Upwelling of volatiles from the mantle and the subsiding slab through faults and tectonic lines at Kinki district, Japan.

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(Geol. Surv. Japan, AIST)

Water circulation at subduction

Magmatic fluid: 100-1000C, pH 0-2

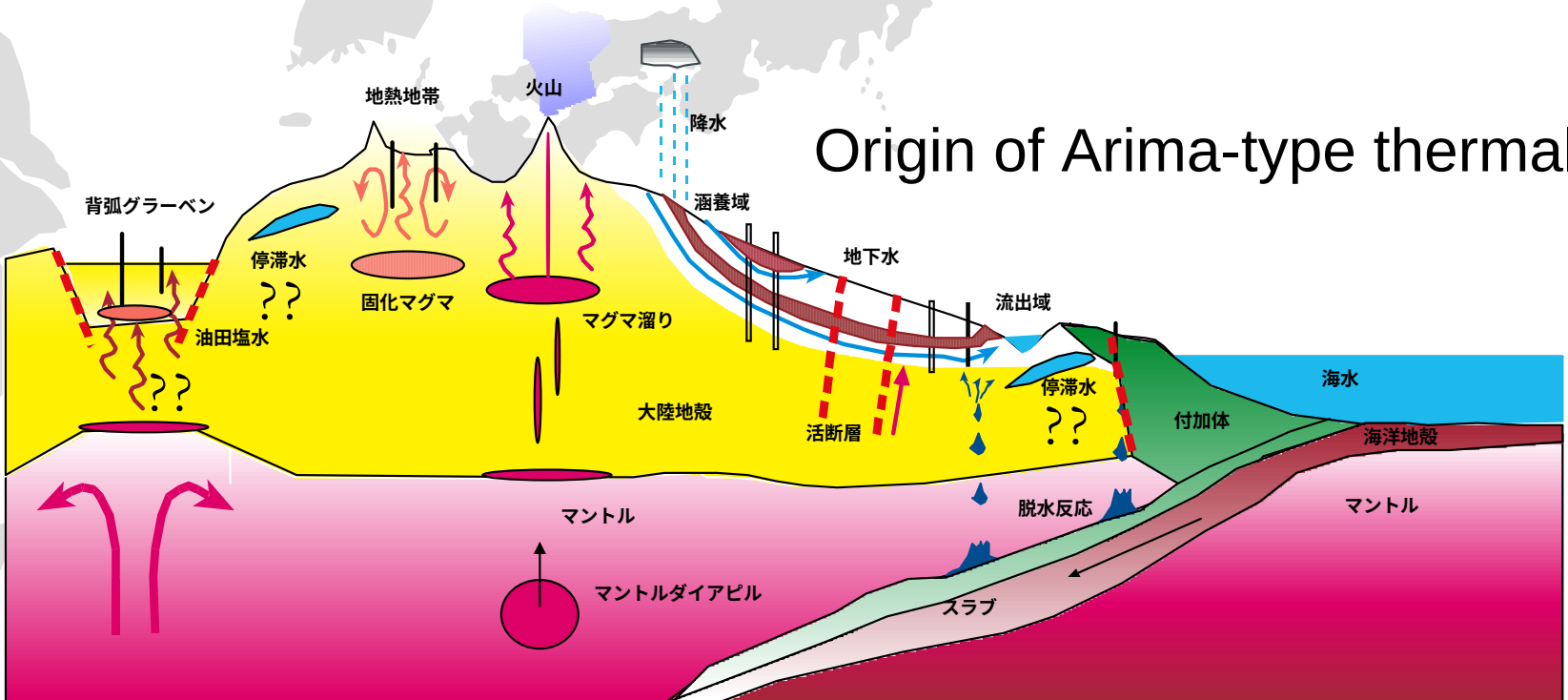
Non-magmatic fluid: 20-300C, pH 3-9

Amounts of CO_2 degassing at 2000m-deep

Stagnant water: 10-80C, pH 8-9

Where does non-volcanic thermal fluid come from?

Origin of Arima-type thermal water



Non-magmatic thermal water:

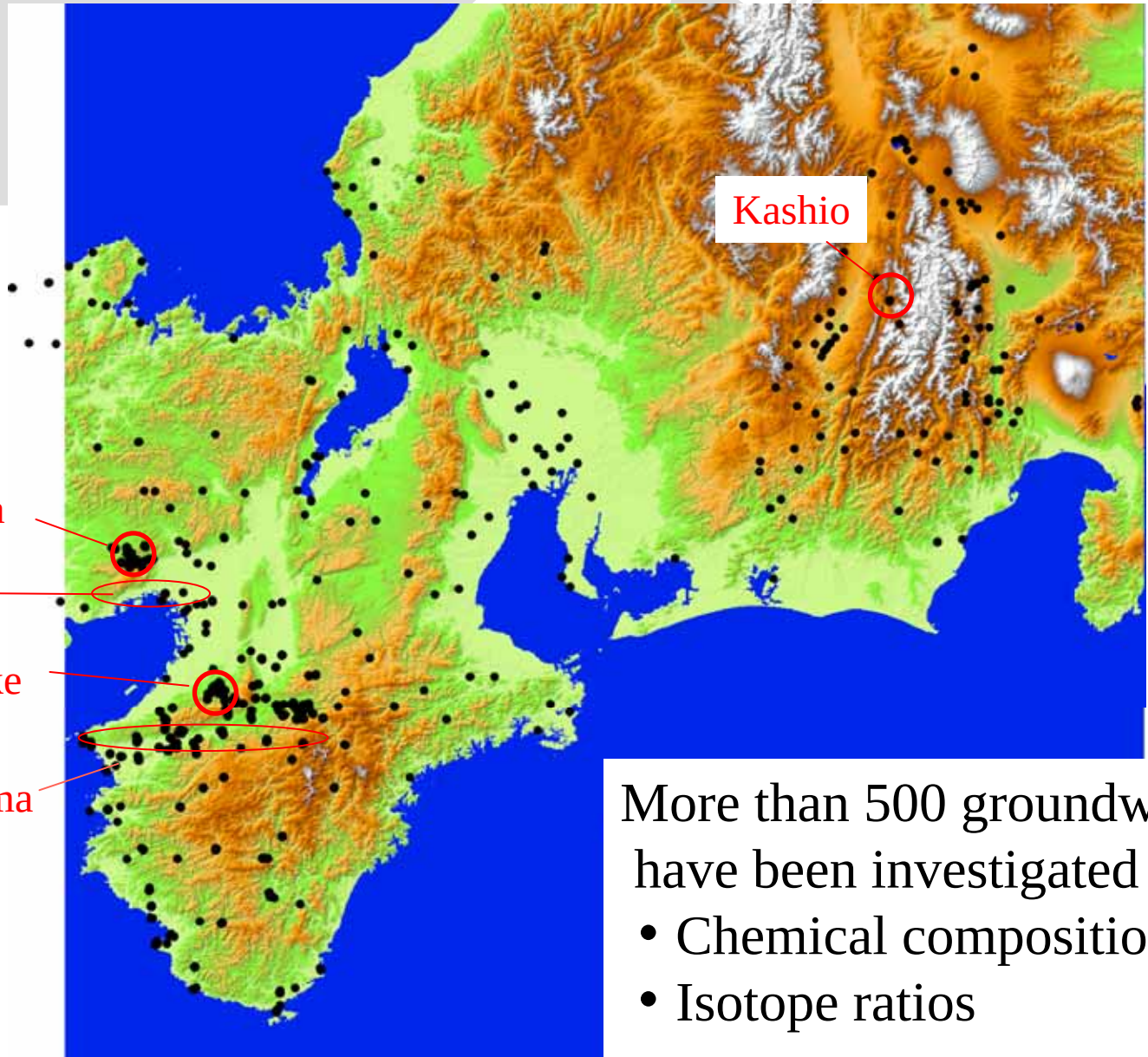
Isotopically categorized as “Arima-type” brine (Matsubaya and Sakai 1976)

