Radioactivity (U & Th) in the Lithosphere: Xenolith Analyses & Data Compilation

- Background & Objectves
- Approach
- U & Th data
- Discussion
- Conclusions

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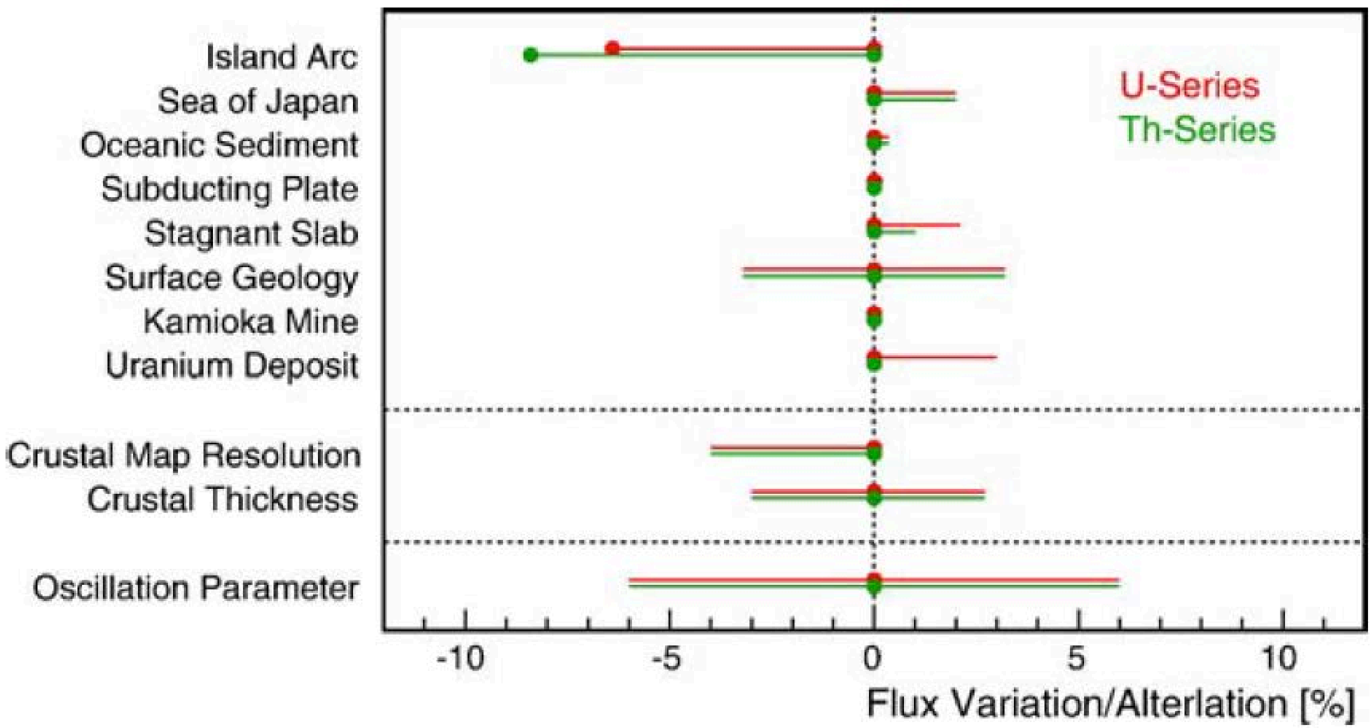
Workshop on Geoneutrino @ Tohoku Univ. 27 October, 2016

Relevance to Geoneutrino

150 S. Enomoto et al. / Earth and Planetary Science Letters 258 (2007) 147–159

Table 2
Geoneutrino fluxes for observation

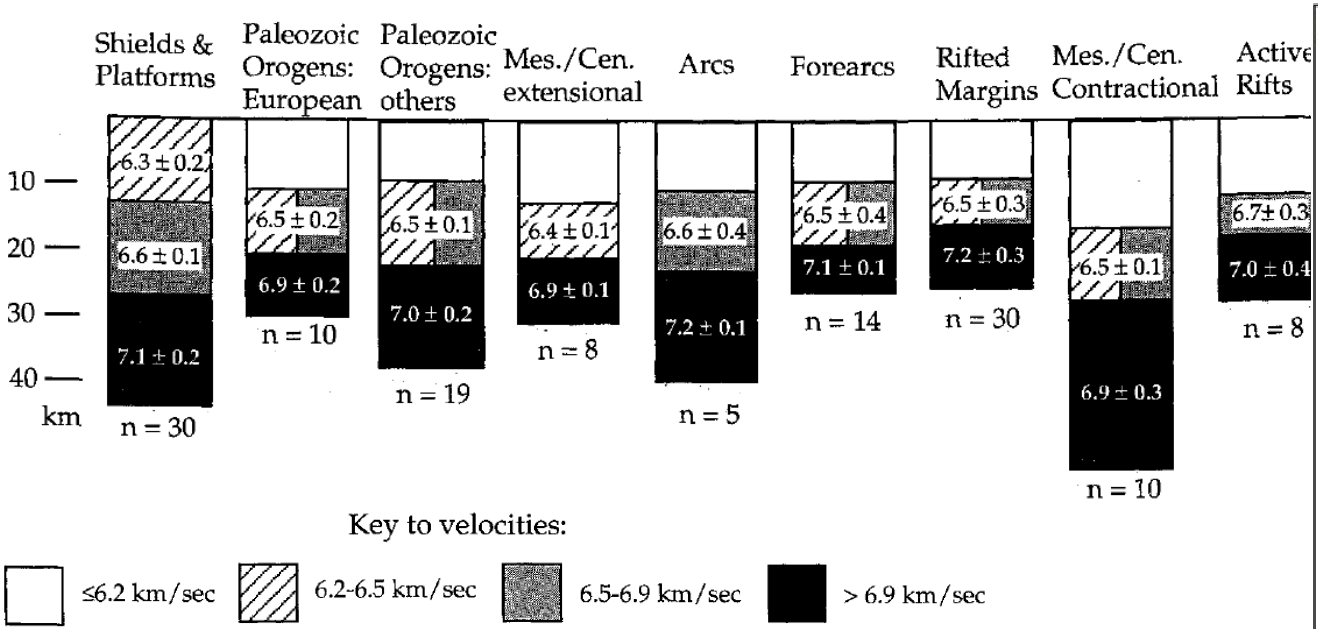
Reservoir
Sediment
Continental crust
Oceanic crust
Mantle
Core
Bulk silicate Earth



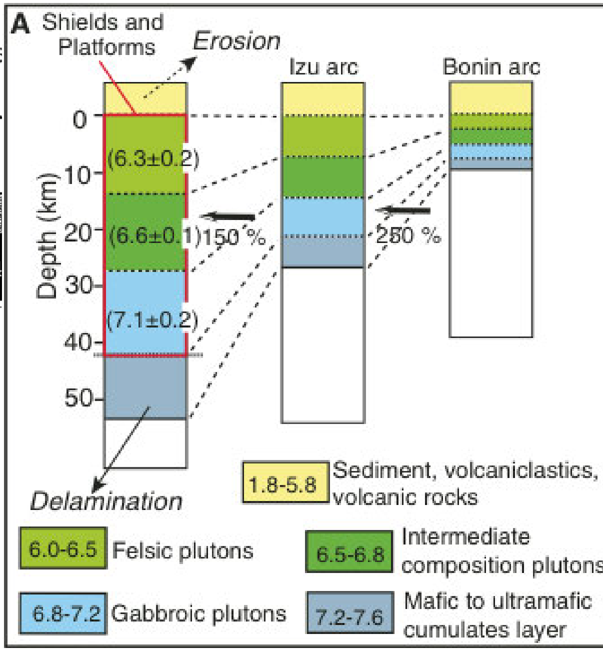
Regional study of the Archean to Proterozoic crust at the Sudbury Neutrino Observatory (SNO+), Ontario: Predicting the geoneutrino flux

