Stability of smectite under hyperalkaline fluids including Fe, Mg, Al ions

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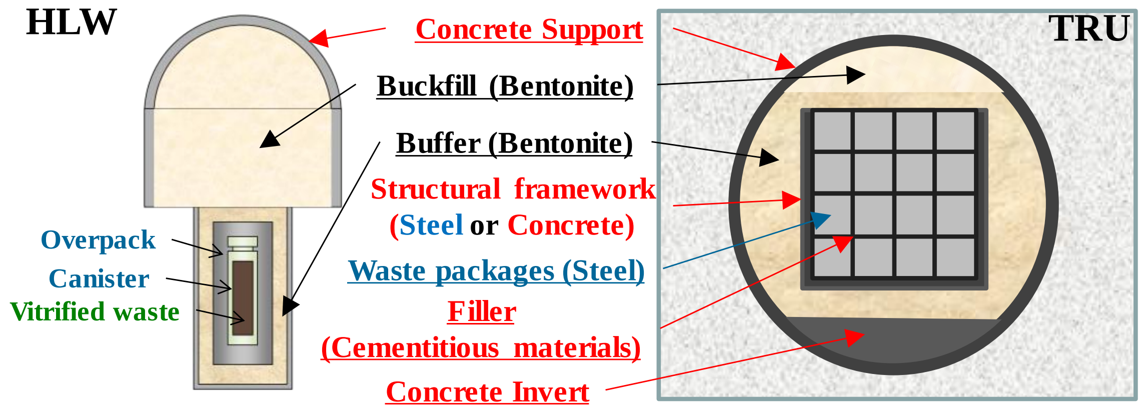
Contents

1. Background

Influence of Hyperalkaline Fluid

- **Much of Cement Materials** are used for TRU waste disposal system in Japan.
- **High pH cement leachate** affects bentonite (dissolution/ alteration of smectite), as a result, may cause the loss of its favorable properties.
- **The long-term phenomenon** of the hyperalkaline influence is a key issue of the safety assessment of waste disposal.

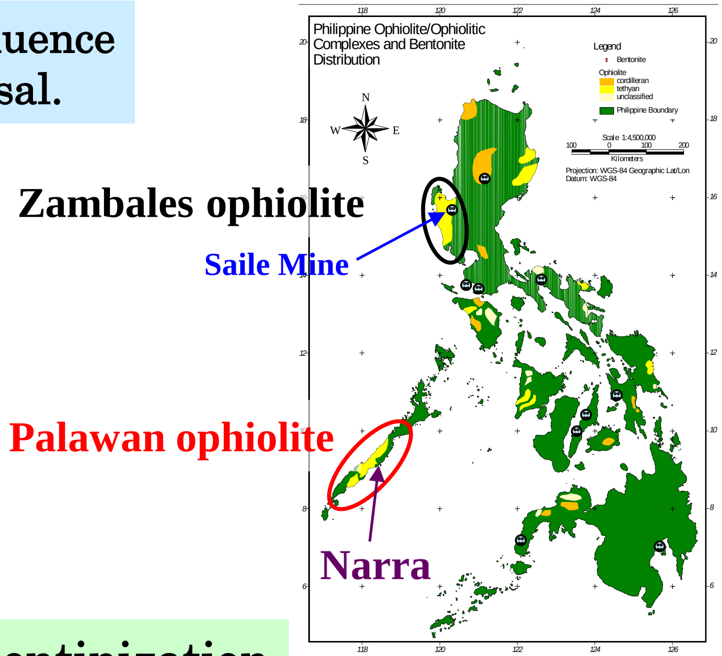


High-level waste and TRU waste Repository in Japan

Natural Evidence

- **Hyperalkaline Groundwater** evolved by **Serpentinization** of **Ultramafic rocks in Ophiolite** is **high pH, high Ca,** reducing and 30~40°C.
- Many serpentinizing ophiolites are distributed in the Philippines. Palawan ophiolite is one of the typical ophiolites.

⇒Hyperalkaline groundwater gerenated by serpentinization is regarded as a natural analogue of the cement leachate

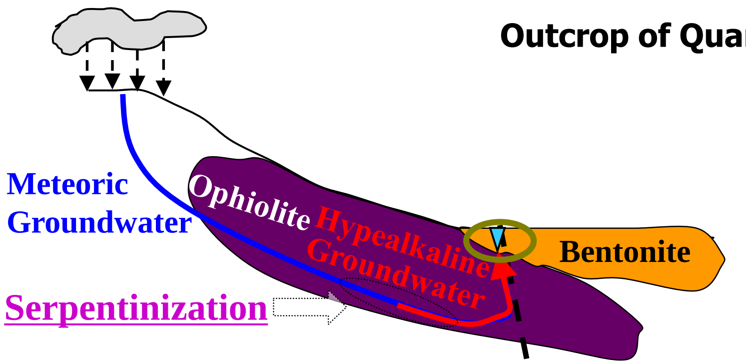


Distribution of Ophiolite and Bentonite deposits in the Philippines

2. Survey sites

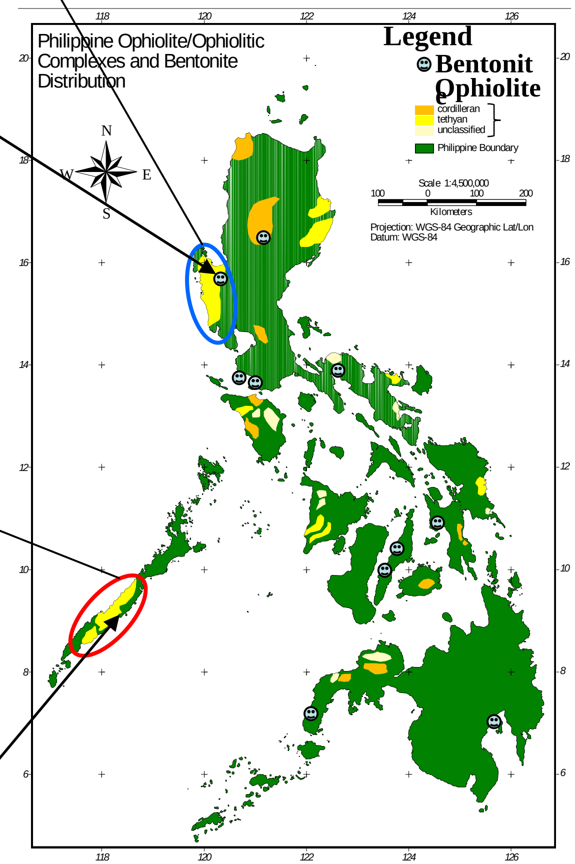
Natural Analogue in Saile Mine

Zambales Ophiolite



Fracture system as the flow path

Outcrop of Quarry

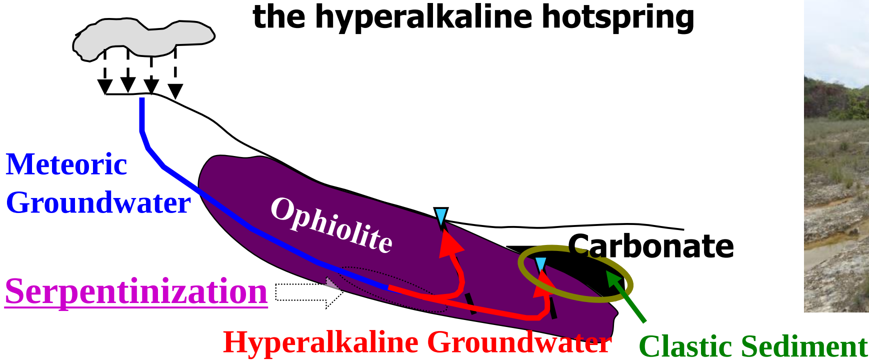


Distribution of Ophiolite and Bentonite deposits in the Philippines

Natural Analogue in Narra

Palawan Ophiolite

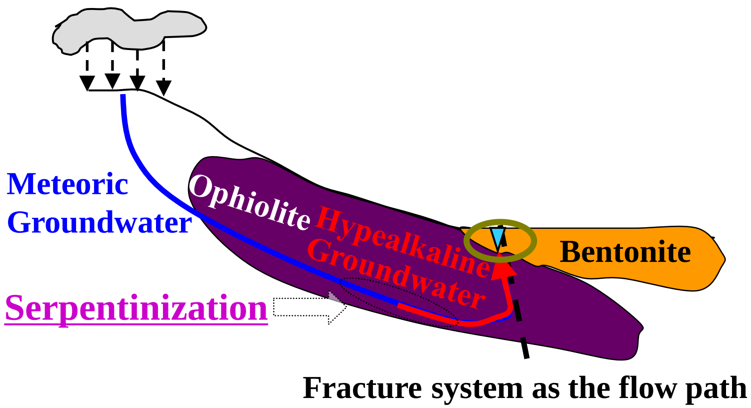
Travertine in down-stream from the hyperalkaline hotspring



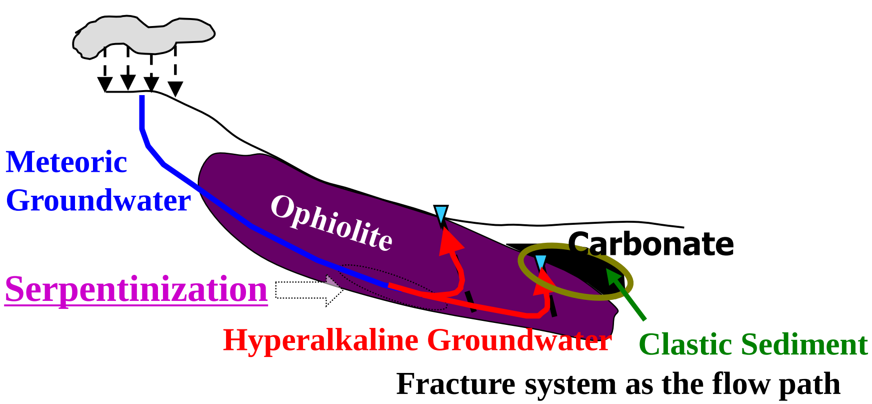
Fracture system as the flow path

2. Survey sites

Natural Analogue in Saile Mine



Natural Analogue in Narra



Advantages of Narra

- **Hyperalkaline groundwater have been seeping into overlying clastic sediment still now.**

  We can directly measure **properties of hyperalkaline groundwater**, and observe **metastable reactions** between the groundwater and sediment, and estimate **the reacton time** by C-14 dating.

  No hyperalkaline groundwater flow in Saile mine now.

- **pH > 11**

  It is the reruired condtion as cement analogue.

  pH at Manleluag hotspring near Saile mine is under 11.

Disadvantages of Narra

- **The sediment is not bentonite.**

  Sediment is smectite-rich clay, but the smectite is not montmorillonite.

  It is imposible to observe Natural analogue of **bentonite** buffer **system** only at Narra site.

However, we can study several impotant **reaction processes** concerning alkaline alteration of bentonite in Narra.