Origin and genesis is unknown

This is the target of this study using geochemical and hydrological methods

Arima-type thermal brines

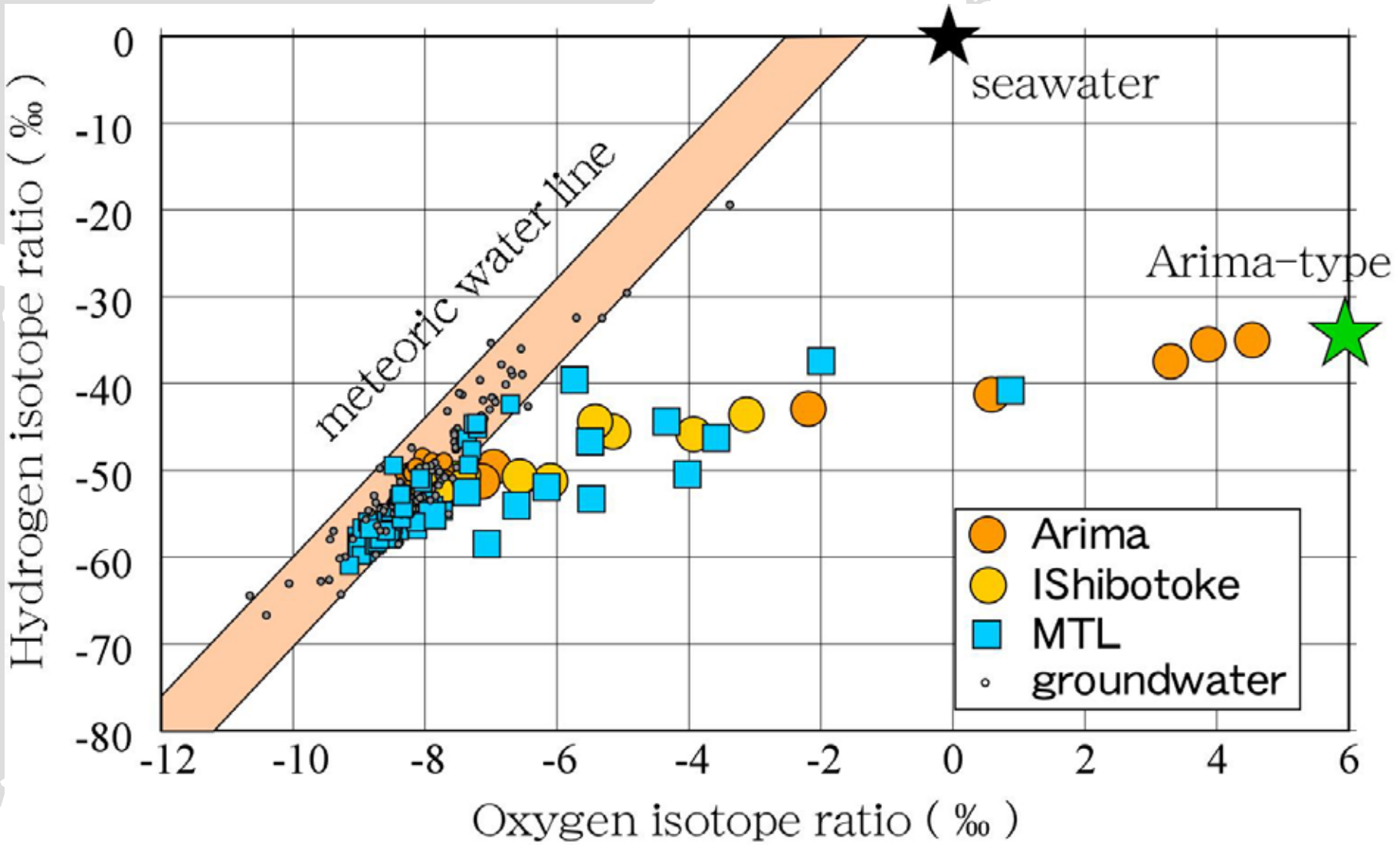
The location where Arima-type thermal brine found