Yu Huang[1], Virginia Strati[2,3], Fabio Mantovani[2,3,4], Steven B. Shirey[5], and William F. McDonough[6]

Variable Composition of CC



Rudnick & Fountain '95



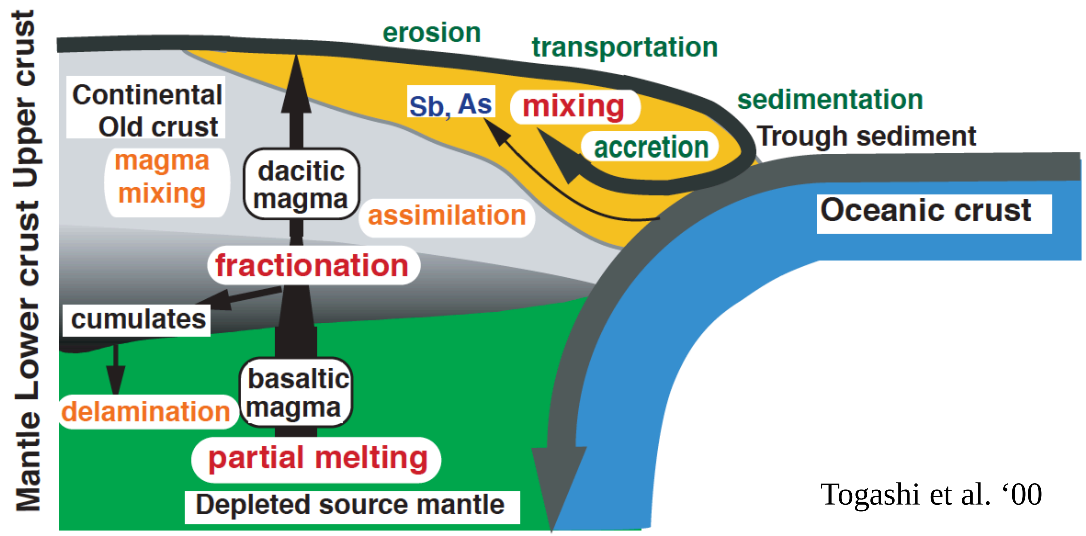
Kodaira et al. '06

- The thickness and composition of CC vary with tectonic setting, resulting from the evolution of CC.
- The average CC composition is reasonably well established based on the data for mature CC, but island arc crust composition is not yet.

Evolution of CC

- Generation of new CC by mantle partial melting.
- Differentiation of CC by fractional cryst./re-melting.
- Erosion/weathering of CC.
- Accretion of sediments/oceanic crust.
- Recycling of CC via subduction/delamination.

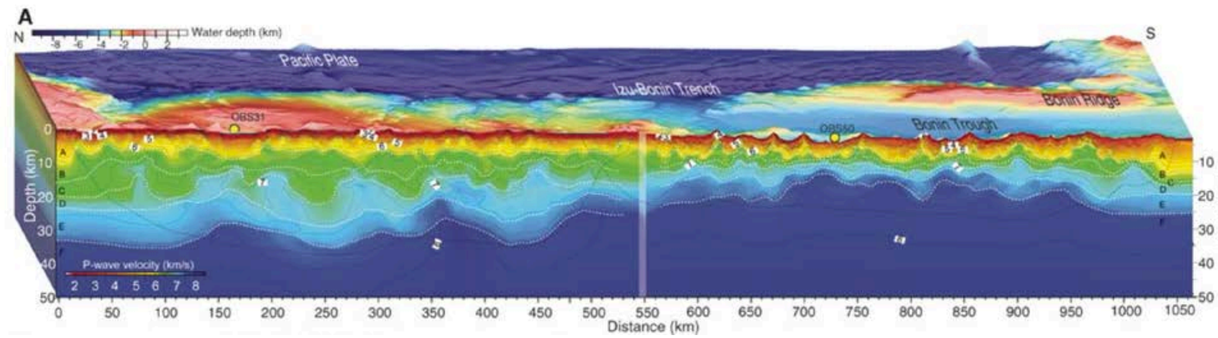
Kemp & Hawkesworth '03



Togashi et al. '00

Objective

Toward understanding the evolution of CC & establishing the mantle composition, we determine the chemical composition of Japanese island arc crust.



Kodaira et al. '06

Approach

(i) Seismic Properties

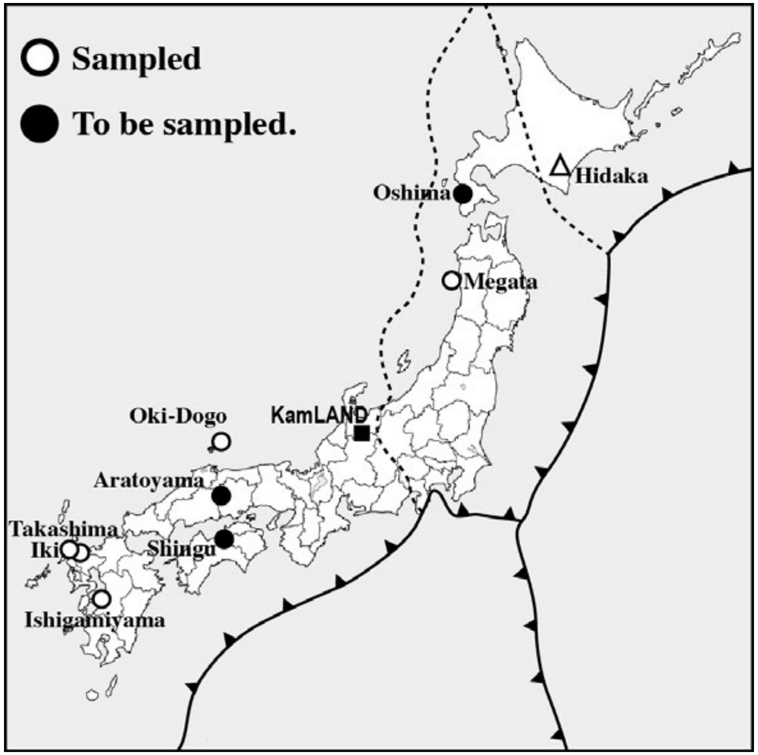
providing *in-situ* data for wide region

