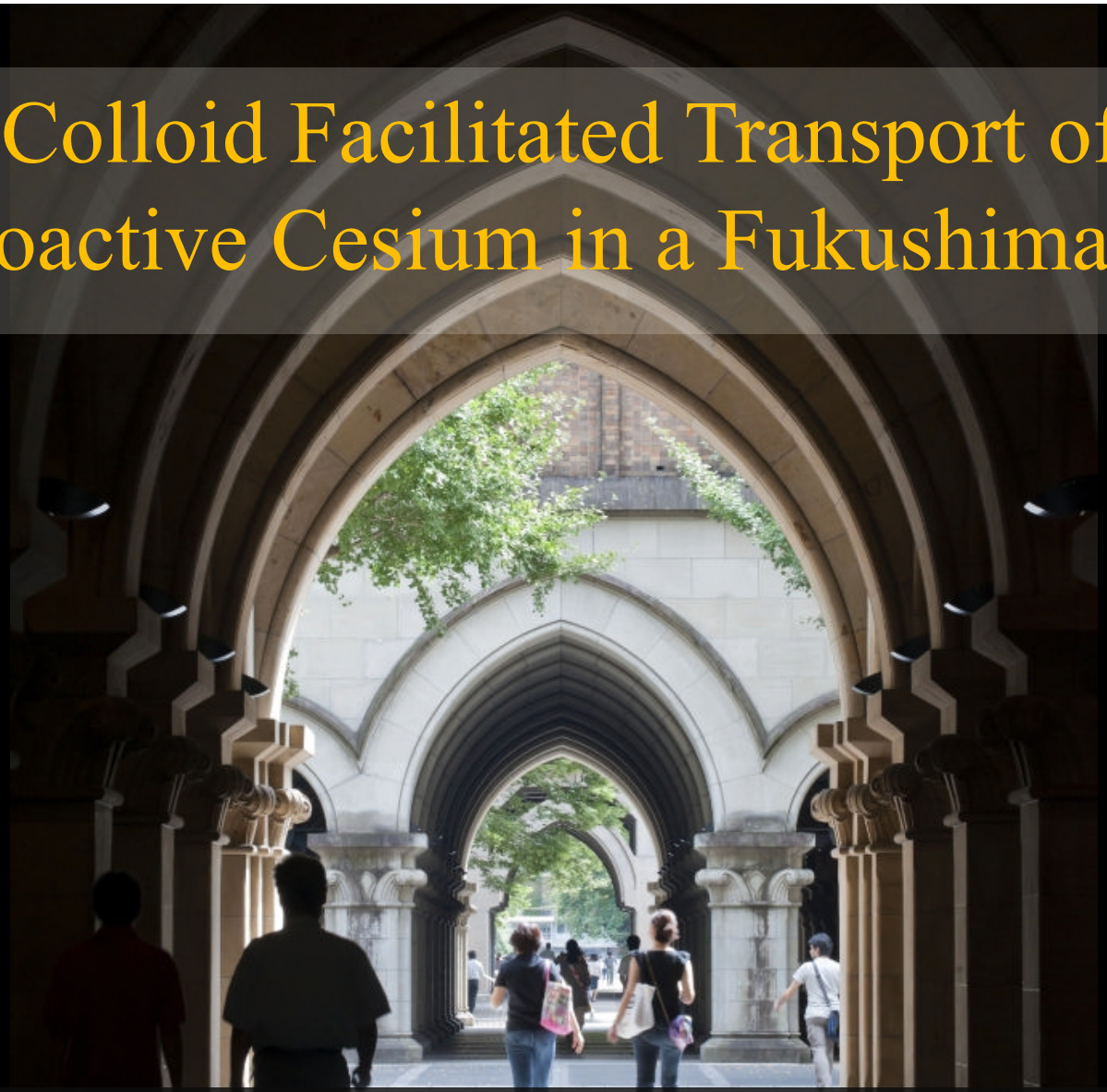
Colloid Facilitated Transport of Radioactive Cesium in a Fukushima Soil.



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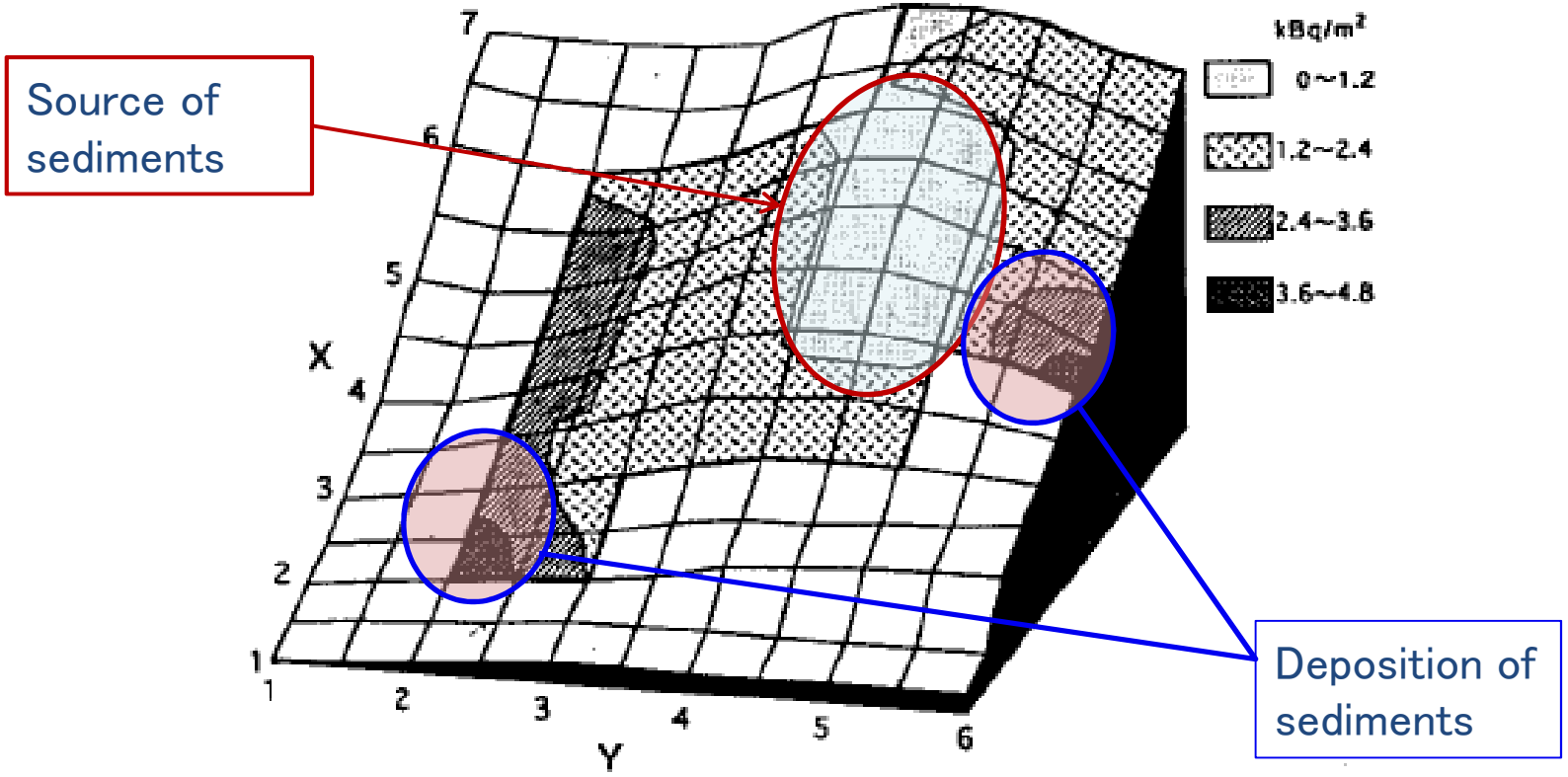
Why we need to consider colloids in Cs transport?