3. Objectives

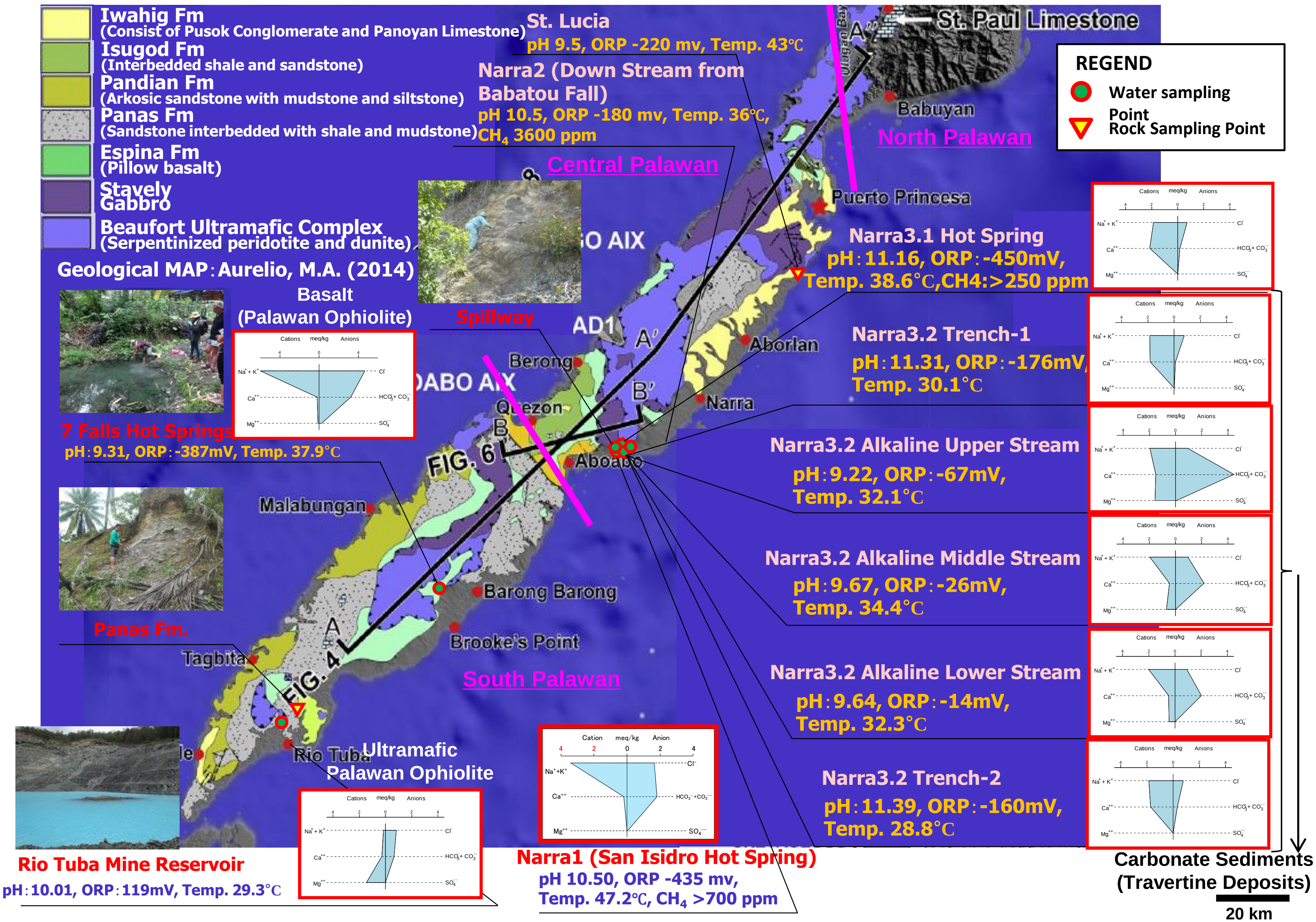
This NA project has field survey at the Narra site in central Palawan, SW Philippines and chemical and mineralogical analysis,

- **To better understand alteration process under hypealkaline conditions.**
  - **Dissolution/Formation reactions by hypealkaline fluid**
  - **Mass balance of Fe, Mg, Si, Al, Ca in mineral formation**
  - **Stability of smectite**
- **To establish comprehensive scenario of bentonite reaction under realistic hyperalkaline environment.**






4.1 Groundwater Chemistry and Geology in Palawan Island



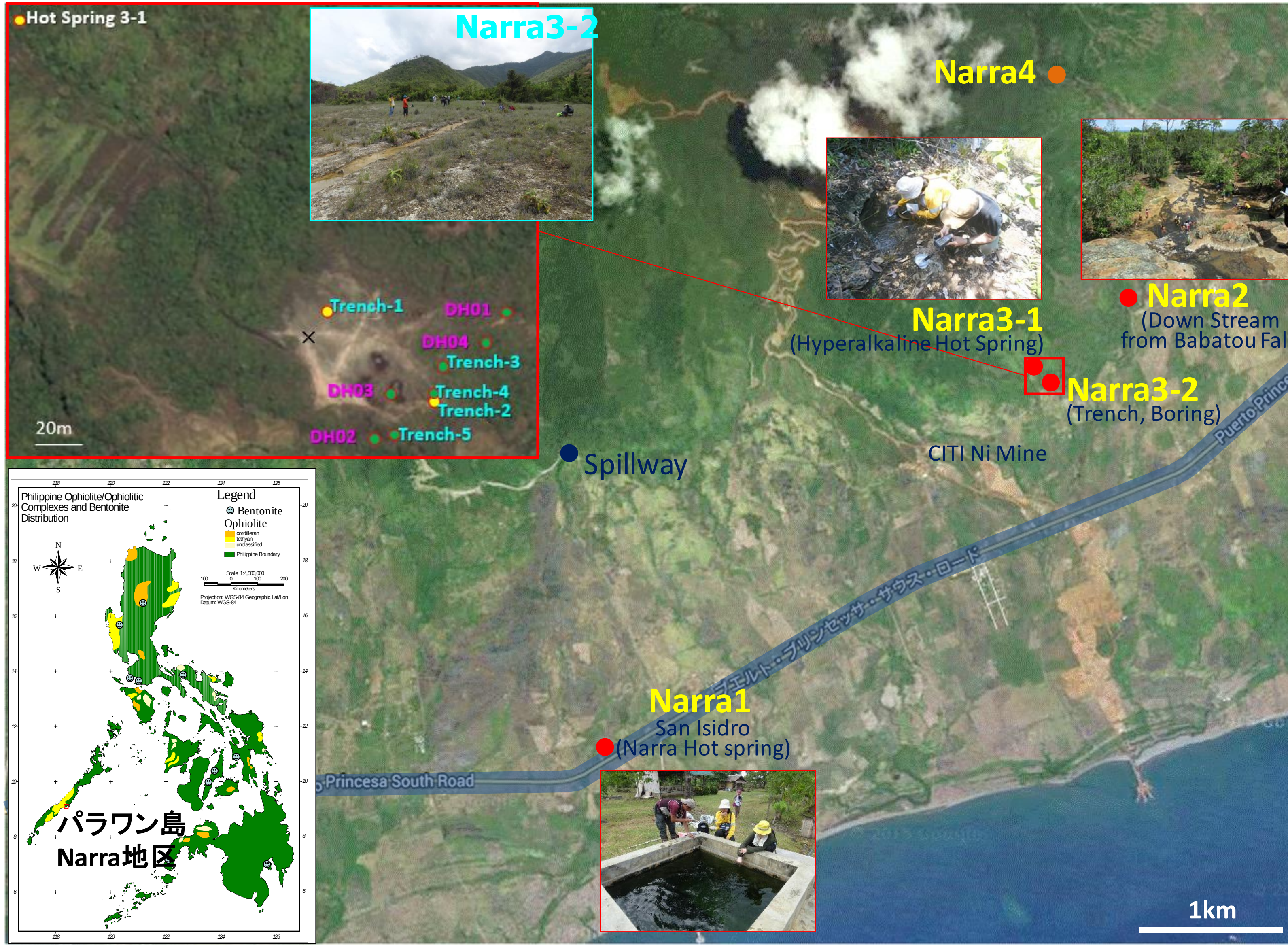
4.1 Groundwater Chemistry in Palawan

Site	Palawan Narra -1 Hot Spring	Palawan Narra -3.2 Trench5	Palawan Narra -3.2 Trench4	Palawan Narra -3.2 Trench3	Palawan Narra -3.2 Trench2	Palawan Narra -3.2 DH04	Palawan Narra -3.1 Hot Spring	Luzon Poonbato	Luzon Manleluag Hot Spring – M1*	Luzon Bigbiga - Well-1	Low alkali cement leachates (PNC 1997)**
採取年 Sample No.	2016 Narra1 San Isidro O	2016 Narra3-2 Trench5 O	2016 Narra3-2 Trench4 O	2016 Narra3-2 Trench3 O	2015 Narra3-2 Trench2 O	2016 PW-DH04 O	2016 Narra3-1 O	2013 P-2 G	2013 M1 G	2014 Well1 G	1997
pH	10.64	11.36	11.17	11.37	11.39	11.39	11.37	11.41	10.80	9.52	11.09
ORP(Eh) [mV]	-270	-152	-30	-111	-160	-119	-867	-111	-420	8	-
Temp [°C]	39.3	29.9	33.4	33.7	28.8	33.0	38.5	28.0	32.9	29.2	60
CH_4 [ppm]	>700	0	0	0	0	0	200	> 5000	2090	0 (0~560)	-
H_2 [ppm]	0	0	0	0	0	0	0	50~1320	0 (0~62)	0 (0~130)	-
Na^+ [ppm]	78.0	48.2	47.1	50.4	46.1	51.8	50.4	24.3	26.3	100.6	43
K^+ [ppm]	0.60	2.24	2.54	2.39	2.32	2.96	2.36	1.45	0.375	1.05	13
Ca^{2+} [ppm]	3.70	44.8	36.4	48.5	26.9	22.4	50.6	92.5	29.9	1.63	16.8
Mg^{2+} [ppm]	0	0	0.02	0.01	0.02	0.02	0.01	0.24	0.03	0.02	-
Si^{2+} [ppm]	38	4.1	2.3	2.5	2.5	2.9	0.29	11	17	72.3	
Al^{3+} [ppm]	0.29	0.13	0.10	0.08	0.08	0.06	0.13	1.41	1.05	0.97	0.3
$Fe^{(2^+ + 3^+)}$ [ppm]	0.01	0.01	0.03	0.05	0.02	0.03	0.01	0.18	< 0.001	0.0058	-
Cl^- [ppm]	58.8	27.8	28.5	27.0	27.3	21.1	28.0	12.9	17.8	4.50	-
SO_4^{2-}[ppm]	2.56	0	0.21	0.02	0.13	0.14	0.05	0.05	0.364	48.0	-
HCO_3^{-}* [ppm]	11.3	3.6	2.1	0	0.67	2.8	0.5	1.6	30.0	135.6	-