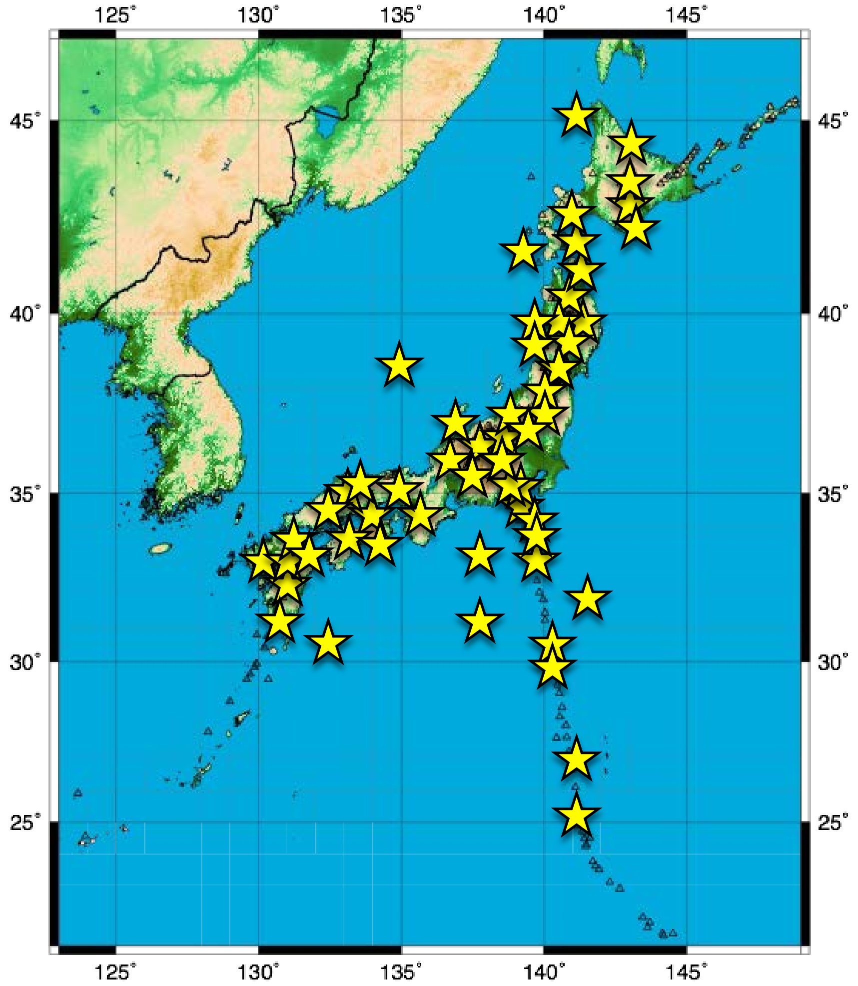
(ii) Petrology and chemistry of rock samples

- mainly from uppermost crust
- rarely from deep crust (e.g., xenoliths)

providing precise trace element data

This Study





<u>Xenolith Samples</u> (by Nagao)

- Megata: 55 samples
- Takashima: 68 samples
- Oki: 92 samples

Total…215 samples

<u>Compiled Data</u> (by Ueki)

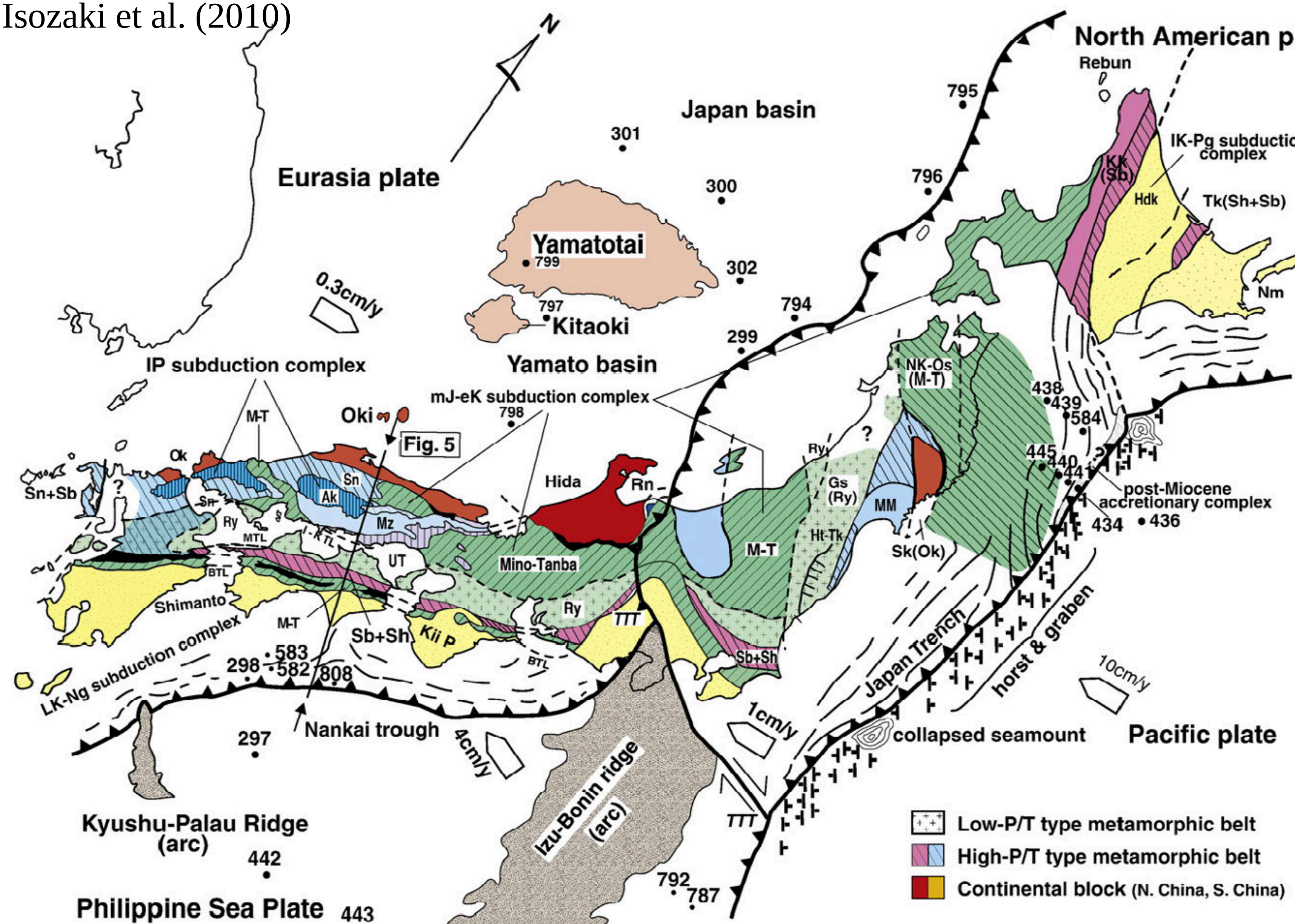
2932 datasets from 96 papers

7930 datasets from GSJ

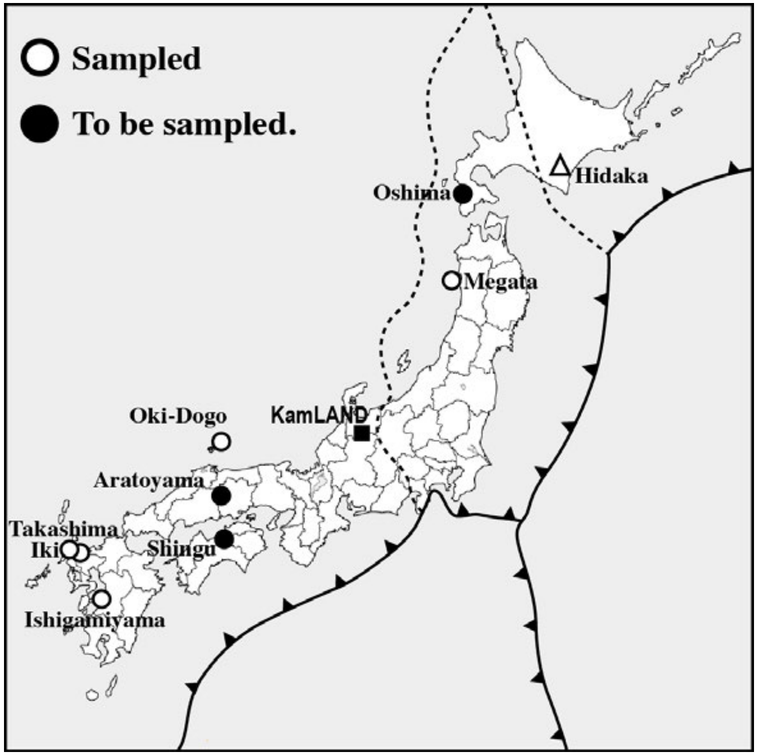
Total…10862 datasets.