- Chemically, Cs is less hydrated and thus prefer to bound with soil particles.
- Transport of ionic Cs is very slow.
- Alternative process may be considered
  - inorganic colloids facilitated
  - organic colloids facilitated
- Migration of soil colloids in a Fukushima soil was limited (Mizoguchi, 2013)

Use radioactive Cs as a tracer to evaluate soil loss. A rolling hill in northern Japan (Hokkaido).

Kashiwagi and Sakuma (1995)



Source of radioactive Cs was nuclear experiments in atmosphere during 1960's.

Large K_d of radio-active Cs in Japanese soils

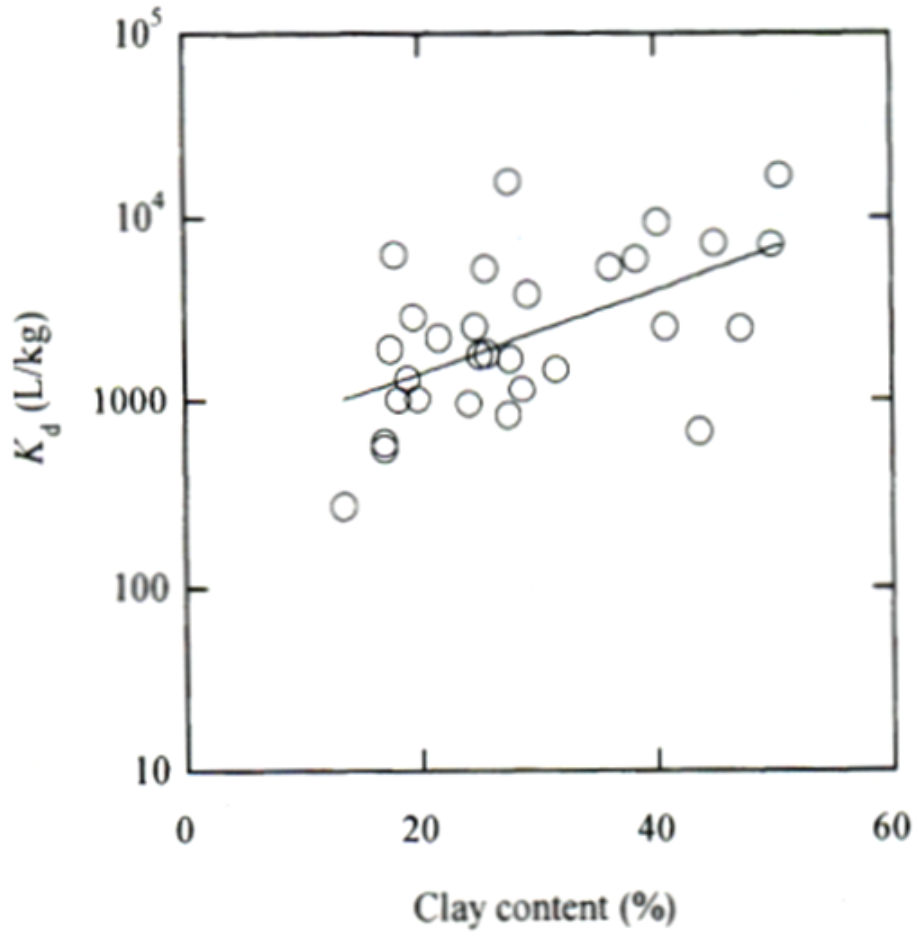


Fig. 2 Correlation between clay content and K_d ($R_c = 0.55$, $p < 0.005$).

$$Cs_{adsorb} = K_d \times Cs_{solution}$$

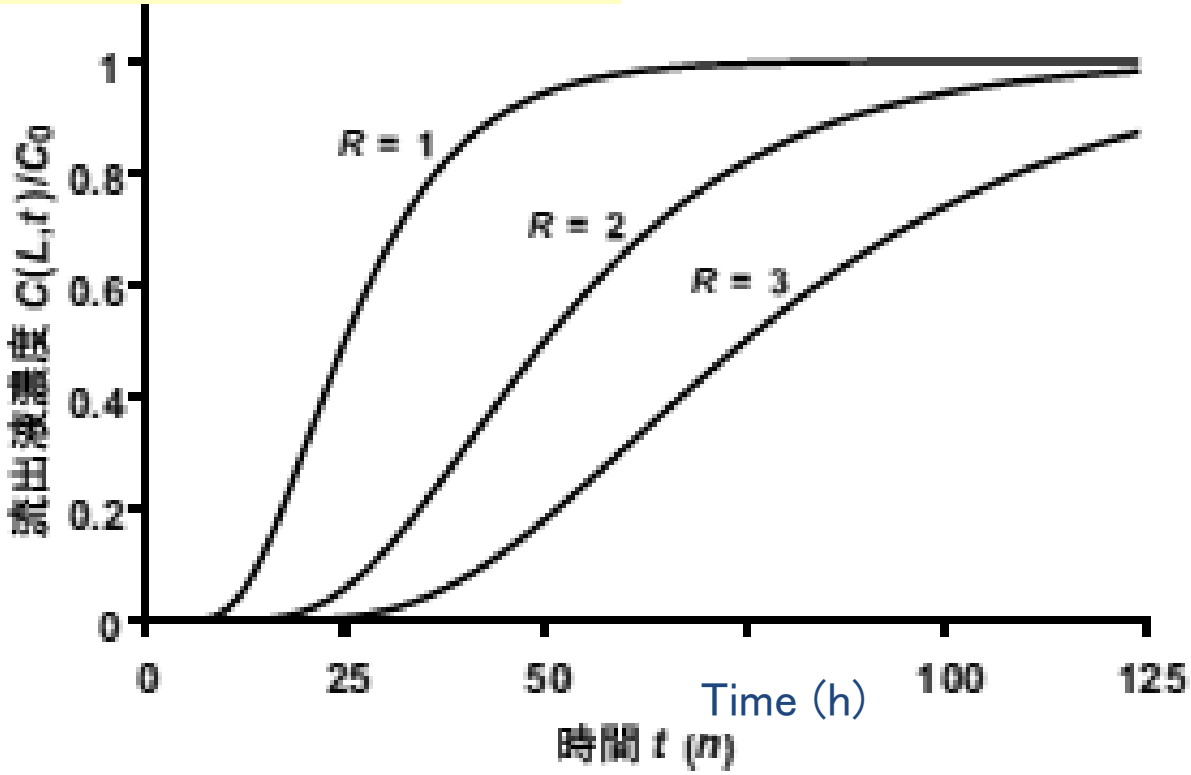
Ishikawa et al. 2007
Radioisotopes
56: 519-528