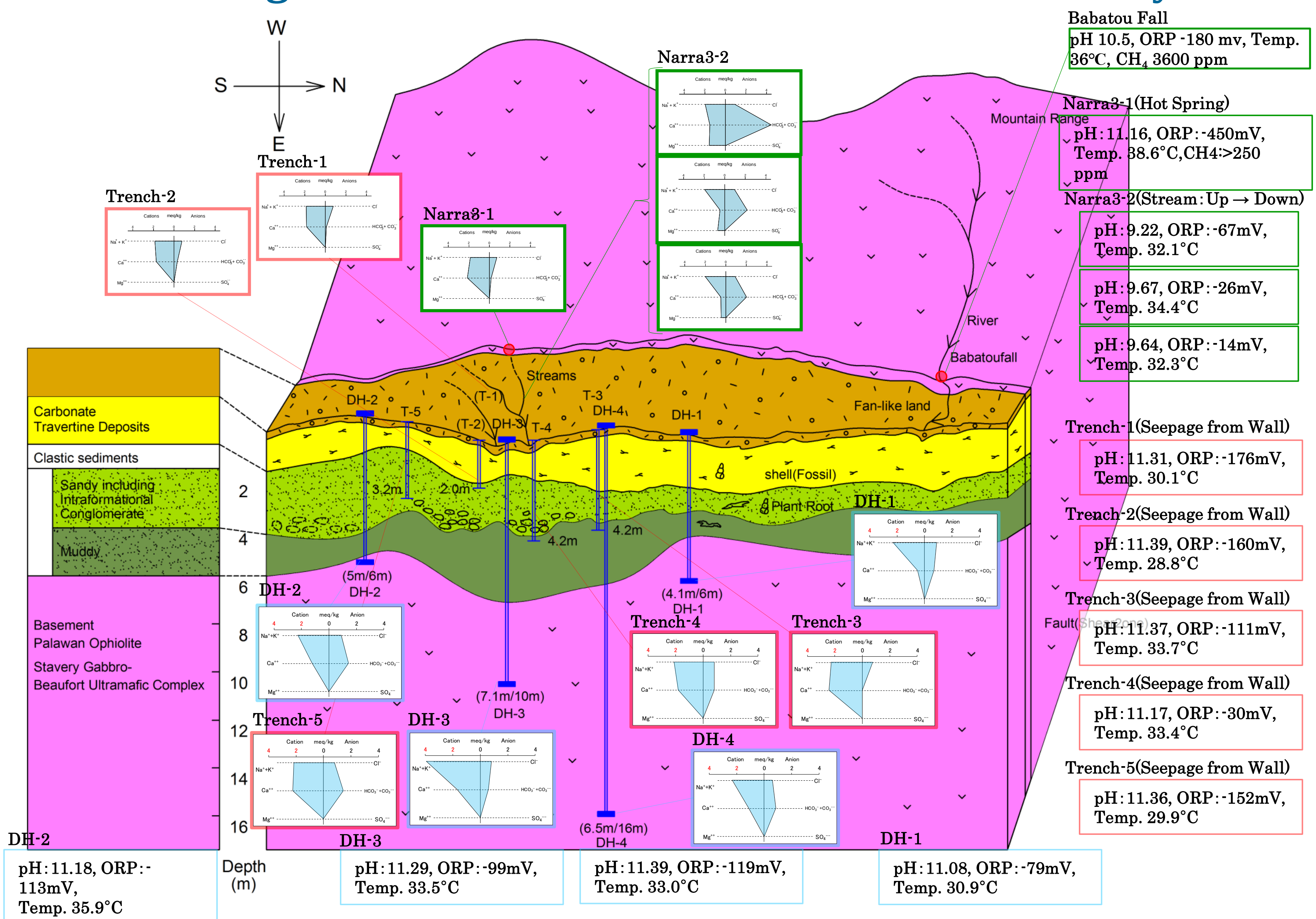
*** wt % - Manleluag hot spring is located in the 2.7km SW of Saile mine**

**** wt % - Portlandite Cement: Silica Fume: Fly Ash=40: 20: 40**

4.2 Narra Site – Investigation Points of Trench and Borehole

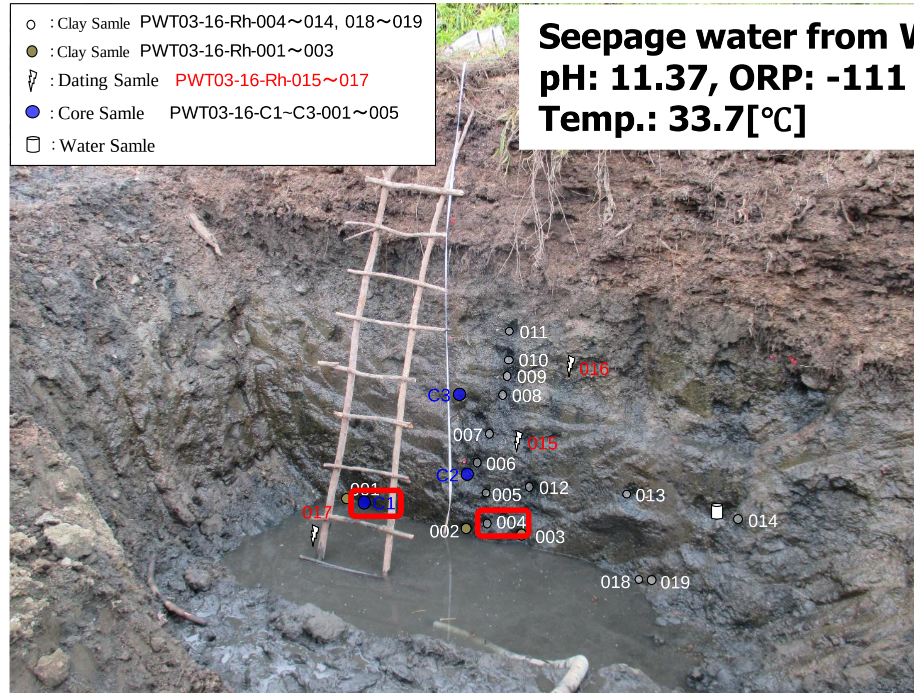


4.3 Conceptual Cross-Section at Narra site in central Palawan
- Geological Structure and Groundwater Chemistry -



4.4 Trench Survey

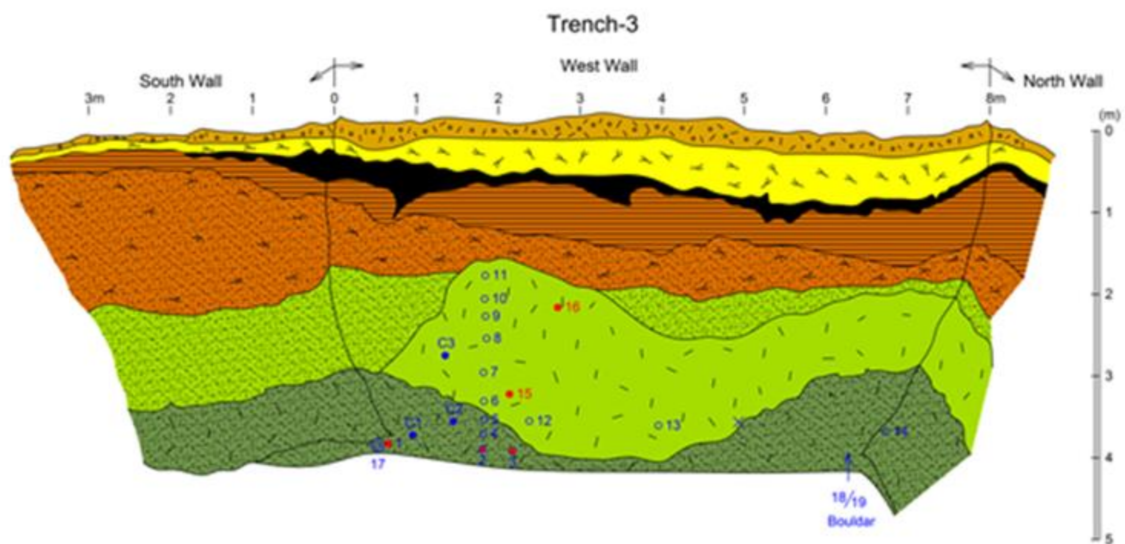
Trench-3



Seepage water from Wall
pH: 11.37, ORP: -111 [mv]
Temp.: 33.7[℃]

Summary of Lithological Units and Legend in Narra

1		Alluvium unconsolidated deposits
2		Pale brownish [or pale gray] and loosed Carbonate Sediment
2A		Pale brownish bedded(laminated) Carbonate Sediment
2B		Dark and pale brownish Massive Carbonate Sediment
3A		Carbonaceous and Sandy Clastic sediment
3B		Carbonaceous and Coarse-grained Sandy Clastic sediment
4		Blackish Sandy Clastic sediment with patchy clayey matrix including boulder and pebble of Palawan Ophiolite
5		Blackish Sandy Clastic sediment including granule of Palawan Ophiolite
6		Blackish and fine-grained Sandy Clastic sediment with patchy clayey matrix
7		Palawan Ophiolite(Harzbergite Basement)
8		Organic Matter, likely buried Plant-Roots
9		Occurrence of Living Shells
10		Poorly sorted interformational Conglomerate (Congiomeratic Sandy Sediment)



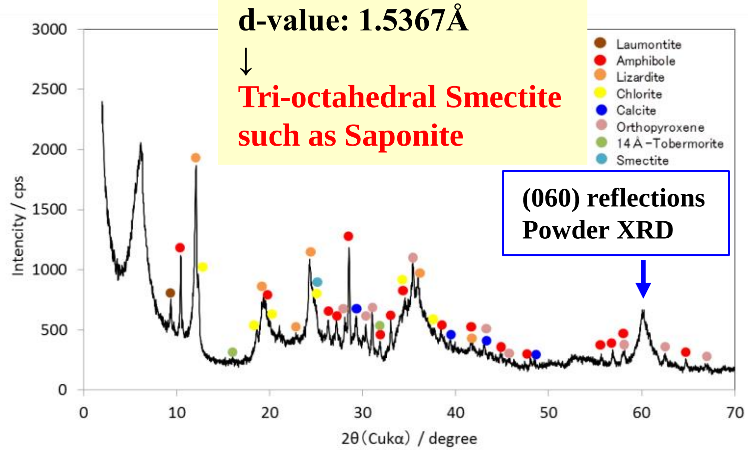
4.4 Trench Survey -XRD-

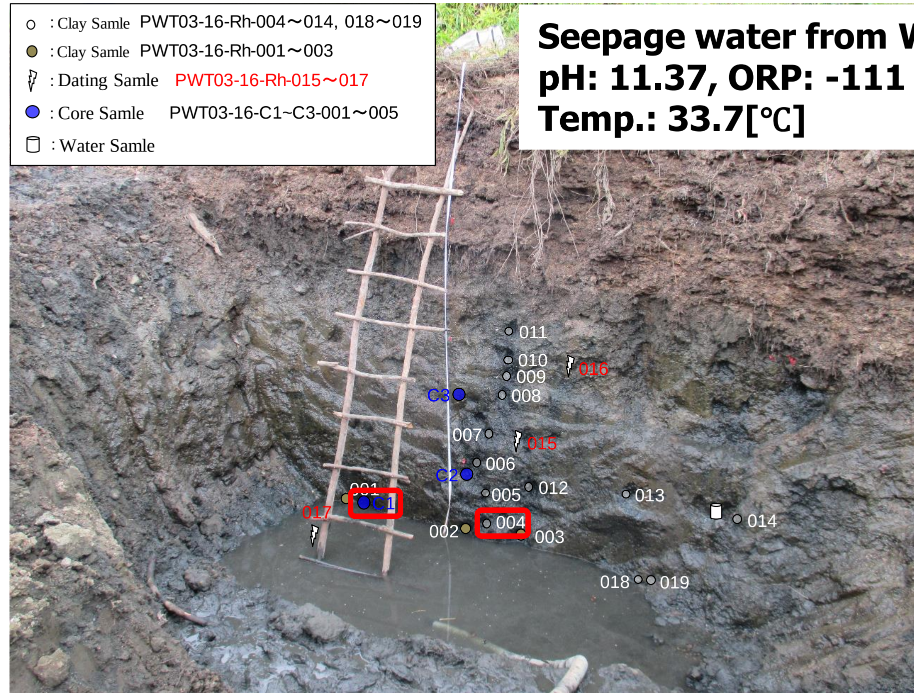
Trench-3

PWT03-16-Rh-004 (Powder XRD)