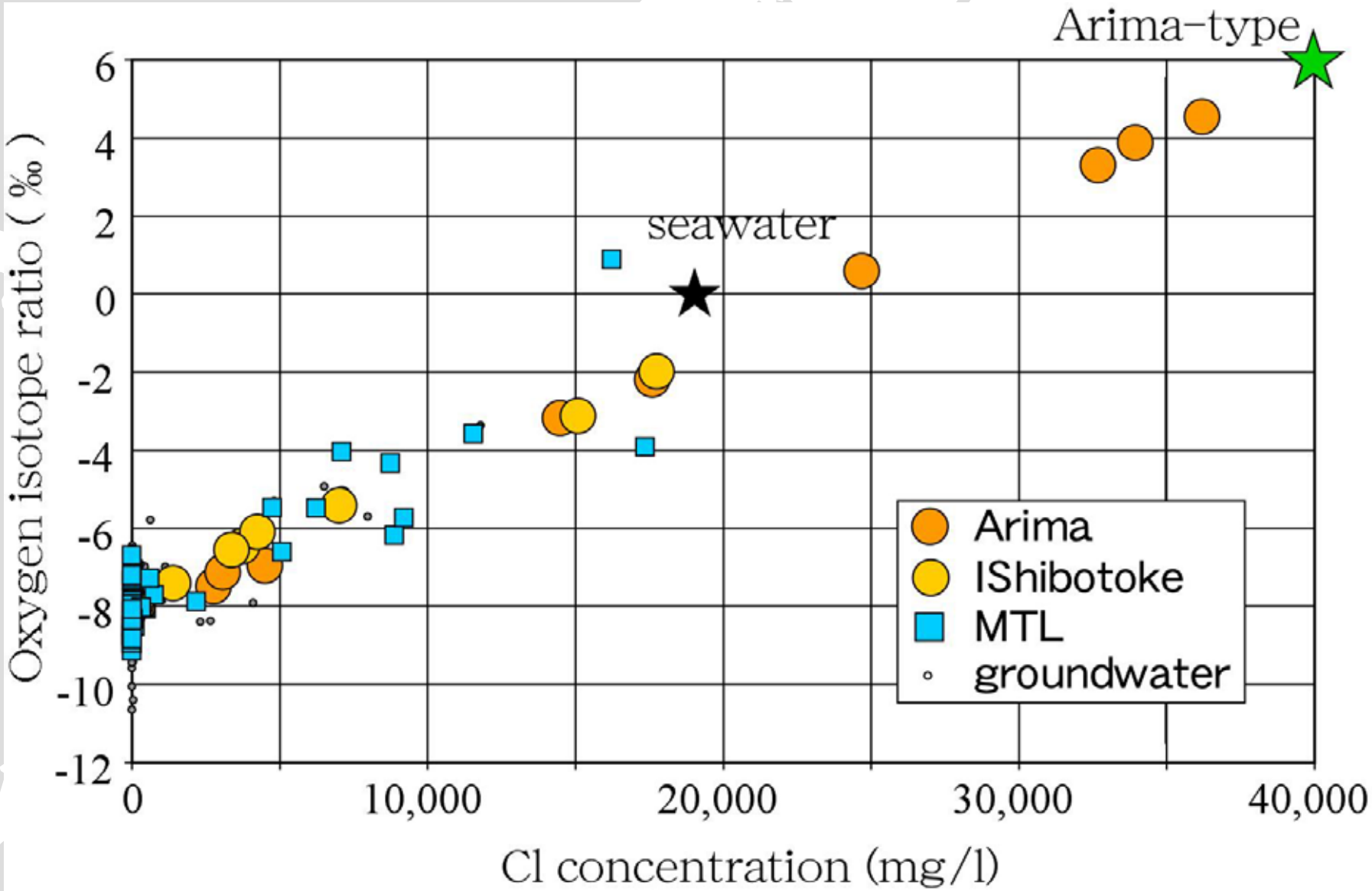


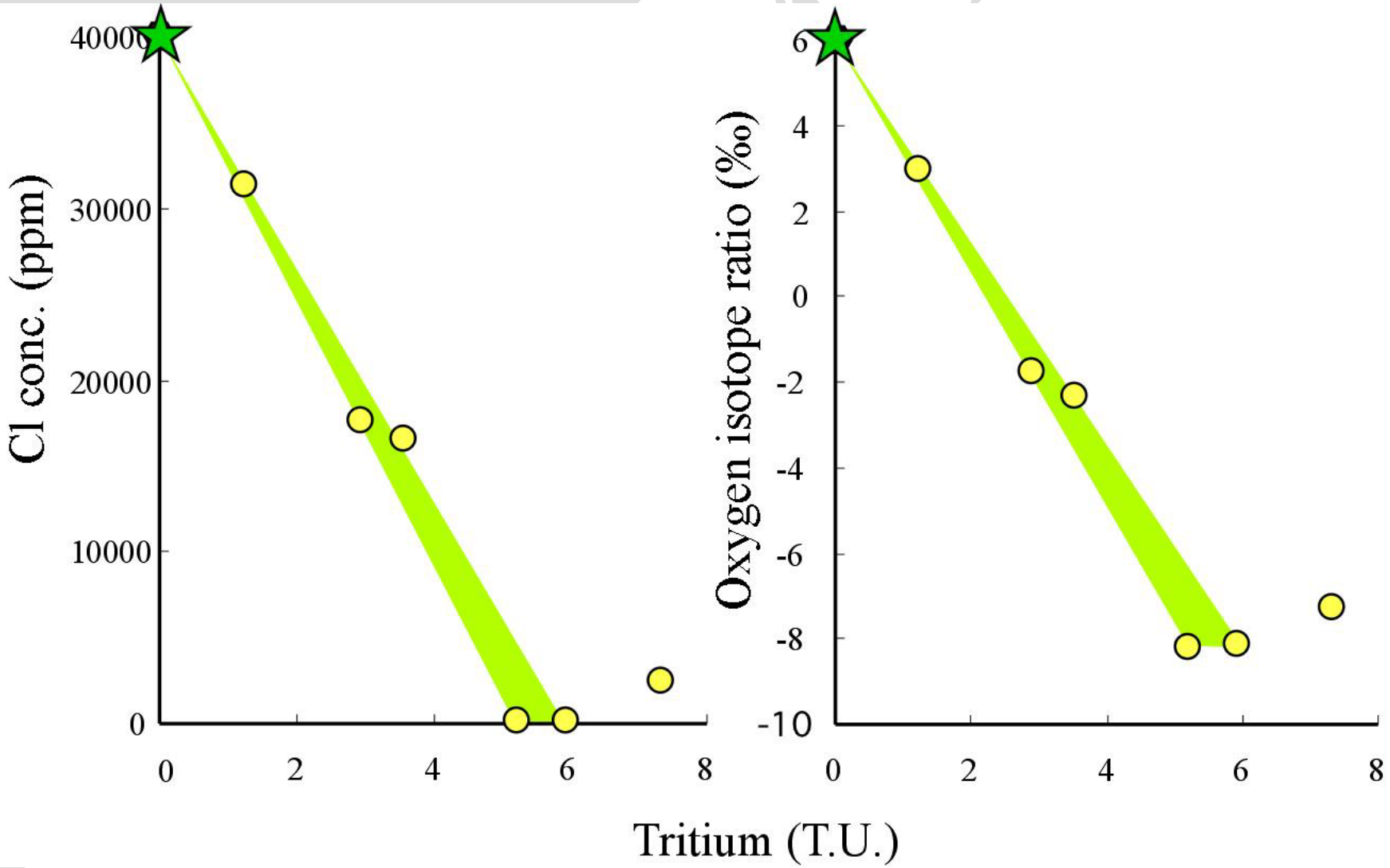
More than 500 groundwater have been investigated

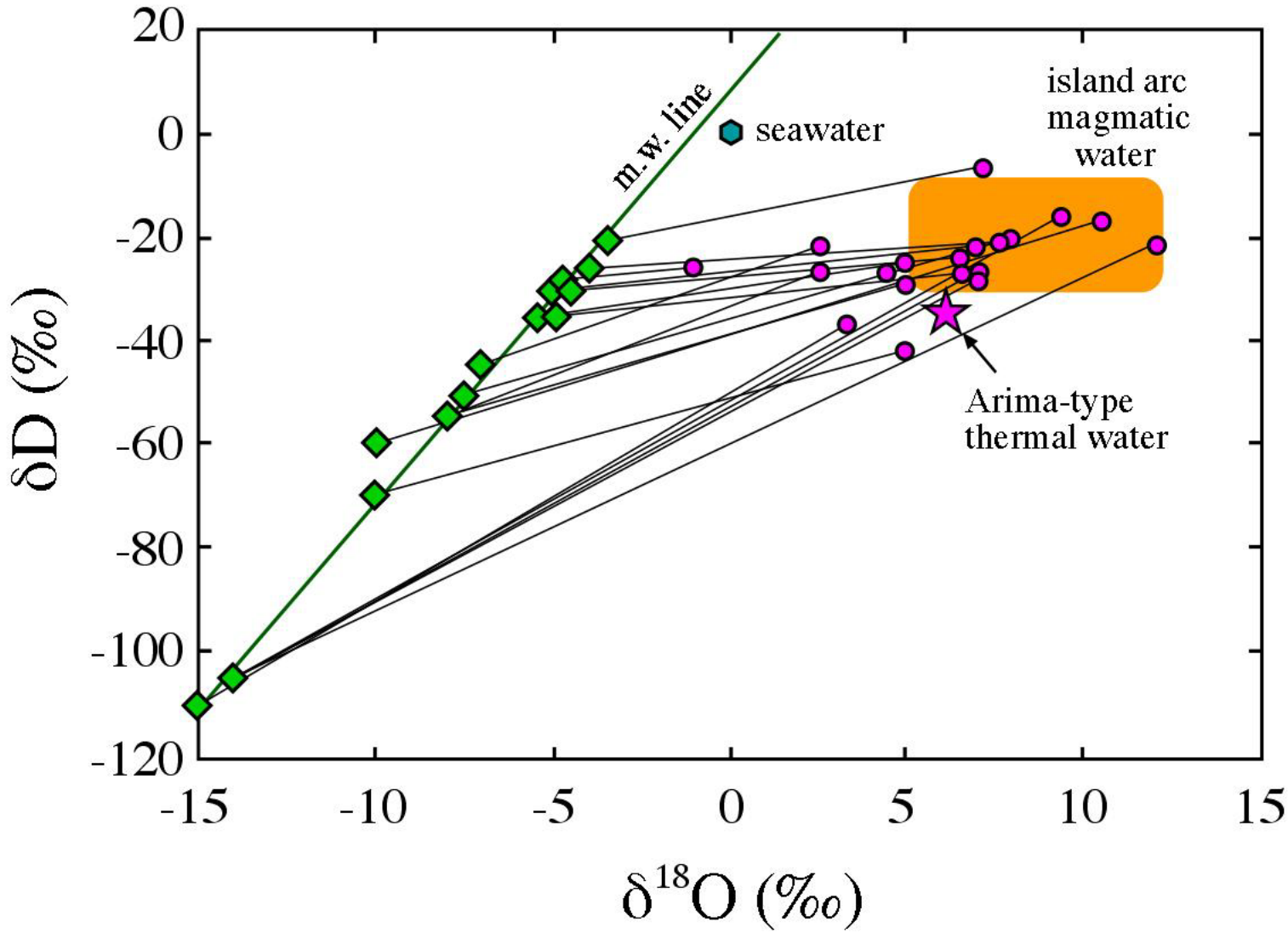
- Chemical composition
- Isotope ratios

Chemical and isotopic evidence for origin and genesis of Arima-type water


seawater
meteoric water line
Arima-type
Arima
IShibotoke
MTL
groundwater
Hydrogen isotope ratio (‰)
Oxygen isotope ratio (‰)
0
-10
-20
-30
-40
-50
-60
-70
-80
-12
-10
-8
-6
-4
-2
0
2
4
6