K_d and retardation factor, R

$$R = 1 + \frac{\rho_d}{\theta} K_d$$

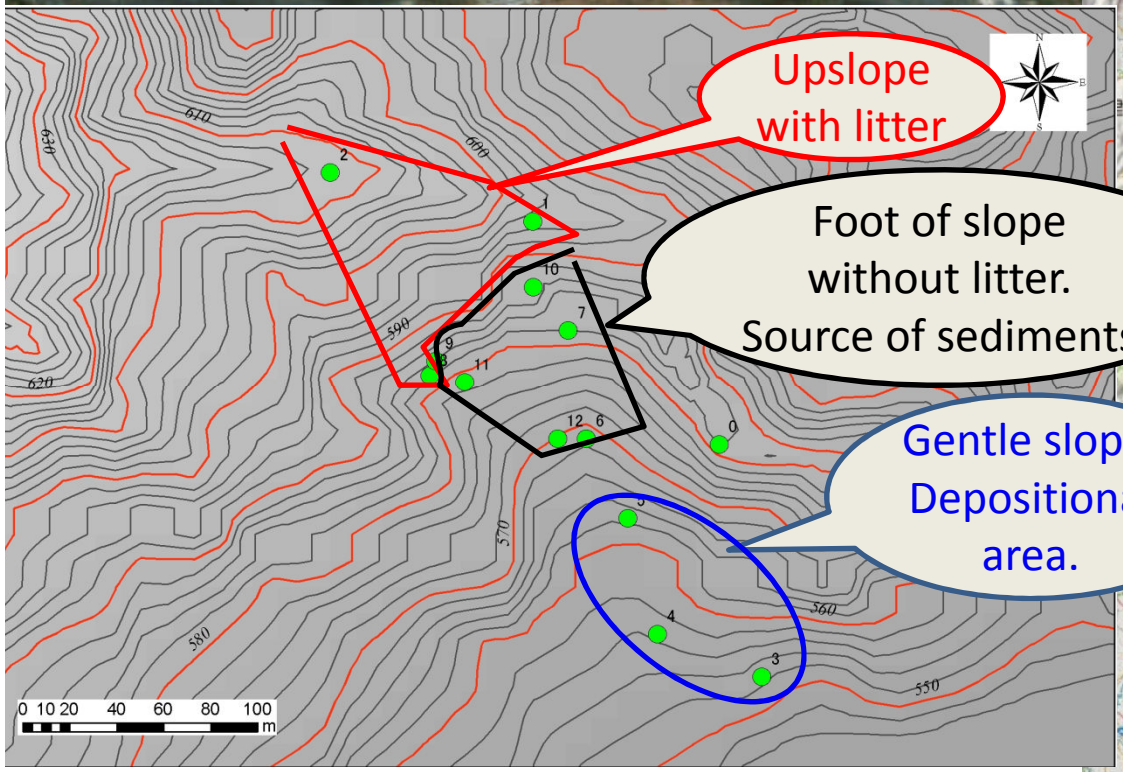
Typical ground water recharge: 400(mm/y)×30(yrs)=12000mm

