

**Use of information on distribution  
and mode of occurrence of uranium  
deposits in Japan, as a PA tool to  
develop confidence of geological  
disposal system**

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- I engaged in Uranium Exploration Project for 10 years.
- After I joined HLW project, I mainly engaged in natural analogue study of the Tono Uranium Deposit (largest uranium orebody in Japan). Now I'm in Mizunami URL.
  
- Simply speaking (from my experience),
  - ✓ I think that geological environment in Japan has good ability for HLW disposal (so far we do not seek complete “containment”).
  - I want to say many rock units in Japan contain uranium deposit in this presentation (as part of my lifework, U exploration geologist is one of “the endangered species” in Japan).
  - and indicate suitable geological environment might exist even in geologically active Japanese Islands.

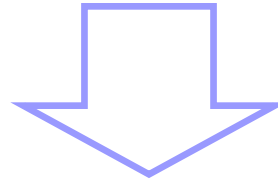
- Many **geological processes** inherent to tectonically active island-arc systems have a long history in the Japanese Islands due to their location along tectonically active plate boundaries.
  - ✓ RAPID PROCESS --- seismicity with associated **fault activity**, **volcanism**
  - ✓ SLOWER PROCESS --- **uplift** (exhumation), **erosion** and subsidence
  - ✓ Coastal areas have also been affected by global **sea-level changes**.

## Public View

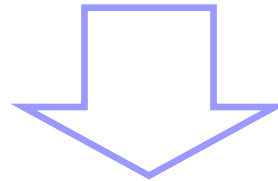
Geological activity = Unstability of Geological Environment

→ Is this correct ??? (I don't think so)

**Uranium deposits** exist in various rock types in Japan.



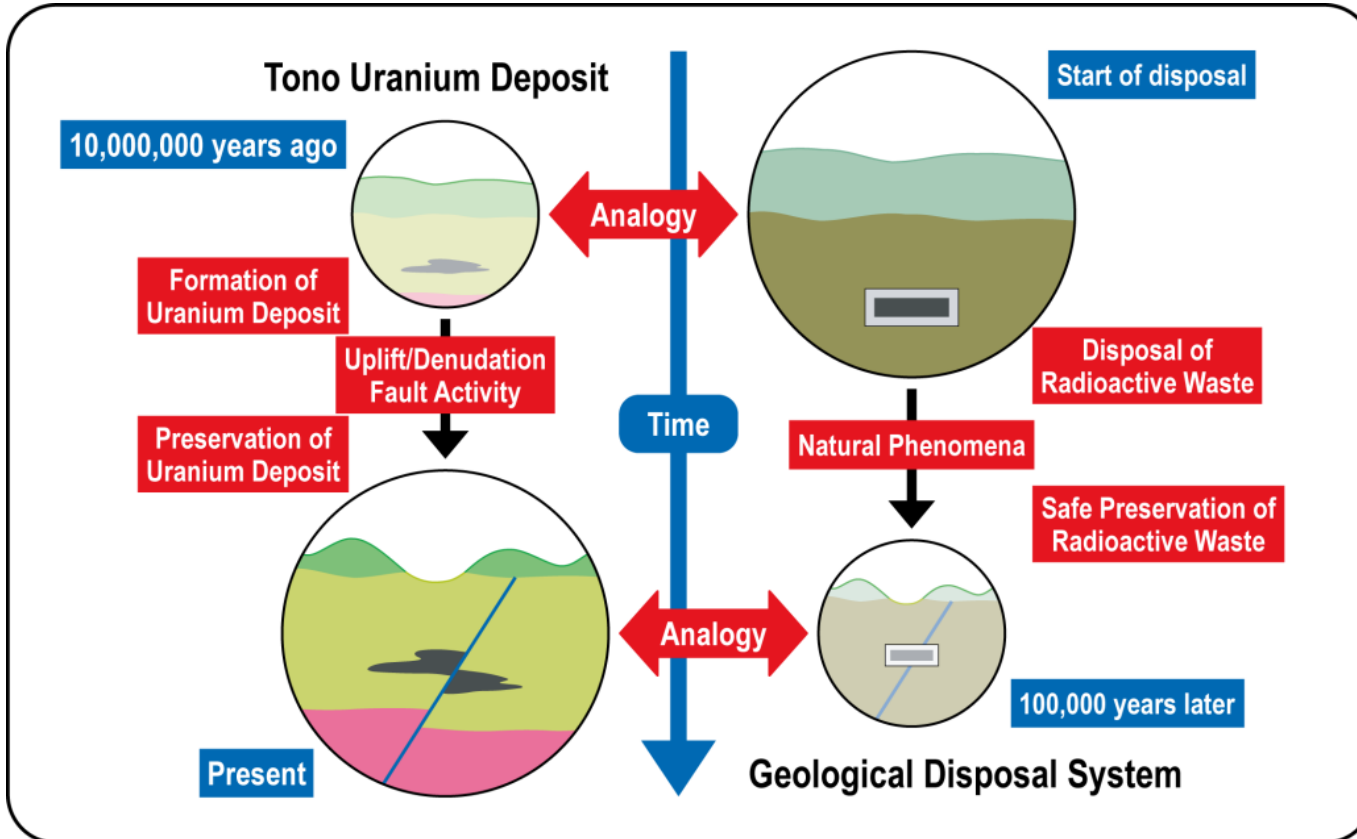
**Uranium deposits** suggest **stable geological environments** (basically reducing condition and its stability).



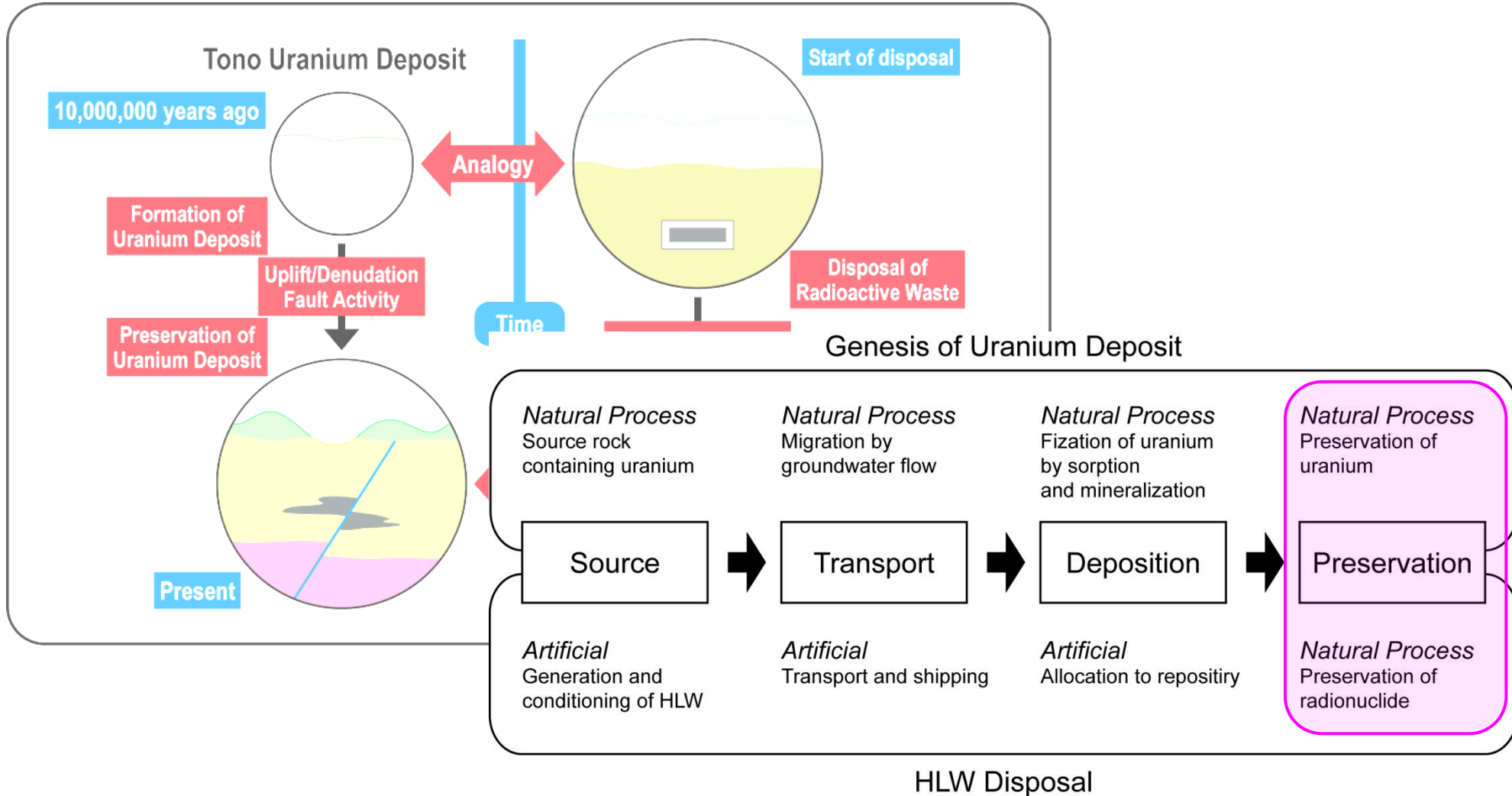
**Stable geological environments** suitable for HLW disposal could be widely distributed.

\* “deposit” should be used for economic grade ore. In this study, the term of “deposit” is used for uranium concentrated zone. “Radiometric anomaly is used for high radiation reading above background level without uranium assay.

- Uranium deposits has been utilized as a natural analogue of HLW disposal.



- Uranium deposits has been utilized as a natural analogue of HLW disposal.



