Uranium-series Disequilibrium in Subduction Zone Volcanic Rocks

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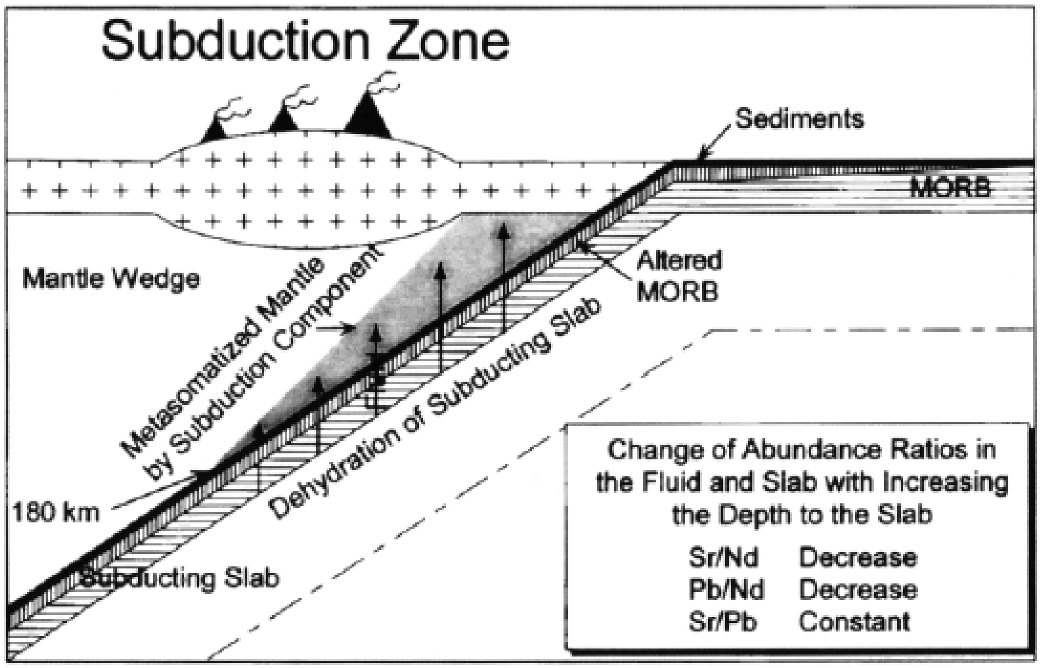
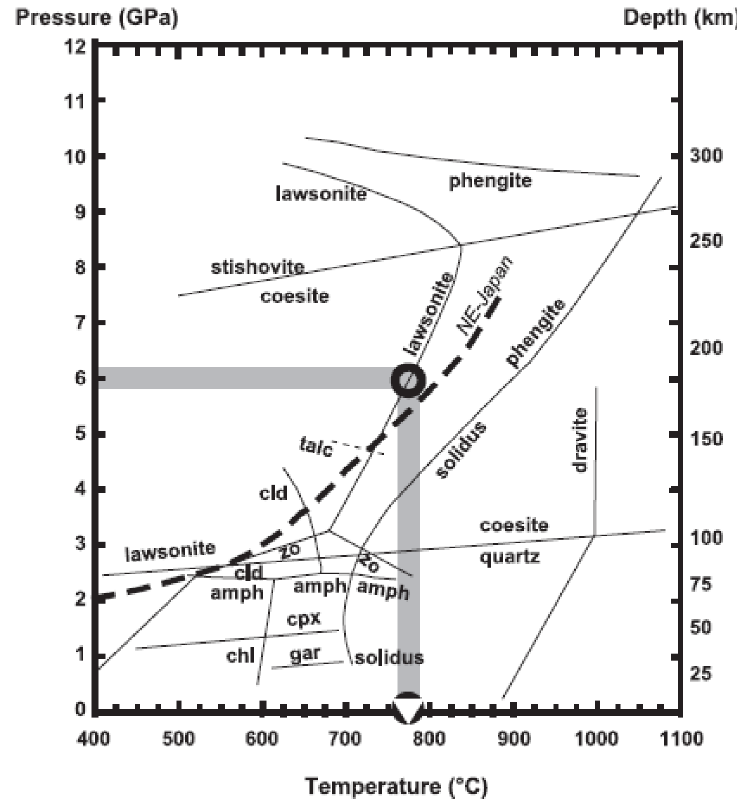
Subduction zone magmatism