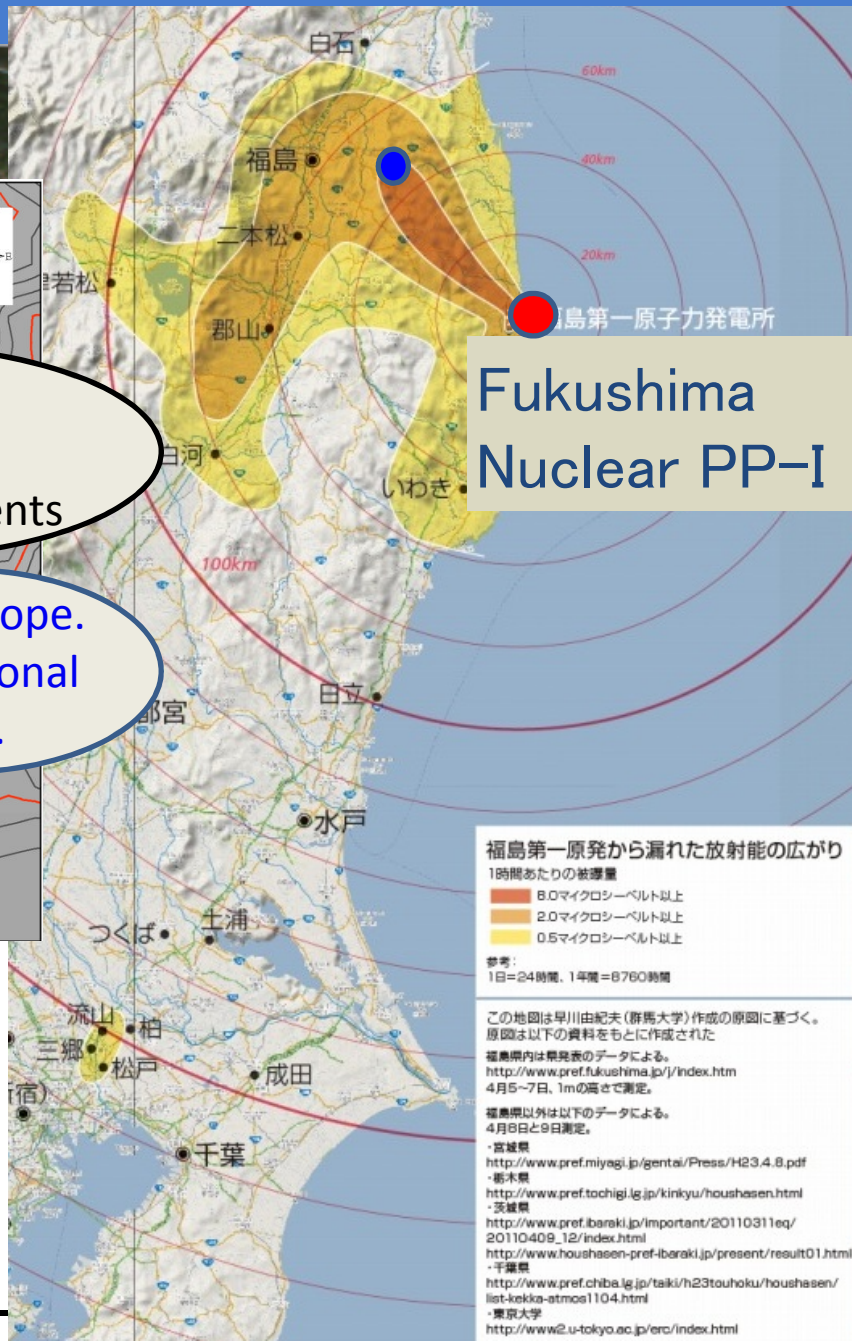
K_d=1000 L/kg →R≒2000 → 6mm/30yrs



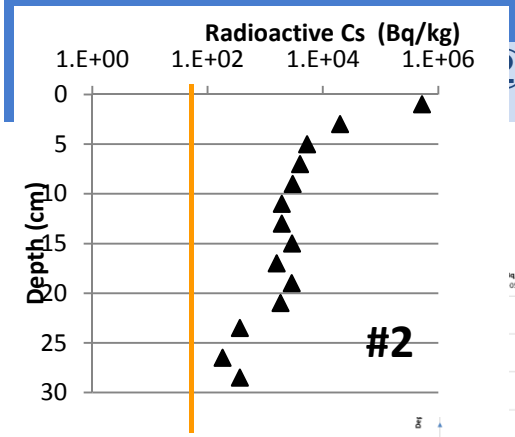
From Soil Physics 6th ed. by Jury and Horton

May 2013, Myojindake (明神岳)
Iitate, Fukushima

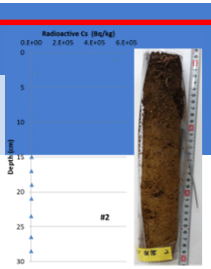


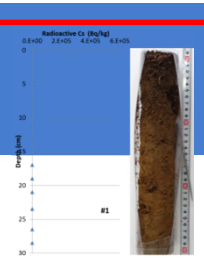


In Fukushima region, 70% of land is covered by forest.
Annual precipitation is around 1200mm
Temp. ranges -2 to 30 ℃ (13 ℃ in average)

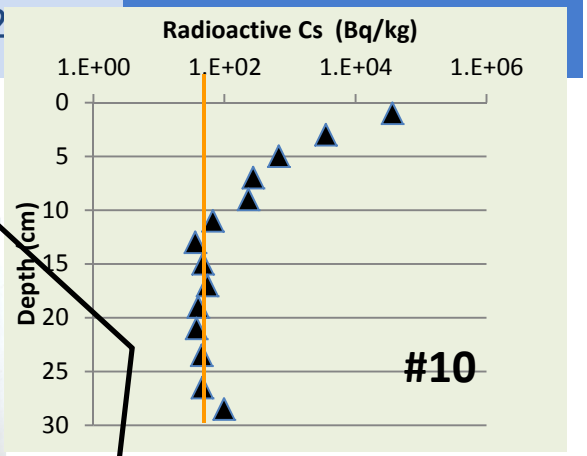


⑤530000
20000





①2



⑧226000
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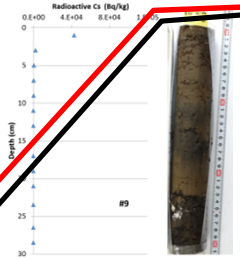

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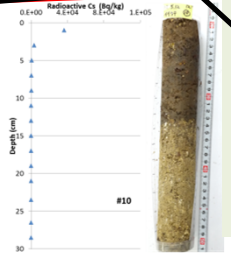

⑩36000
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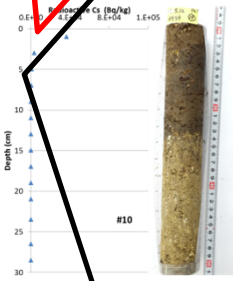
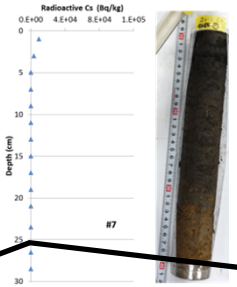
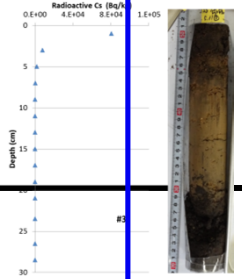


⑪12000
1100



⑦9400
3300

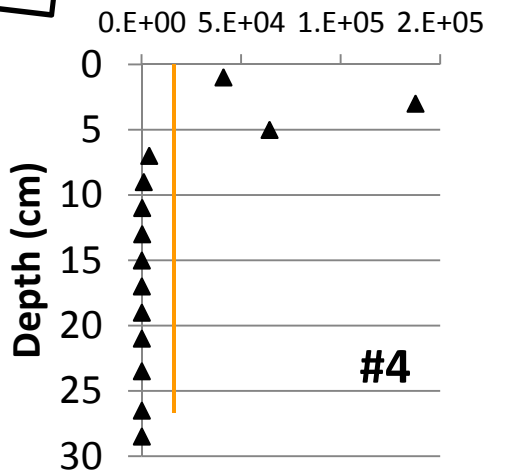
④41000
137000
64000



③80000
7700

site Number
top 0-2cm [Bq/kg]
middle 2-4cm [Bq/kg]
Green 4-6cm

Radioactive Cs (Bq/kg)