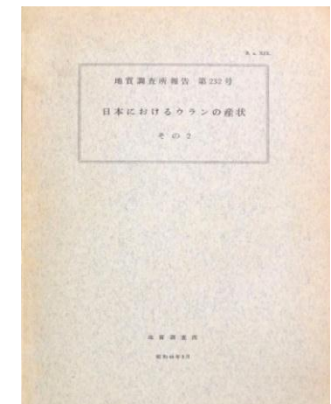
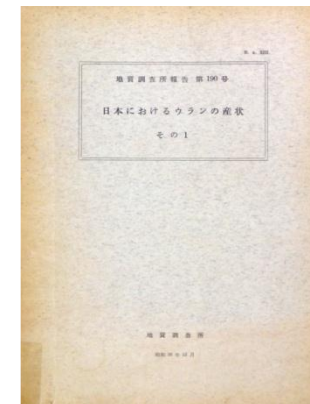
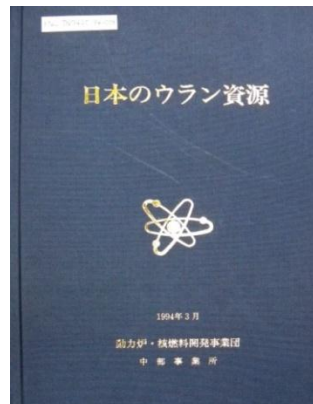
**Uranium deposits** exist in various rock types in Japan.

**Information on host rock and mode of occurrence** of uranium deposit is essential to utilize the uranium deposit to support existence of stable geological.

**Stable geological environments** suitable for HLW disposal could be widely distributed.

# Introduction

- Information on host rock and mode of occurrence of uranium deposit is compiled from the published data.
  - ✓ Uranium Resources in Japan  
PNC Technical Report (1994)
  - ✓ Natural Occurrences of Uranium in Japan Part 1  
Report of Geological Survey of Japan (1961)
  - ✓ Natural Occurrences of Uranium in Japan Part 2  
Report of Geological Survey of Japan (1969)
- Total **93 uranium deposit** and **62 radiometric anomaly** were identified.



## Long-term stability avoiding

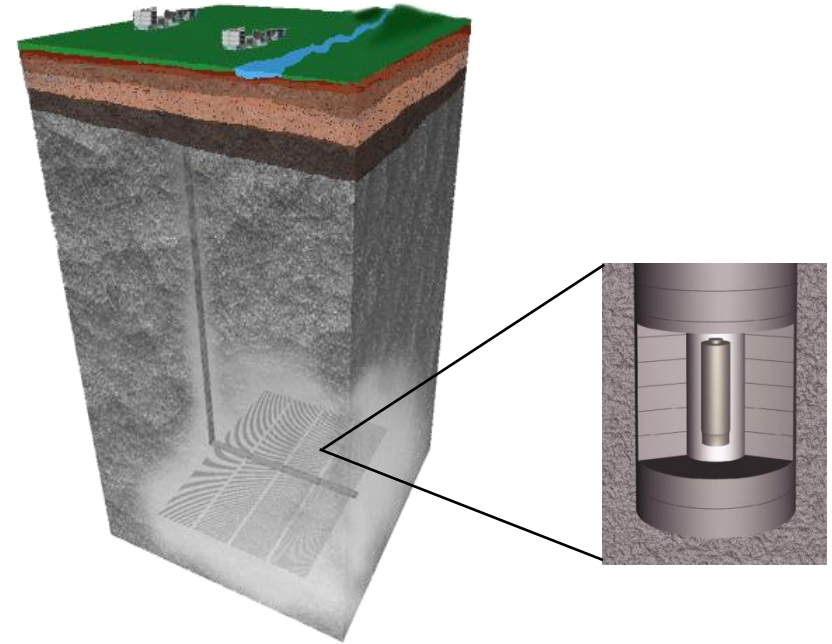
- Volcanic activity
- Significant fault movement
- Significant effects due to uplift/denudation
- Significant effects due to climate/sea-level change
- Presence of natural resources

## Favorable geological environment

- Favorable geochemistry (e.g. chemically reducing)
- Low groundwater flux
- Rock mechanical stability
- Isolation from the human environment

## Function as a natural barrier system

- Retardation and dilution/dispersion of released radionuclides



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Suggested by uranium deposit  
(traditional natural analogue study)

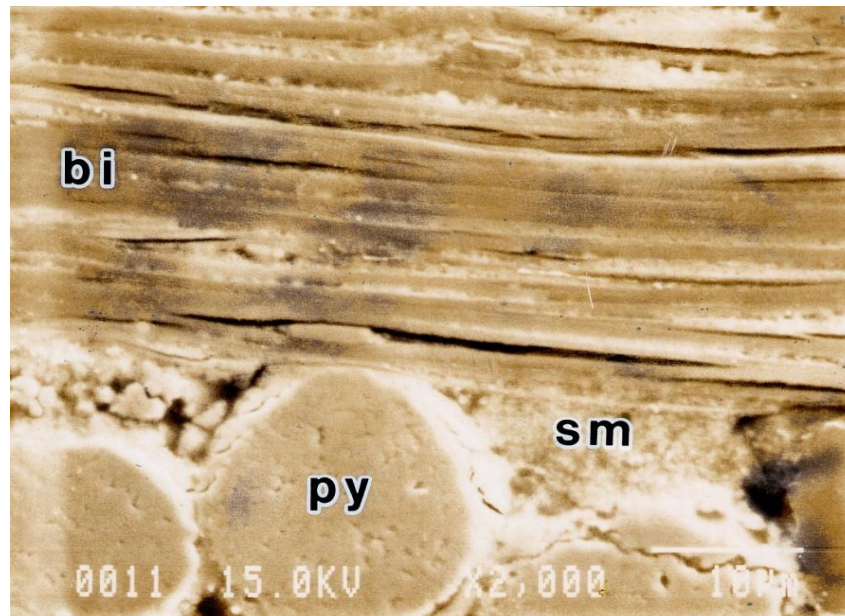
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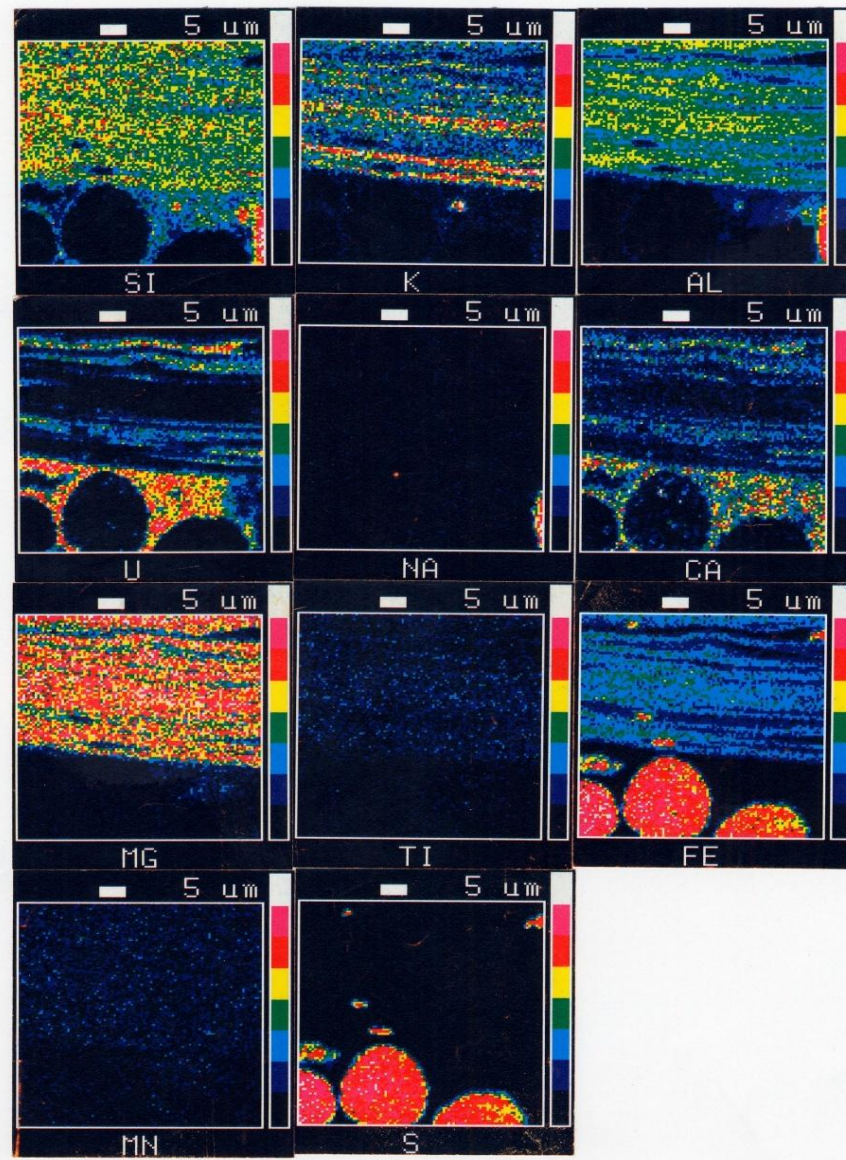
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## Function as a natural barrier system

