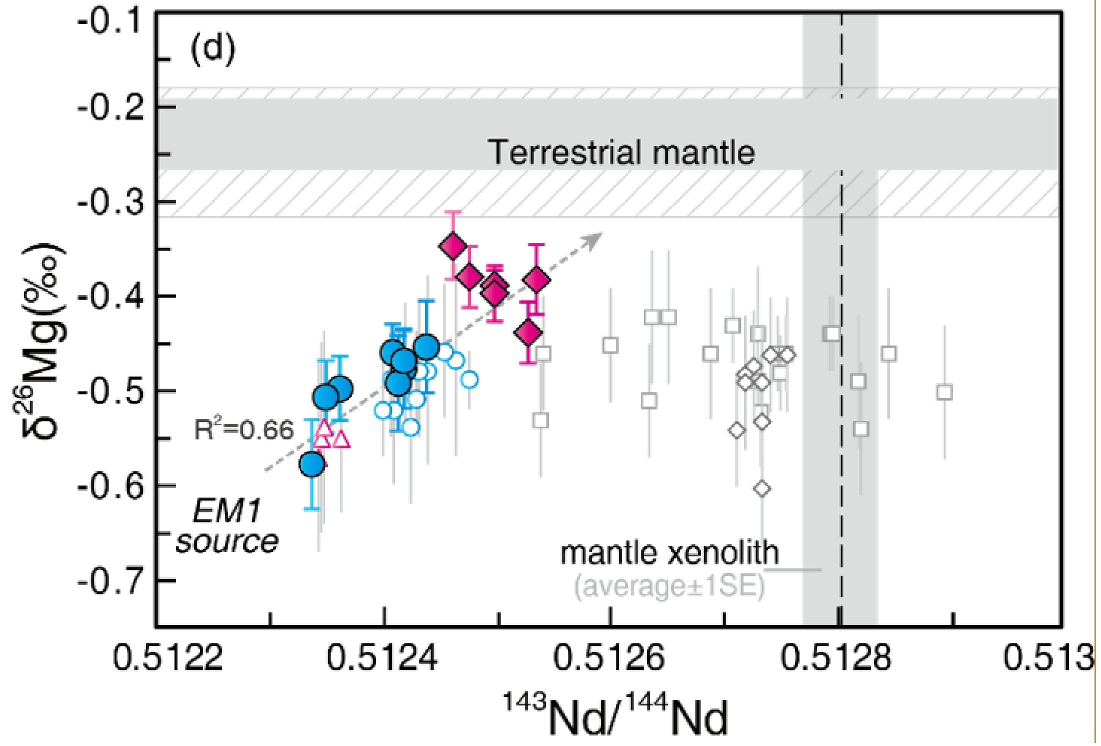


以五大连池为代表的东北新生代钾质玄武岩具有极端的Sr-Nd-Pb同位素组成，其$^{206}Pb/^{204}Pb$比值比Pitcairn还要低。



Wang et al., 2017, EPSL