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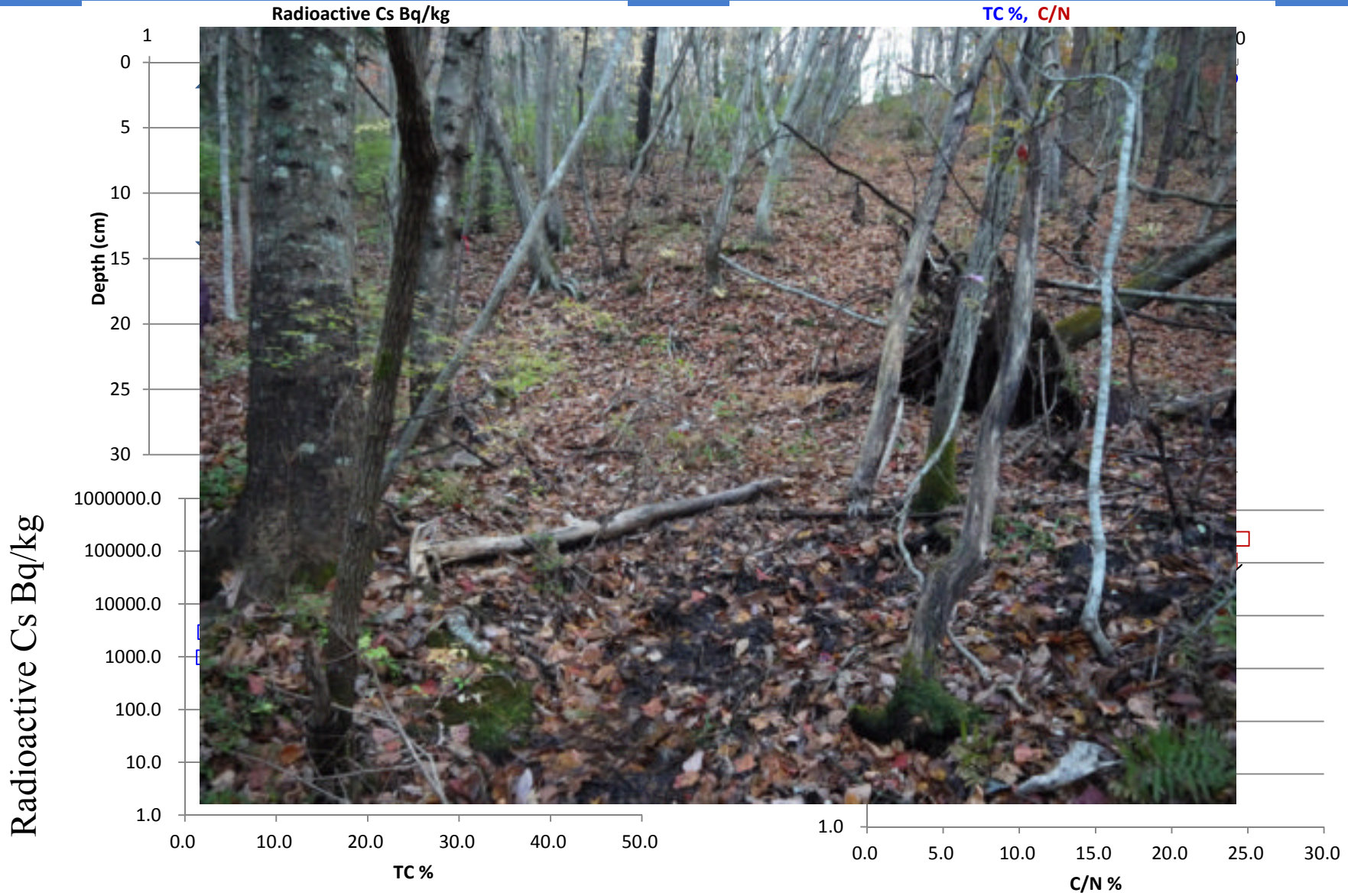
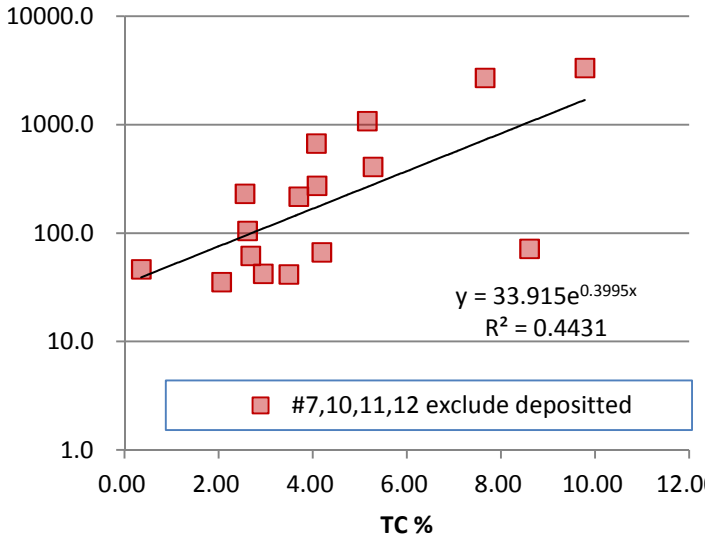
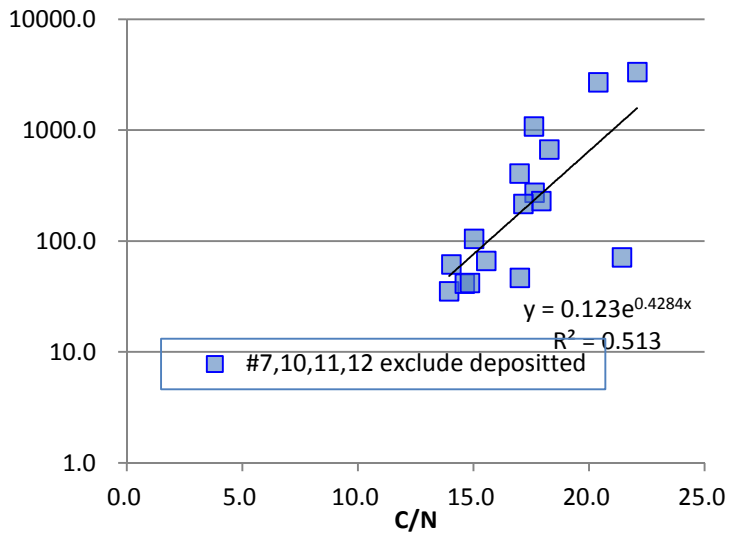
Upslope with litter layer. No soil loss.