Arima-type
seawater
Oxygen isotope ratio (‰)
6
4
2
0
-2
-4
-6
-8
-10
-12
0
10,000
20,000
30,000
40,000
Cl concentration (mg/l)
Arima
IShibotoke
MTL
groundwater


Cl conc. (ppm)
40000
30000
20000
10000
0
0
2
4
6
8
Oxygen isotope ratio (‰)
6
4
2
0
-2
-4
-6
-8
-10
0
2
4
6
8
Tritium (T.U.)



after Giggenbach (1993)

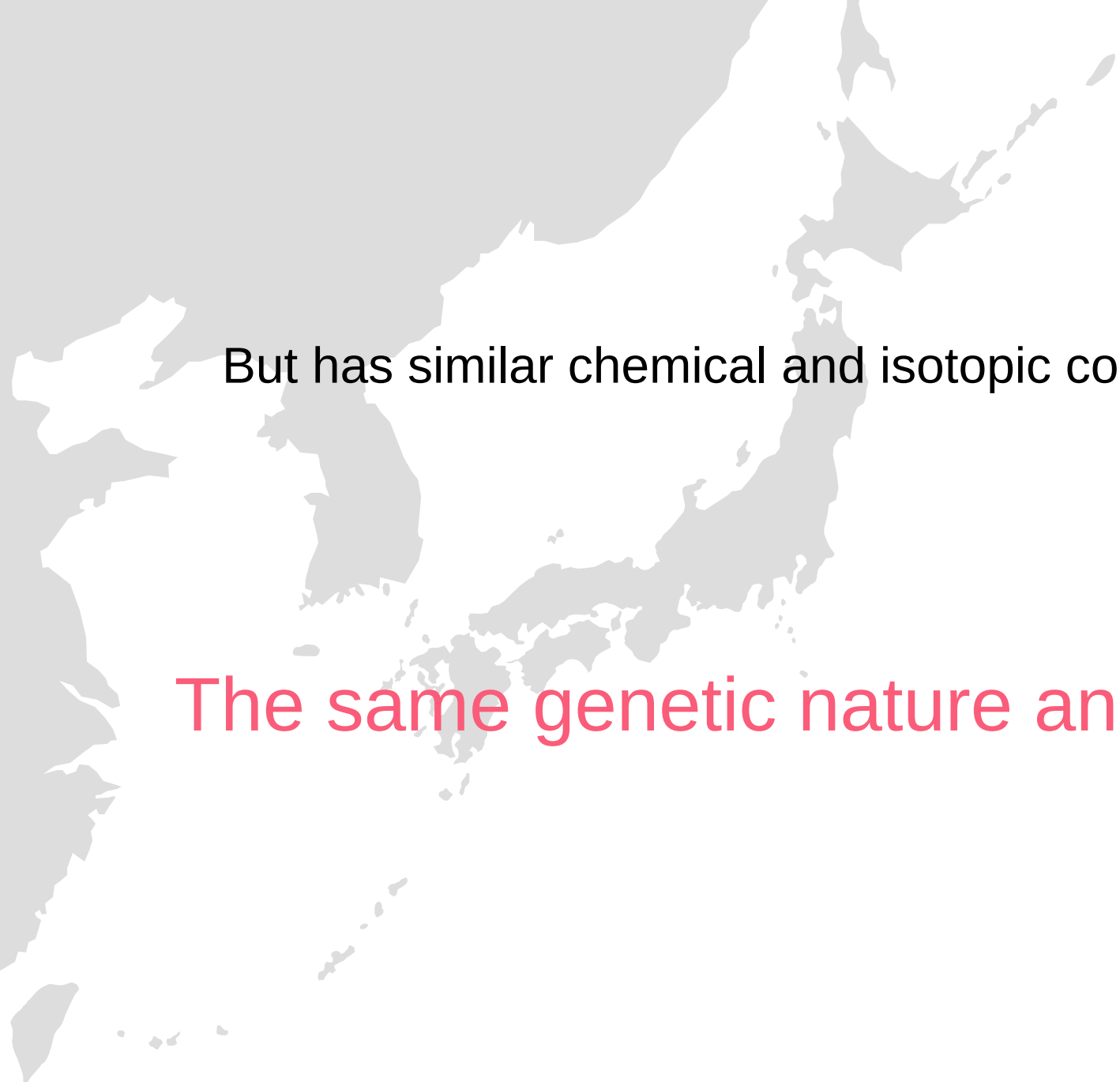
Comparison between Arima-type thermal fluid and island-arc magmatic water

Similar chemical and isotopic feature

		Arima-type	magmatic
Cl (wt%)		4	1 ～ 3
D/H (‰)	H_2O	−35	−35 ～ −15
$^{18}O/^{16}O$ (‰)	H_2O	+6	+5 ～ +10
$^{13}C/^{12}C$ (‰)	CO_2	−5	−8 ～ −4
$^{3}He/^{4}He$	He	1×10^{-5}	$1 \sim 1.2 \times 10^{-5}$

Origin of Arima-type fluid?