Geology of Japan

Isozaki et al. (2010)



This Study



<u>Xenolith Samples</u>

Megata…55 samples.

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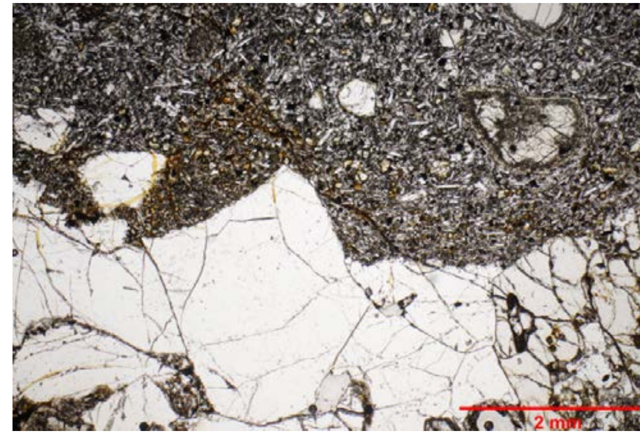
Total…215 samples.

Methodology



Petrology

Determining mineral assemblages using sample thin sections.

Major element analysis using glass bead

X-ray fluorescence analysis.

(PANalytical Axios @ Uni. Tokyo)

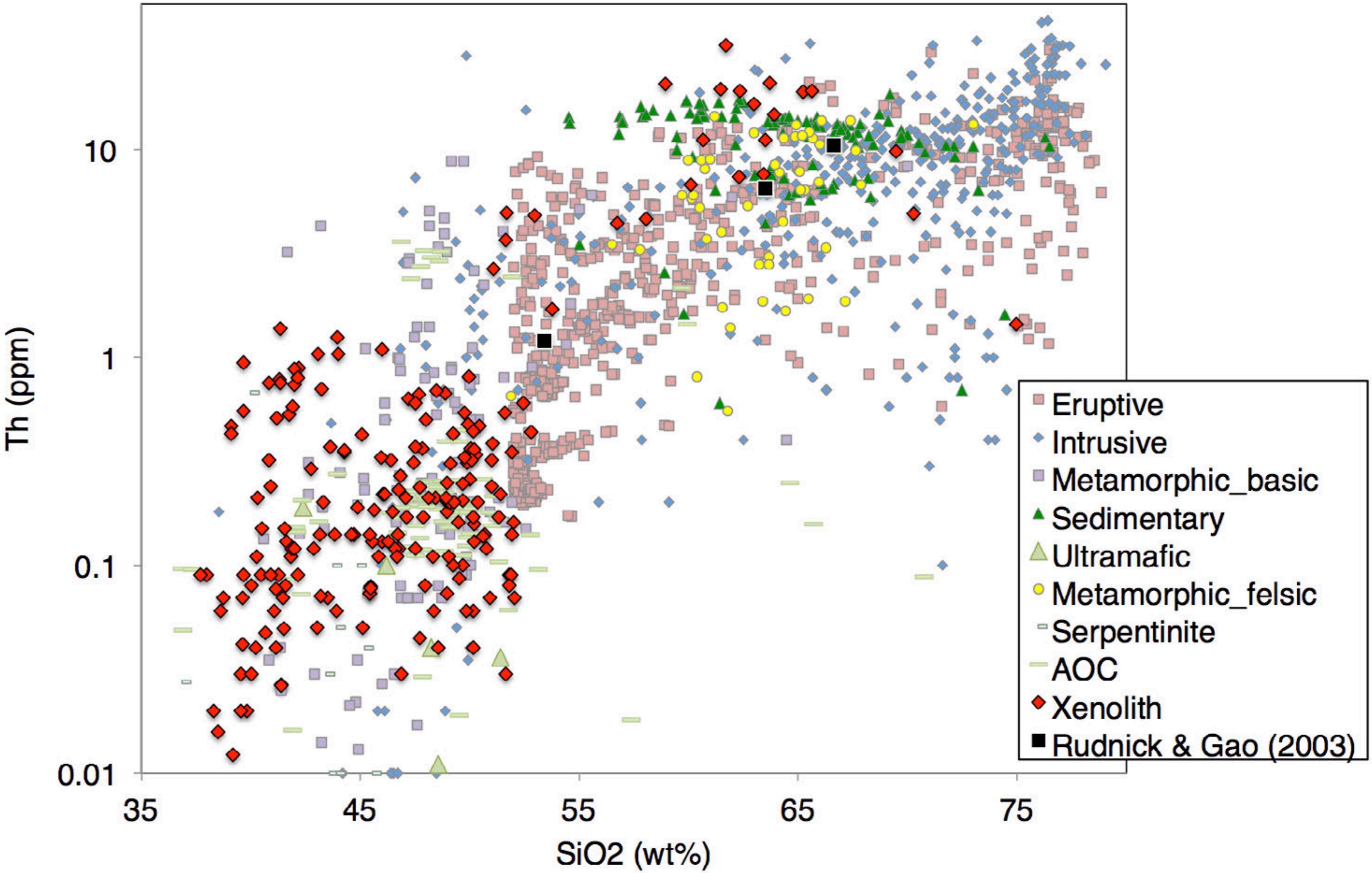
Trace element analysis using glass bead

Laser ablation-ICPMS.