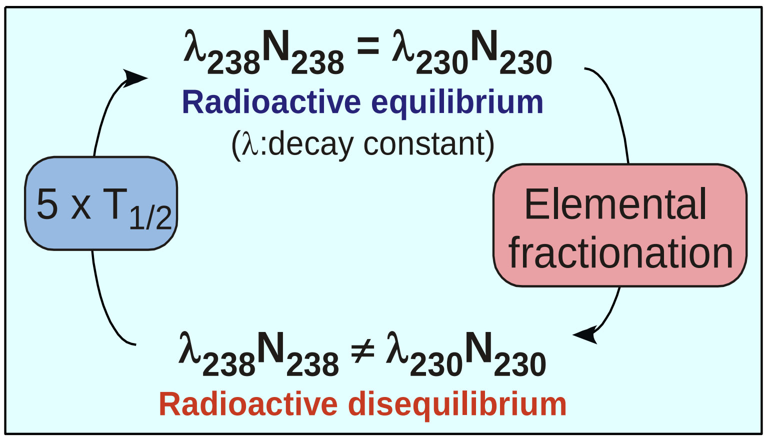


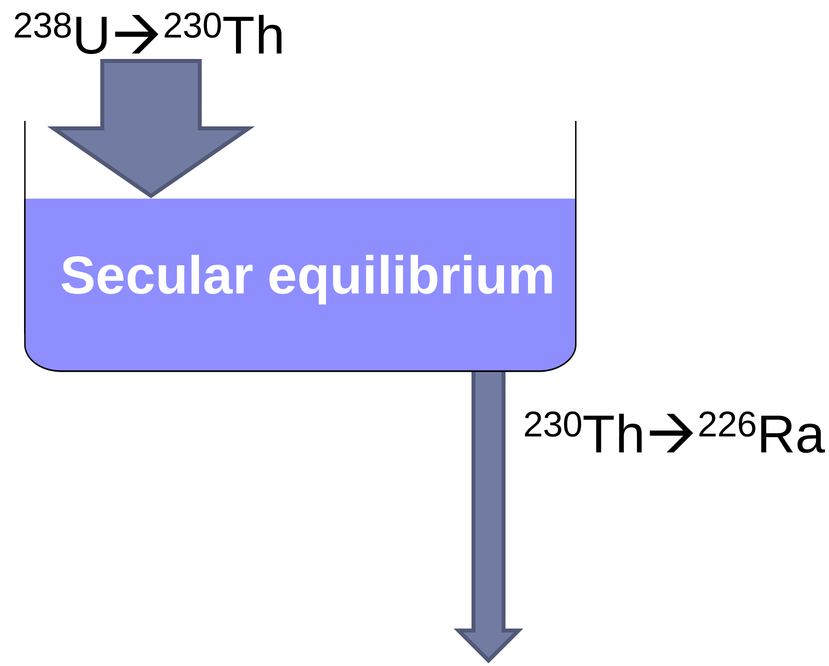


- Subducting slabs release fluid components due to mineralogical reactions during progressive metamorphic dehydration.
- The fluid released from the slab subsequently induces mantle melting as it ascends, resulting in subduction zone magmatism.

Secular equilibrium and U-series disequilibrium

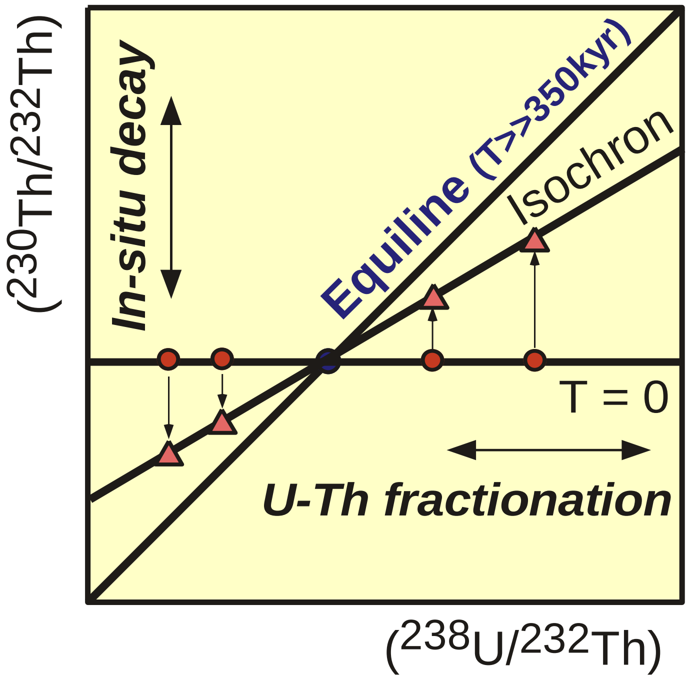
	$^{238}U \rightarrow$	... $\rightarrow$	$^{230}Th \rightarrow$	$^{226}Ra \rightarrow \cdot \cdot \cdot$	^{206}Pb
$T_{1/2}$ (yr)	4.5×10^9		7.5×10^4	1600	Stable





- ^{238}U - ^{230}Th disequilibrium: fractionation within the last 350 kyr
- ^{230}Th - ^{226}Ra disequilibrium fractionation within the last 8 kyr