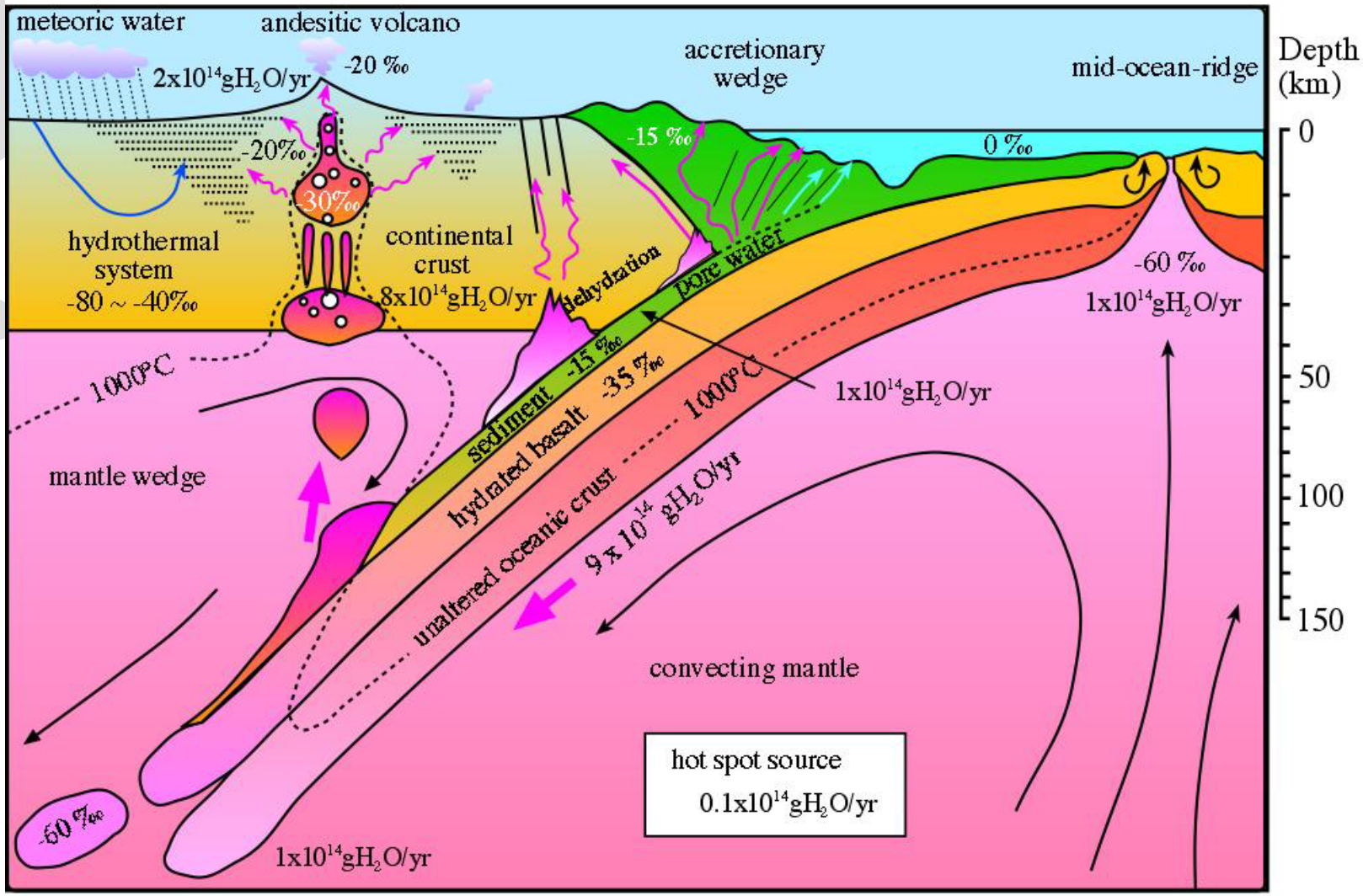
~~Not magmatic~~



But has similar chemical and isotopic composition

The same genetic nature and origin?

missing water: $6 \times 10^{14} g H_2O/yr$



summarized by Kazahaya (1997)
flux data given by Ito et al.(1983)

Water budget in the solid earth (Ito et al., 1983)

source (10^{14}g/y)	
mid ocean ridge	1.1 (0.8-1.4)
hot spot	0.13 (0.06-0.26)
arc magmatism	1.0 (0.05-3)
subtotal	2.2 (0.9-4.6)

sink (10^{14}g/y)	
hydrated basalt	8.8 (5.9-11.7)
sediment	1.3 (0.4-2.2)

Total: 6.6 net subduction (1.3-11)

Mean retention time for seawater is 2 Ga

Fig. 11. Summary of water circulation budget in the solid earth (Ito et al., 1983).

Missing water

A Question

Arima-type fluid come from subducting slab?
Arima-type fluid is the answer for the missing water?

To answer the question

Flux measurement of Arima-type fluid

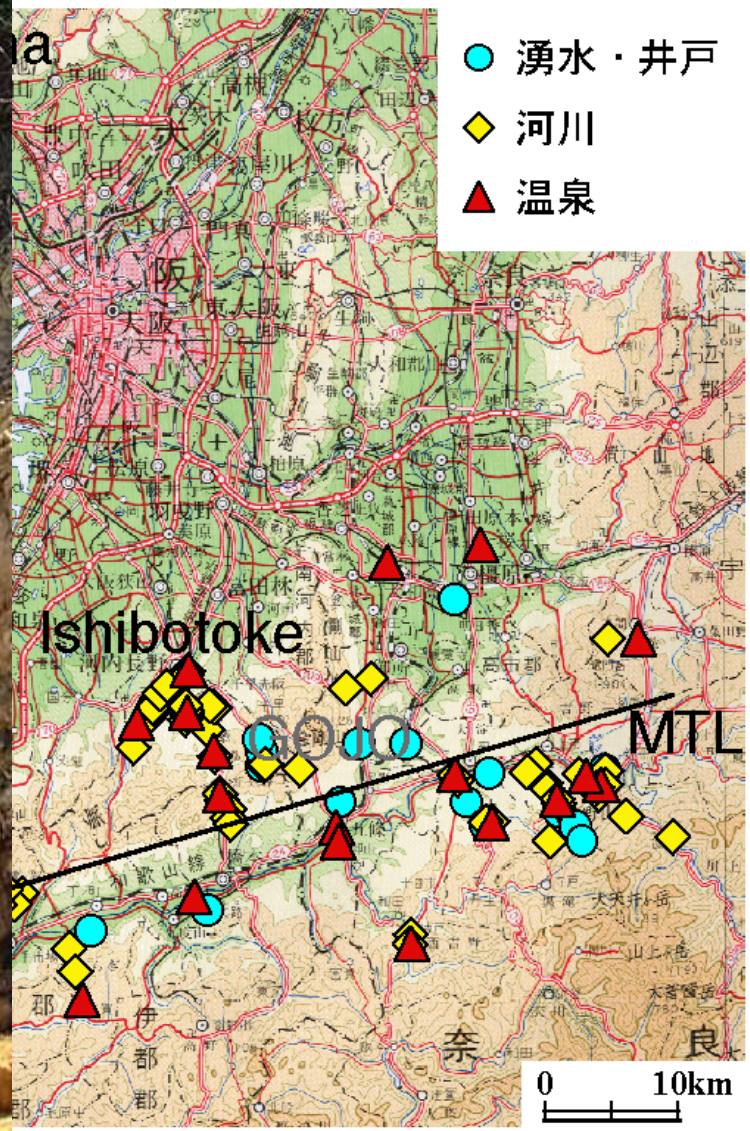
and compare with missing water flux

Photos showing wells and self-spouting outcrops

Short visit to the field

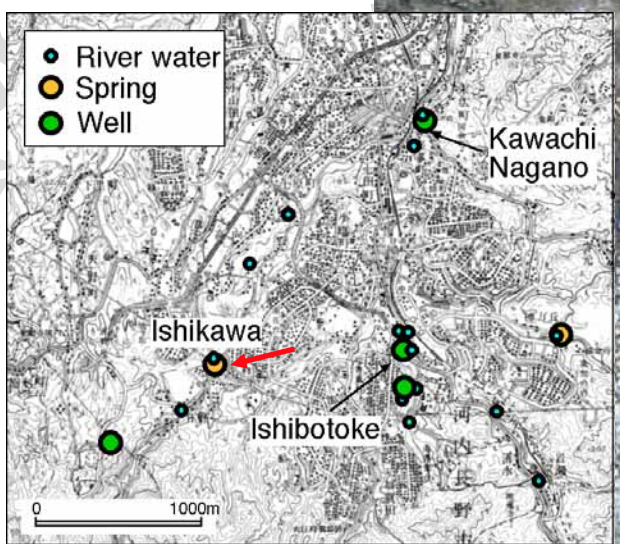
at Arima, Gosha and Ishibotoke
In Kinki district, Central Japan