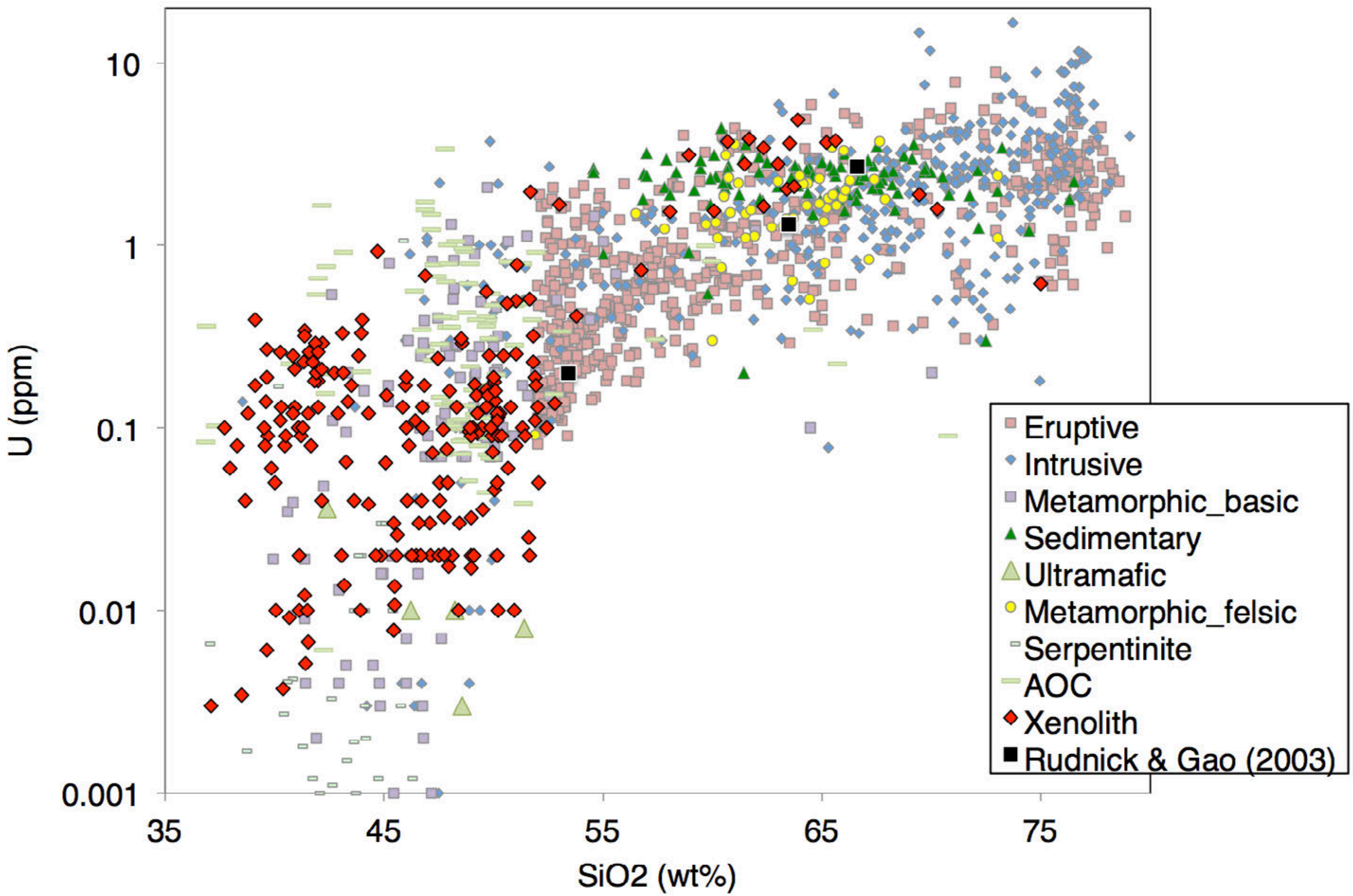
(Cetac LSX-213 Nd:YAG+Thermo icapQ

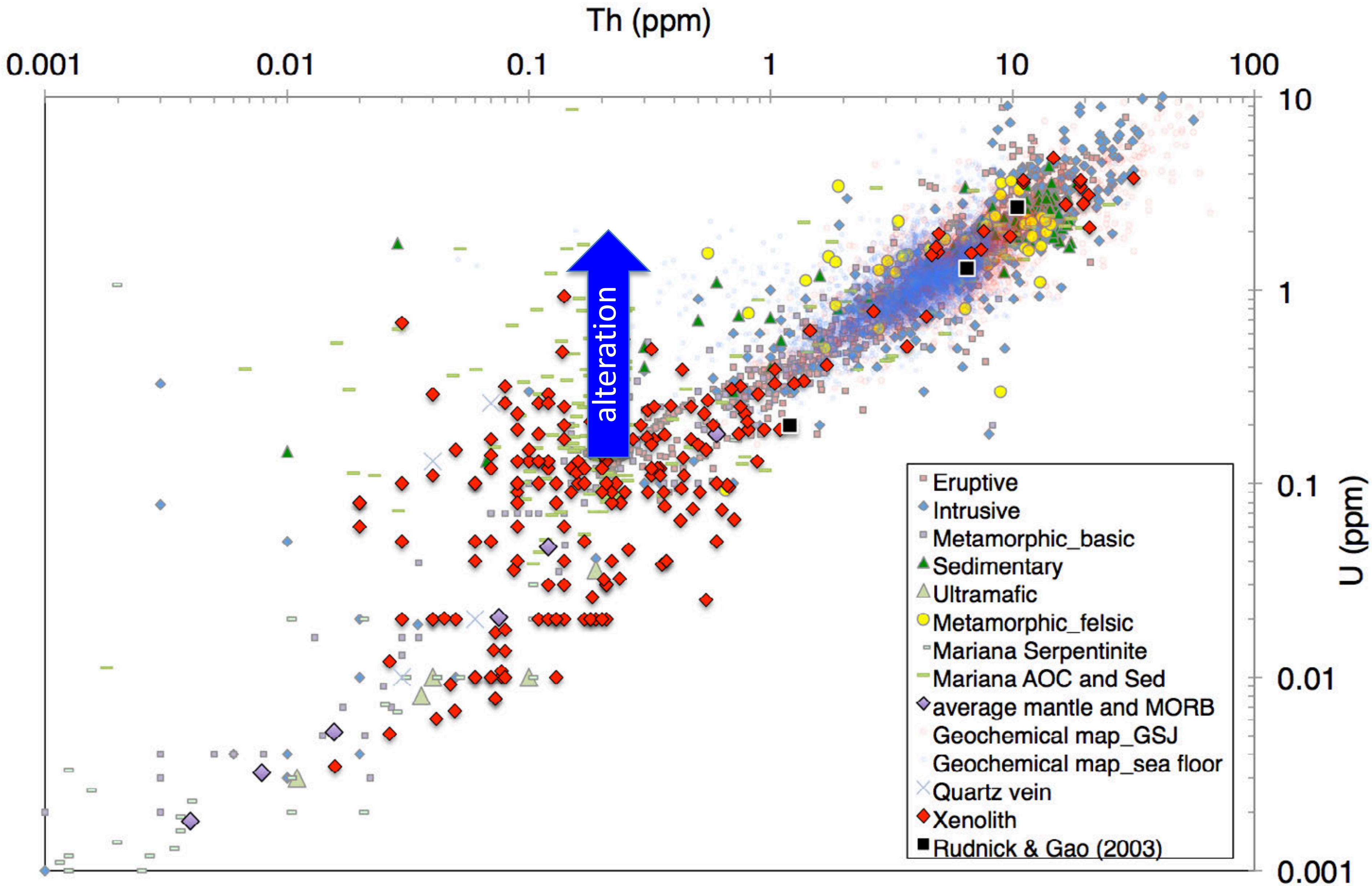
@ Uni. Tokyo)