^{238}U-^{230}Th equiline diagram

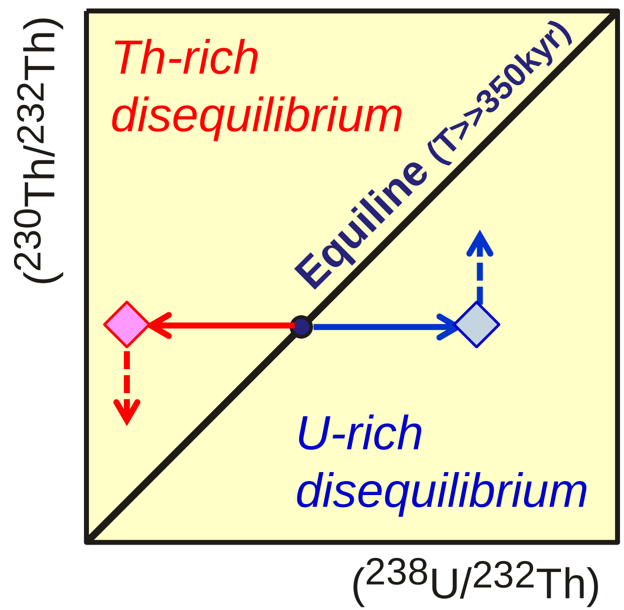


Equiline

$\lambda_{238U}N_{238U} = \lambda_{230Th}N_{230Th}$ (Activity)

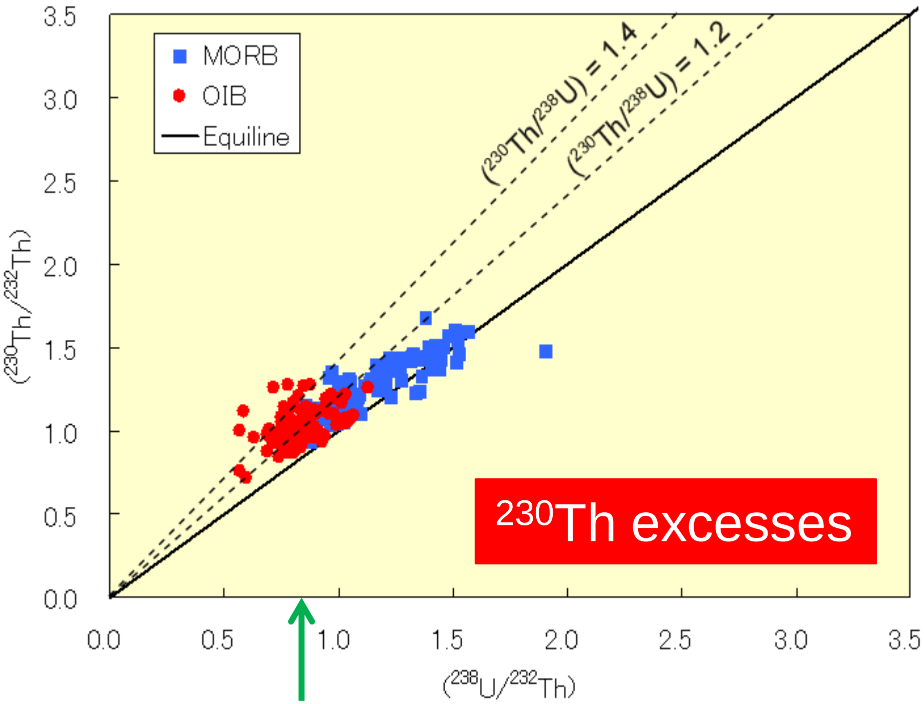
$$\left(\frac{^{230}Th}{^{232}Th}\right) = \left(\frac{^{238}U}{^{232}Th}\right)^0 \cdot \left(1 - e^{-\lambda_{230} \cdot t}\right) + \left(\frac{^{230}Th}{^{232}Th}\right)^0 \cdot e^{-\lambda_{230} \cdot t}$$

