Hydrothermally Dissolved Dolerite Reservoir in the Akita Basin, Japan*

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Abstract

Altered sheeted dolerite dykes form important oil reservoirs in the Ayukawa oil field. Secondary porosities are created in dolerite by dissolution of pyroxene and plagioclase. The Ayukawa oil filed is located in the Akita Basin, a back-arc basin in northern Japan. The Onnagawa Formation is mainly composed of Neogene siliceous rock, and is the major source rock of the area. Dolerite sheets intrude into the Onnagawa Formation, and form stratigraphic traps.

Dolerite in the area is classified into three types. Type I Fresh Dolerite: fresh pyroxene remains, Φ0-3%. Type II Altered Dolerite: most pyroxenes are altered to clay minerals such as saponite and talc. Φ5-8%. Type III Dissolved White Dolerite: mafic minerals and some plagioclase are dissolved to create secondary porosity. Φ15-25%. One dolerite sheet is about 100m thick. The top 40m and the bottom 15m are mainly Type III highly altered dolerite, and produce oil. The middle part is Type II or Type I, and non-reservoir.

The Akita Basin was initiated by opening of the Sea of Japan. Petrographic analyses suggest the following model. Rift related submarine volcanic activity continued until the Middle Miocene Onnagawa stage. Dolerite intruded into the Onnagawa diatomaceous siliceous rock. Heat form dolerite and circulation of seawater hydrothermally altered the dolerite and surrounding sediments. A large volume of hydrothermal fluid must have circulated along dolerite-sediments boundary to dissolve minerals. Surrounding siliceous rocks are dolomitized, and also a reservoir. Mg and Ca were removed from the dolerite and precipitated in siliceous rock as dolomite. We expect similar dolerite reservoir to be discovered in other rift related basins where early submarine volcanic activities existed.

Hydrothermally Dissolved Dolerite Reservoir in the Akita Basin, Japan

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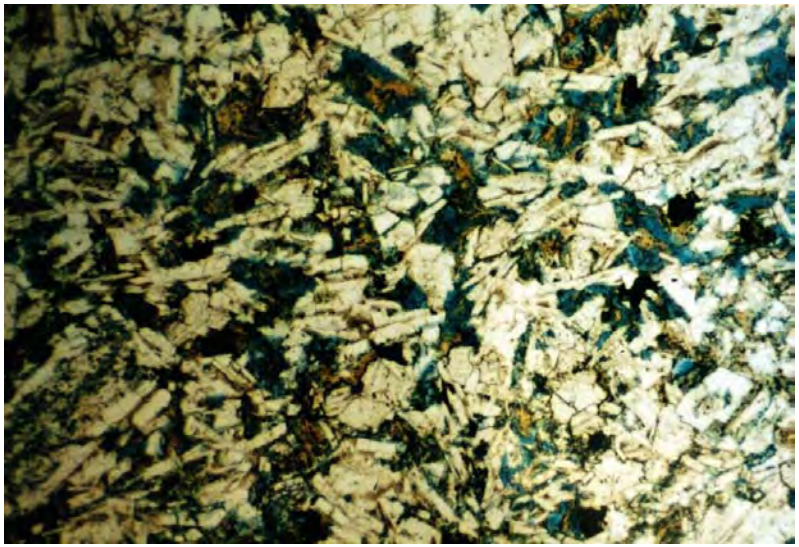
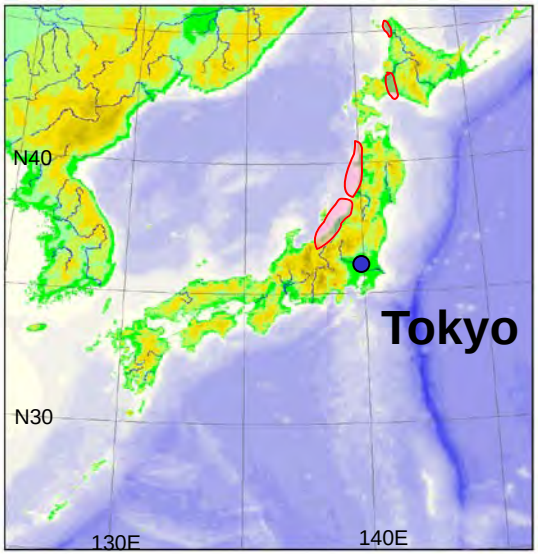