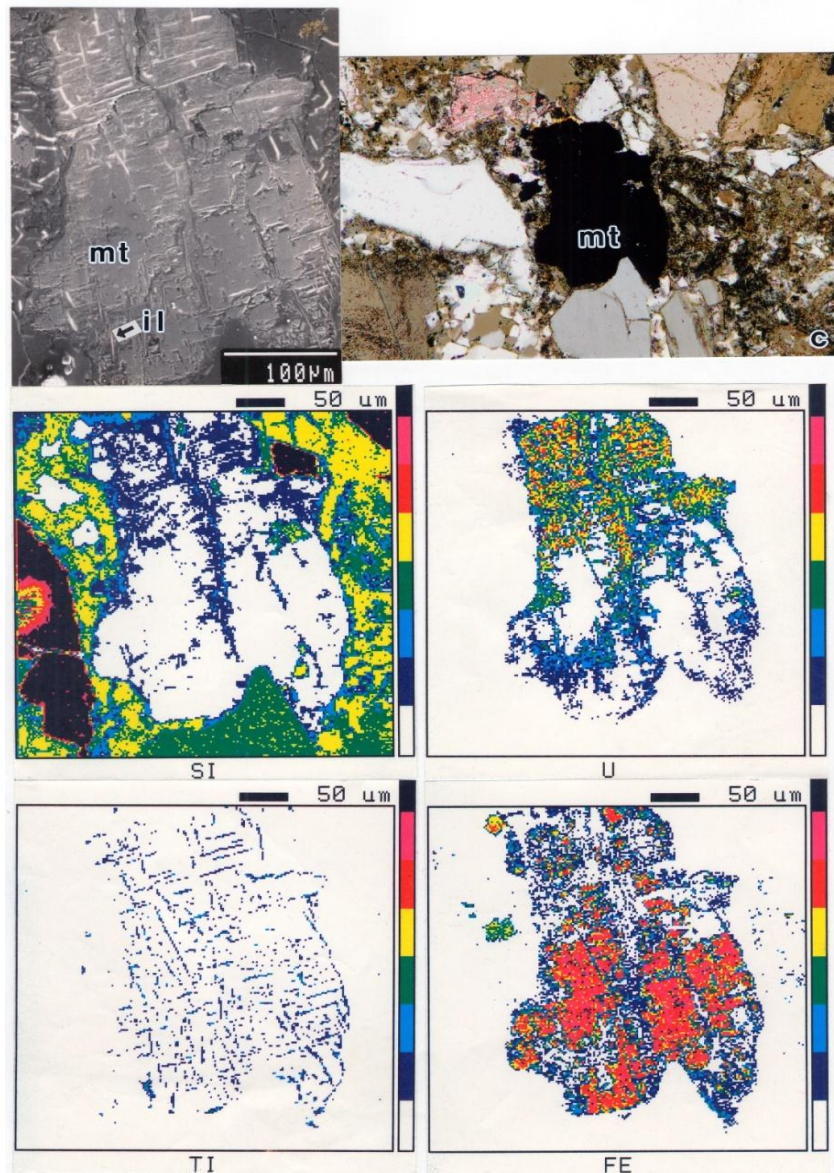
- Retardation and dilution/dispersion of released radionuclides



Uranium are closely associated with **smectite**.



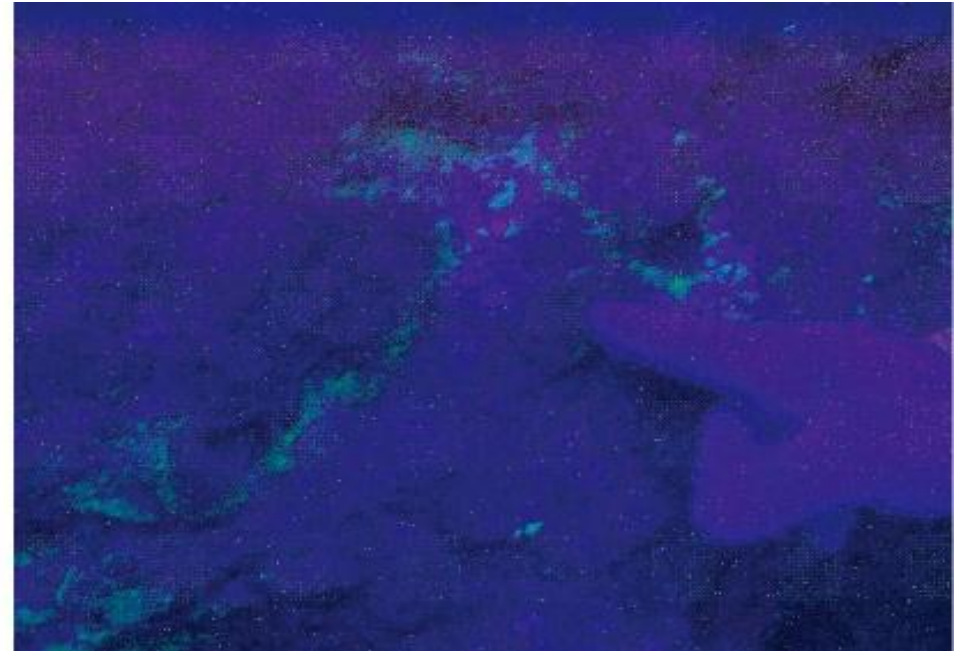
Adapted from Komuro & Sasao (2004)  
JNC Technical Report



Uranium occurred in **altered** portion of iron-titanium mineral.

Adapted from Komuro & Sasao (2004)  
JNC Technical Report

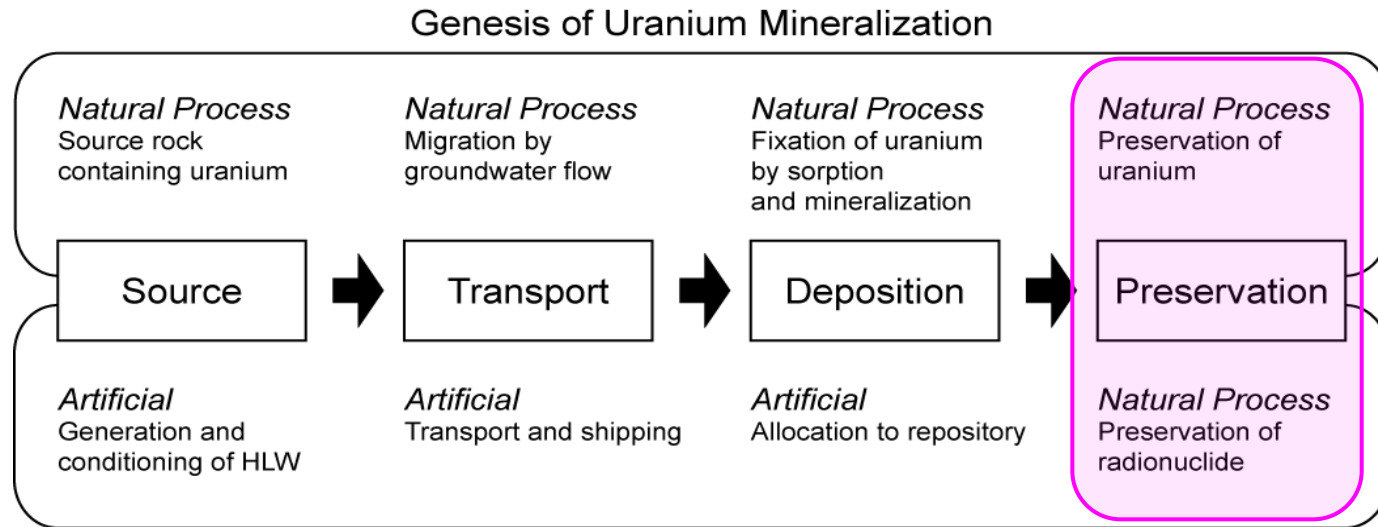
Secondary uranium mineral on the drift wall at the Tono Mine.



Secondary mineral is reported to be formed during oxidation of the gallery wall after the excavation of mine drift.

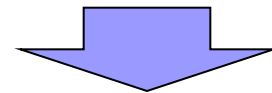
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JNC Technical Report

# Natural analogue study of uranium deposit

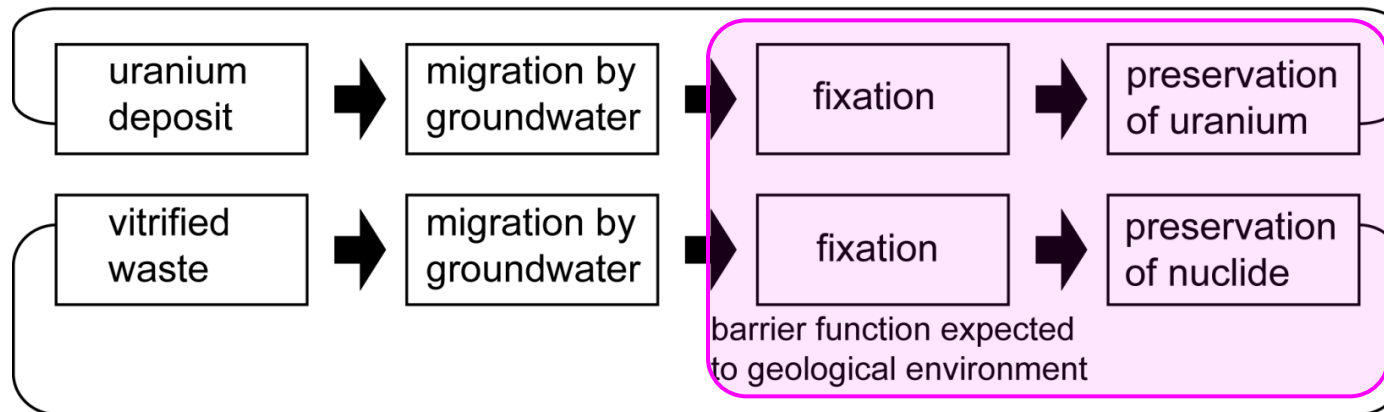


HLW Disposal

Modified from Yusa et al. (1993)