slope *intercept*



^{238}U-^{230}Th disequilibrium and tectonic settings

MORB, OIB

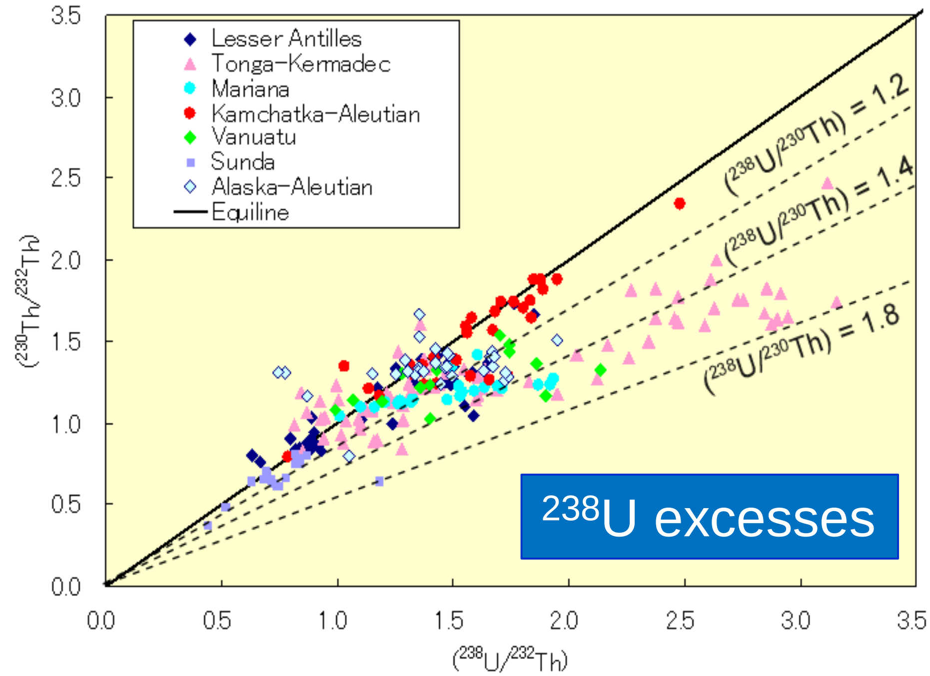


CI chonrite (U/Th = 0.26)

Garnet: D_U/D_{Th} >1
Pyroxene: D_U/D_{Th} <1

MORB and OIB melts originated from garnet stability fields

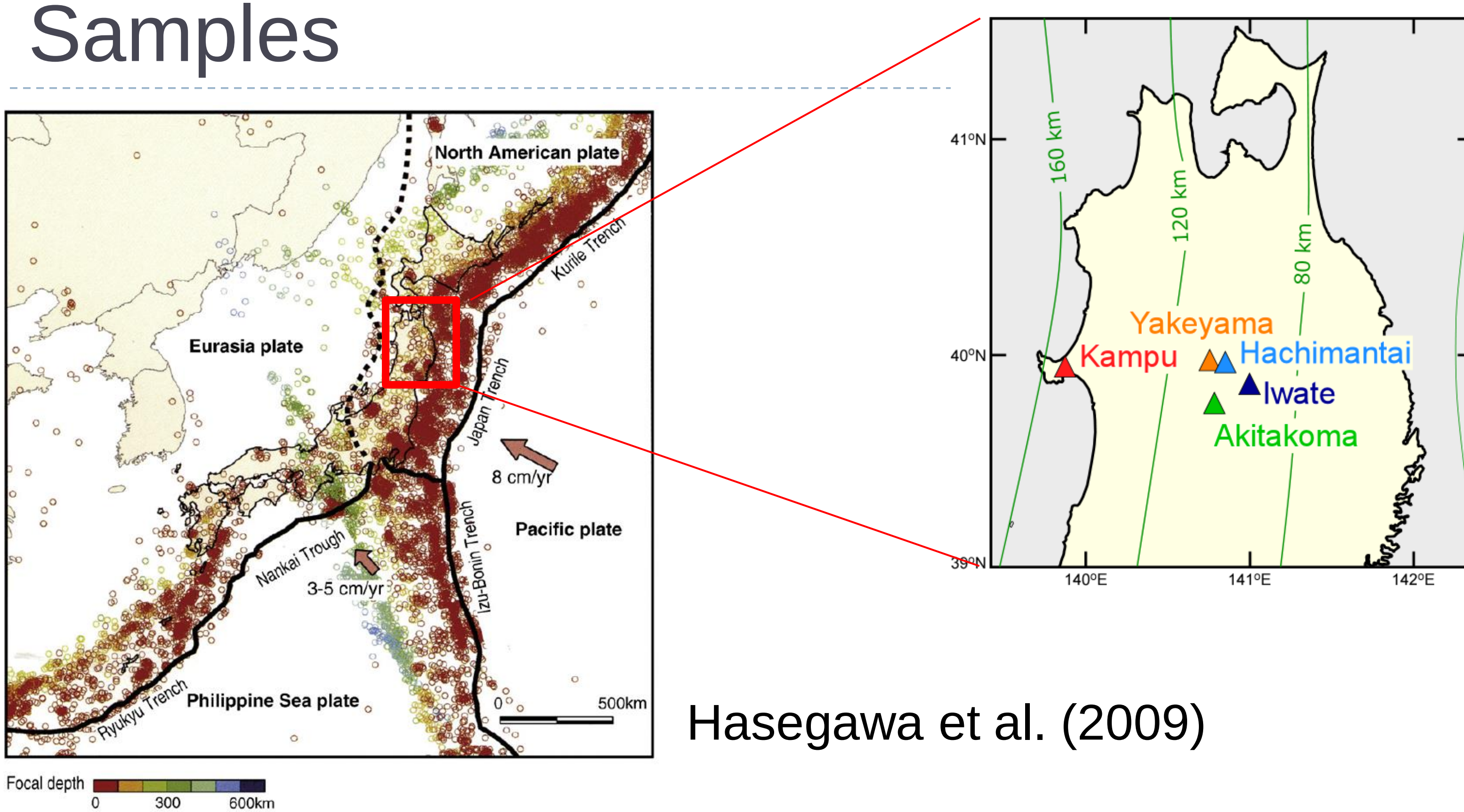
Subduction zone



U is more fluid mobile than Th.

Slab derived fluid preferentially transfers U than Th.