Japan: Oil and Gas Consumption vs. Domestic Production

Year 2007

	Japan Consumption		JAPEX Production	
		Import/Total		JAPEX/Total
Oil	1.53 Bbbl	99.6%	7 MMbbl	0.4%
Natural Gas	3.3 Tcf	96.5%	45 Bcf	1.4%

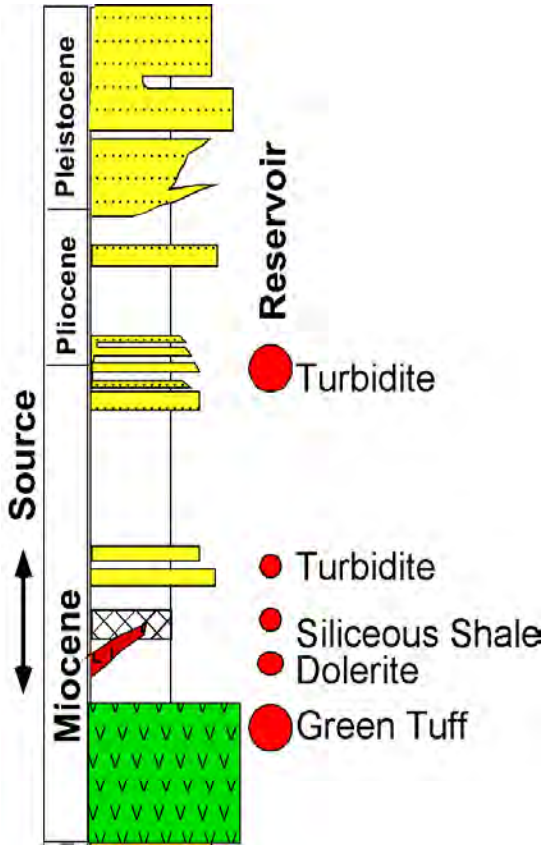


International Exploration and Production: Canada (JACOS, Oil sand), Indonesia, Iraq, Libya,

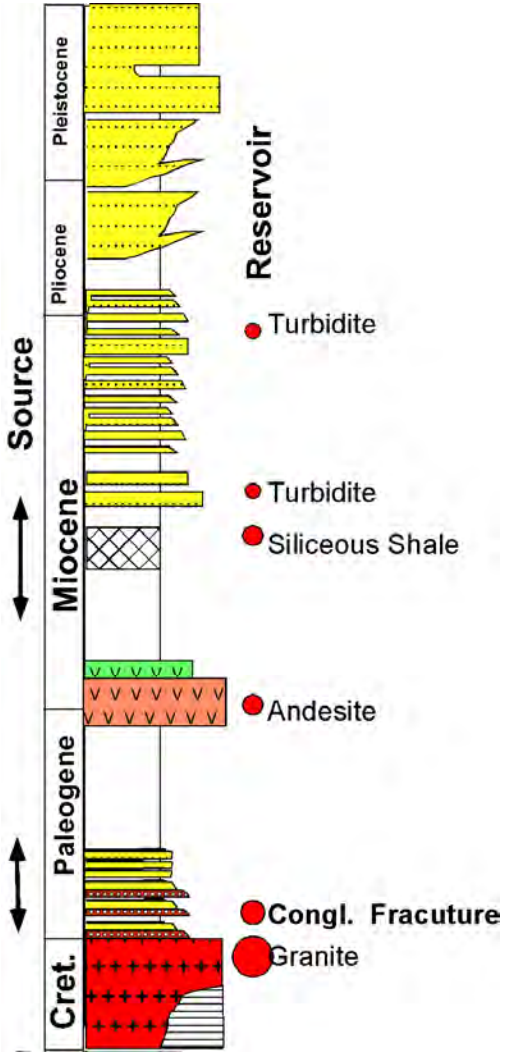
Key Play Type
In Japanese Domestic Exploration

- Volcanic Reservoir
  - Rhyolite Lava
  - Basalt Lava
  - Dolerite
- Turbidite
  - Stratigraphic trap
  - Thin Bed Sand
- Fractured Granite
- Siliceous Shale
  - Source & Reservoir