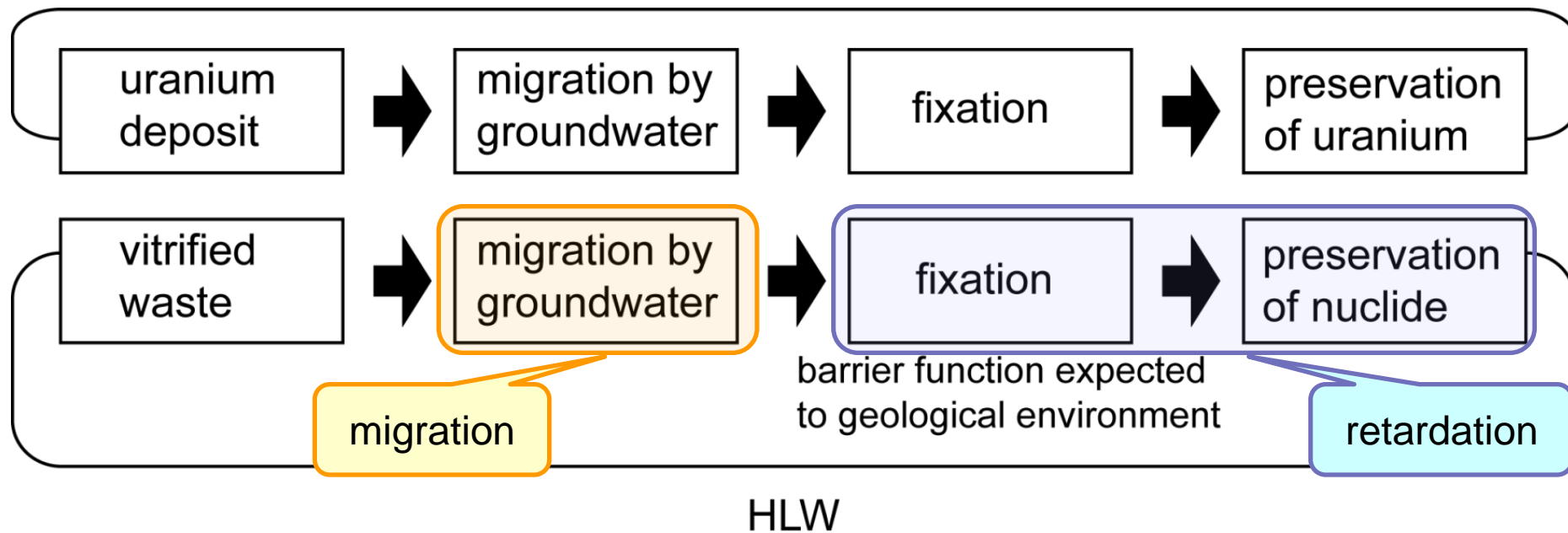
Uranium Deposit



HLW

# Natural analogue study of uranium deposit

## Uranium Deposit



## Long-term stability avoiding

- Volcanic activity
- Significant fault movement
- Significant effects due to uplift/denudation
- Significant effects due to climate/sea-level change
- Presence of natural resources

Suggested by uranium deposit  
(traditional natural analogue study)

## Favorable geological environment

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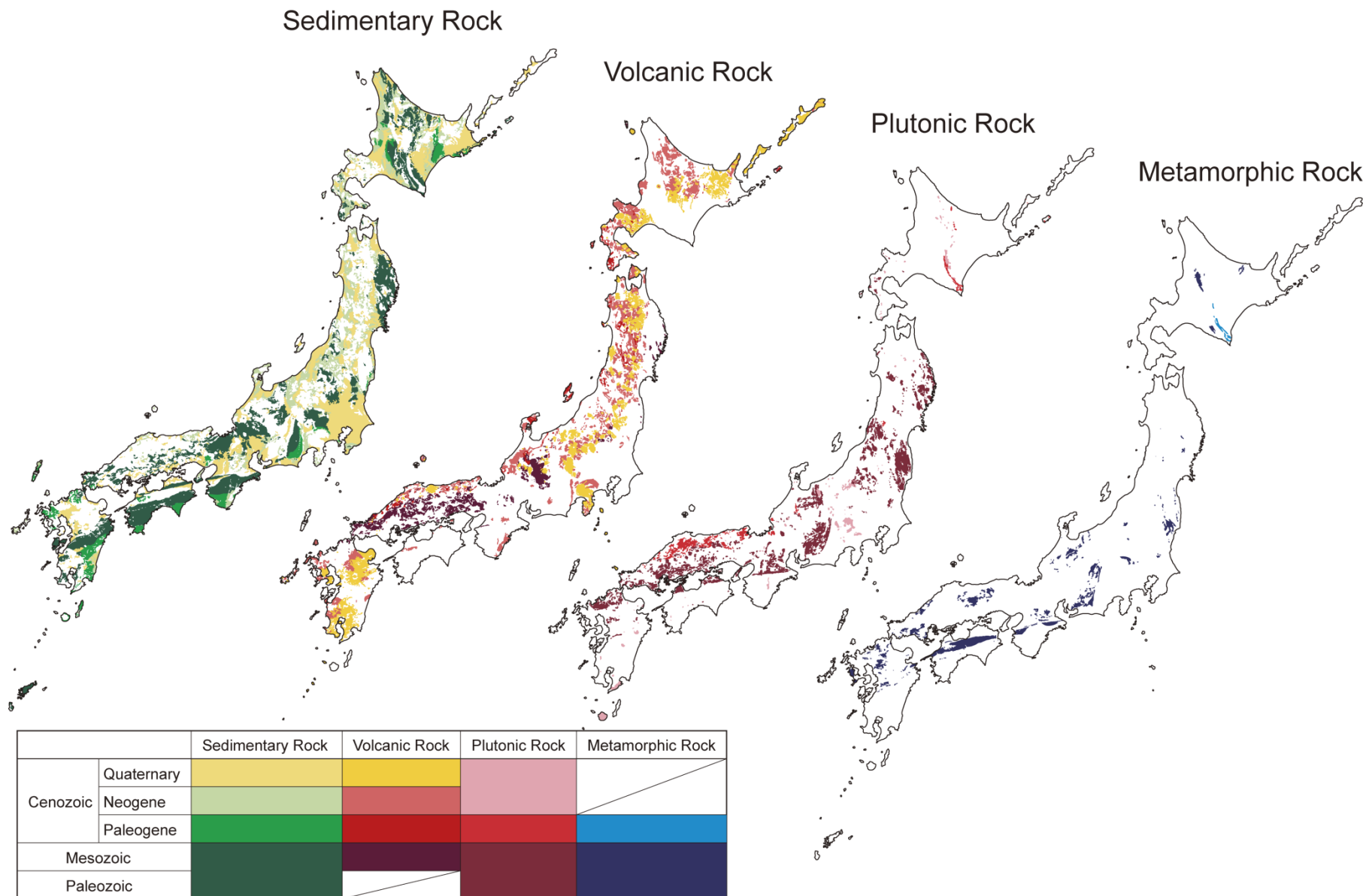
## Function as a natural barrier system

- Retardation and dilution/dispersion of released radionuclides

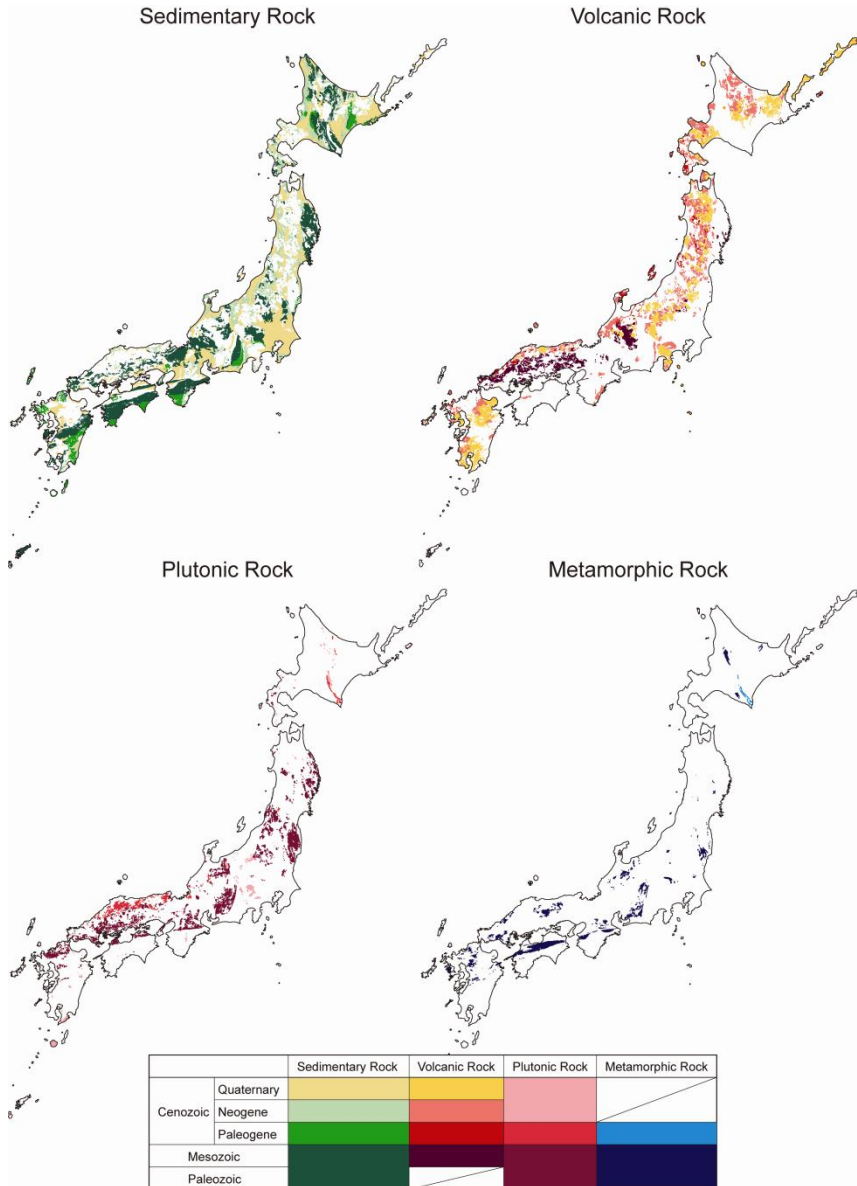
Suggested by mode of occurrence  
of uranium mineralization

- Geology and distribution of uranium deposit in Japan

# Geological Setting of the Japanese Islands



# Geological Setting of the Japanese Islands



Rock types	Geological age	Area (km <sup>2</sup> )	Ratio (%)
Sedimentary rocks	Quaternary	80,228.16	21.36
	Neogene	46,822.76	12.47
	Paleogene	7,122.90	1.90
	Cretaceous	10,207.19	2.72
	Jurassic	757.06	0.20
	Triassic	1,139.80	0.30
	Paleozoic	3,571.21	0.96
Accretionary complex (sedimentary rocks dominant)	Paleogene to Paleozoic	60,802.94	16.19
Accretionary complex (volcanic rocks dominant)	Paleogene to Paleozoic	3,661.73	0.98
Ultramafic igneous Rocks	Pre-Paleogene	1,876.98	0.50
Volcanic Rocks	Quaternary	41,629.97	11.09
	Neogene	44,685.16	11.90
	Paleogene	4,261.61	1.13
	Cretaceous	15,092.42	4.02
Plutonic Rocks	Neogene	3,947.43	1.05
	Paleogene	5,339.90	1.42
	Cretaceous	28,498.26	7.59
	Pre-Cretaceous	1,422.46	0.38
Metamorphic Rocks	Pre-Neogene	14,472.51	3.85
TOTAL		375,540.47	
Sedimentary rocks			56.10
Igneous Rocks			40.05
Metamorphic Rocks			3.85

# Typology of uranium deposit in Japan

Traditionally, following typology has been used for uranium deposit in Japan.