Samples



Hasegawa et al. (2009)

	Iwate			Akitakoma			Hachi mantai	Yake yama	Kampu		
Sample#	IW1	IW4	IW7	0415	0426	0607	HM04	0508	KAM60	KAM64	KAM65
SiO2 (%)	53.6	50.9	52.8	52.3	51.5	53.4	55.3	57.4	63.8	54.1	53.0
MgO (%)	6.50	5.80	7.24	3.92	6.37	5.26	5.94	5.62	2.04	5.29	5.80
Age	1732	<10ka	<10ka	5-10ka	5-10ka	2ka	?	0Ma	<30ka	<30ka	<30ka

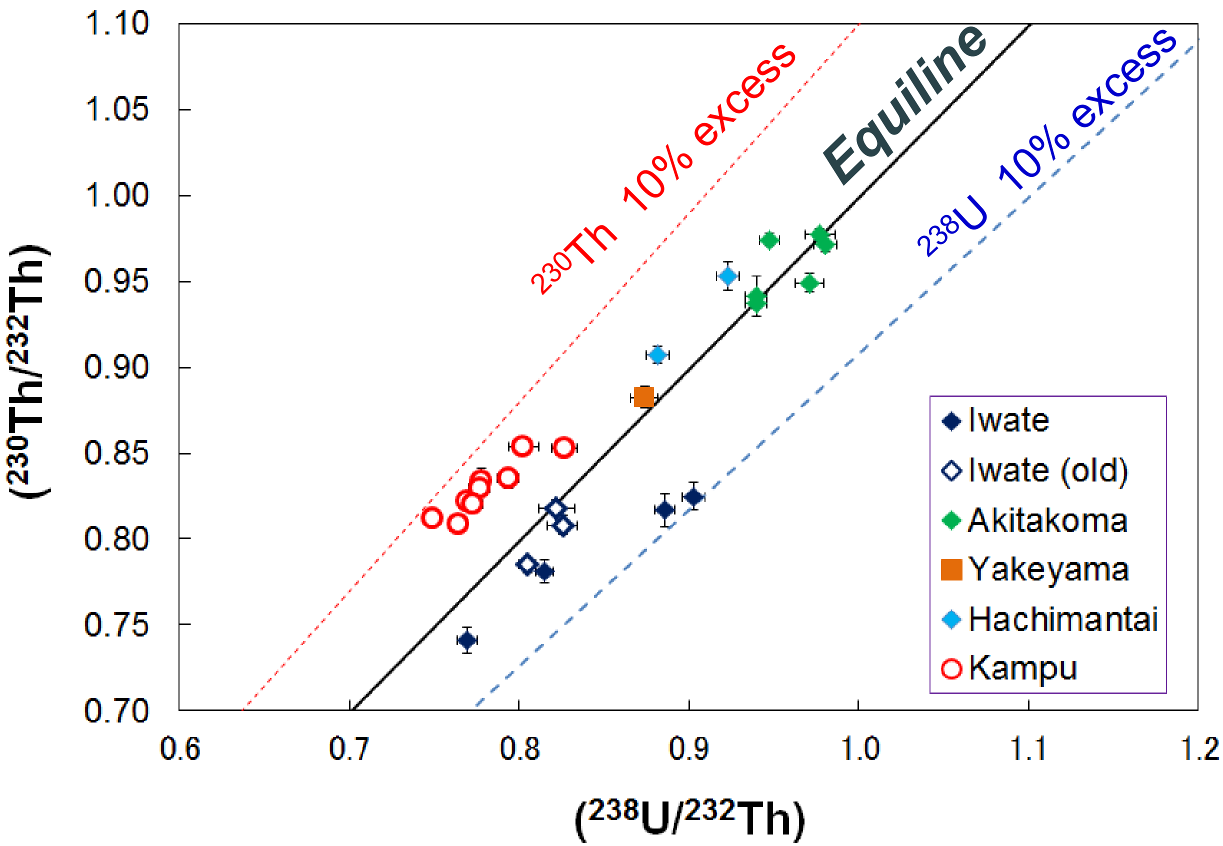
Analytical techniques

- ➢ Chemical separation: U/TEVA spec (Eichrom)
- ➢ Th and U isotopes: TIMS (TRITON plus)
- ➢ Th and U abundances: ID-ICP-MS (X-series II)