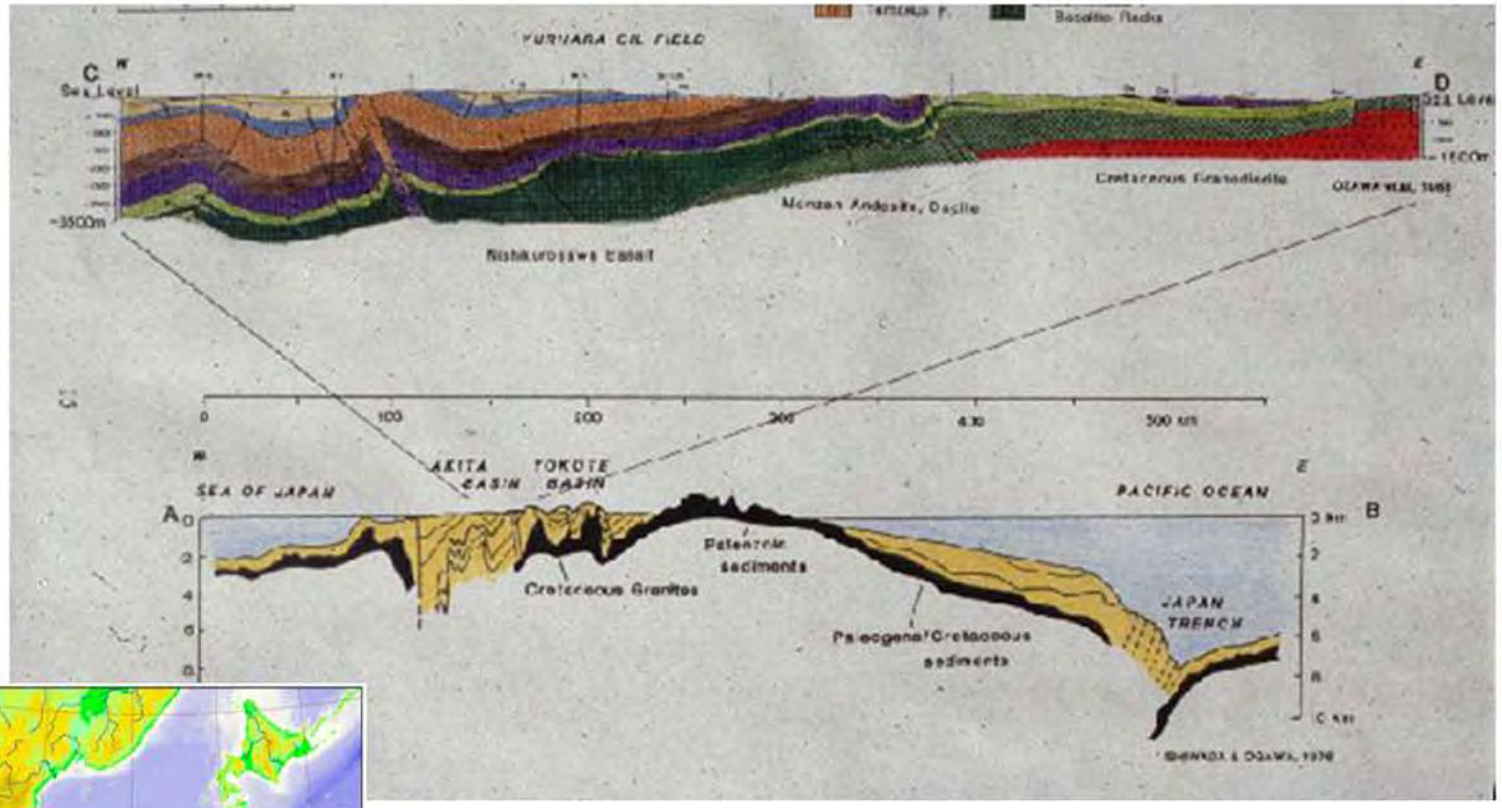
Back-arc basin

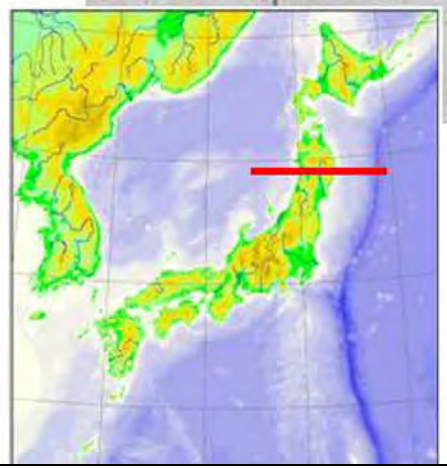


Hokkaido



Cross section: North-East Honshu





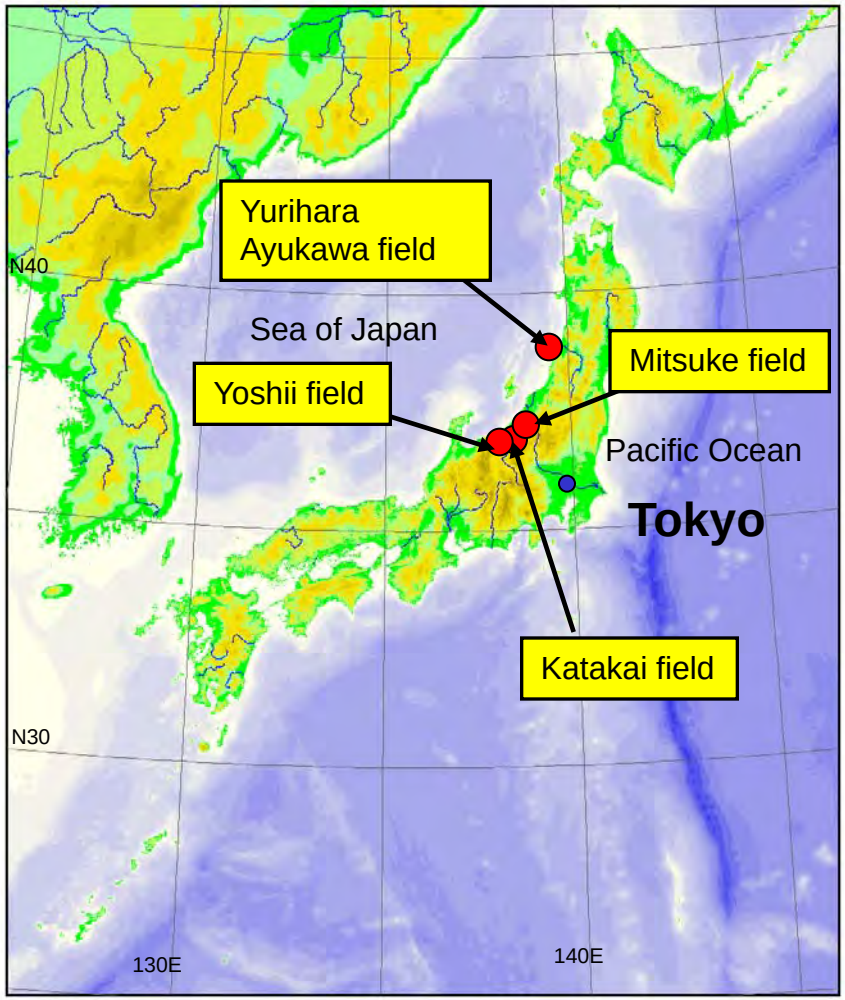
JAPEX

Notes by Presenter: East West Cross section of Japan. Fore arc basin, and back arc basin, shown in yellow color. There are several gas fields in the fore arc basin, and most field are in this back arc basin. Close up of Yurihara oil field. Green is basalt reservoir. Purple is source rock.