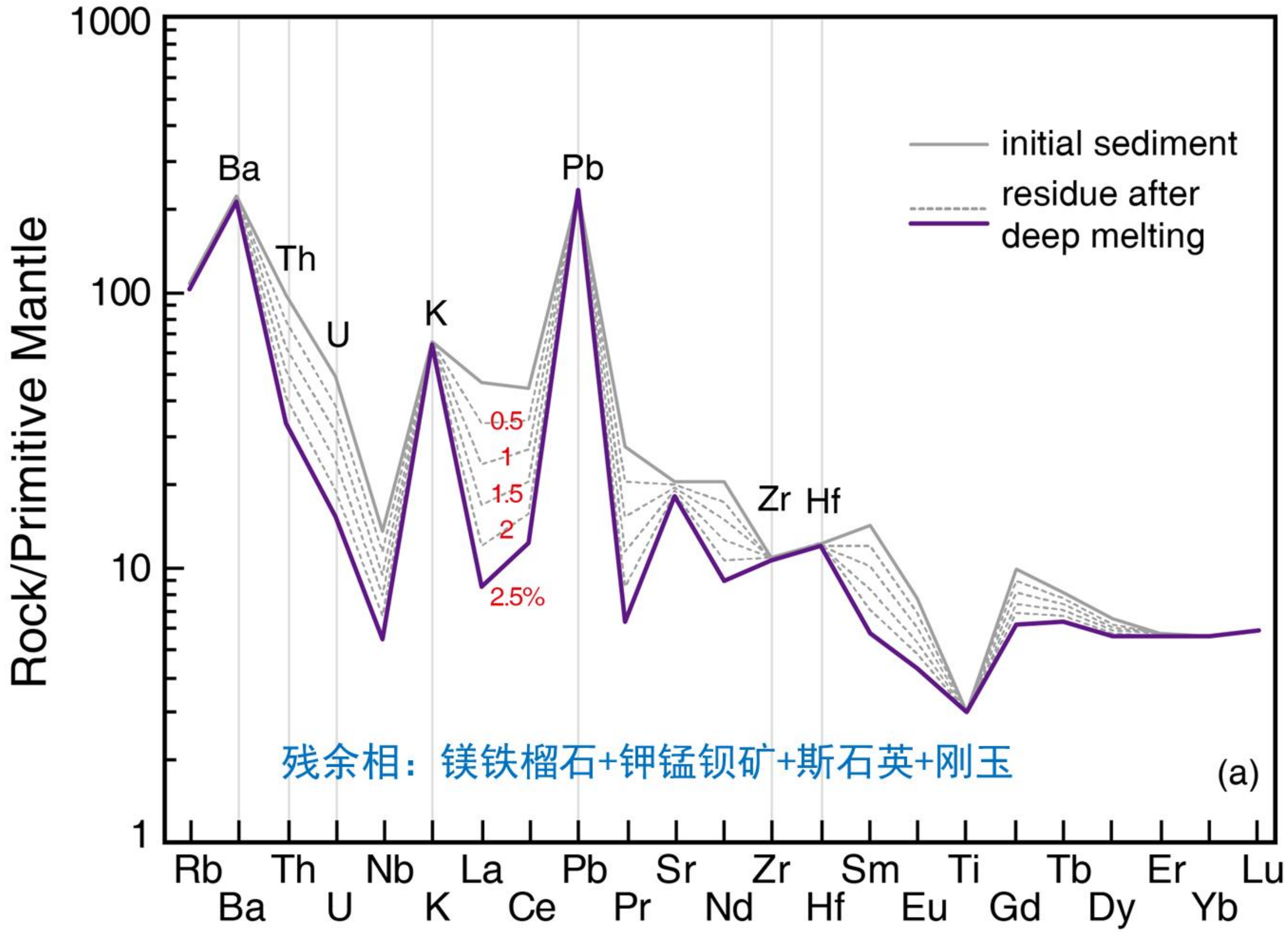


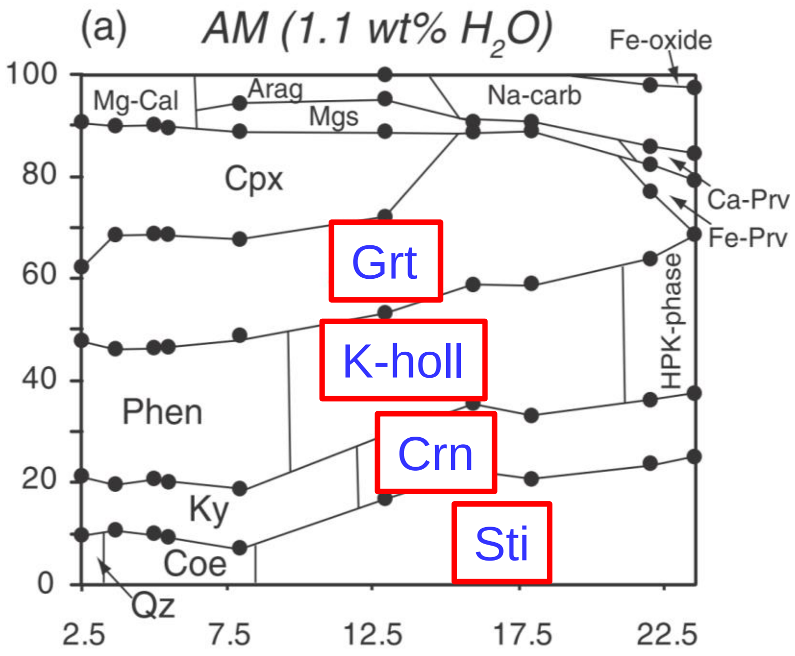


- ➢ EM1组分是软流圈中的低δ^{26}Mg物质（曾含有碳酸盐沉积物）；
- ➢ 具有异常高的K/U、Ba/Th、Hf/Hf*比值