TRITON plus @ Titech

X series II @ Titech

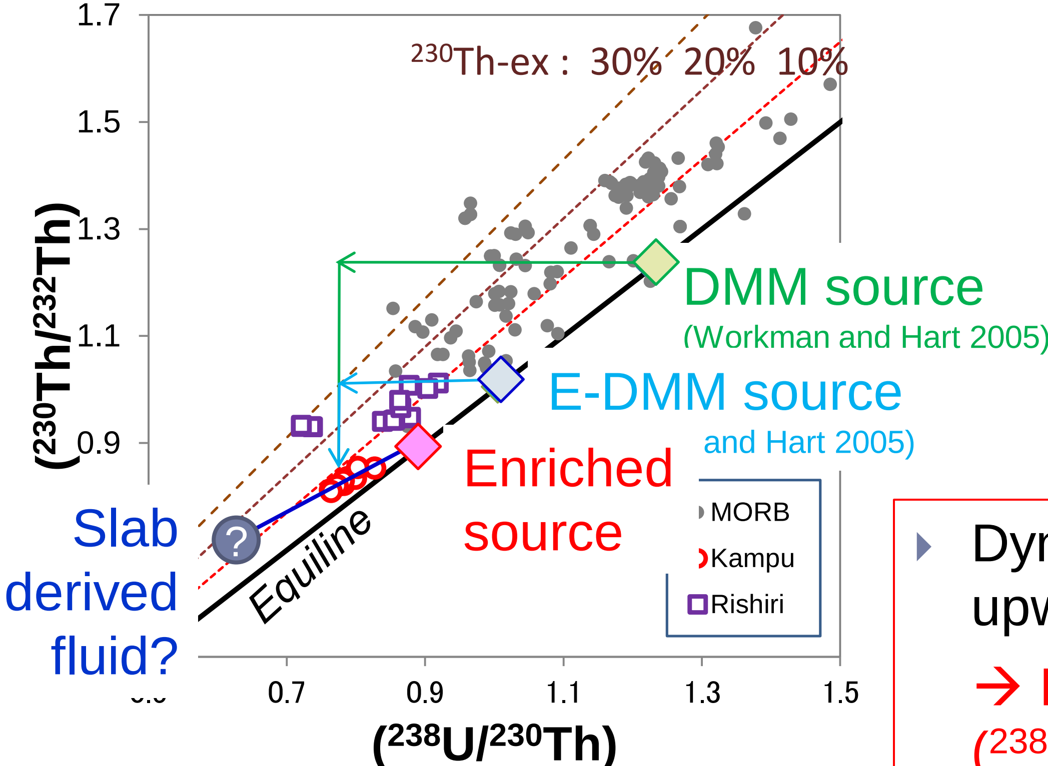
U-Th disequilibrium of NEJ volcanic rocks

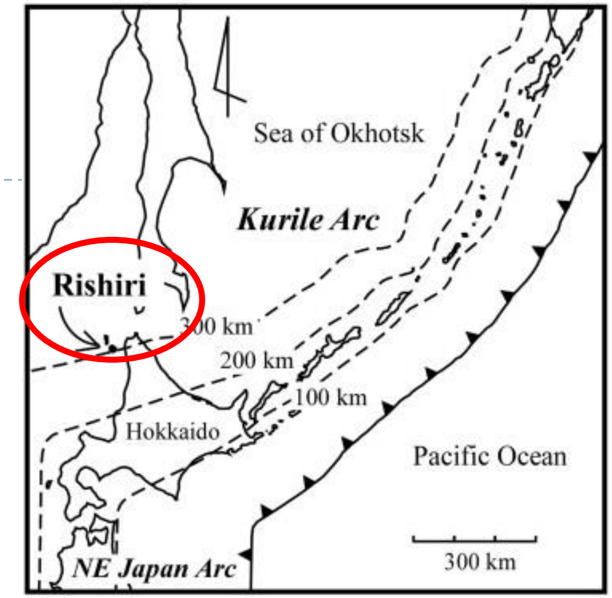


- Fore arc lavas: ^{238}U-excesses
- Rear arc lavas: ^{230}Th-excesses
- The extent of ^{238}U enrichment decreases as the slab depth increases.

Gradual decrease of the amount of slab derived fluid mixed into the wedge mantle.

Rear arc samples





Kuritani et al. (2008)

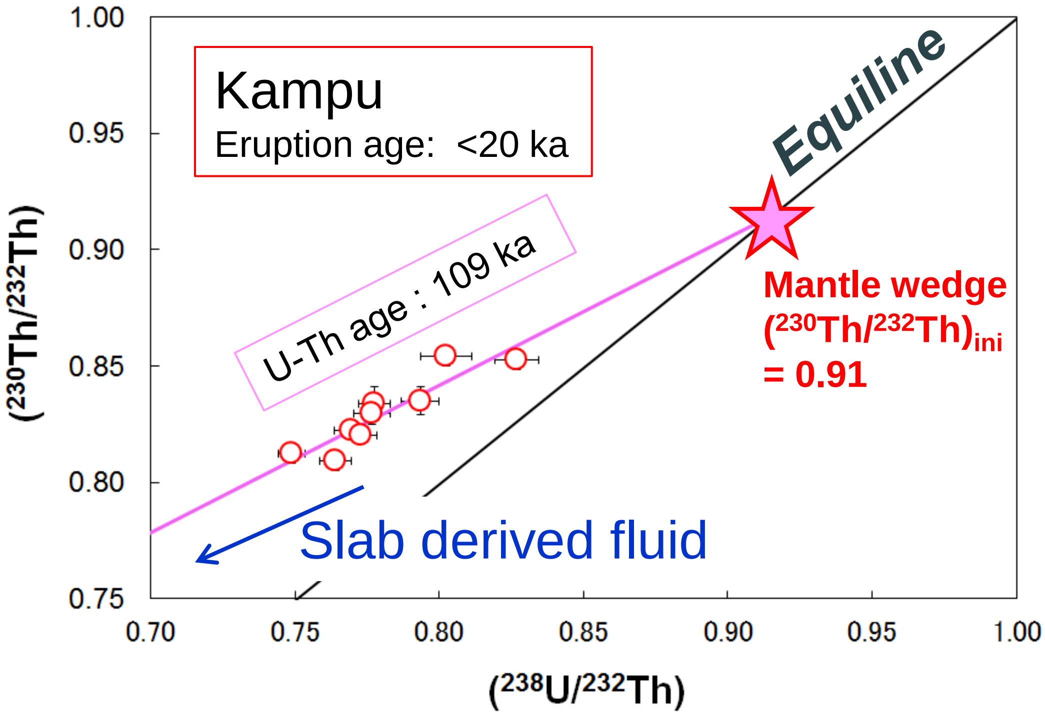
- Dynamic melting of garnet-bearing upwelling DMM-like mantle ?