2θ: 60.22 °
d-value: 1.5367Å
↓
Tri-octahedral Smectite such as Saponite

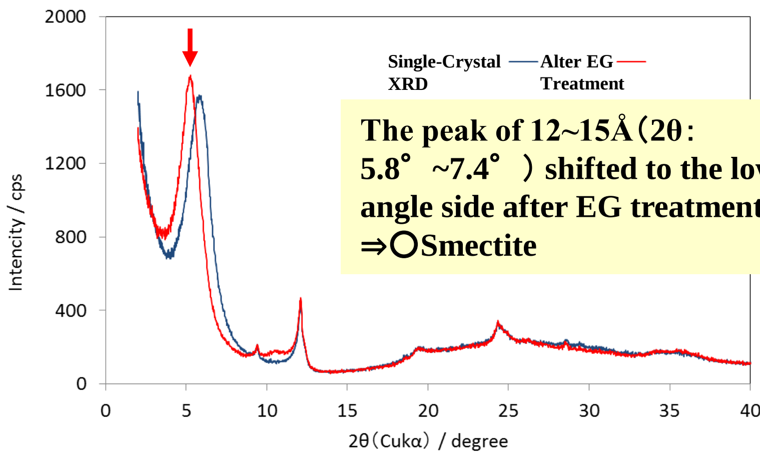
(060) reflections Powder XRD





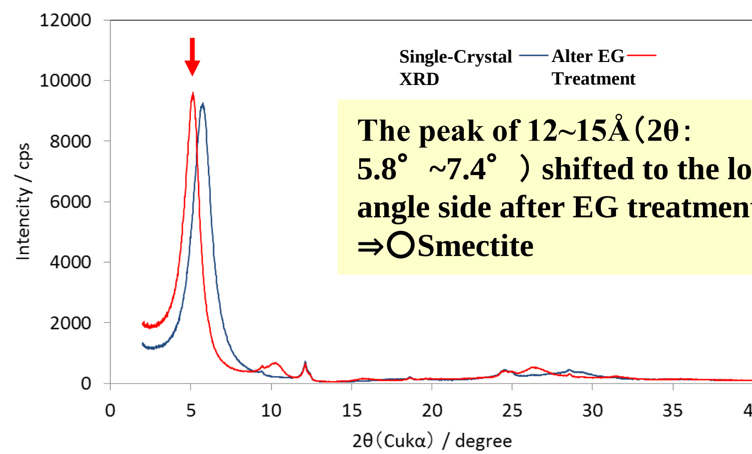
Seepage water from Wall
pH: 11.37, ORP: -111 [mv]
Temp.: 33.7[℃]

PWT03-16-Rh-004（Single-Crystal XRD）



The peak of 12~15Å(2θ: 5.8° ~7.4°) shifted to the low angle side after EG treatment.
⇒〇Smectite

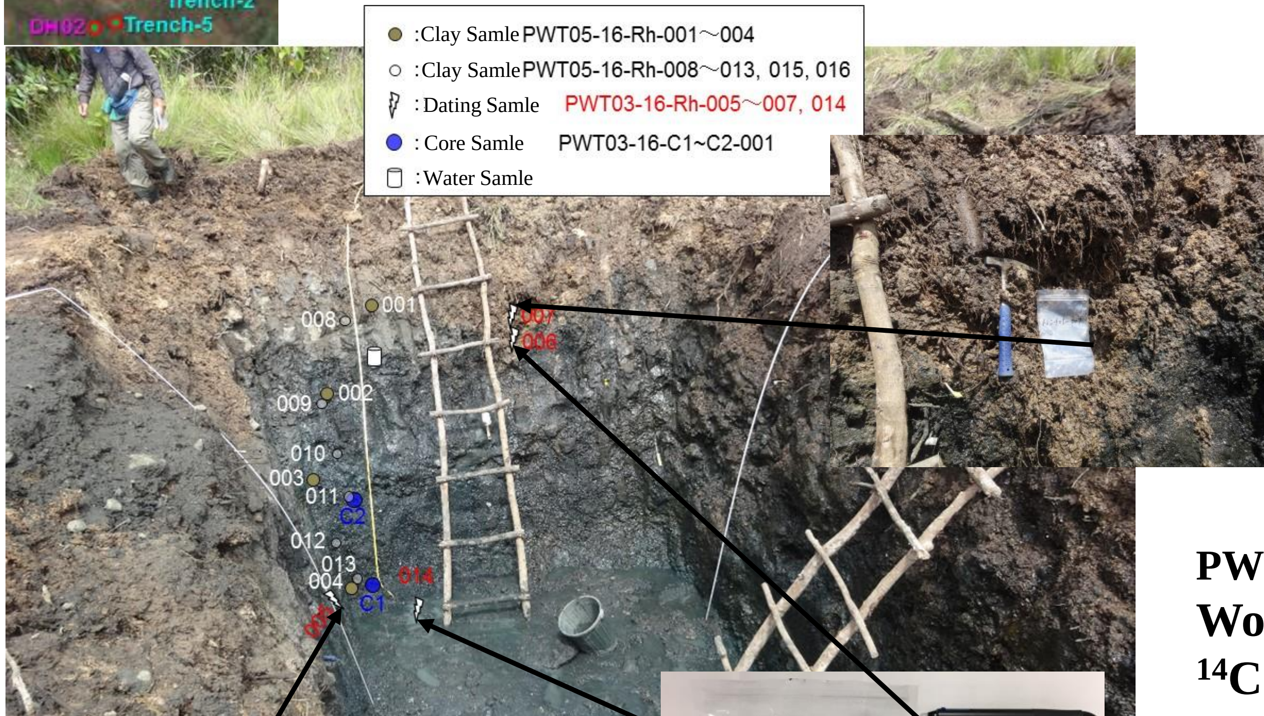
PWT03-16-C1-002（ Single-Crystal XRD ）

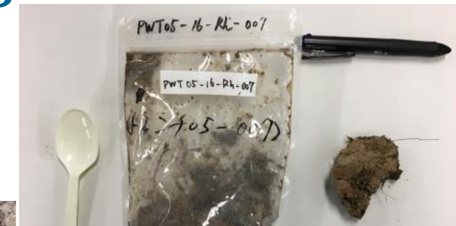


The peak of 12~15Å(2θ: 5.8° ~7.4°) shifted to the low angle side after EG treatment.
⇒〇Smectite

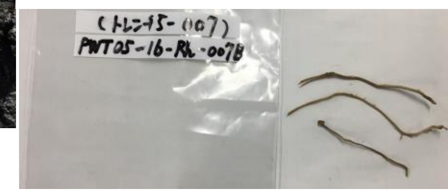
4.4 Trench Survey - ^{14}C Dating -

Trench-5





PWT05-16-Rh-007
Carbonate
^{14}C age：1965±46 year



PWT05-16-Rh-007B
Wooden Root (in Carbonate)
^{14}C age：1209±46 year

PWT05-16-Rh-005
Wooden branch (in Sediment)
^{14}C age：2443±46 year

PWT05-16-Rh-014
Clastic Sediment（Bottom）
^{14}C age：9587±56 year：Humic acid
^{14}C age：9647±56 year：Humin

PWT05-16-Rh-006
Shell (Semisulcospira libertina)
^{14}C age：2401±46 year

5.1 Mineralogical Evolution in Narra site
-Identified Minerals and Reactions with regard to Smectite Formation-

Magmatic Evolution and Tectonics of Palawan Ophiolite			Formation of Smectite in Ultramafic-originated Clastic Sediments	
Magmatic Differentiation	Rock Type	Emplacement Main Alteration	Weathering	Interaction between Mafic Minerals, Weathered Minerals and Alkaline Fluids
Formation of Ultramafic Complex onto Oceanic Crust	**Palawan Ophiolite (Ultramafic Complex) <mainly, Harzbergite, Gabbro>**	①Primary Serpentinization Opx(Ol, Cpx)→SP Br Tc (Mt) (Cc) ②Primary Chloritization Opx, Ol, Cpx, (Amph*) →Chl	○Primary Minerals <Mafic Minerals> Opx **Mg, (Fe, Al)** Ol **Mg, (Fe)** (Cpx) **Mg, (Fe), Ca** (Amph*) **Mg, (Fe), Al** <Feldspathic Minerals> Plag **Al, Ca** ○Altered Minerals SP **Mg** Chl **Al** → **Mg・Fe-Sap** [**Tri-octahedral Smectite**] **(Di-octahedral Smectite)** ***Si[from all minerals]**	**Major Ion**: **Mg, Fe, Al, Si** **$ExFe^{3+}_2(Al_{0.33}Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$** **Nont** [**Di-octahedral Smectite**] **Cal** **$Ex(Mg,Fe)_3(Al_{0.33}Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$** **Fe-Sap** [**Tri-octahedral Smectite**] **Fe-Sap[ppt]** [**Tri-octahedral Smectite**] **C-S-H** → **$Ca_5Si_6O_{17} \cdot nH_2O$ Tobermolite**; **$Ca_2Si_6O_8 \cdot 2H_2O$ Gyrolite** **$ExMg_{5.84}Si_8O_{20}(OH)_4 \cdot nH_2O$** **M-S-H** → **Stev[ppt]** [**Tri-octahedral Smectite**] ↓ **Sepiolite**

Legend
Sap: Saponite　**Nont: Nontronite**　**Stev: Stevensite**
Cc: Calcite　**C-S-H: Calcium Silicate Hydrate**
M-S-H: Magnesium Silicate Hydrate
Qz: Quartz　**Plag: Plagioclase**　**Mt: Magnetite**
SP: Serpentine　**Ol: Olivine**　**Br: Brucite**
Opx: Orthopyroxenes　**Cpx: Clinopyroxenes**
Tc: Talc　**Chl: Chlolite**　**Amph: Amphibole**
Cr: Cr-Spinel