Foot of slope without surface litter

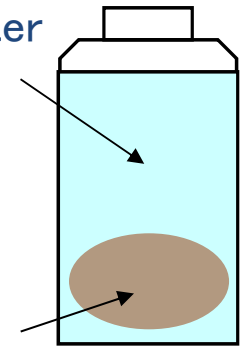
Radioactive Cs Bq/kg



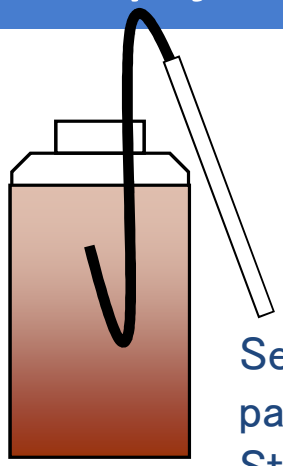


Suspension derived from the Myojin litter

De-ionized water
:約1000 mL



Sieve <53 μm



Settle to fractionate particles smaller than Stokes diameter of 1 μm

Litter from Myojin forest. :44 g
(Cs: 3.09×10^5 Bq/kg-dry)

Suspension A

Cs: 1189 Bq/L

Further disintegration by H_2O_2 and heating..

Suspension B

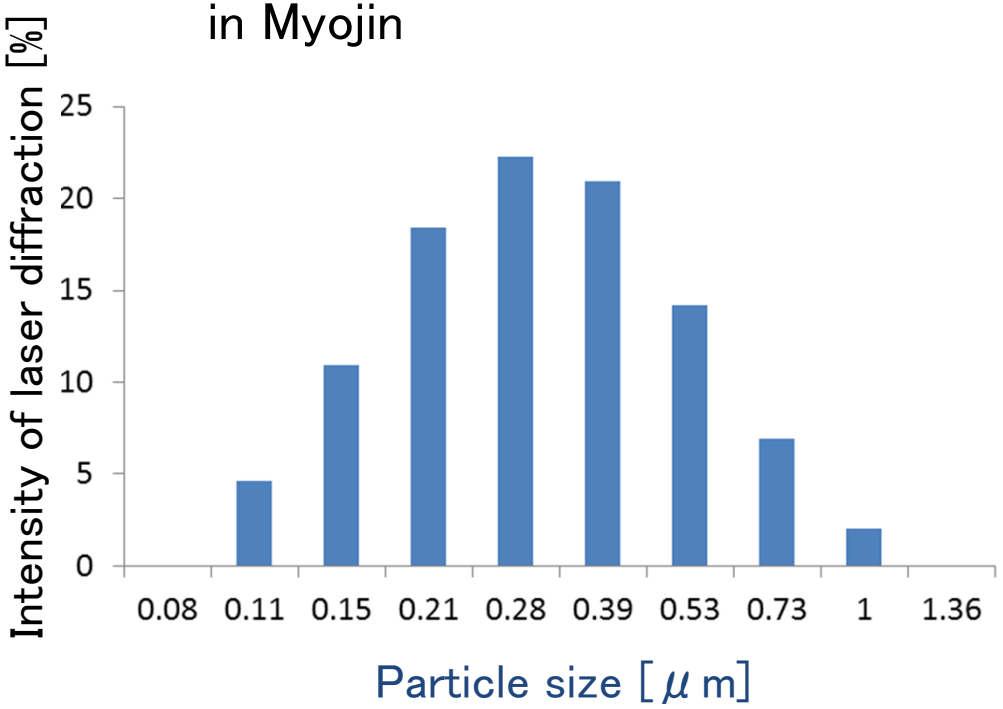
Cs: 1056 Bq/L

Use NaI counter to measure ^{134}Cs and ^{137}Cs (Wizard 2480, Perkin Elmer)

What caused greater movement of the Cs

Particle size distribution of suspension passed 0.45 μm-filter

Suspension extracted
from litter of a forest
in Myojin



Suspension A

	Radio. Cs	suspended particle size
5cm settlement for 16hrs	1189Bq/kg	(1 μm)
Centrifuge (10000rpm,1hr)	sediment: 1189Bq/kg	–
Centrifuge (10000rpm,1hr)	supernatant: ND	0.2 μm (0.08<d<1 μm)
0.2 μm filtered	ND	0.2 μm (0.08<d<0.7 μm)

Suspension B

After (H_2O_2 +Heat) treatment on Suspension A

	Radio. Cs	suspended particle size
5cm settlement for 16hrs	1056Bq/kg	(1 μm)
Centrifuge (10000rpm,1hr)	sediment: 983Bq/kg	–
Centrifuge (10000rpm,1hr)	supernatant: 73	1.2 μm (0.7<d<10 μm)
0.2 μm filtered	67	ND (No particle of greater than 1nm)

Can ionic Cs remain after H_2O_2 treatment?

Column experiment on transport of Cs with organic colloids

- Non-Cs polluted Paddy soil（30-50 cm，Sasu, Iitate, Fukushima）
  → Passed through 2 mm mesh screen