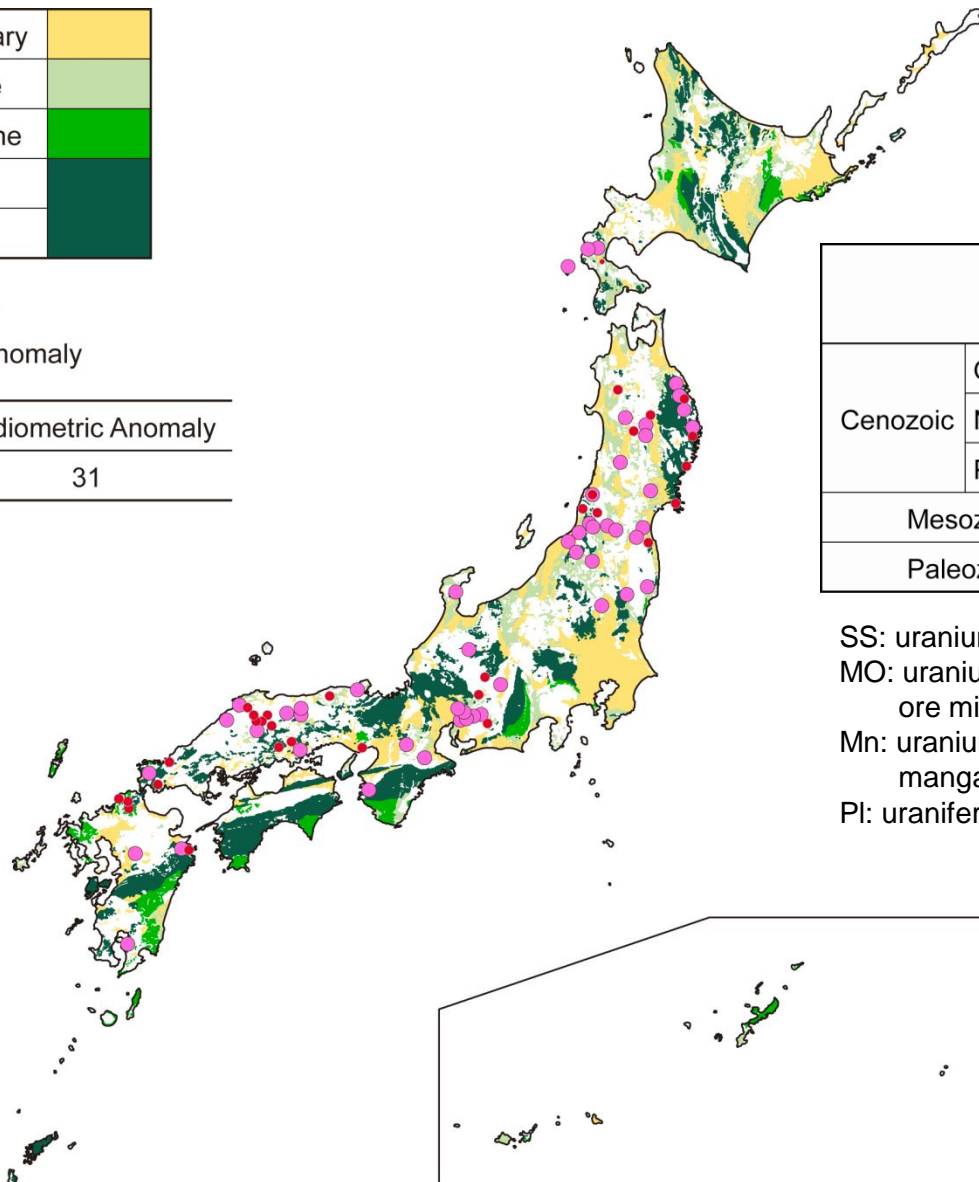
- ✓ Sedimentary type (sandstone type deposit)
  - occurs in “normal” sedimentary rock without other significant element concentration.
- Metallic type
  - associated with metallic ore deposit such as tin, molybdenum, copper etc.
- Manganese type
  - associated with stratiform manganese deposit, mostly hosted by accretionary complex, and rarely metamorphic rock.
- Pegmatite type
  - occurs as uranium-bearing minerals such as fergusonite, samarskite, xenotime, thorite, monazite and zircon etc.
- Uraniferous placer deposit
  - occurs as uranium-bearing minerals and distributed in the present-day river sediments.

# Geology and mineralization –Sedimentary Rock-

Cenozoic	Quaternary	Yellow
	Neogene	Light Green
	Paleogene	Green
Mesozoic		Dark Green
Paleozoic		

- Mineralization
- Radiometric Anomaly

Mineralization	Radiometric Anomaly
50	31



		Sedimentary Rock	
		“Normal” Sediment	Accretionary Complex
Cenozoic	Quaternary	SS, PI	
	Neogene	SS, MO	
	Paleogene	SS	
Mesozoic		SS	Mn, MO
Paleozoic		?SS	?Mn

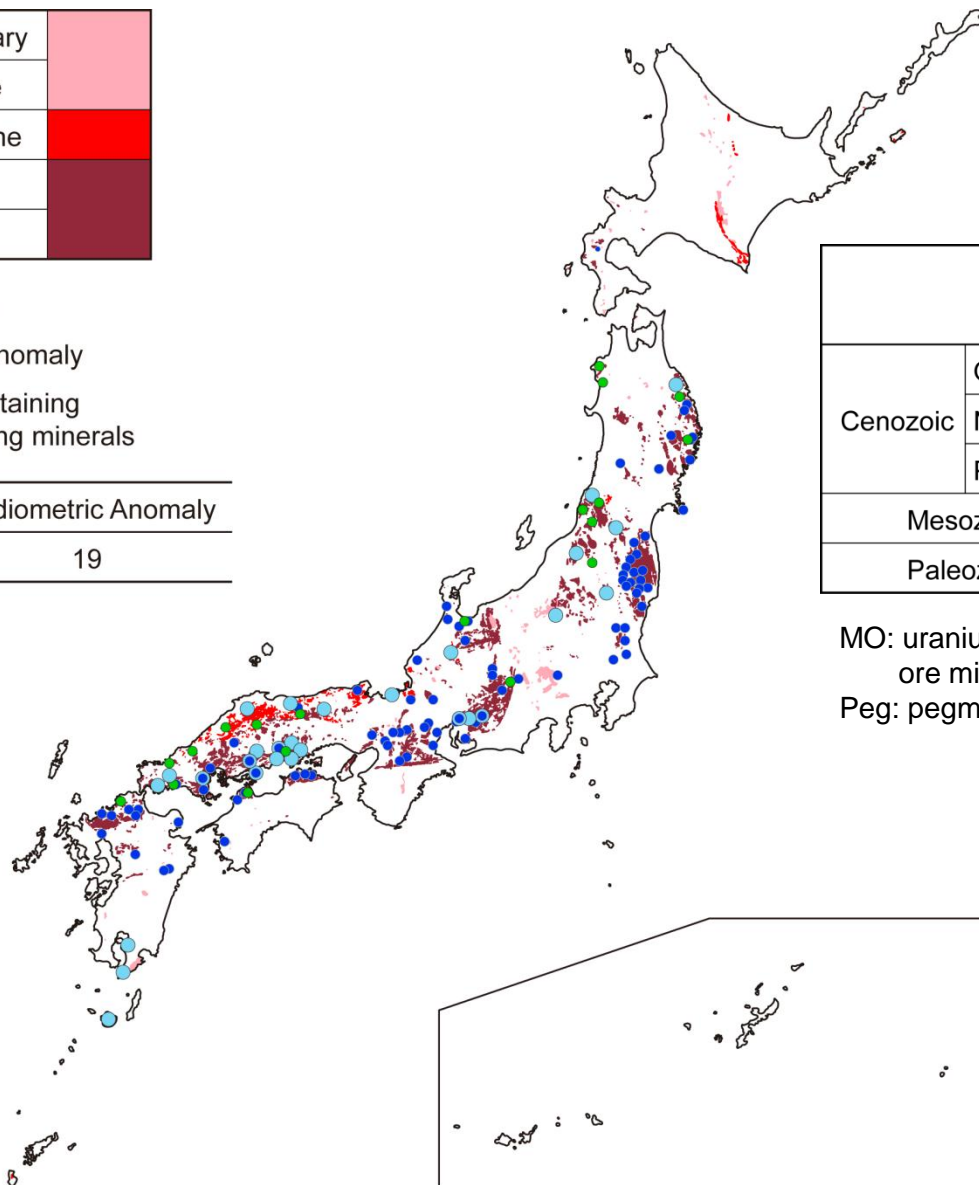
SS: uranium mineralization in sedimentary rocks  
 MO: uranium mineralization associated with metallic ore mineralization  
 Mn: uranium mineralization associated with stratiform manganese mineralization  
 PI: uraniferous placer deposits.