湯 有馬天神

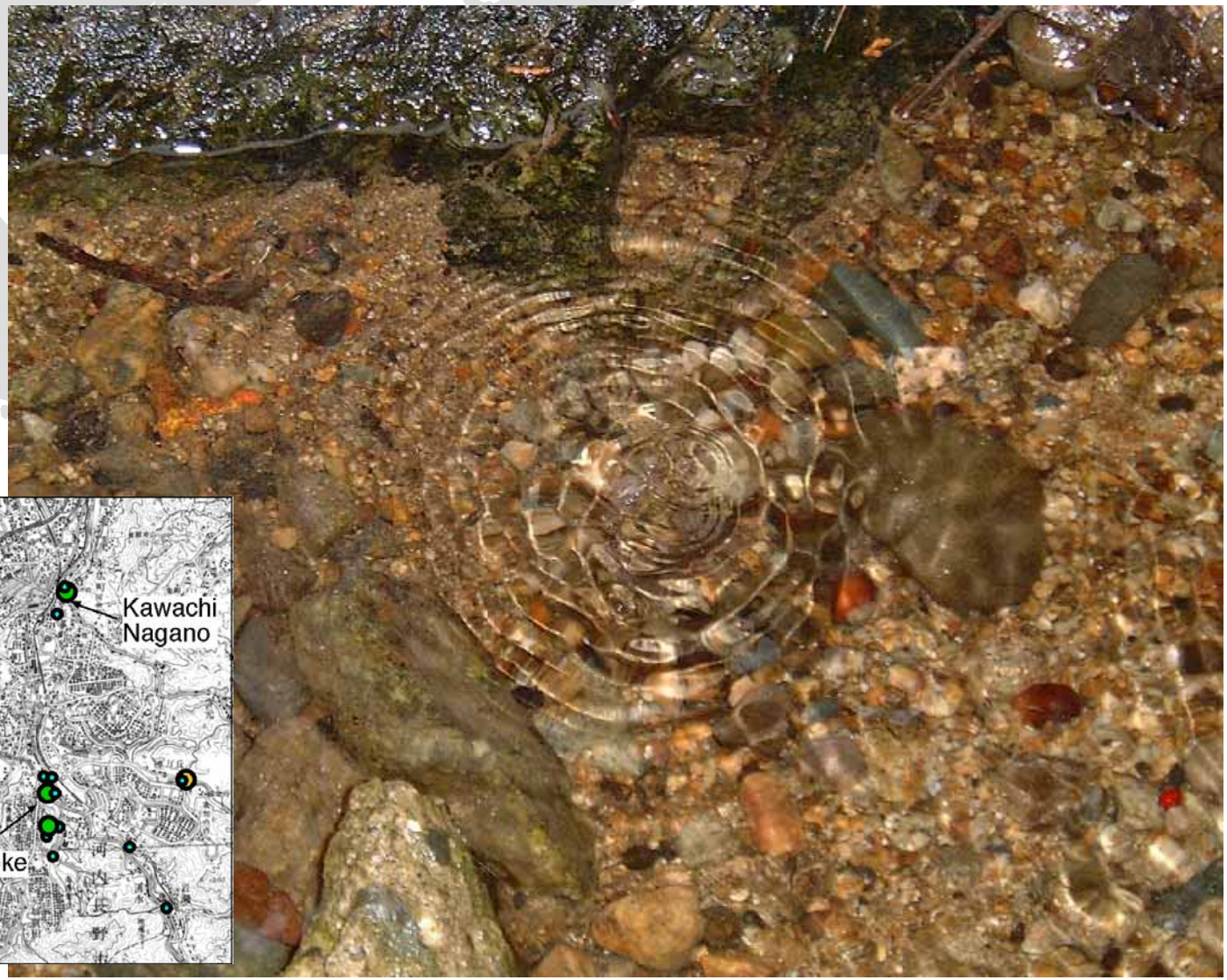

湧水・井戸
河川
温泉
Ishibotoke
MTL
0
10km

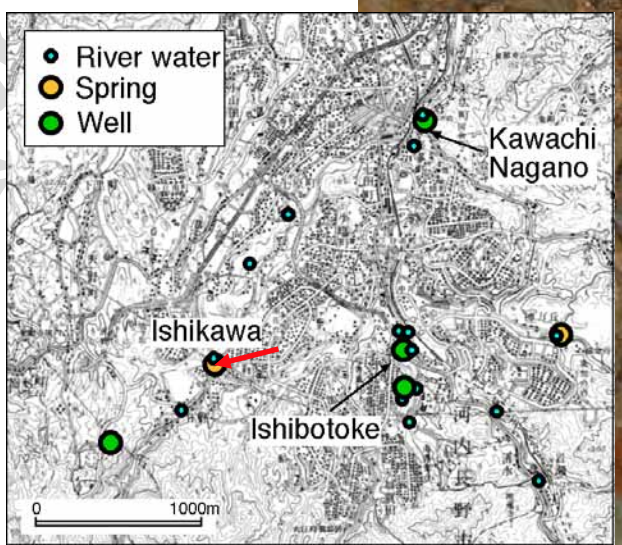
Ishibotoke

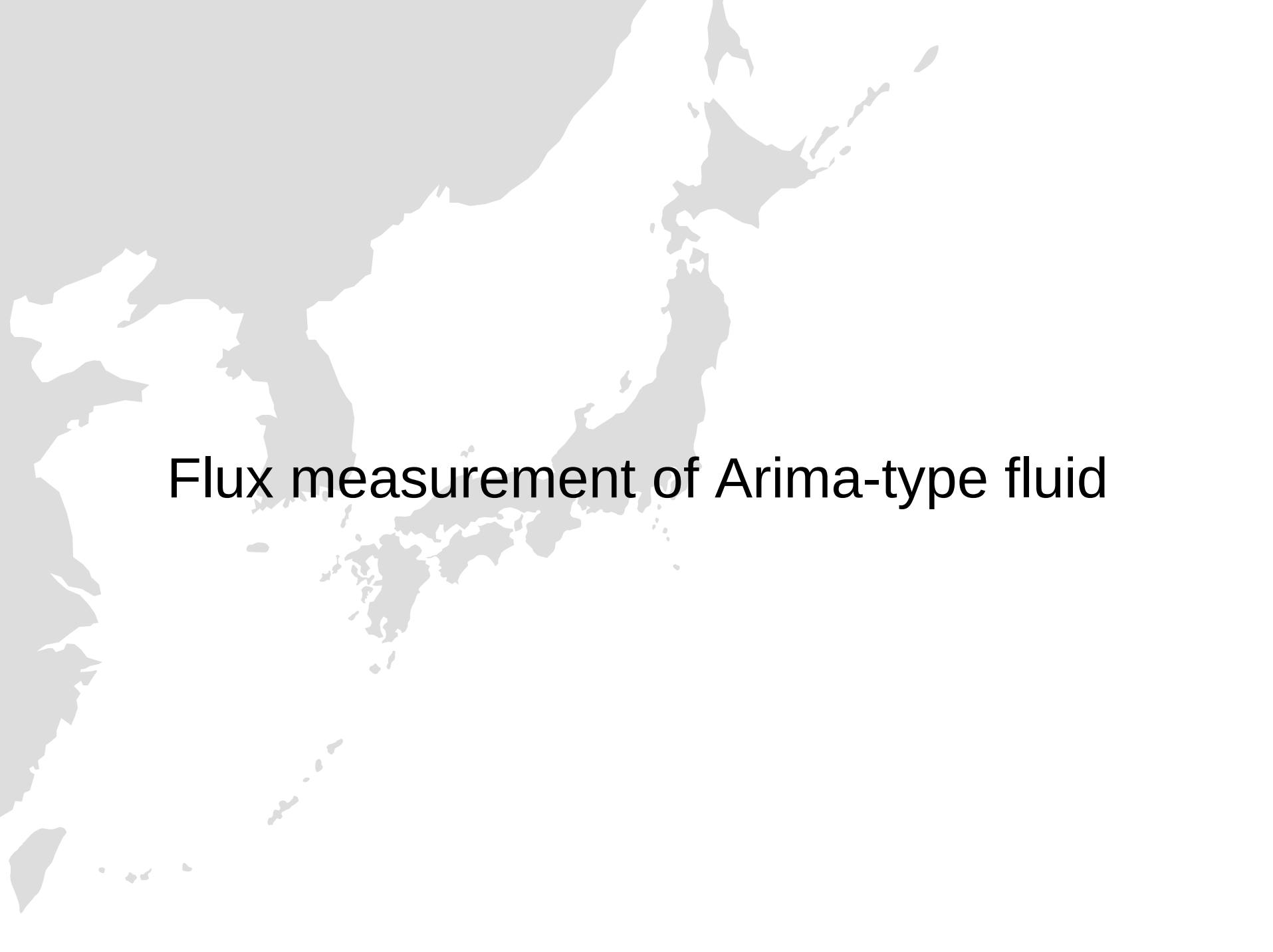
1)Self-spouting from cracks of rocks
2)CO_2-bearing
3)Higher than river water level