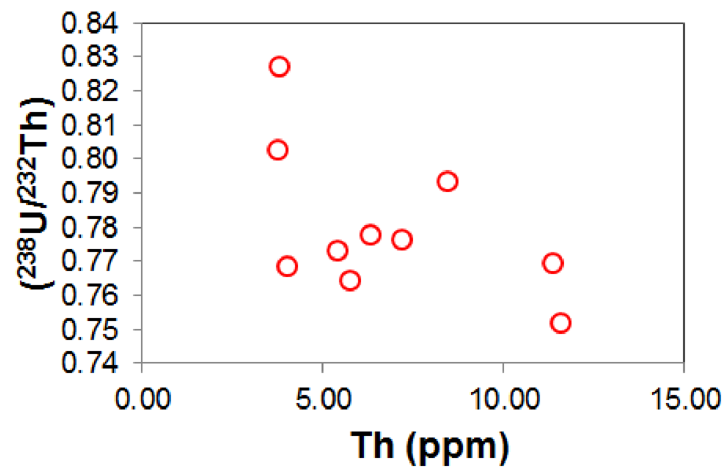
  → No. (^{230}Th/^{232}Th) and (^{238}U/^{232}Th) ratios are too small.

Model 1) Dynamic melting of enriched mantle

Model 2) Flux melting of enriched mantle induced by the addition of ^{230}Th-rich slab-derived fluid.