# Geology and mineralization –Plutonic Rock-

Cenozoic	Quaternary	Light Pink
	Neogene	
	Paleogene	Red
Mesozoic	Dark Red	
Paleozoic		

- Mineralization
- Radiometric Anomaly
- Pegmatite containing uranium-bearing minerals

Mineralization	Radiometric Anomaly
29	19



		Plutonic Rock
Cenozoic	Quaternary	
	Neogene	
	Paleogene	MO
Mesozoic	MO, Peg	
Paleozoic	?MO	

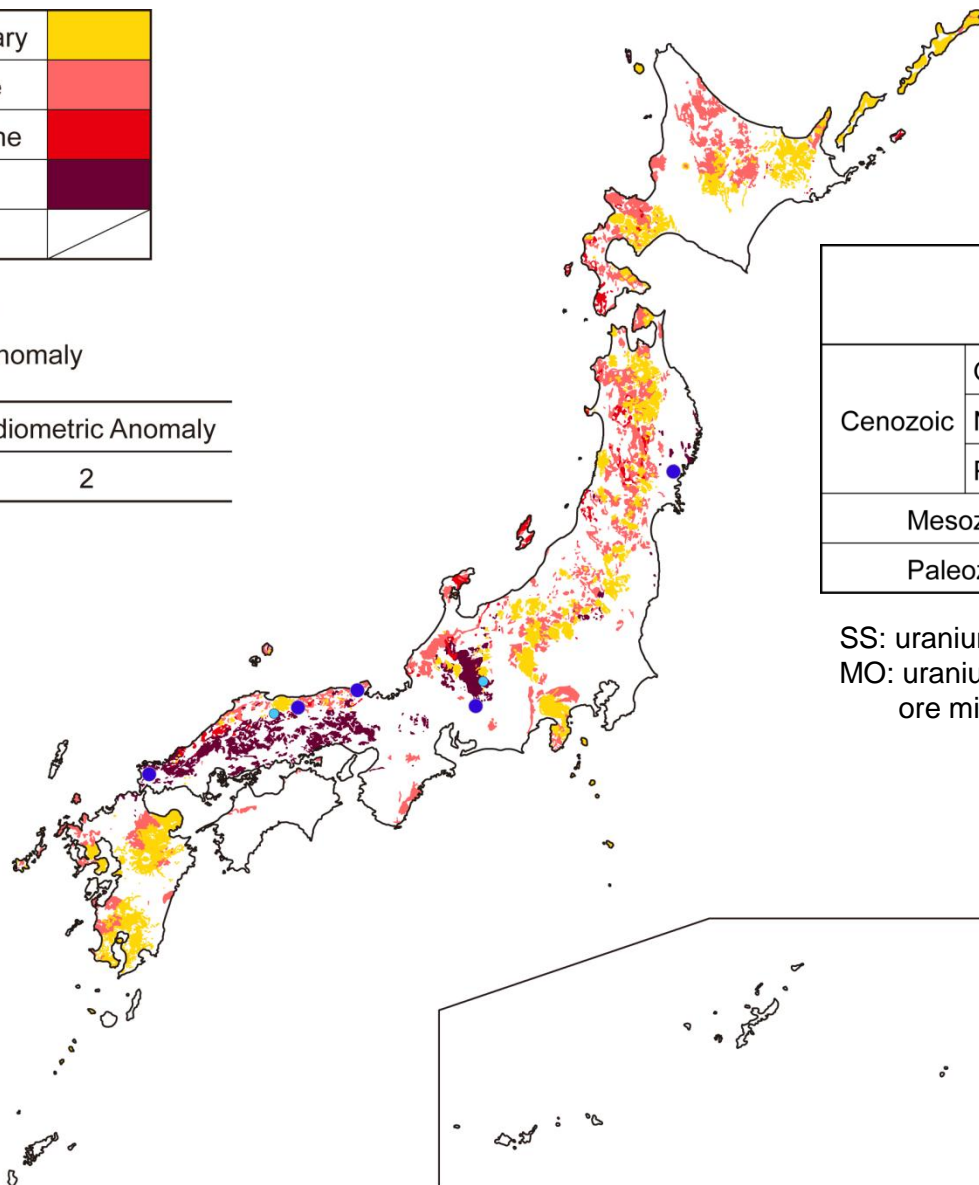
MO: uranium mineralization associated with metallic ore mineralization  
 Peg: pegmatite containing uranium-bearing minerals

# Geology and mineralization –Volcanic Rock-

Cenozoic	Quaternary	Yellow
	Neogene	Light Red
	Paleogene	Dark Red
Mesozoic		Dark Purple
Paleozoic		White

- Mineralization
- Radiometric Anomaly

Mineralization	Radiometric Anomaly
5	2



		Volcanic Rock
Cenozoic	Quaternary	SS
	Neogene	SS
	Paleogene	MO
Mesozoic		MO, SS
Paleozoic		White

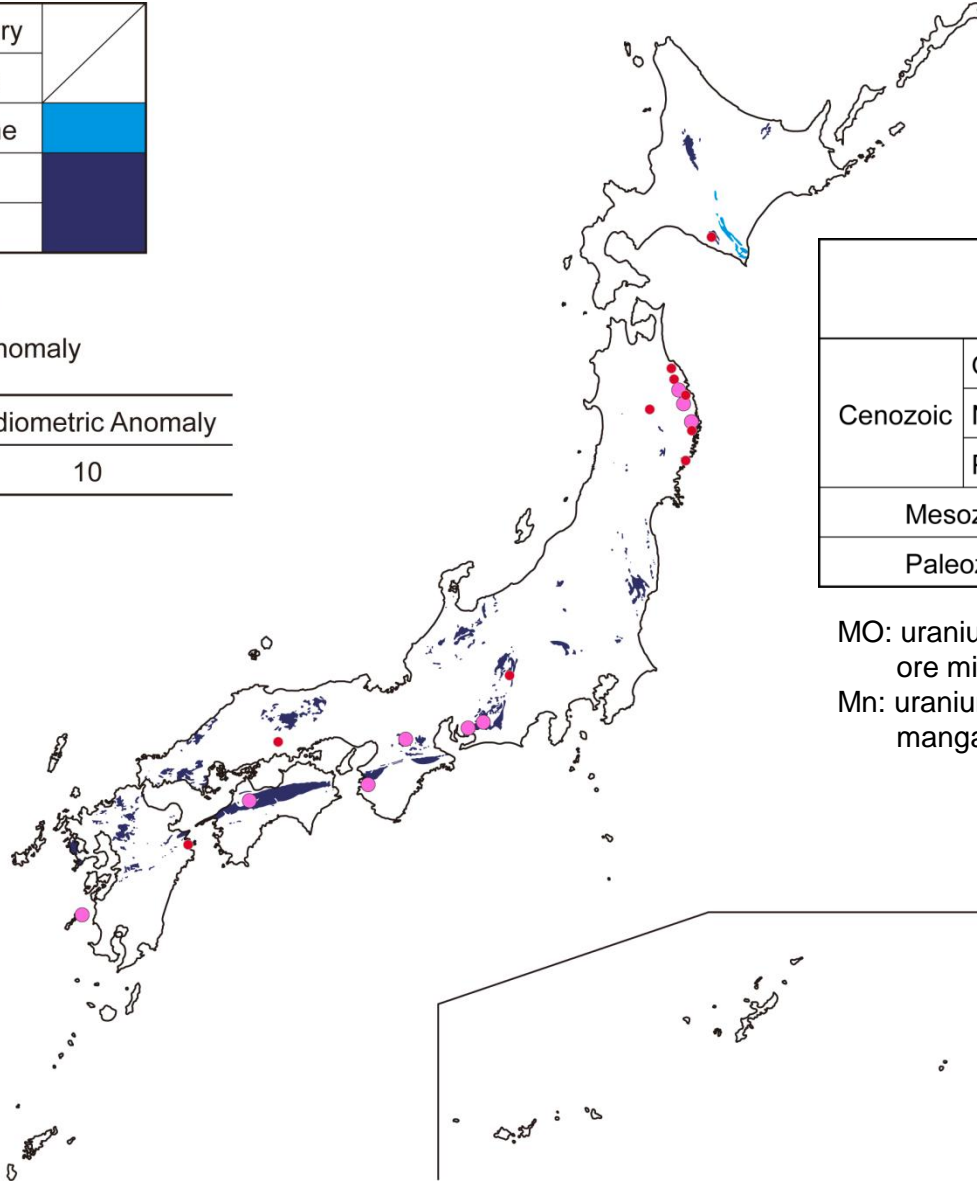
SS: uranium mineralization in sedimentary rocks  
 MO: uranium mineralization associated with metallic ore mineralization

# Geology and mineralization –Metamorphic Rock-

Cenozoic	Quaternary	
	Neogene	
	Paleogene	
Mesozoic		
Paleozoic		

- Mineralization
- Radiometric Anomaly

Mineralization	Radiometric Anomaly
9	10



		Metamorphic Rock
Cenozoic	Quaternary	
	Neogene	
	Paleogene	
Mesozoic		Mn, ?MO
Paleozoic		?Mn, ?MO

MO: uranium mineralization associated with metallic ore mineralization

Mn: uranium mineralization associated with stratiform manganese mineralization

# Host rock of uranium mineralization

	Mineralization	Radiometric Anomaly
Sedimentary Rocks	50	31
Igneous Rocks	34	21
Metamorphic Rocks	9	10
<b>TOTAL</b>	<b>93</b>	<b>62</b>

		Sedimentary Rock		Igneous Rock		Metamorphic Rock
		"Normal" Sediment	Accretionary Complex	Volcanic Rock	Plutonic Rock	
Cenozoic	Quaternary	SS, PI		SS		
	Neogene	SS, MO		SS		
	Paleogene	SS		MO	MO	
Mesozoic		SS	Mn, MO	MO, SS	MO, Peg	Mn, ?MO
Paleozoic		?SS	?Mn		?MO	?Mn, ?MO

SS: uranium mineralization in sedimentary rocks

MO: uranium mineralization associated with metallic ore mineralization

Mn: uranium mineralization associated with stratiform manganese mineralization

Peg: pegmatite containing uranium-bearing minerals

PI: uraniferous placer deposits.