Volcanic Rock Reservoir

Ayukawa Oil Field、Akita, NE Japan

Major Japex Fields with Volcanic Rock Reservoir



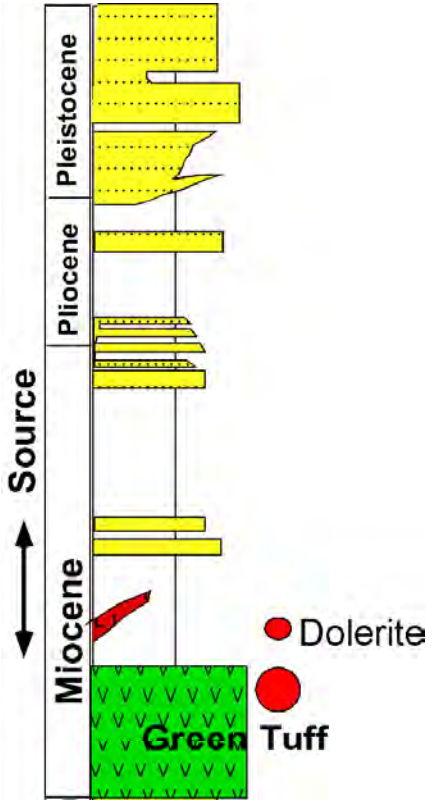
	Discovery	Reservoir Rock
Mitsuke;	1958	Dacite
Yoshii;	1968	Gr.Tf. (Rhyolite)
Yurihara;	1975	Basalt
Katakai;	1977	Gr.Tf. (Rhyolite)
Ayukawa:	1993	Dolerite
Koyosigawa	2000	Andesite/Pyroclastic

Early to Middle Miocene,

- The Sea of Japan opened.
- Back-arc basin initiated.
- Submarine Volcanic Rocks (Green Tuff) are reservoir.

Volcanic Rock Reservoir

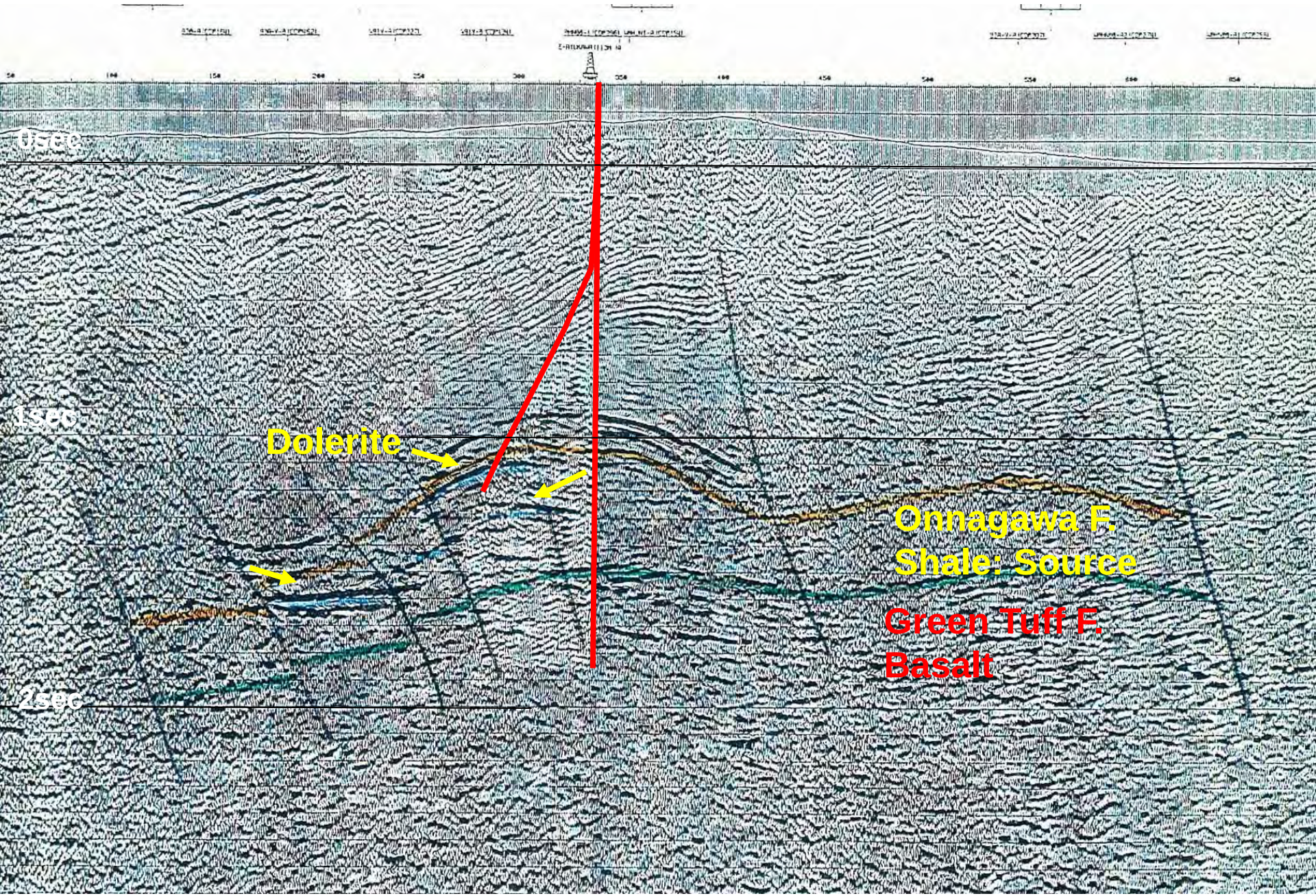
- Green Tuff: Rift stage
  - Early to Middle Miocene submarine volcanics
  - Opening of the Sea of Japan, Initiation of the back-arc basin
  - Basalt, Rhyolite, Dacite >1000m
  - Hydrothermal Alteration, Clay, Dissolution, Cement, Gold/Silver
  - Overlain by deep marine shale
- Reservoir Property is controlled by
  - Volcanic Facies: ○ Lava glassy Tuff
  - ◎ Rhyolite △ Basalt
  - Porosity : Vesicle, Fissure, Dissolution
  - Hydrothermal Alteration: ○ High Temp. Clay rich