0 cm

Surface soil

30 cm

40 cm

Soil sample

subsoil

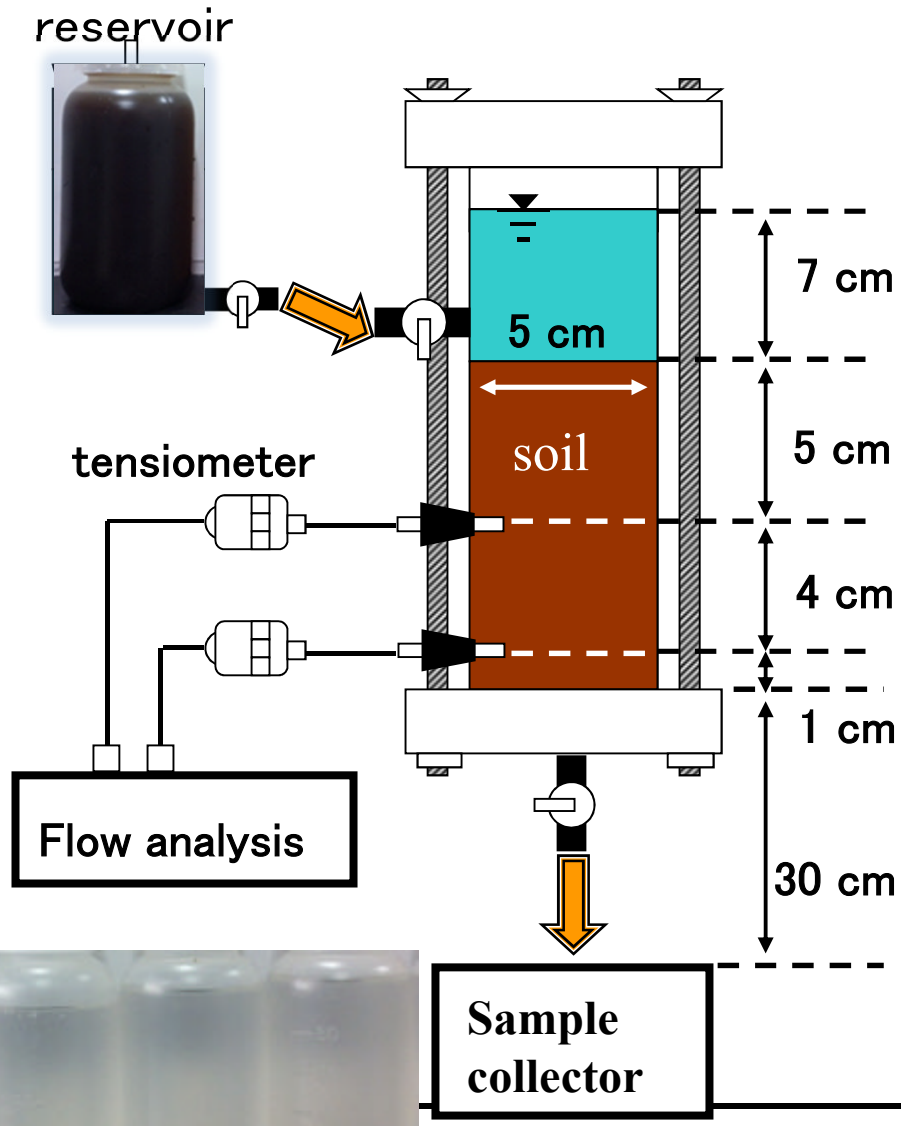
50 cm

70 cm

・Particle density： 2.66 g/cm^3
・Texture：Sandy clay loam

clay	silt	sand
19 %	20 %	61 %

1. Percolation of non-Cs solution
2. Displace to Cs contained suspension
3. After the end of percolation soil column was separated and suffered to Cs analysis.



Use NaI counter to measure ^{134}Cs and ^{137}Cs (Wizard 2480, Perkin Elmer)

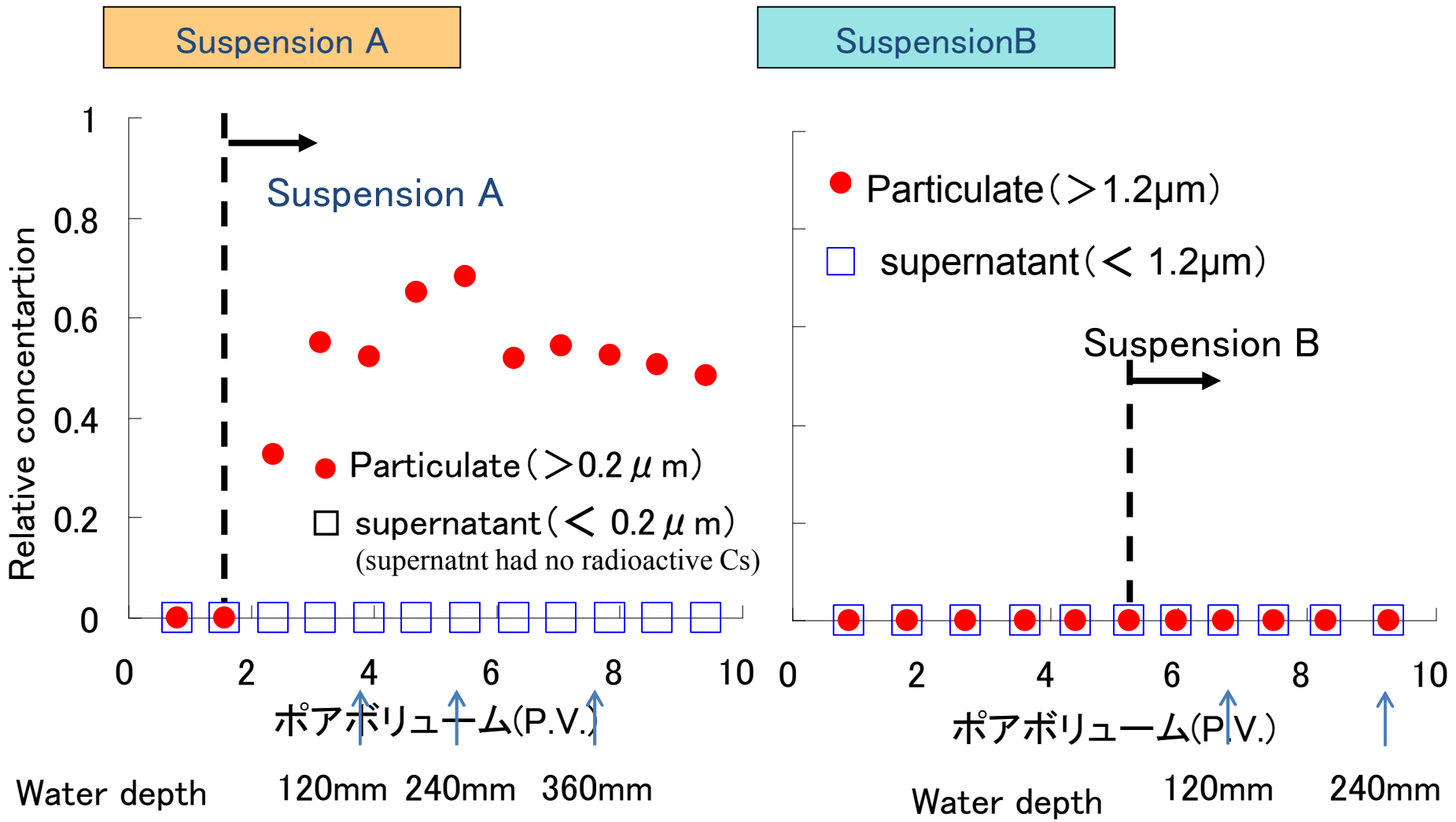
Observation of effluent from bottom of the column