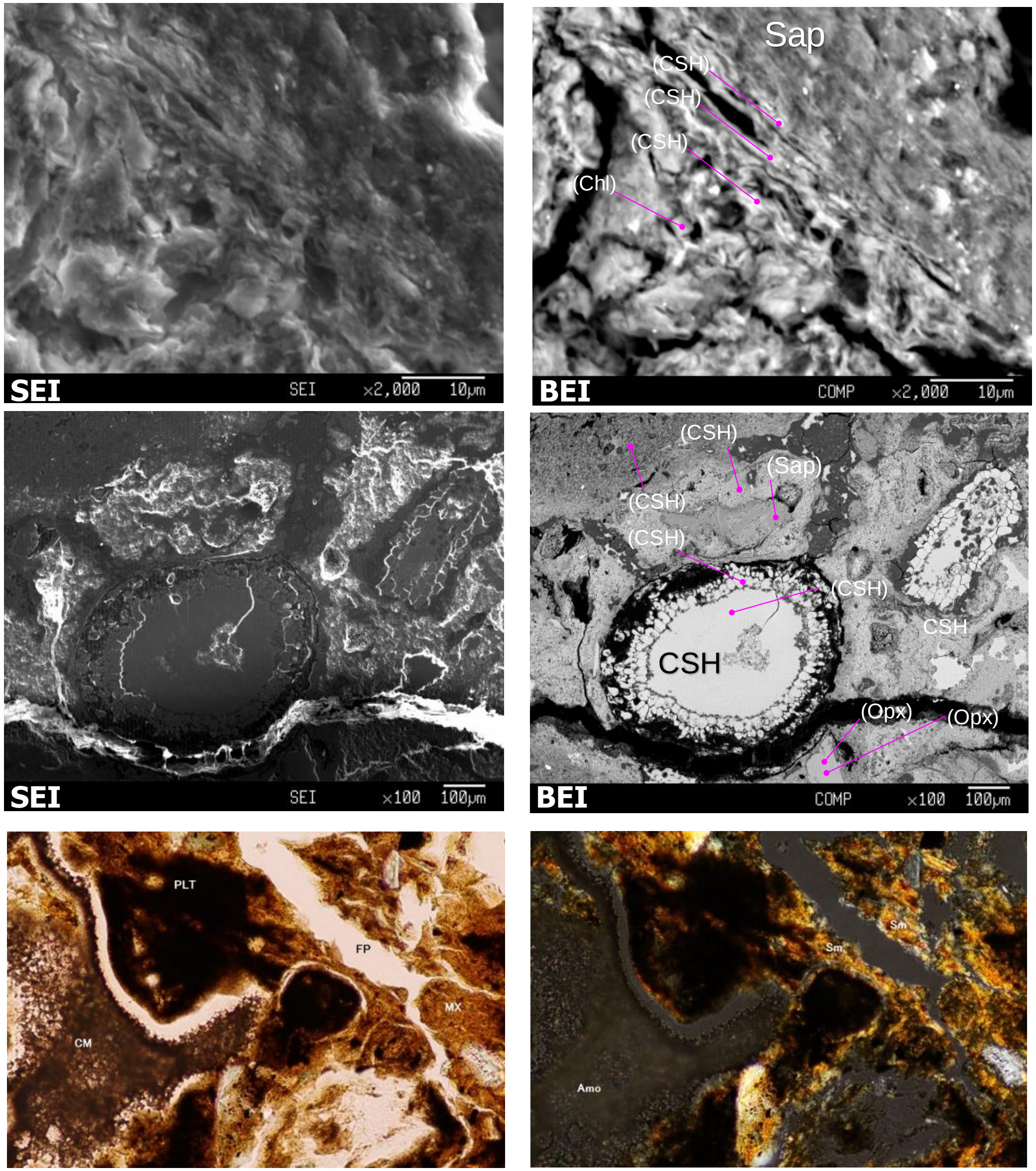
Amph*：Pargasite, (Cummingtonite, Actinolite, Tremolite)　ppt: precipitation