Ishibotoke

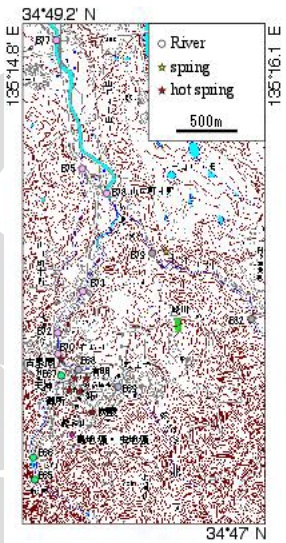



River water
Spring
Well
Kawachi
Nagano
Ishikawa
Ishibotoke
0
1000m



Flux measurement of Arima-type fluid

Arima area


34°49.2' N
135°14.8' E
135°16.1 E
River
spring
hot spring
500m
34°47' N

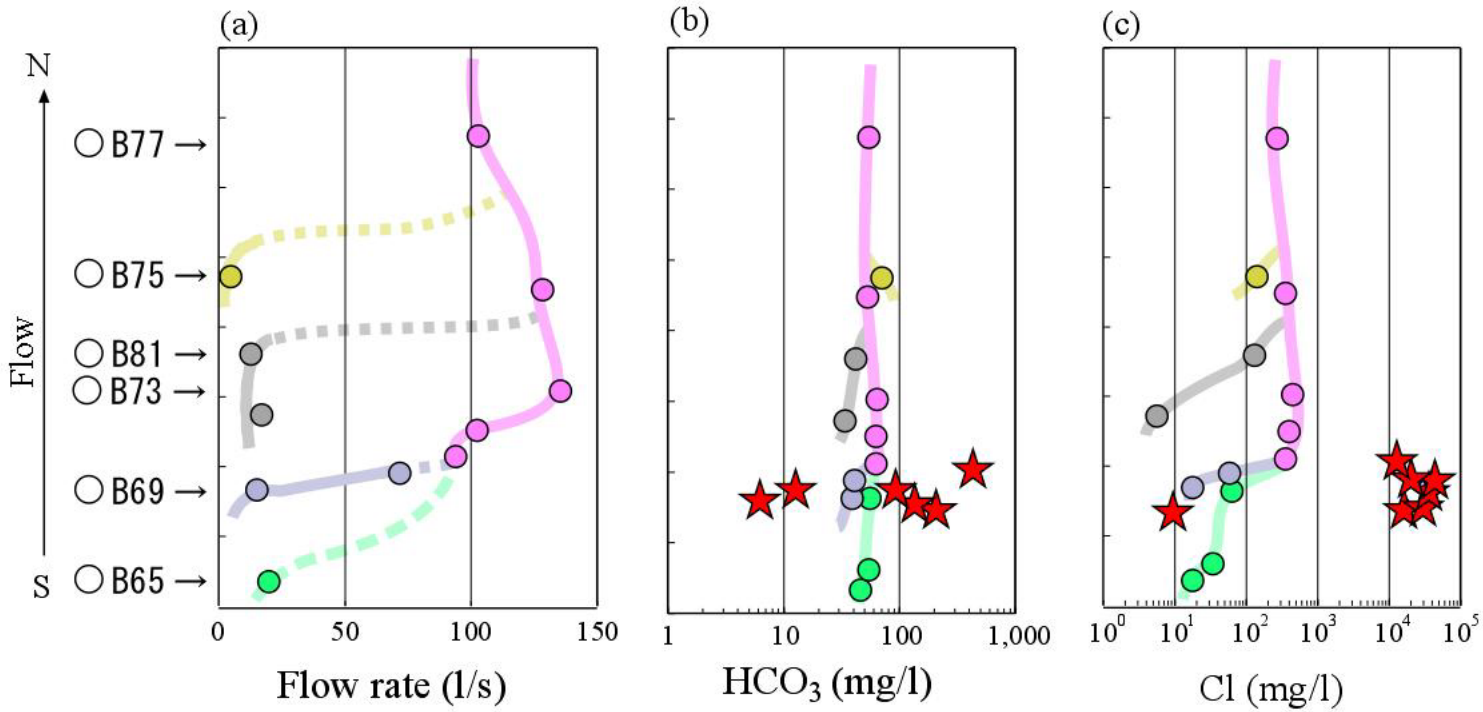

(a)
(b)
(c)
N
S
Flow
B77
B75
B81
B73
B69
B65
0
50
100
150
Flow rate (l/s)
1
10
100
1,000
HCO3 (mg/l)
10^0
10^1
10^2
10^3
10^4
10^5
Cl (mg/l)

Table 1 Arima-type fluid flux from Ishibotoke, Arima and Gosha

Location	Flow rate of river (L/sec)	Arima-type contribution (%)	Arima-type fluid flux (L/sec)
Ishibotoke	33	3.5	1.2
Arima	136	1.2	1.6
Gosha	215	0.25	0.5
Kobe area			(0.6) *
MTL			?
			>4 *l*/sec

after Morikawa et al. (2005)

and compare with missing water

Subducted water flux "F" at kinki district

arc length 36000 km

Kinki 100 km

Philippine sea plate 3 cm/y

(1/3 of worldwide avg.)

global missing water 1.3−11 x 10^{14} g/y

F = 1.3−11 x 10^{14} x 100/36000 x 1/3

= 1.3−11 x 10^{11} g/y

= 4−35 liter/sec

Shallow groundwater circulation: 4 x 10^5 l/sec

Table 1 Arima-type fluid flux from Ishibotoke, Arima and Gosha

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Gosha	215	0.25	0.5
Kobe area			(0.6)
MTL			?

Missing water: 4-35 *l*/sec

>4 *l*/sec

Agree well with each other

Arima-type water has similar chemical and isotopic composition as magmatic water has.