Suspension A

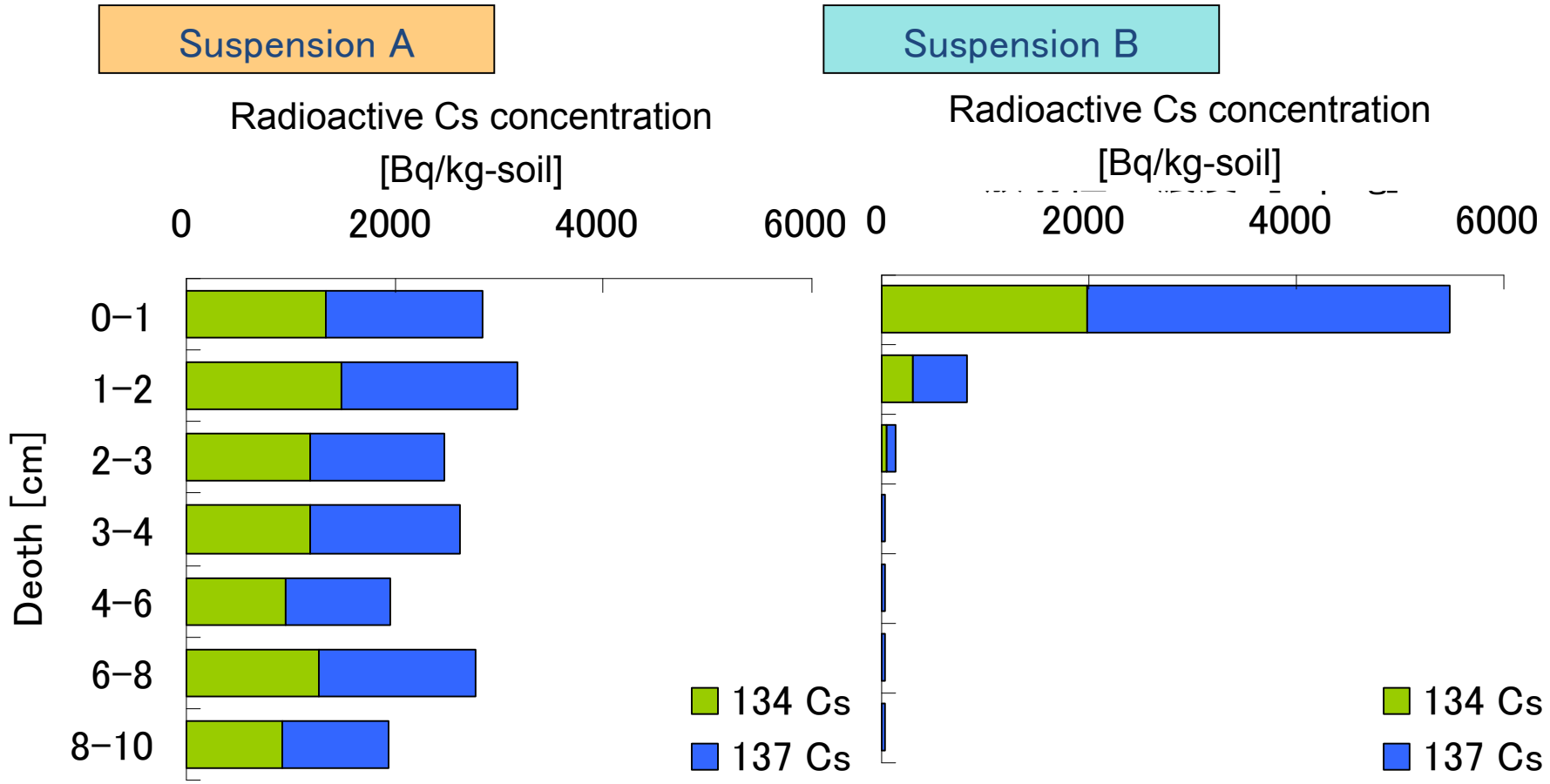
Suspension B

Tap water

Visual results agreed radioactive Cs in the effluent



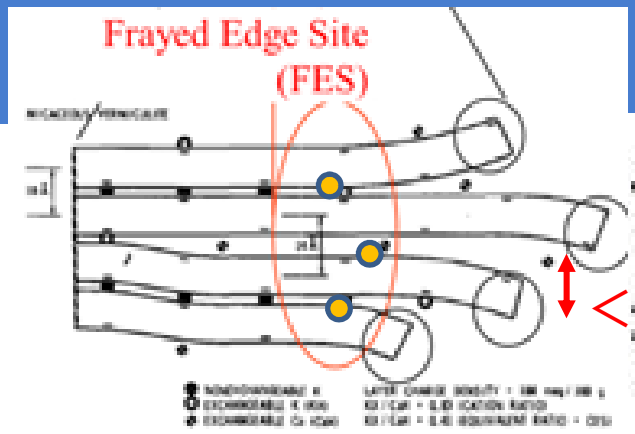
Radioactive Cs in soil column



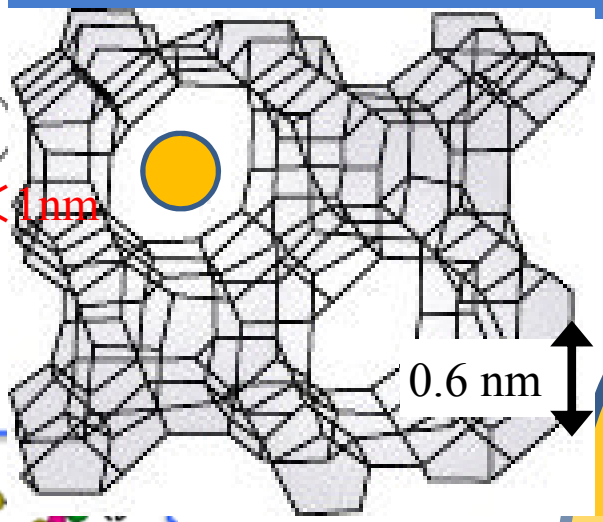
Thank you for attention

Acknowledge: Meiji University Recovery Support project, JSPS (#24380130)

Form of Cs and capture

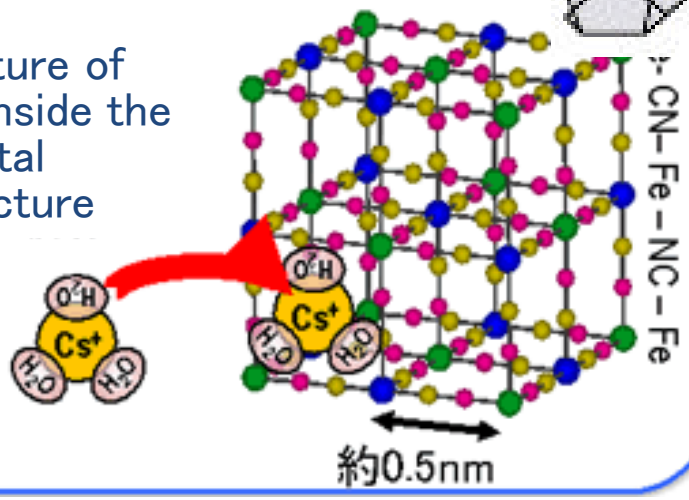


Dolcater et al. Soil Sci.Soc.Am.Proc, 32:795-798 (1968)



D=6 nm

Capture of Cs inside the crystal structure



Moldenite (zeolite)
http://www9.canet.ne.jp/users/soken/zeolito.html

Clinoptilolite (zeollite) (0.3nm)

Organic colloid extracted litter＞80nm

Prussian blue, Iron(III) hexacyanoferrate(II)
AIST (Tsukuba)
http://www.aist.go.jp/aist_j/new_research/nr20120905/nr20120905.html