U-Th age of Kampu

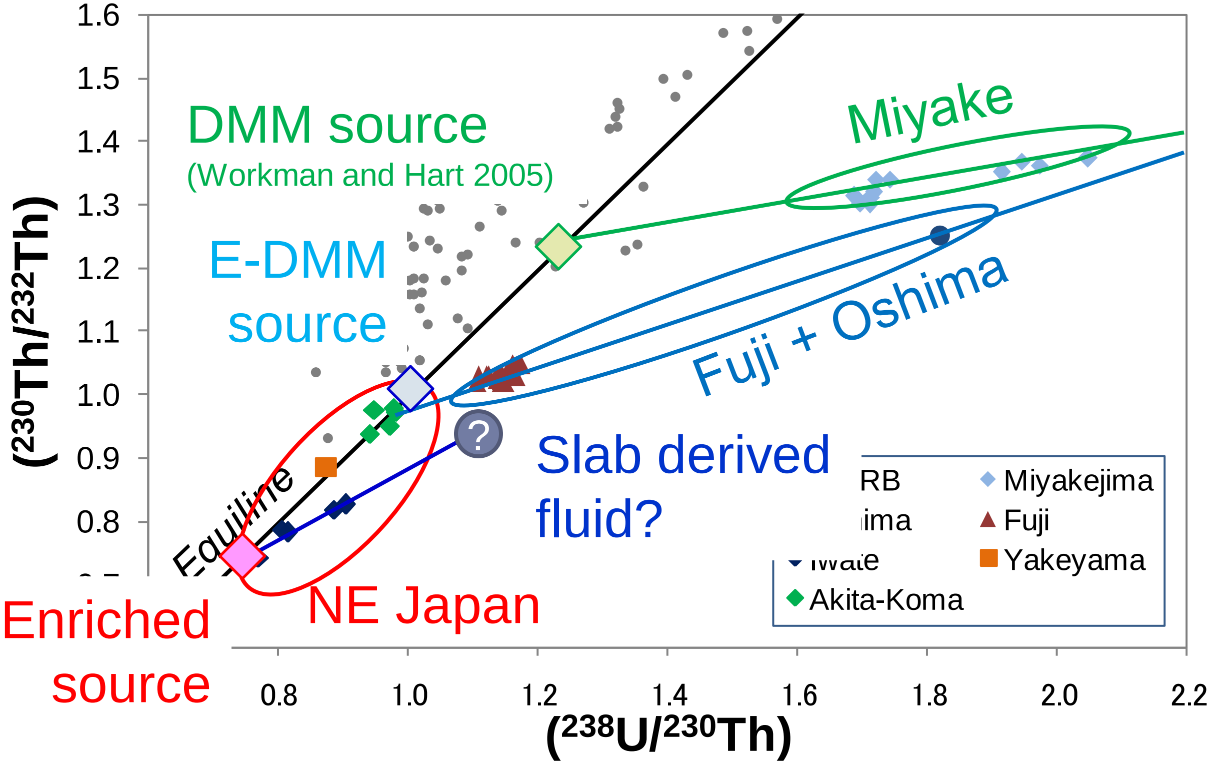




No correlation between U-Th fractionation and magma differentiation

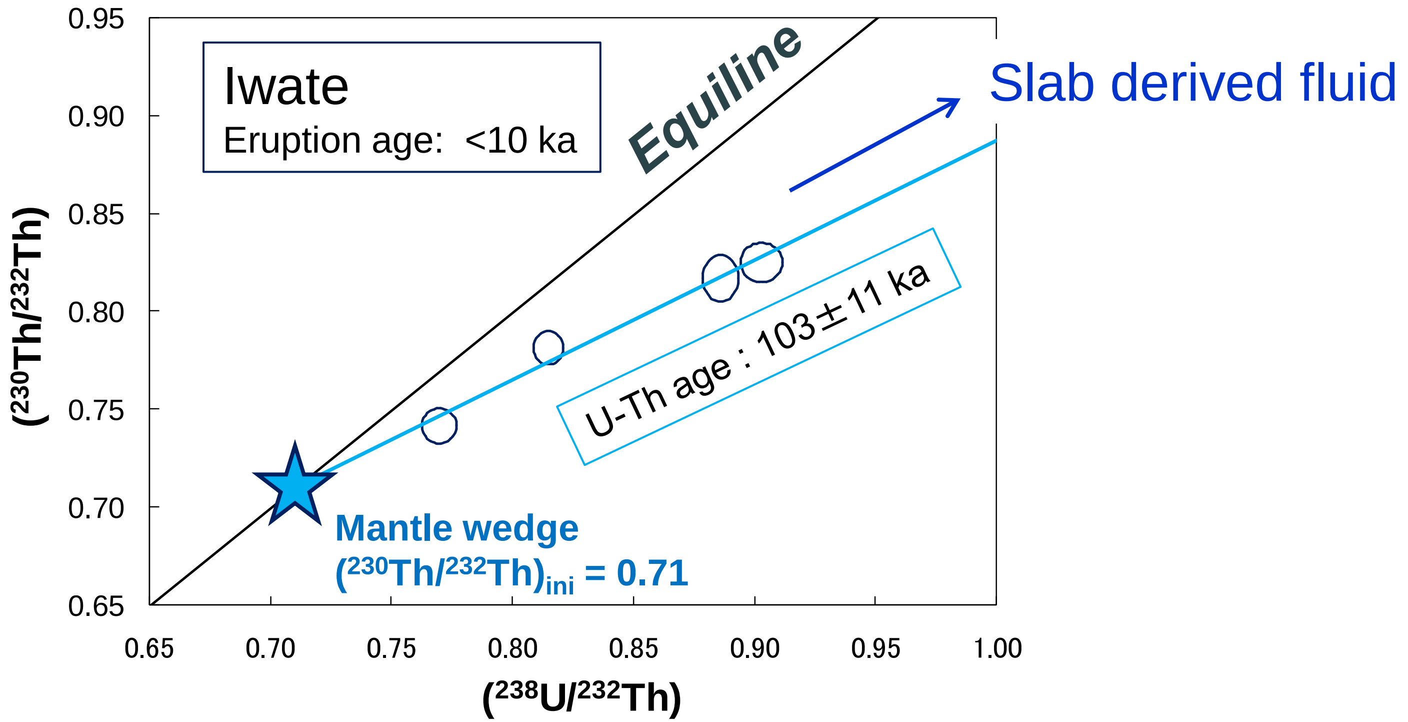
- ^{238}U-^{230}Th age and eruption age are decoupled.
  - A long (>80kyr) residence time before eruption? → NO
  - Assimilation and fractional crystallization? → NO
  - Mixing line produced by the addition of Th enriched slab-derived fluid w/o age significance.

Frontal-arc samples (NE Japan and Izu arc)



- Miyakejima: DMM-like source mantle
- Fuji+Oshima+Komagatake: E-DMM source mantle
- Iwate: More enriched source mantle ?

U-Th age of Iwate



- ^{238}U-^{230}Th age and eruption age are decoupled.
  - A long (>90kyr) residence time before eruption? → NO
  - Addition of slab derived fluid to extremely enriched mantle wedge

Summary

- Rear arc samples have ^{230}Th excesses due either to the dynamic melting of enriched source mantle or flux melting by the addition of Th-rich slab-derived fluid.
- Frontal arc samples have ^{238}U excesses due to the addition of U-rich slab-derived fluid to the mantle wedge that is more enriched than E-DMM.
- Wedge mantle beneath NE Japan can be heterogeneous regarding U/Th and Th isotope ratios due to ancient mantle metasomatism.