Wang et al., 2017, EPSL

含碳酸盐沉积物在地幔过渡带熔融的元素分馏行为





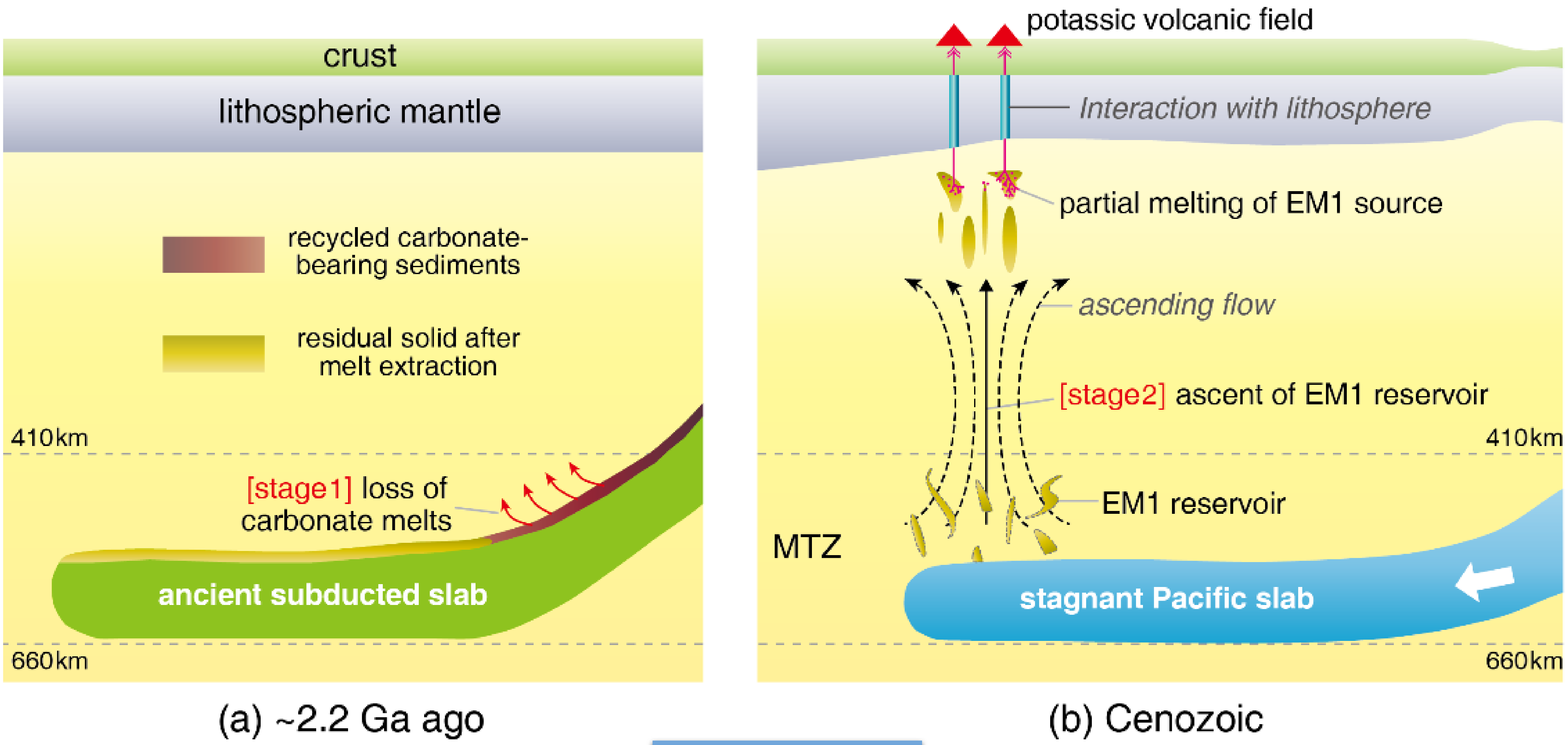
Grassi and Schmidt (2011)

含碳酸盐沉积物在MTZ的关键行为：

（1）含有Liebermannite;