- The geological environments preserving uranium are widely distributed, even in the geologically active Japanese Islands, because a variety of rocks of various age are known to host the Japanese uranium deposit.
- Geological environments associated with uranium deposit are reduced condition (favorable for HLW disposal) and stable in geological time-scale.
- Main issue of this consideration is that mineralizing age is unknown in most of deposit.
  - Only few examples; 5 million years ago at Tono, 10 million years ago at Ningyo-toge, 100 million years ago at Yamaguchi (Miyagi pref. metallic type in scarn), in the order of 100 million years at Noda-tamagawa (Iwate pref. manganese type)

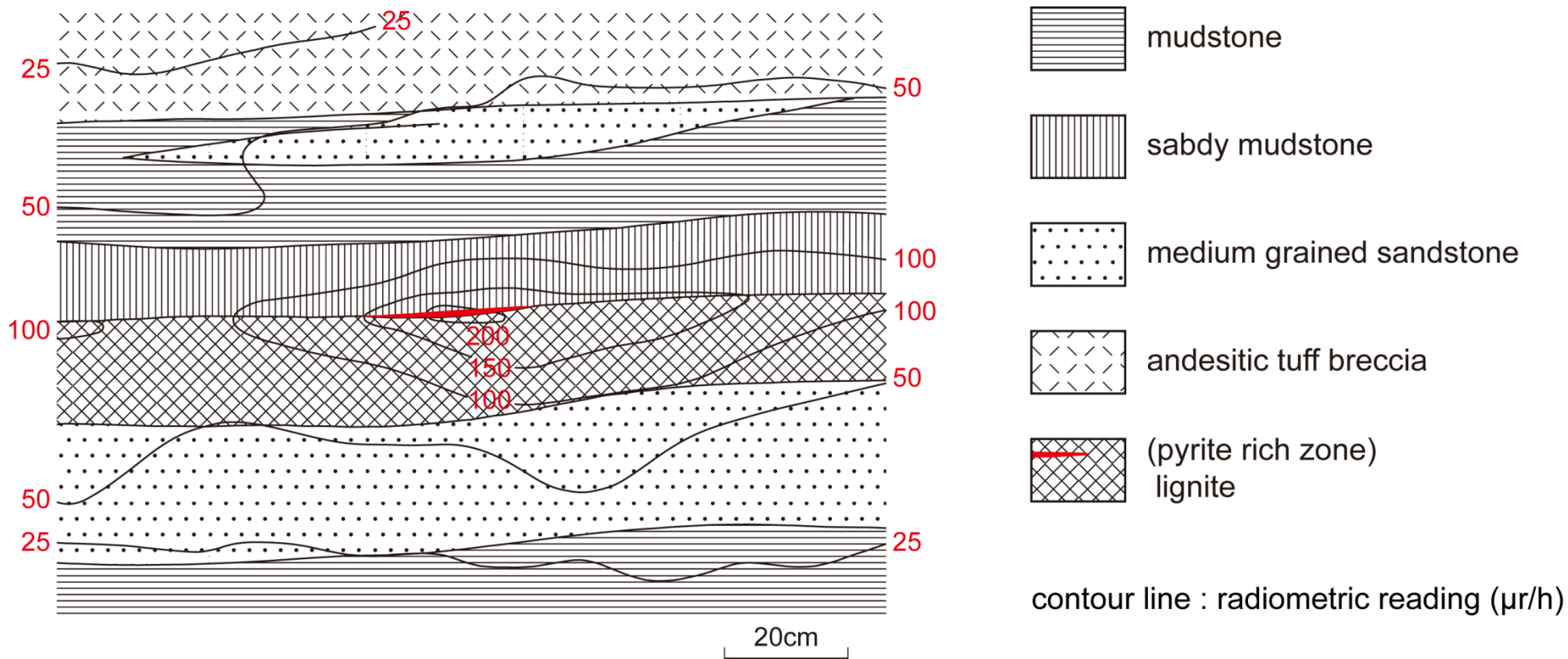
- Mode of occurrence of uranium deposit in Japan

- In crystalline rock (mainly granitic rock),  
Sorption onto clay, limonite and secondary bismuth minerals are pervasively observed.
- In sedimentary rock,  
Sorption onto clay, limonite, carbonaceous matter and silicified wood are pervasively observed.



*These occurrences indicate that dissolved uranium in groundwater has been sorbed onto various minerals and materials.*

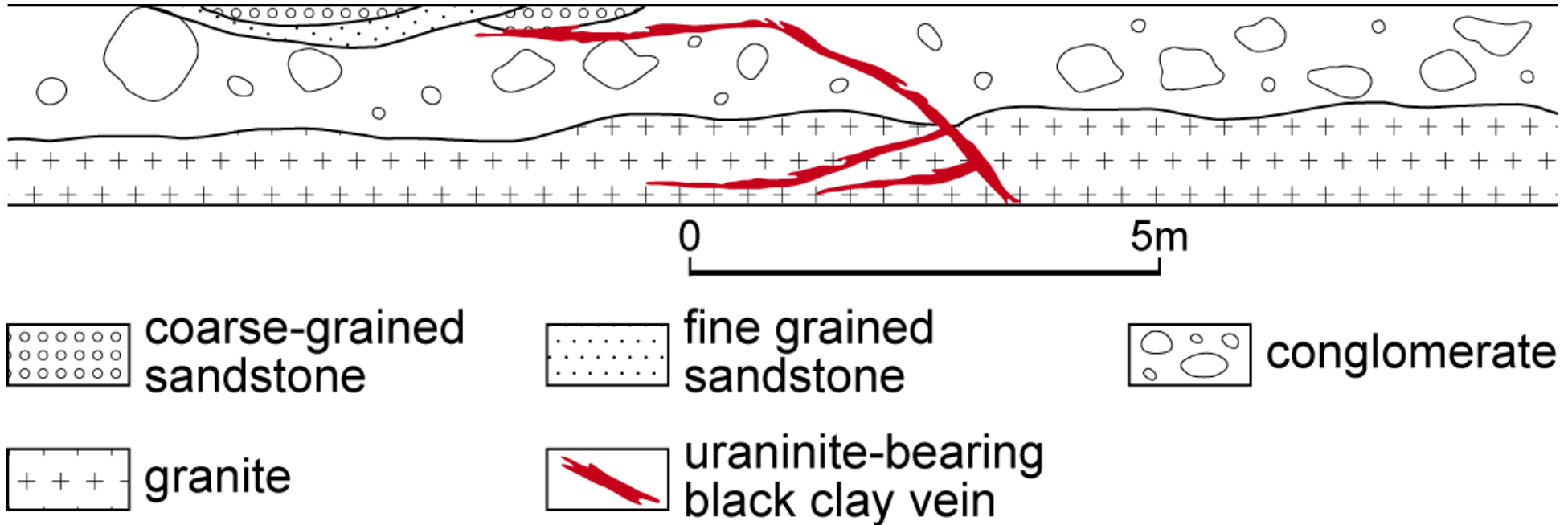
# Radiometric anomaly in sedimentary rock



✓ High radiometric reading is observed along a lignite layer, especially in the pyrite-rich zone.

(Futuro area)

# Uranium mineralization in sedimentary rock

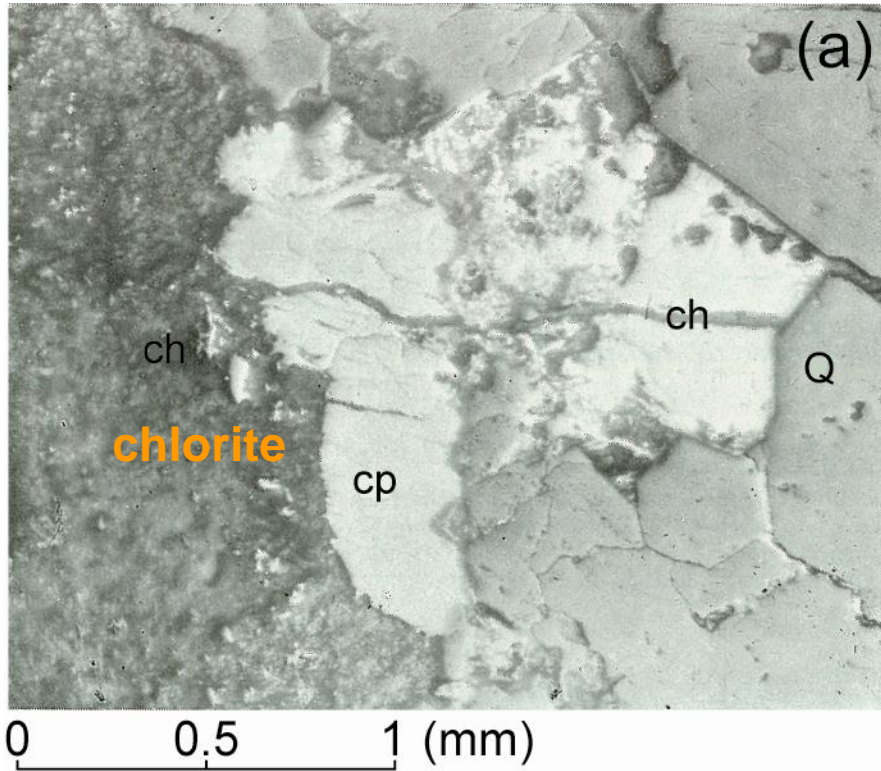


- ✓ **Uranium-bearing black clay** is distributed along a fault cutting both the granite basement and the overlying conglomerate.

(Nakatsugo-main orebody in the Ningyo-toge area)

- Coffinite is the most common uranium mineral occurring in uranium-bearing hydrothermal metallic mineralization.
- At the the Tsukiyoshi orebody, uranium was fixed initially by a combination of sorption by diagenetic clay and oxidation/reduction processes, and then coffinite formed during diagenesis.
- Coffinite in metallic type mineralization occurrences could be formed by a similar process for the Tsukiyoshi orebody.
- If this is the case, existence of **primary mineral** may indicate their function as the natural barrier **to retard uranium** by **uptake of uranium in the mineral**.