Th Contents in Japanese Rocks



U Contents in Japanese Rocks



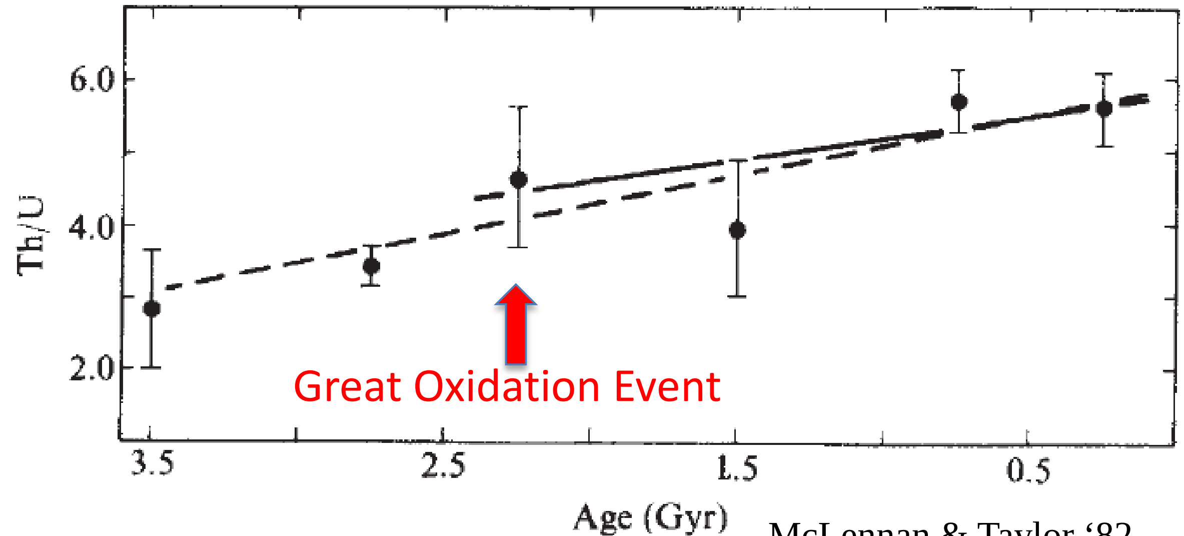

Th (ppm)
0.001
0.01
0.1
1
10
100
U (ppm)
10
1
0.1
0.01
0.001
alteration
Eruptive
Intrusive
Metamorphic_basic
Sedimentary
Ultramafic
Metamorphic_felsic
Mariana Serpentinite
Mariana AOC and Sed
average mantle and MORB
Geochemical map_GSJ
Geochemical map_sea floor
Quartz vein
Xenolith
Rudnick & Gao (2003)