（2）会发生低程度熔融。

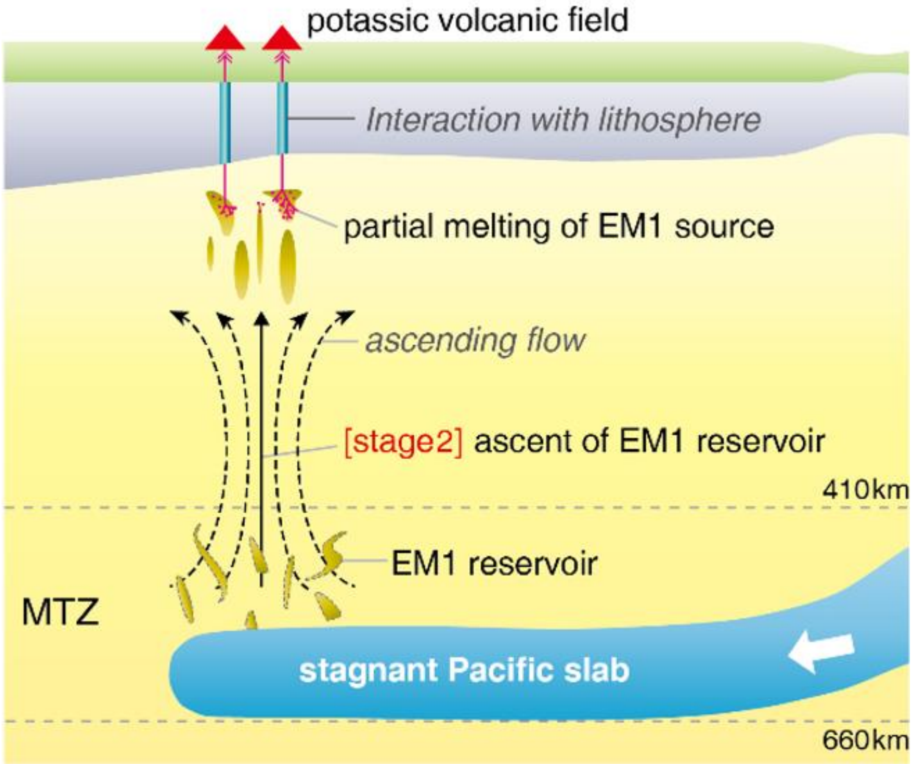
Wang et al., 2017, EPSL



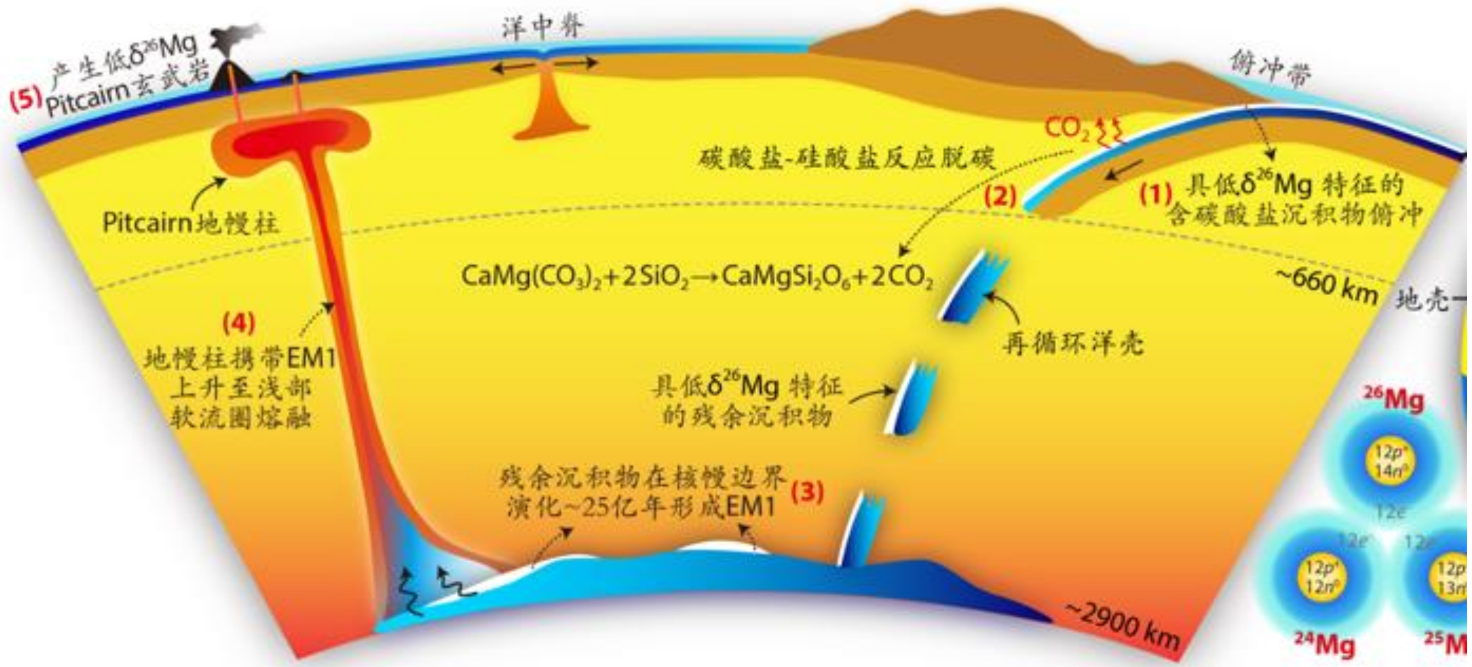
挤出模型

Wang et al., 2017, EPSL

问题：富集地幔EM1到底在哪里?



Wang et al., 2017, EPSL



Wang et al., 2018, PNAS

地幔过渡带 vs 核幔边界

谢谢！ 欢迎讨论！