Photograph of polished section

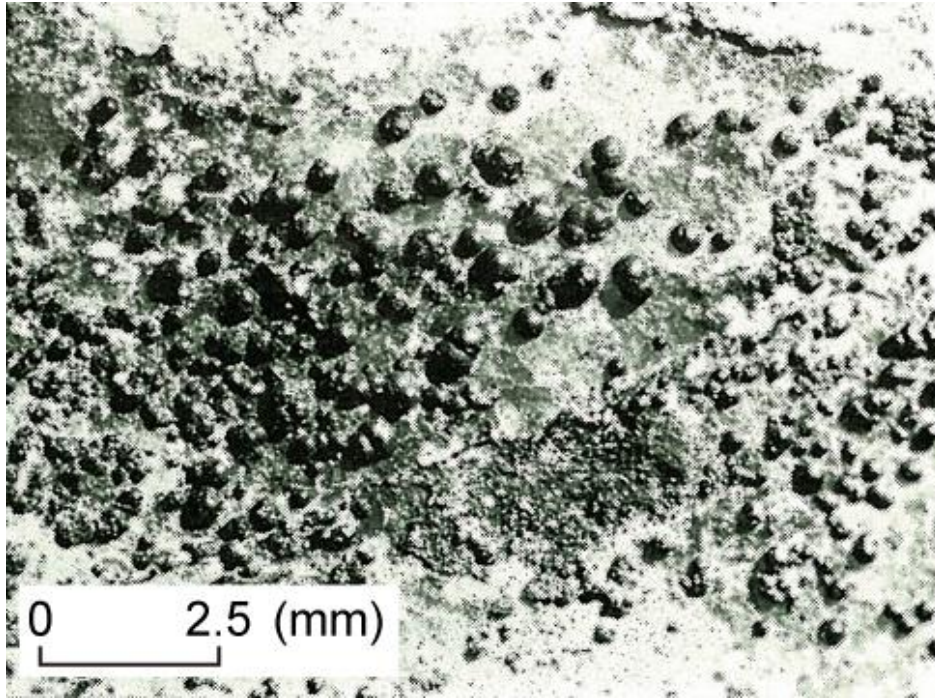


autoradiograph of polished section

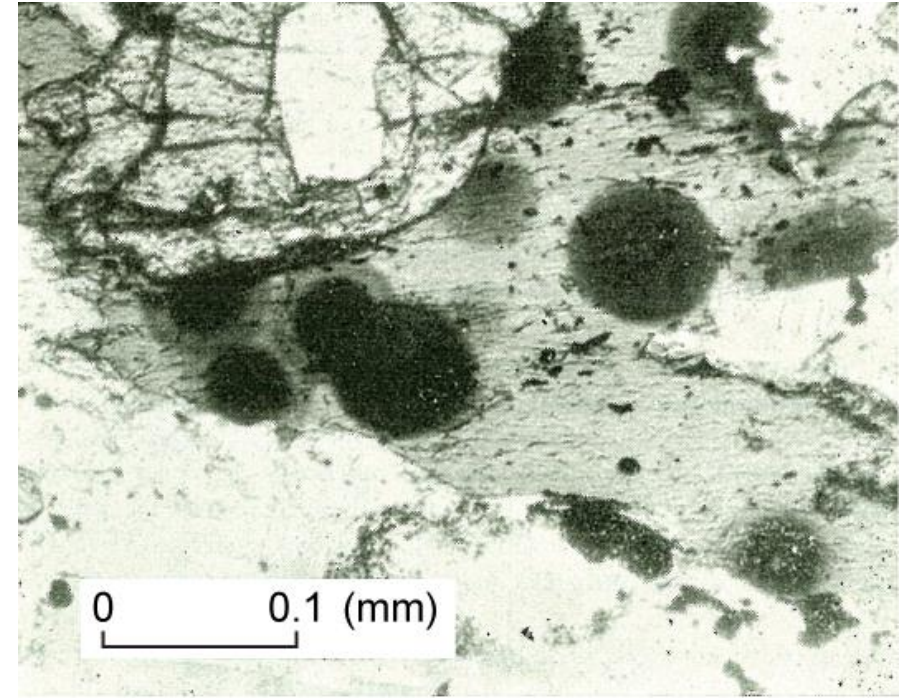


- ✓ Coffinite and uraninite occur at the chloritic altered zone with dissemination of chalcopyrite and minor pyrite.

(Yasaka Mine)

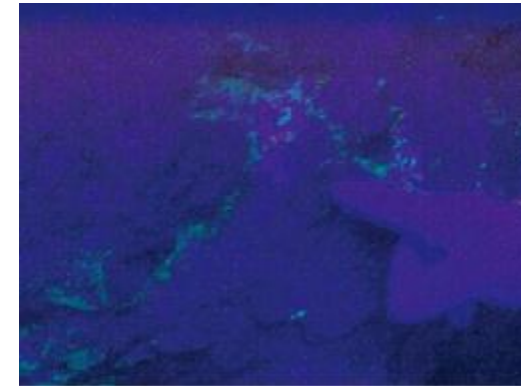


- ✓ Uraninite on surface of pyrite in a crack in a quartz vein (in granite).  
(Higashiyama Mine)



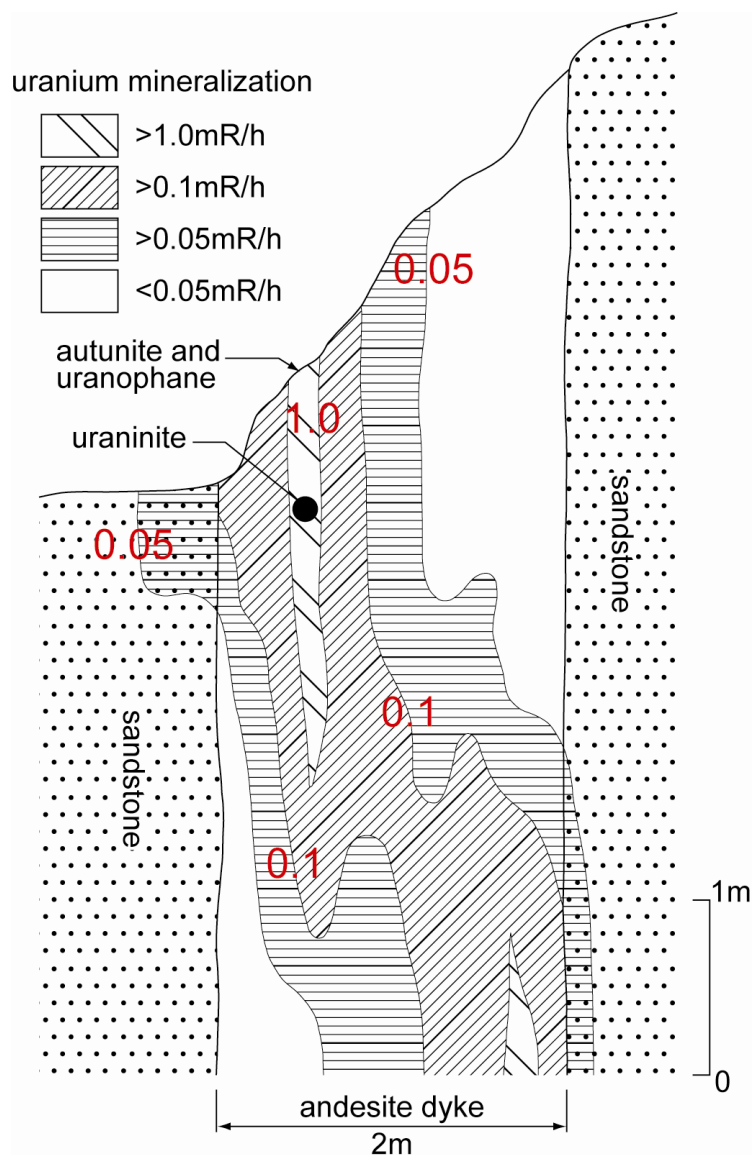
- ✓ Uraninite in biotite (in metamorphic rock).
- ✓ Pleochroic halos develop around uraninite grain.  
(Taguchi Mine)

- Various **secondary minerals** are reported from many locations throughout Japan.
- In the Tsukiyoshi orebody, secondary minerals such as andersonite and zippeite **crystallized during oxidation of the gallery wall** after the excavation of mine gallery.



*Secondary mineralization indicates that such mineralization is a possible retardation mechanism, even in the oxidization zone near ground surface and along geological structures such as fractures.*

# Uranium mineralization in sedimentary rock



- ✓ Uranium mineralization occurs along fractures (a few millimeter thickness) in an andesite dyke.
- ✓ Autunite and uranophane occurs in the oxidization zone near ground surface though uraninite occurs in unoxidized (reduced) zone.

(Toyoda area)

- These examples indicate that formation of uranium-bearing mineral as well as sorption is expected in both sedimentary and crystalline rocks.
- In conclusion, the functioning of the natural barrier, to retard uranium would be expected in various geological environments in the Japanese Islands.

		Sedimentary Rock		Igneous Rock		Metamorphic Rock
		"Normal" Sediment	Accretionary Complex	Volcanic Rock	Plutonic Rock	
Cenozoic	Quaternary	SS, PI		SS		
	Neogene	SS, MO		SS		
	Paleogene	SS		MO	MO	
Mesozoic		SS	Mn, MO	MO, SS	MO, Peg	Mn, ?MO
Paleozoic		?SS	?Mn		?MO	?Mn, ?MO

## General View

Geological activity ≠ Unstability of Geological Environment

- Stable geological environment is suggested by distribution of uranium deposit.
- Utilization of the information on uranium deposit
  - Broad NA as public communication tool
  - specially, for promoting mutual understanding with public and building confidence in HLW disposal in the Japanese Islands even though they are located in a tectonically active island-arc.