5.1 Mineralogical Evolution in Narra site - Smectite coprecipitated with C-S-H -

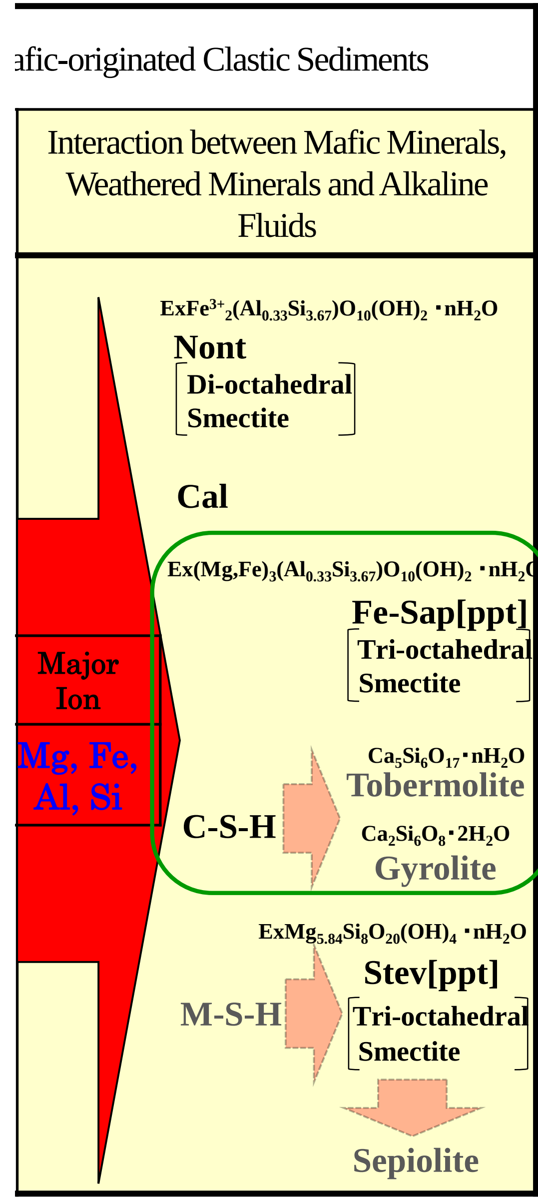
PWT02-15-Rh-016

PWT02B-15-C2-2-001

PWT03-16-C2-001

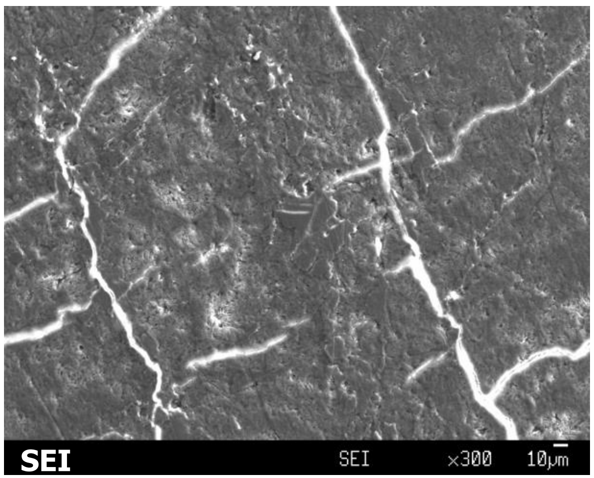


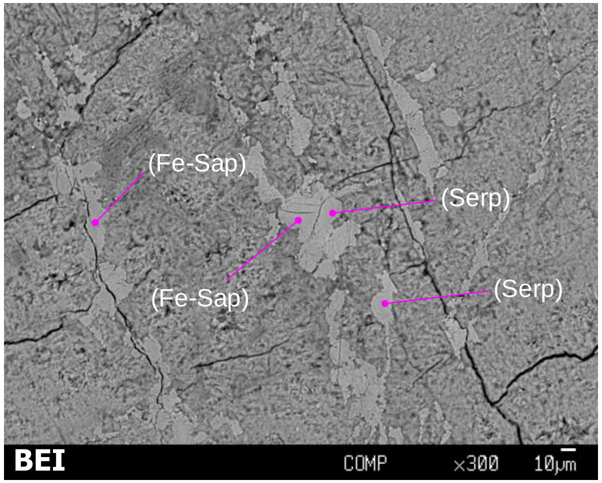
One Nicol **Crossed Nicol** **0.1mm**

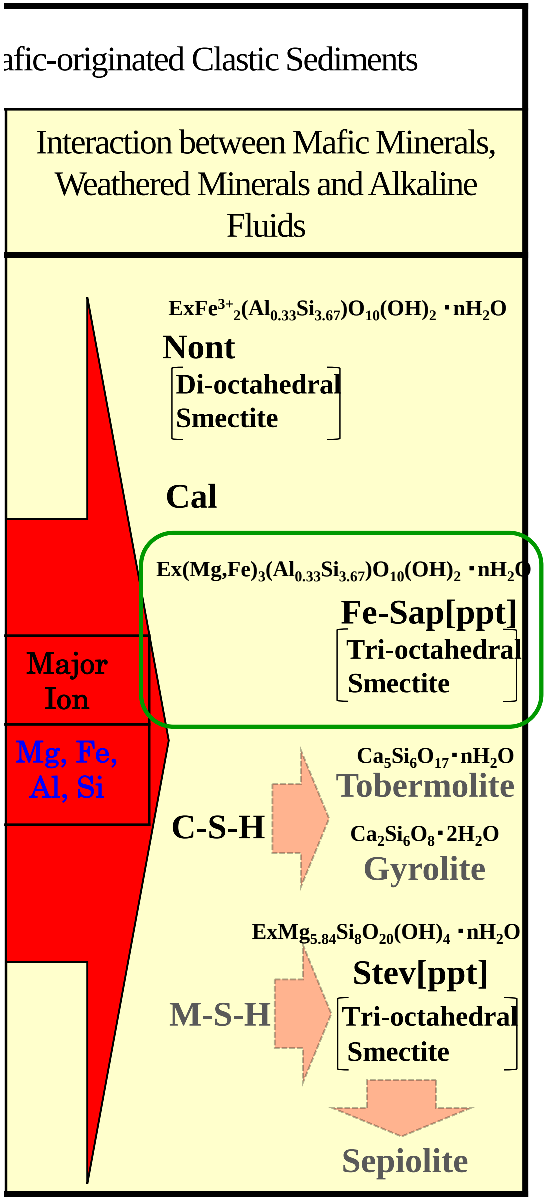


5.1 Mineralogical Evolution in Narra site - Smectite precipitated in grain boundary -

PWT02B-15-C2-2-001

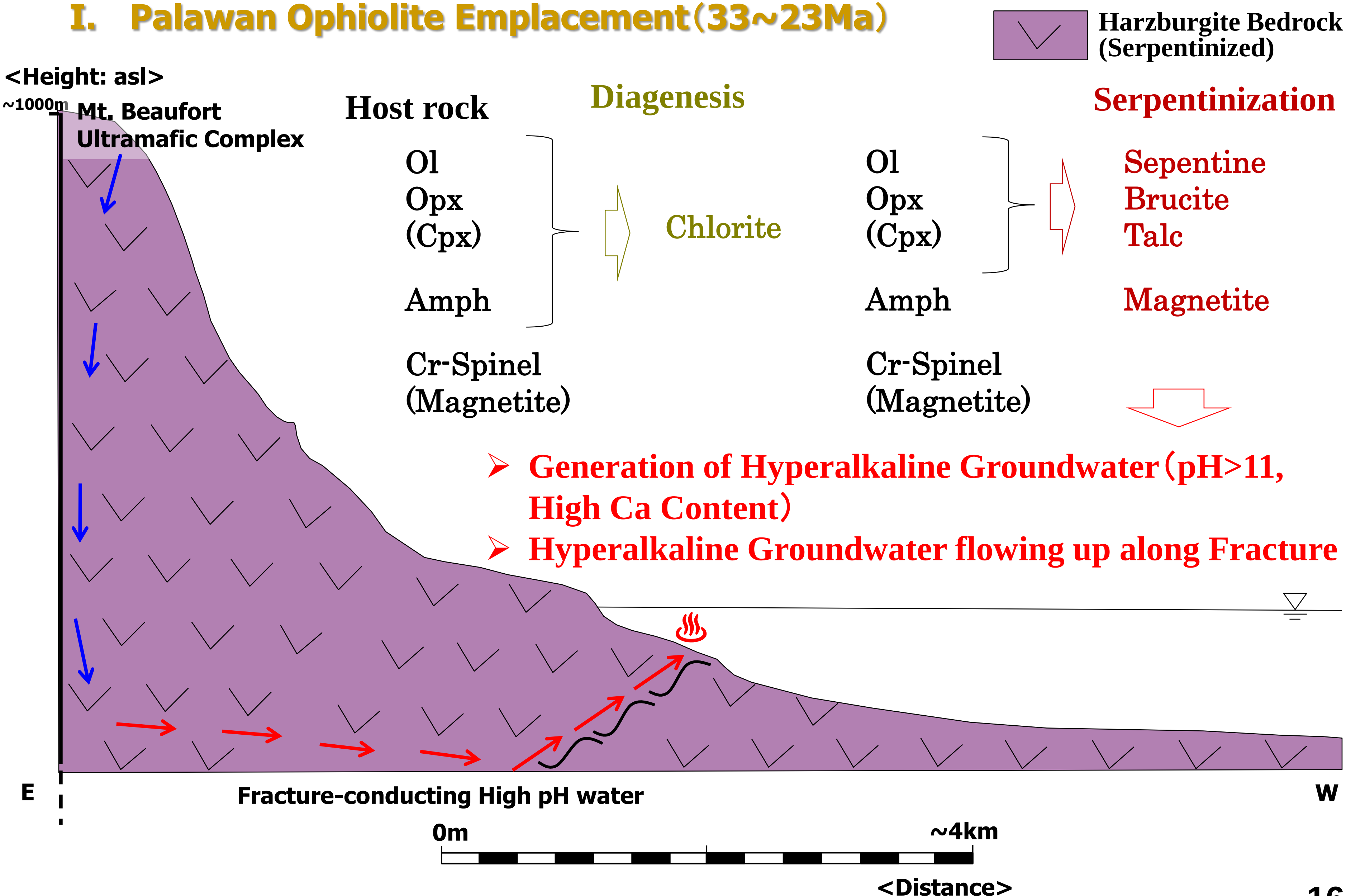






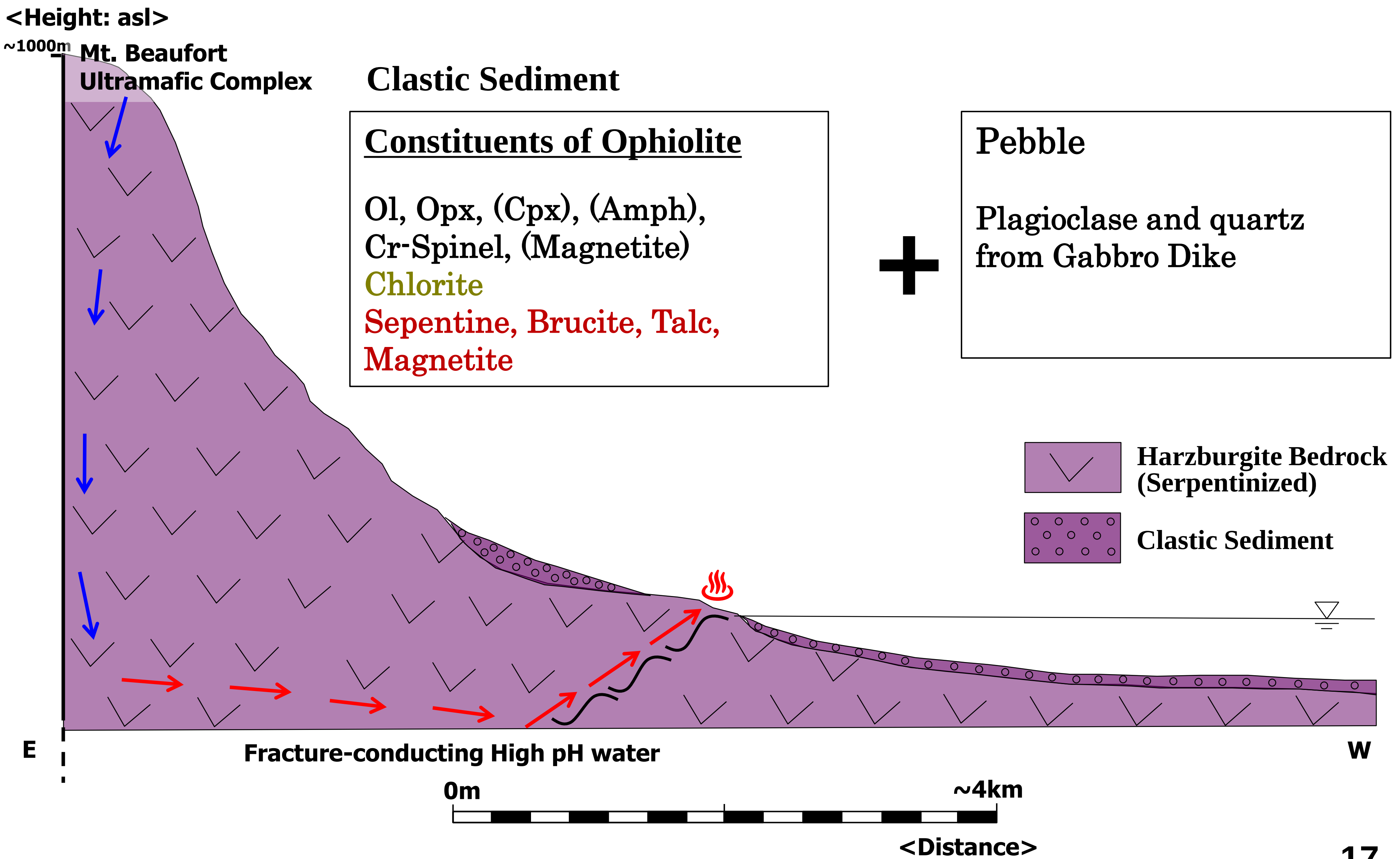
5.2 Tectonic Evolution of the Palawan Ophiolite and Smectite Formation in Clastic Sediment

I. Palawan Ophiolite Emplacement（33~23Ma）



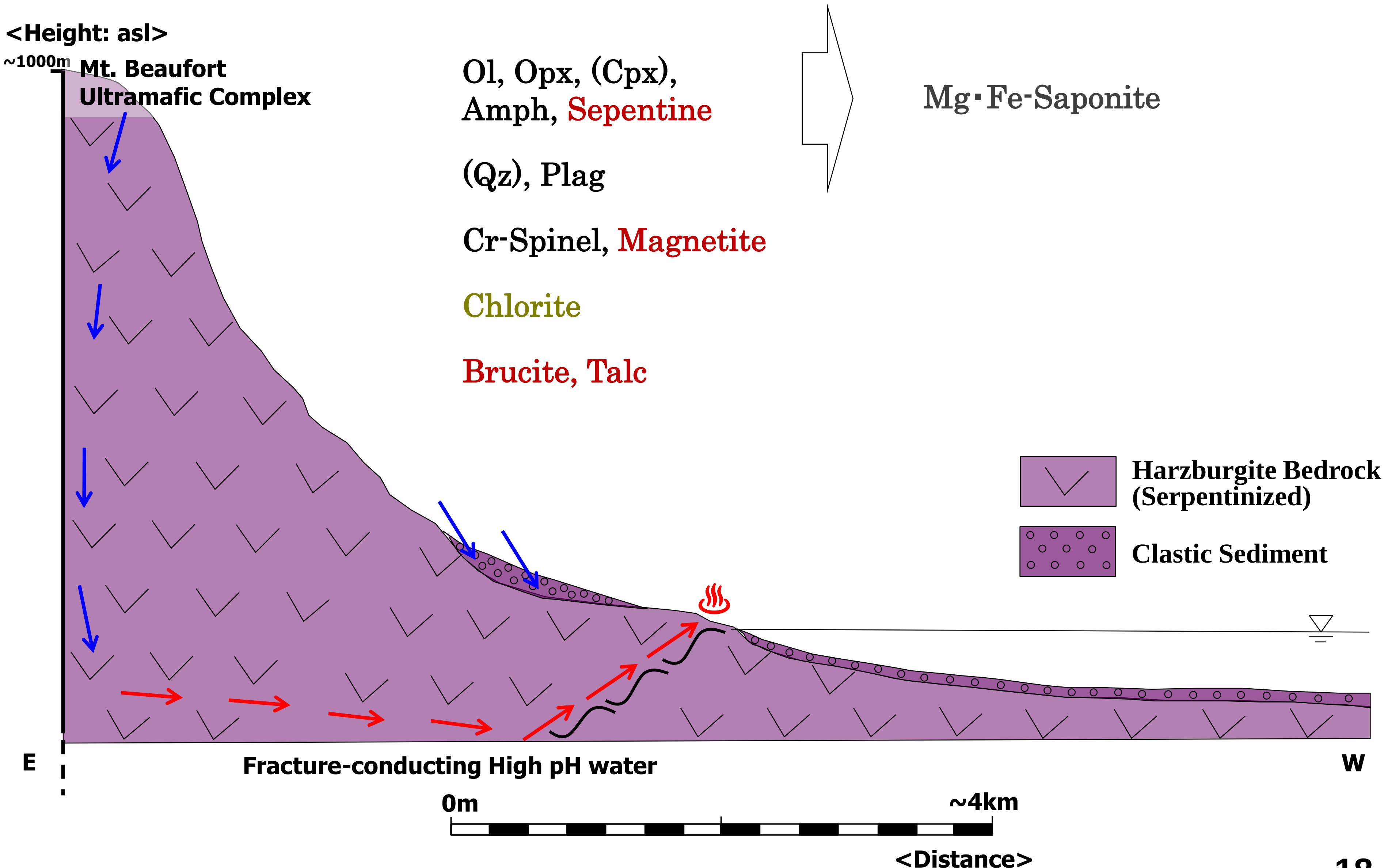
5.2 Tectonic Evolution of the Palawan Ophiolite and Smectite Formation in Clastic Sediment