→Similar genetic process

→Originated from slab dehydration

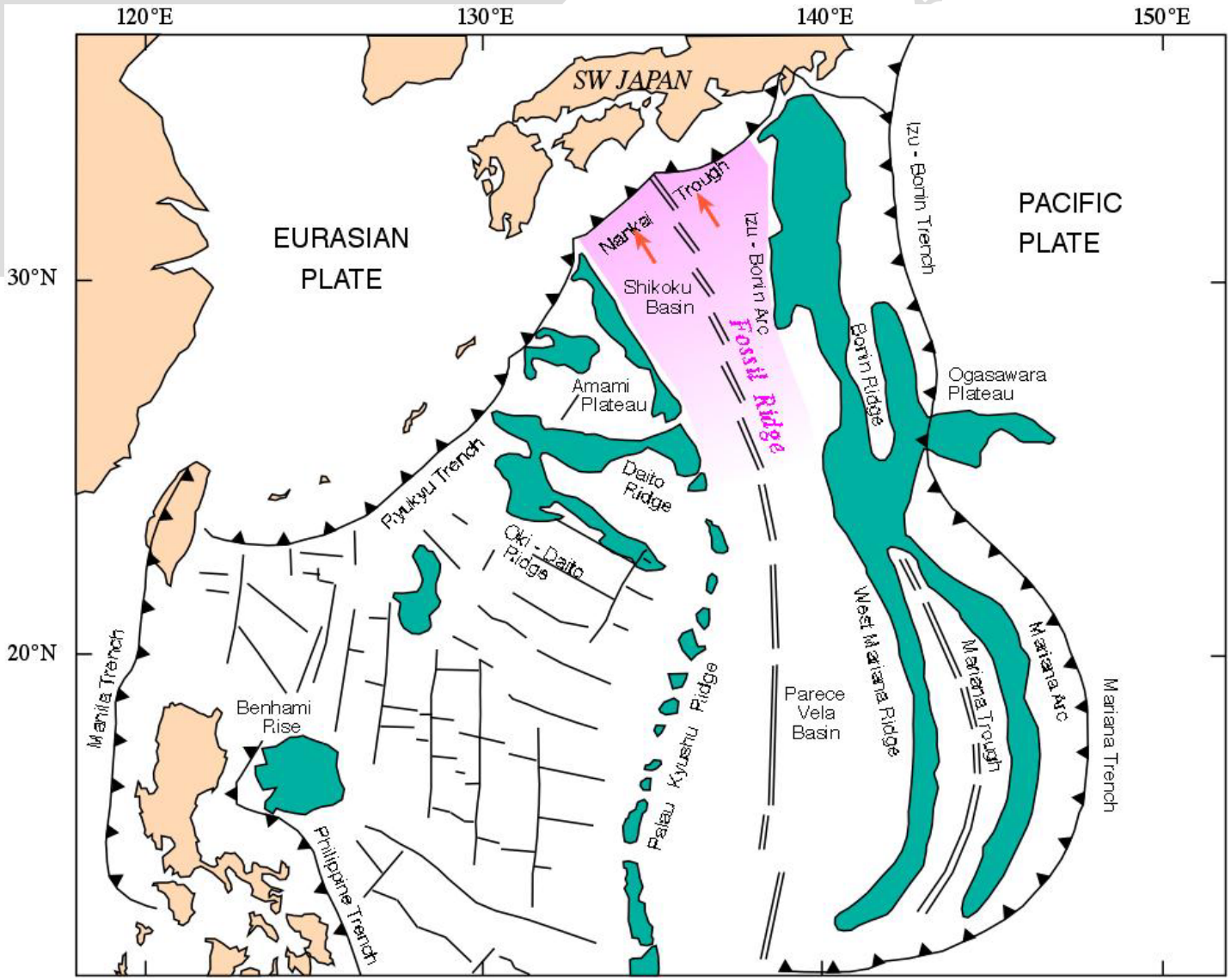
Arima-type water flux agree well with that of missing water of water circulation in the solid earth.

→Strong evidence for the model of Arima-type fluid genesis

Arima-type has only found at southwest Japan!
Especially in Kinki district!

Why?

Difference in plate character?


120°E
130°E
140°E
150°E
30°N
20°N
SW JAPAN
EURASIAN
PLATE
PACIFIC
PLATE
Nankai
Trough
Izu - Bonin Arc
Izu - Bonin Trench
Shikoku
Basin
Fossil Ridge
Bonin Ridge
Ogasawara
Plateau
Amami
Plateau
Daito
Ridge
Ryukyu Trench
Oki - Daito
Ridge
Manila Trench
Benhami
Rise
Philippine Trench
Palau Kyushu Ridge
Parece
Vela
Basin
West Mariana Ridge
Mariana Trough
Mariana Arc
Mariana Trench

Philippine Sea Plate is young, thin and hot

Easy to dehydrate?

Effective dehydration occurs at Philippine Sea Plate

Summary

- Wide distribution of Arima-type thermal brine is found.
- Flux of Arima-type fluid is consistent with amount of missing water estimated from water circulation in solid earth.
- Arima-type fluid likely occur by dehydration of subducting slab and upwell through tectonic lines and faults.

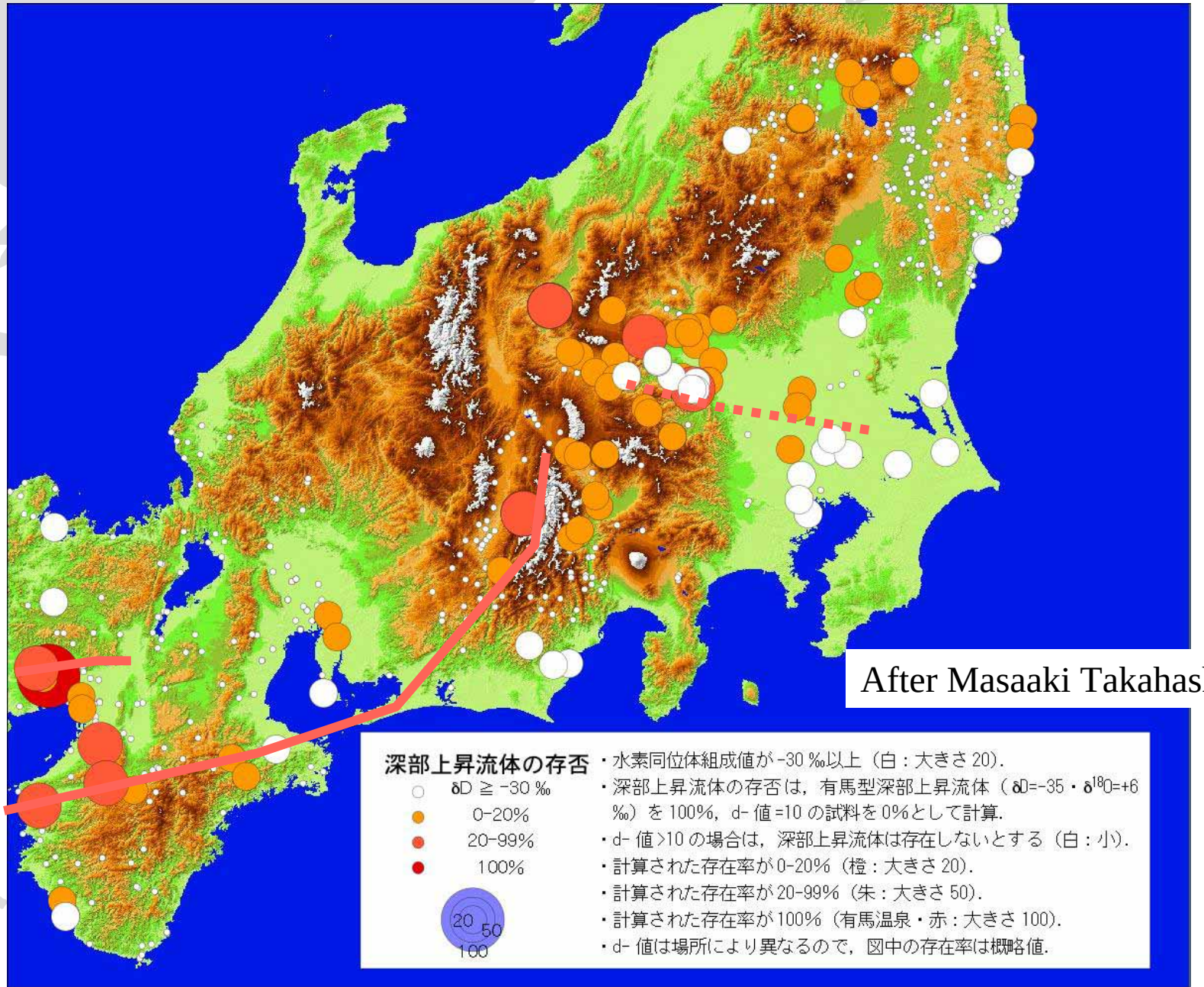
Future study

- Reveal relation of Arima-type activity with geological structure and seismic activity

- Proceed measurement of Arima-type regional flux in different area

- Compare chemical and isotopic difference between the fluids from different Plates

Spatial distribution of Arima-type



After Masaaki Takahashi