U-Th Decoupling

U^{4+}: fluid immobile

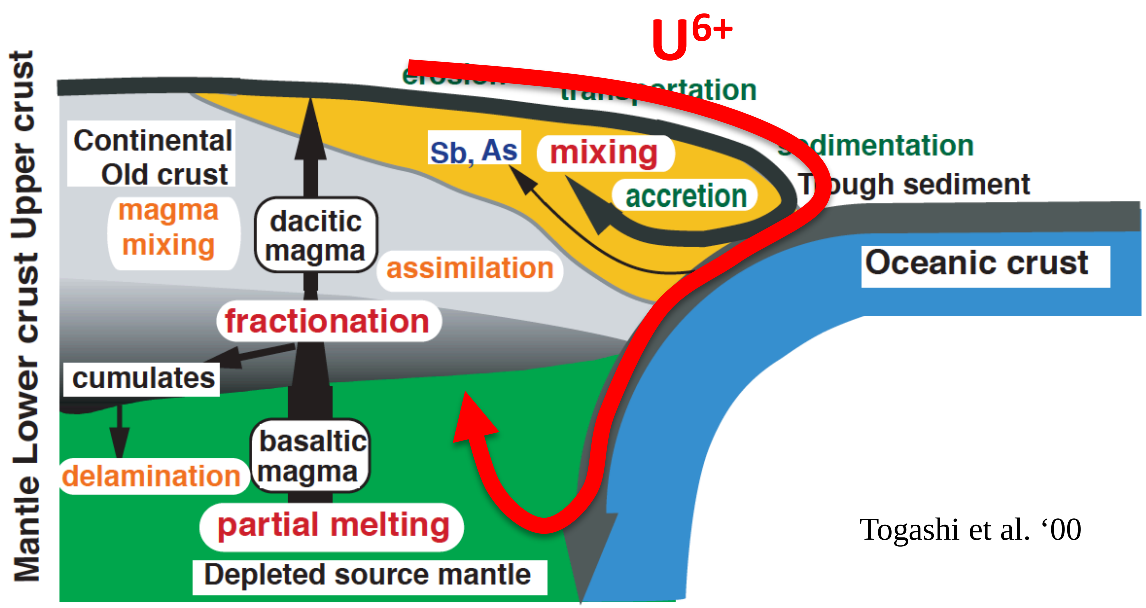
U^{6+}: fluid mobile

Th^{4+}: fluid immobile

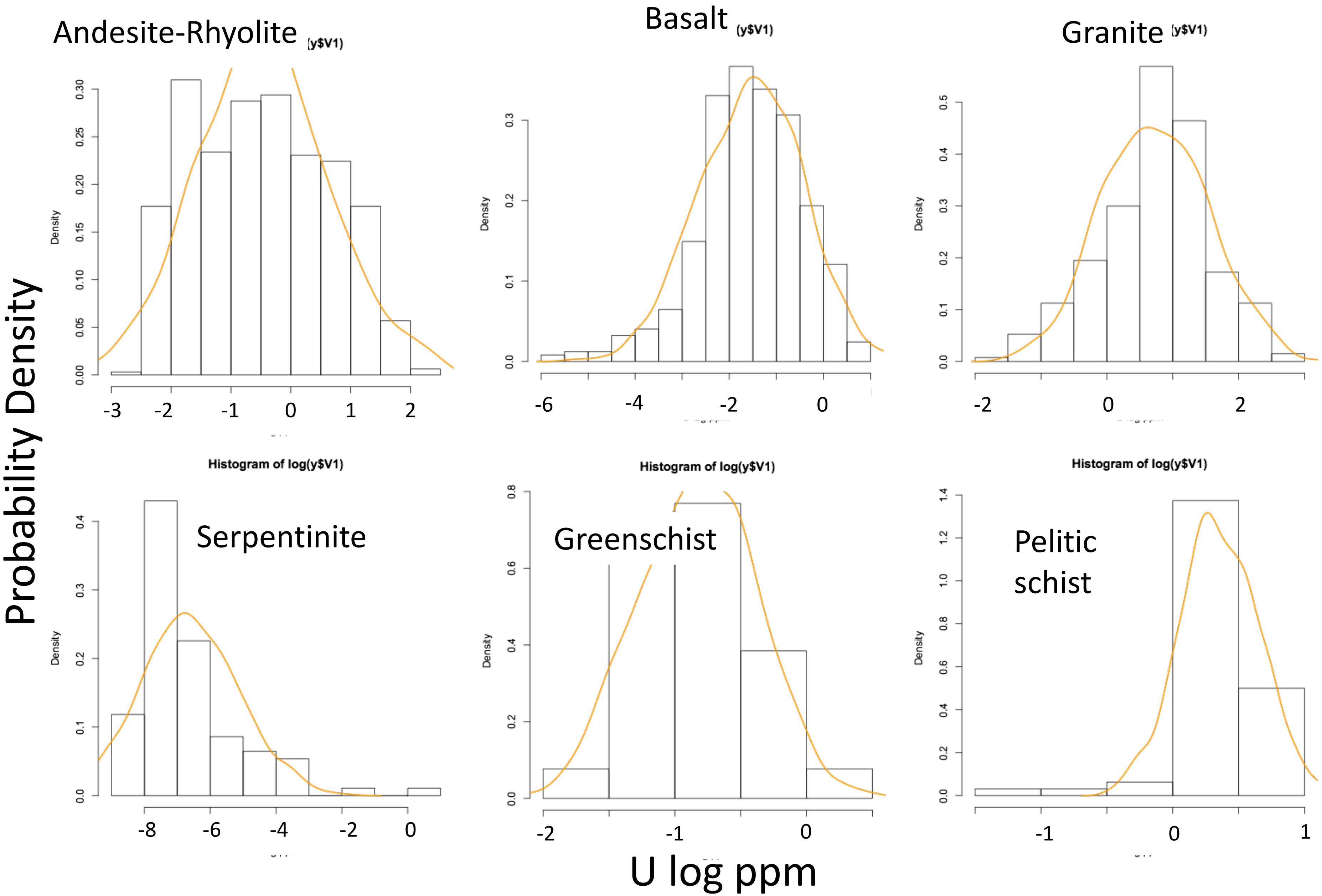


McLennan & Taylor '82

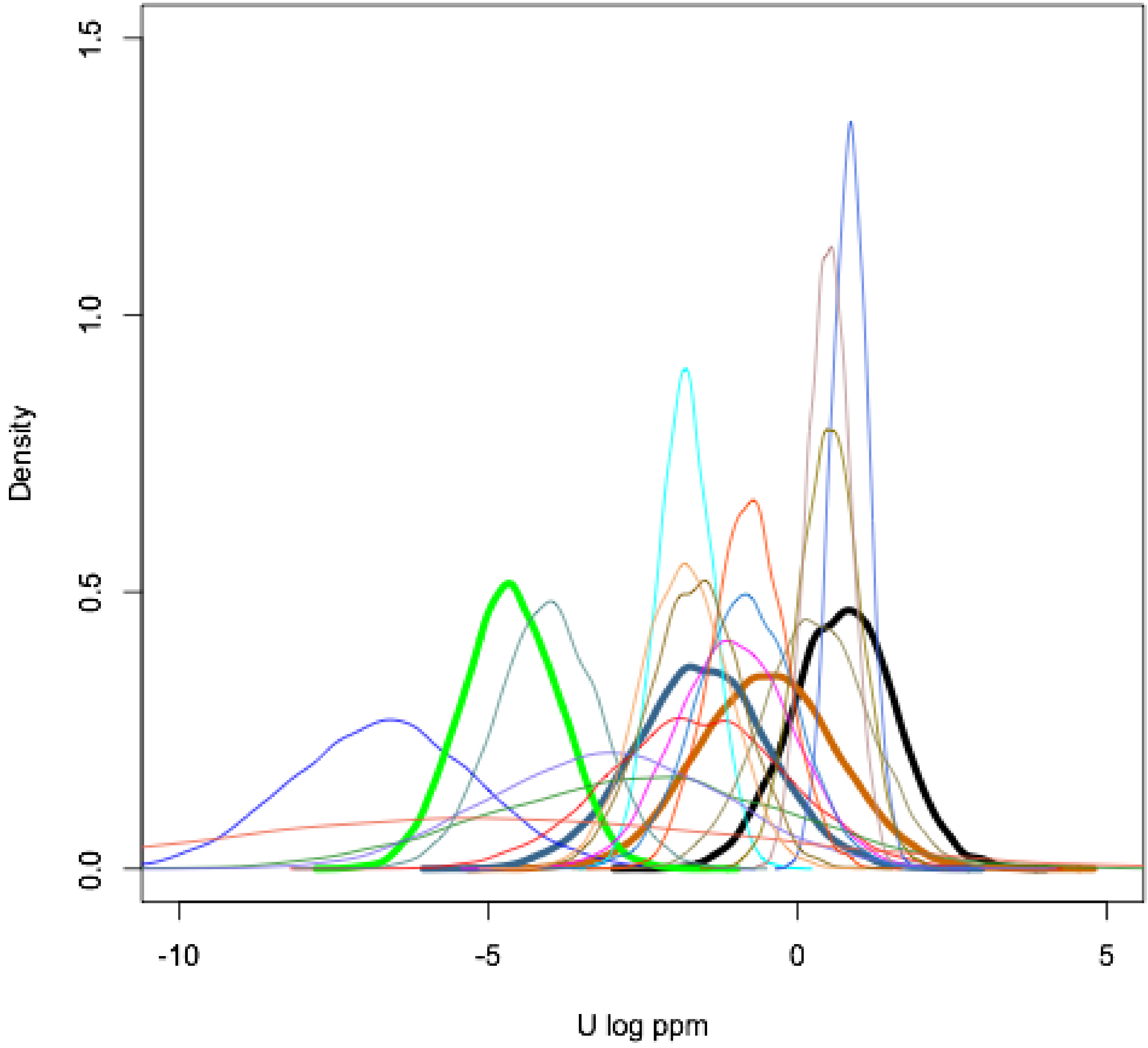
Young upper crust has lost U due to weathering, while young lower island crust has gained U due to fluid addition.



Togashi et al. '00



Log U normal distributions in each rock type.



1.5
1.0
0.5
0.0
Density
-10
-5
0
5
U log ppm

Conclusions

- 215 xenolith samples were analyzed for U-Th.
- 10862 datasets were compiled.
- The combined datasets reveal that:

  (i) upper island crust is depleted in U c.f. GCC.

  (ii) lower island crust is enriched in U c.f. GCC.

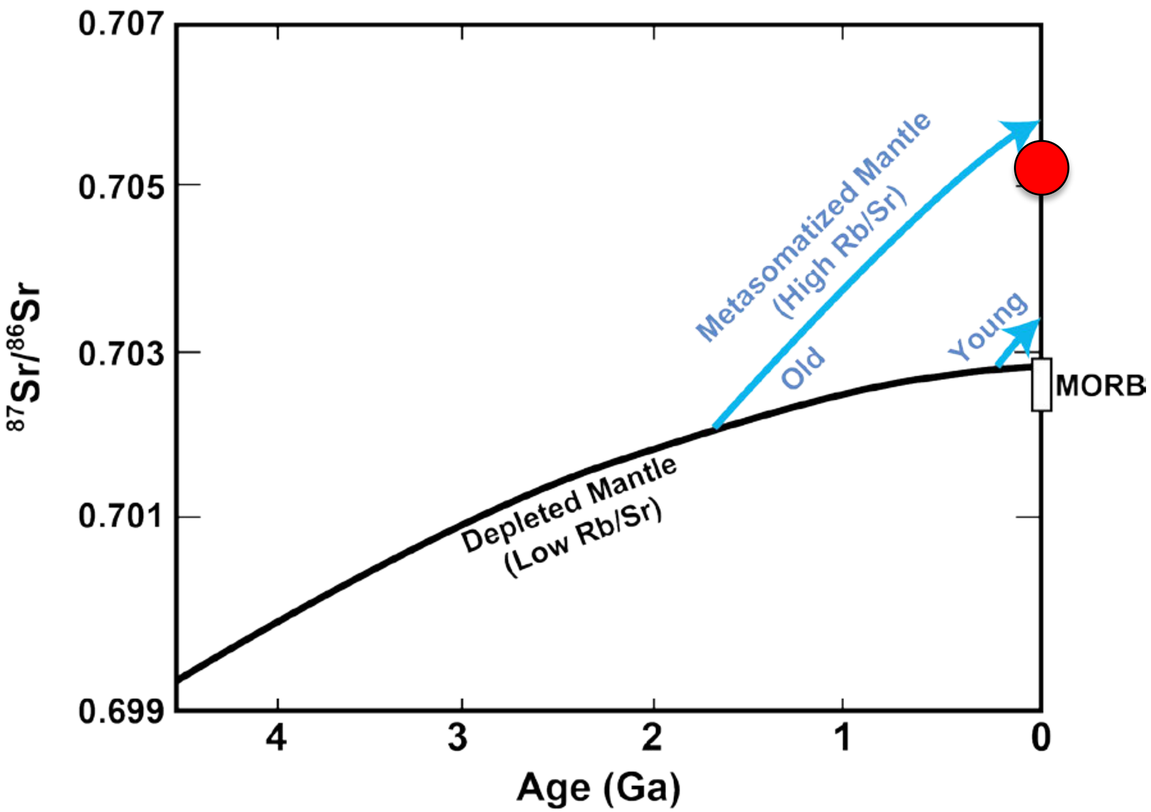
  (iii) Each rock type shows log U normal distribution.
- The discrepancy between IC & GCC may be due to U^{6+} mobility in young crust.