II. Uplift-Erosion-Transport-Deposition(Clastic Sediment)



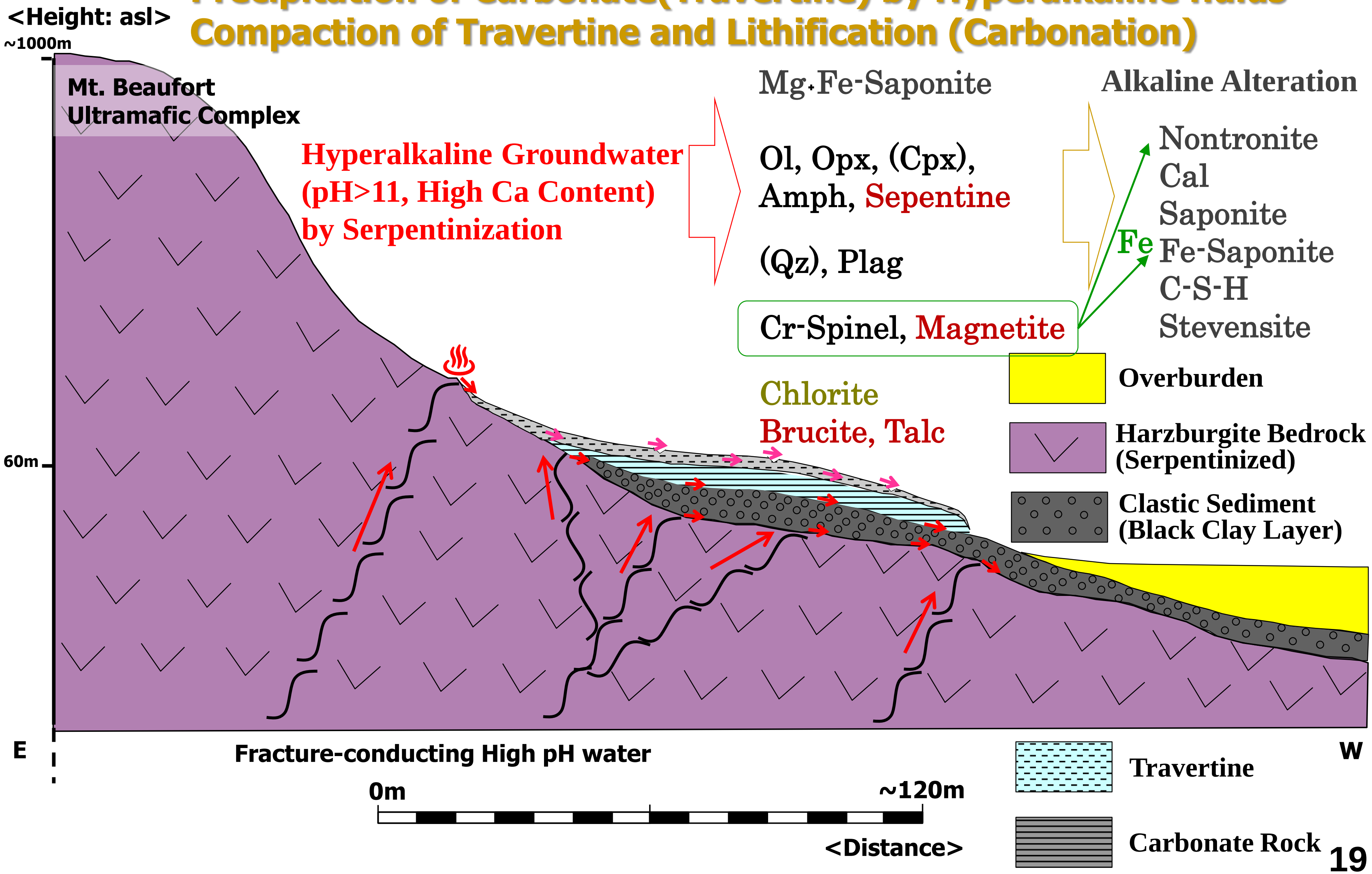
5.2 Tectonic Evolution of the Palawan Ophiolite and Smectite Formation in Clastic Sediment

III.Formation of Smectite by Weathering



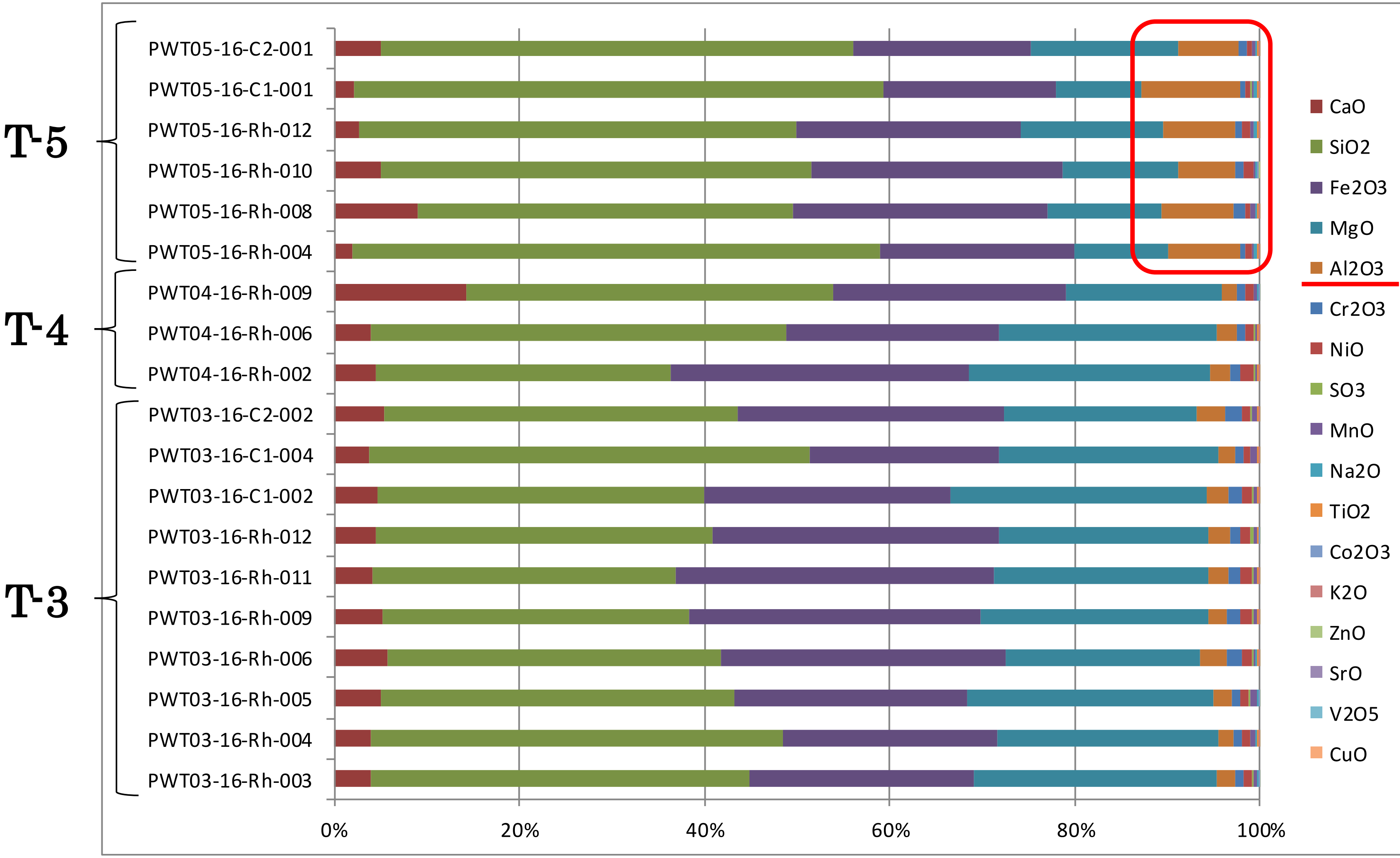
5.2 Tectonic Evolution of the Palawan Ophiolite and Smectite Formation in Clastic Sediment

IV. Formation of Smectite by Hyperalkaline Fluids
Precipitation of Carbonate(Travertine) by Hyperalkaline fluids
Compaction of Travertine and Lithification (Carbonation)



6.1 XRF

Trench-3~5



➢ The Sediment of Trench-5 has more Al_2O_3 and less MgO than that of Trench-3 and 4.

6.2 Mineral Assemblage - XRD (Trench) -

	Clay mineral		Amphibole	Pyroxene	Serpentine	C-S-H	Carbonate	Zeolite
	Smectite	Chlorite	Amphibole	Orthopyroxene	Chrysotile	14ÅTobermorite	Calcite	Laumontite
PWT02-15-Rh-016	● Tri-octahedral	▲	△	△	○	△	△	△
PWT03-16-Rh-004	● Tri-octahedral	●	○	△	○	△	△	△
PWT03-16-Rh-006	○ Tri-octahedral	○	△	○	○	△	△	△
PWT03-16-Rh-009	○ Tri-octahedral	○	△	△	○	△	△	△
PWT03-16-Rh-011	○ Tri-octahedral	○	○	△	○		○	△
PWT03-16-Rh-012	○ Tri-octahedral	○	○	○	○		△	△
PWT03-16-C1-002	●	●	○	○	○		△	△
PWT03-16-C1-004	●	●	○	○	○		△	△
PWT03-16-C2-002	○ Tri-octahedral	○	○	△	○	△	△	△
PWT04-16-Rh-002	○ Tri-octahedral	○	△	○	○		△	△
PWT04-16-Rh-006	○	○	○	△	○		△	△
PWT04-16-Rh-009	▲ Tri-octahedral	●	△	△	○	△	△	△
T-5 PWT05-16-Rh-004	○ Di-octahedral	○	○	△	△		△	△
PWT05-16-Rh-008	○ Tri-octahedral	○	○	○	△		○	△
PWT05-16-Rh-010	● Di-octahedral	●	△	△	△		△	△
PWT05-16-Rh-012	○ Di-octahedral	○	○	△	○		△	△

※Black Symbol means identification by Single-Crystal XRD with EG treatment.

6.3 Mineral Assemblage - μ-XRD (Trench) -

Sample ID	Chrm	Mag	Cpx	Opx	Serp	Plag	Ca-Amph	Cum	Act	Chl	Stev	Sap	Nont	Cal	C-S-H	Unknown
Trench-3																
PWT03-16-Rh-004	○	○	×	◎	○	×	○	○	○	◎	○	◎	×	×	◎	
PWT03-16-C1-004	○	○	×	◎	○	○	○	○	○	○	○	◎	×	×	×	
Trench-4																
PWT04-16-Rh-006	○	○	×	◎	○	○	○	○	○	×	○	◎	×	×	×	
PWT04-16-Rh-009	○	○	×	◎	○	○	○	○	○	×	×	◎	×	○	◎	
Trench-5																
PWT05-16-Rh-008	○	×	◎	○	×	×	○	○	○	◎	×	◎	×	◎	×	
PWT05-16-Rh-010	○	○	○	○	○	○	◎	×	○	◎	×	○	◎	×	×	

6.4 Formation of Smectite under hypealkaline condtion in Narra site
-Environment with little Al (Trench-3 and 4)-

Magmatic Evolution and Tectonics of Palawan Ophiolite			Formation of Smectite in Ultramafic-originated Clastic Sediments	
Magmatic Differentiation	Rock Type	Emplacement / Main Alteration	Weathering	Interaction between Mafic Minerals, Weathered Minerals and Alkaline Fluids
Formation of Ultramafic Complex onto Oceanic Crust	Palawan Ophiolite (Ultramafic Complex) <mainly, Harzbergite, Gabbro>	①Primary Serpentinization Opx(Ol, Cpx)→SP Br Tc (Mt) (Cc) ②Primary Chloritization Opx, Ol, Cpx, (Amph*) →Chl	○Primary Minerals <Mafic Minerals> Opx Mg, (Fe, Al) Ol Mg, (Fe) (Cpx) Mg, (Fe), Ca (Amph*) Mg, (Fe), Al <Feldspathic Minerals> Plag Al, Ca ○Altered Minerals SP Mg Chl Al → Mg・Fe-Sap [Tri-octahedral Smectite] (Di-octahedral Smectite) Major Ion: Mg, Fe, Al, Si *Si[from all minerals]	$ExFe^{3+}_2(Al_{0.33}Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$ Nont [Di-octahedral Smectite] Cal $Ex(Mg,Fe)_3(Al_{0.33}Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$ Fe-Sap [Tri-octahedral Smectite] Fe-Sap[ppt] [Tri-octahedral Smectite] C-S-H → $Ca_5Si_6O_{17} \cdot nH_2O$ Tobermolite; $Ca_2Si_6O_8 \cdot 2H_2O$ Gyrolite M-S-H → $ExMg_{5.84}Si_8O_{20}(OH)_4 \cdot nH_2O$ Stev[ppt] [Tri-octahedral Smectite] → Sepiolite

Legend

Sap: Saponite Nont: Nontronite Stev: Stevensite
Cc: Calcite C-S-H: Calcium Silicate Hydrate
M-S-H: Magnesium Silicate Hydrate
Qz: Quartz Plag: Plagioclase Mt: Magnetite
SP: Serpentine Ol: Olivine Br: Brucite
Opx: Orthopyroxenes Cpx: Clinopyroxenes
Tc: Talc Chl: Chlolite Amph: Amphibole
Cr: Cr-Spinel

Amph*：Pargasite, (Cummingtonite, Actinolite, Tremolite) ppt: precipitation

6.4 Formation of Smectite under hypealkaline condtion in Narra site
-Environment supplied Al from the pebbles of gabbro oringin (Trench-5)-

Magmatic Evolution and Tectonics of Palawan Ophiolite			Formation of Smectite in Ultramafic-originated Clastic Sediments	
Magmatic Differentiation	Rock Type	Emplacement Main Alteration	Weathering	Interaction between Mafic Minerals, Weathered Minerals and Alkaline Fluids
Formation of Ultramafic Complex onto Oceanic Crust	**Palawan Ophiolite (Ultramafic Complex) <mainly, Harzbergite, Gabbro>**	①Primary Serpentinization Opx(Ol, Cpx)→SP Br Tc (Mt) (Cc) ②Primary Chloritization Opx, Ol, Cpx, (Amph*) →Chl	○Primary Minerals <Mafic Minerals> Opx **Mg, (Fe, Al)** Ol **Mg, (Fe)** (Cpx) **Mg, (Fe), Ca** (Amph*) **Mg, (Fe), Al** <Feldspathic Minerals> Plag **Al, Ca** ○Altered Minerals SP **Mg** Chl **Al** → **Mg・Fe-Sap** [**Tri-octahedral Smectite**] **(Di-octahedral Smectite)** **Major Ion**: **Mg, Fe, Al, Si** ***Si[from all minerals]**	$ExFe^{3+}_2(Al_{0.33}Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$ **Nont** [**Di-octahedral Smectite**] **Cal** $Ex(Mg,Fe)_3(Al_{0.33}Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$ **Fe-Sap** [**Tri-octahedral Smectite**] **Fe-Sap[ppt]** [**Tri-octahedral Smectite**] **C-S-H** → $Ca_5Si_6O_{17} \cdot nH_2O$ **Tobermolite**; $Ca_2Si_6O_8 \cdot 2H_2O$ **Gyrolite** **M-S-H** → $ExMg_{5.84}Si_8O_{20}(OH)_4 \cdot nH_2O$ **Stev[ppt]** [**Tri-octahedral Smectite**] ↓ **Sepiolite**

Legend
Sap: Saponite **Nont: Nontronite** **Stev: Stevensite**
Cc: Calcite **C-S-H: Calcium Silicate Hydrate**
M-S-H: Magnesium Silicate Hydrate
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Opx: Orthopyroxenes **Cpx: Clinopyroxenes**
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6.4 Formation of Smectite under hypealkaline condtion in Narra site
-Environment with high CO_2 partial pressure (The upper part of Trench-5)-

Magmatic Evolution and Tectonics of Palawan Ophiolite			Formation of Smectite in Ultramafic-originated Clastic Sediments	
Magmatic Differentiation	Rock Type	Emplacement Main Alteration	Weathering	Interaction between Mafic Minerals, Weathered Minerals and Alkaline Fluids
Formation of Ultramafic Complex onto Oceanic Crust	Palawan Ophiolite (Ultramafic Complex) <mainly, Harzbergite, Gabbro>	①Primary Serpentinization Opx(Ol, Cpx)→SP Br Tc (Mt) (Cc) ②Primary Chloritization Opx, Ol, Cpx, (Amph*) →Chl	○Primary Minerals <Mafic Minerals> Opx Mg, (Fe, Al) Ol Mg, (Fe) (Cpx) Mg, (Fe), Ca (Amph*) Mg, (Fe), Al <Feldspathic Minerals> Plag Al, Ca ○Altered Minerals SP Mg Chl Al *Si[from all minerals] Mg・Fe-Sap [Tri-octahedral Smectite] (Di-octahedral Smectite) Major Ion: Mg, Fe, Al, Si High CO_2 content because of close to a surface	$ExFe^{3+}_2(Al_{0.33}Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$ Nont [Di-octahedral Smectite] Cal $Ex(Mg,Fe)_3(Al_{0.33}Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$ Fe-Sap [Tri-octahedral Smectite] Fe-Sap[ppt] [Tri-octahedral Smectite] C-S-H → $Ca_5Si_6O_{17} \cdot nH_2O$ Tobermolite $Ca_2Si_6O_8 \cdot 2H_2O$ Gyrolite M-S-H → $ExMg_{5.84}Si_8O_{20}(OH)_4 \cdot nH_2O$ Stev[ppt] [Tri-octahedral Smectite] ↓ Sepiolite

Legend

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7. Summary

➢ **Natural Evidences of Narra in Palawan**

1. **The smectite various type ((Mg-)Saponite, Stevensite, Fe-Saponite and Nontronite) was identified in clastic sediment under hyperalkaline (pH>11, low Eh, 35~45°C and high Ca content) condition by serpentinization.**
2. **C-S-H coprecipitated with (Fe-)Saponite. This evidence show that (Fe-)Saponite was precipitated from hyperalkaline groundwater.**
3. **Primary minerals of Clastic Sediment are olivine, orthopyroxenes, clinopyroxenes, amphibole of ultramafic rock origin and plagioclase in the pebbles of gabbro origin. Smectite was mainly formed as a result of the interaction between these minerals and hyperalkaline groundwater. A part of smectite may have been formed by weathering of these minerals.**
4. **Fe, Mg, Si, Al and Ca in the hyperalkaline fluid affected the formation of smctite.**

- **Could we use these natural evidences as a natural analogue of EBS system, especially analogous to bentonite?**

7. Summary

－Alkaline Alteration Process shown from the natural analogues in the Philippines－

High pH Fluids

Reducing Conditions

35~45 °C

[Major Dissolved Ions]

Si^{4+}, Al^{3+}

(Fe^{2+}, Fe^{3+})

Ca^{2+}, (Mg^{2+})

Na^{+}, K^{+}

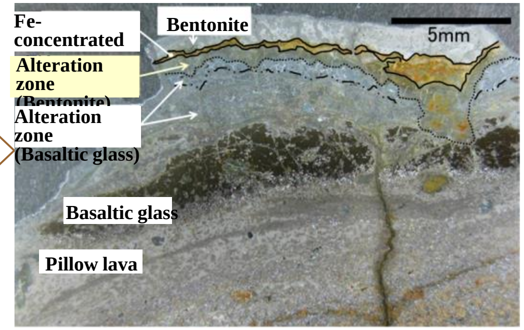
OH^{-}, Cl^{-}

① Cation Substitution dominant Process

Fe-Montmorillonite

(Di-Octahedral Smectite)

[Mg･Al→Fe^{2+}]



③ Oxidation Process

Fe-concentrated zone

Nontronite

(Di-Octahedral Smectite)

+

Goethite

[Al･Si→Fe^{3+}]

[Basaltic Glass →Fe]

Ca-Bentonite; Ca-montmorillonite

+ Accessory minerals (Ca-zeolites, Anorthite, Chalcedony, Calcite)

② Dissolution-Precipitation (Growth) dominant Process

[Al･Mg→Fe^{2+}]

[Si / Al, Na + K, Ca]

Saile Mine

Fe-Smectite

(Tri-Octahedral Smectite)

(Ca･Na)-Zeolites

+

K-Feldspar

±

Silica Mineral

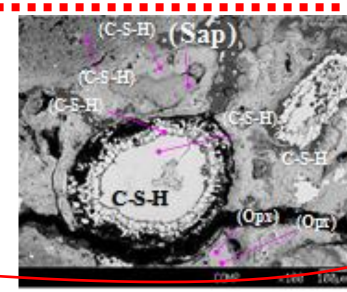
I. Precipitation Process

[Primary minerals of Ultramafic Rock →Mg, Fe, Al, Si]

+

C-S-H

(Calcium-Silicate-Hydrate)



Narra

II. Stable under High pH condition

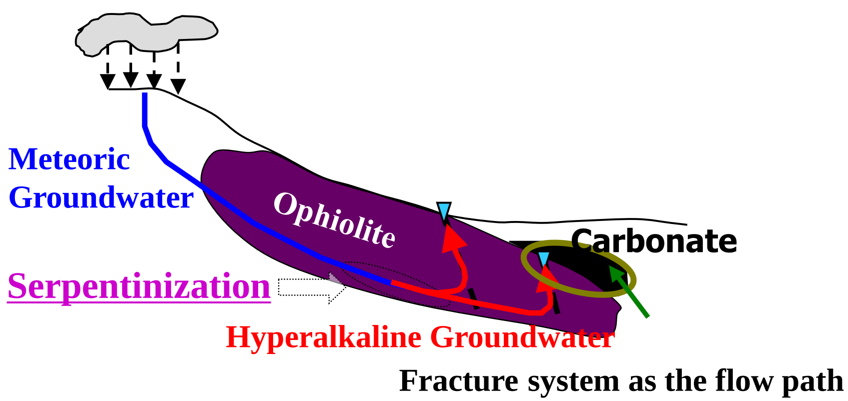
7. Summary

Hyperalkaline Fluids from much of cement materials in the TRU repository.

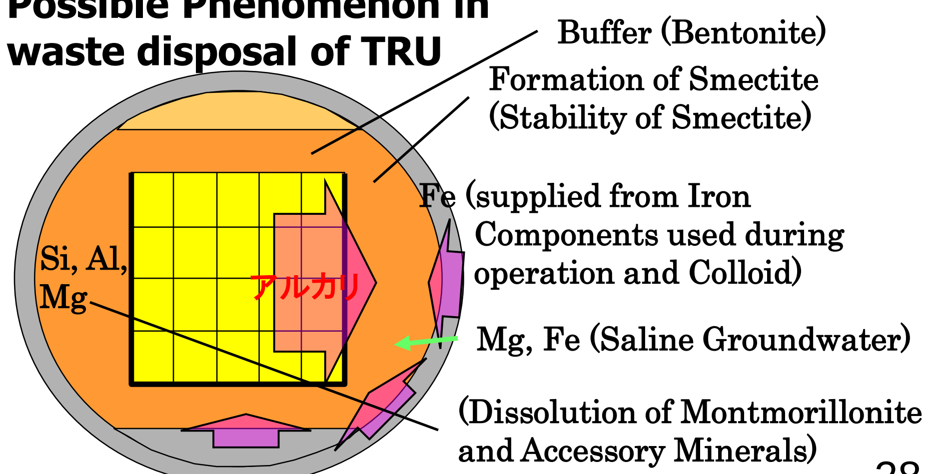
- Decreasing the desirable functions of bentonite as a buffer from Dissolution of Smectite (Montmorillonite)
- Formation and Stability of Smectite

- Natural Analogue at Narra site supports the latter, the positive reaction.
- The worst scenario is that montmorillonite alters non-swelling mineral (zeolite, chlorite and illite). Natural Analogues in the Philippines can show a type of Smectite (Montmorillonite) altered another type of semctite (Saponite, Nontronite etc) under hyperalkaline with Fe, Mg condition and that suggests Hyperalkaline fuluid make not much decrease the desirable functions.

NA of Narra in Palawan



Possible Phenomenon in waste disposal of TRU




Thank you for your kind attention.