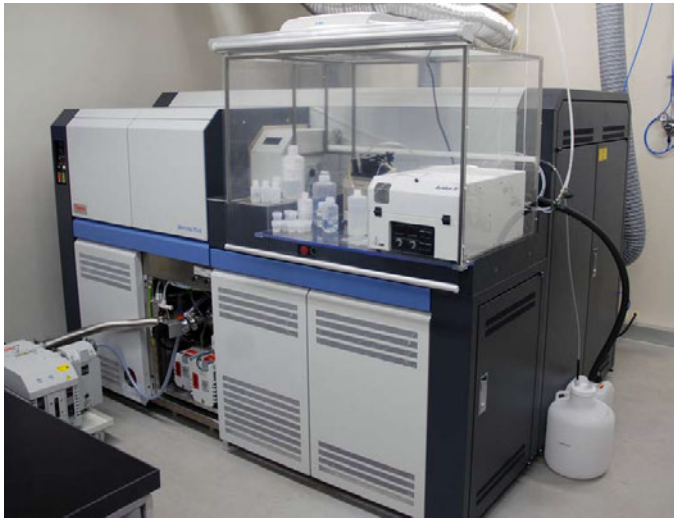
Sr Isotope Data

$$^{87}_{37}Rb \Rightarrow ^{87}_{38}Sr + e^{-} + \overline{\nu}_e$$

$T_{1/2} = 4.88 \times 10^{10}$ yr

Fluid mobility: Rb > Sr





High $^{87}Sr/^{86}Sr$ suggests ancient metasomatism (Rb addition).

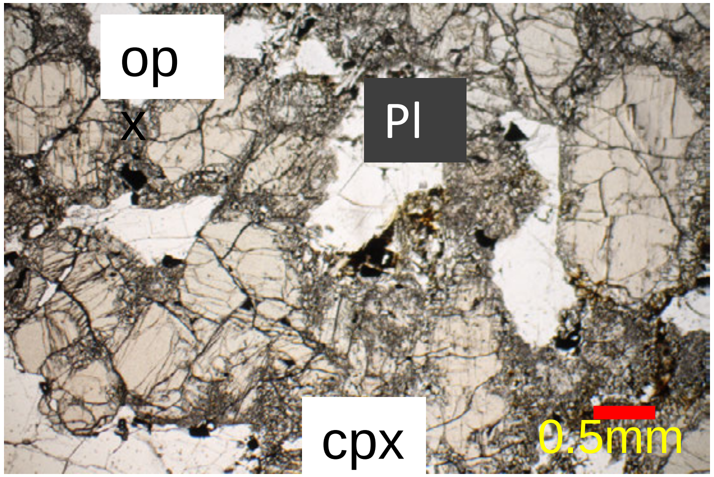
Petrology

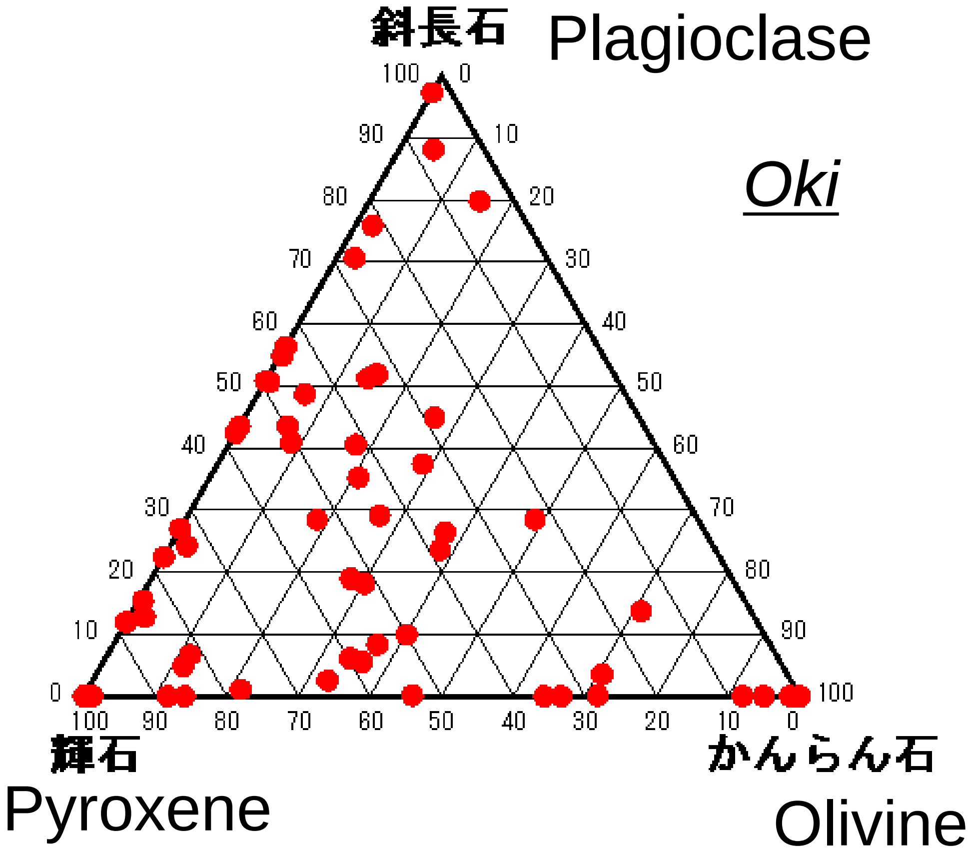
<u>*Oki*</u>
Thin section：100 samples.
Mineral assemblage：60 samples.

<u>*Iki*</u>
Thin section：17 samples.

<u>*Takashima*</u>
Thin section：75 samples

<u>*Megata*</u>
Thin section：50 samples.





Continental Crust (CC)

- covers ~40% of the Earth's surface.
- sits at high elevations due to its lower density.
- contains significantly old (~4.0 Ga) rocks.
- is a major reservoir of incompatible elements (U & Th).
- controls the oceanic & atmospheric compositions.

Understanding the evolution of CC is a fundamental goal in Earth Sciences.