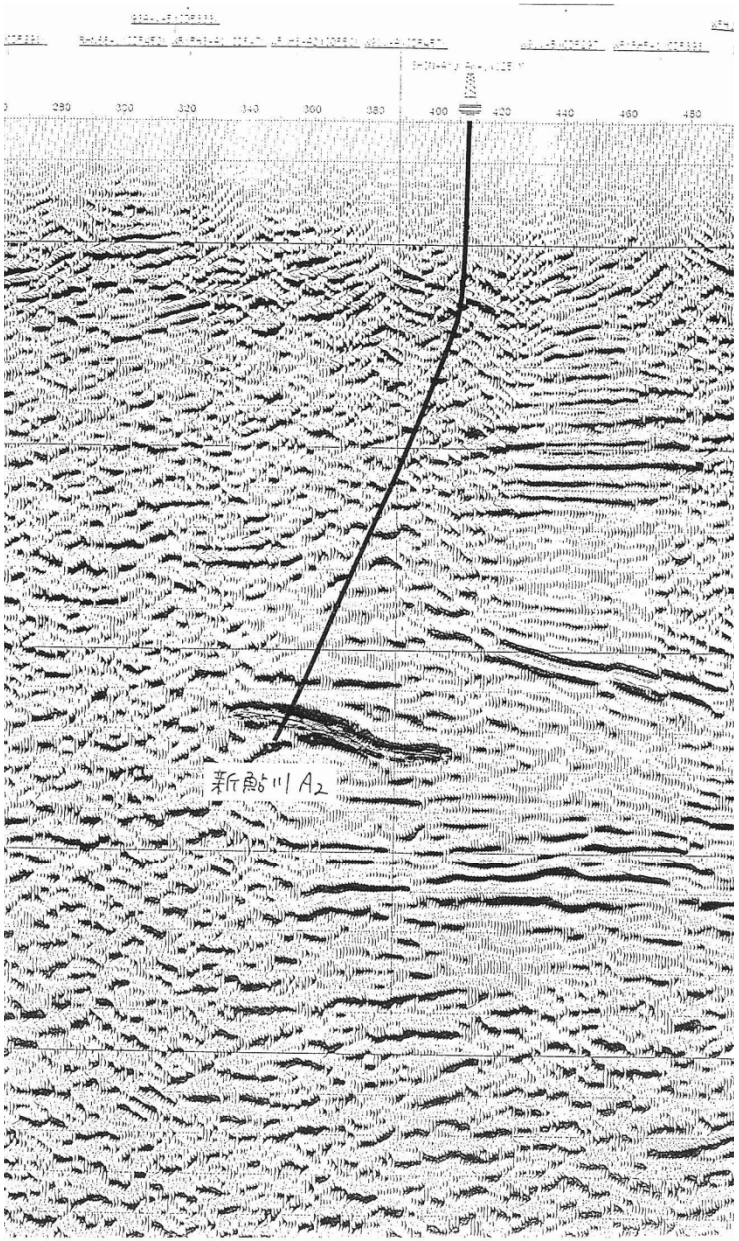


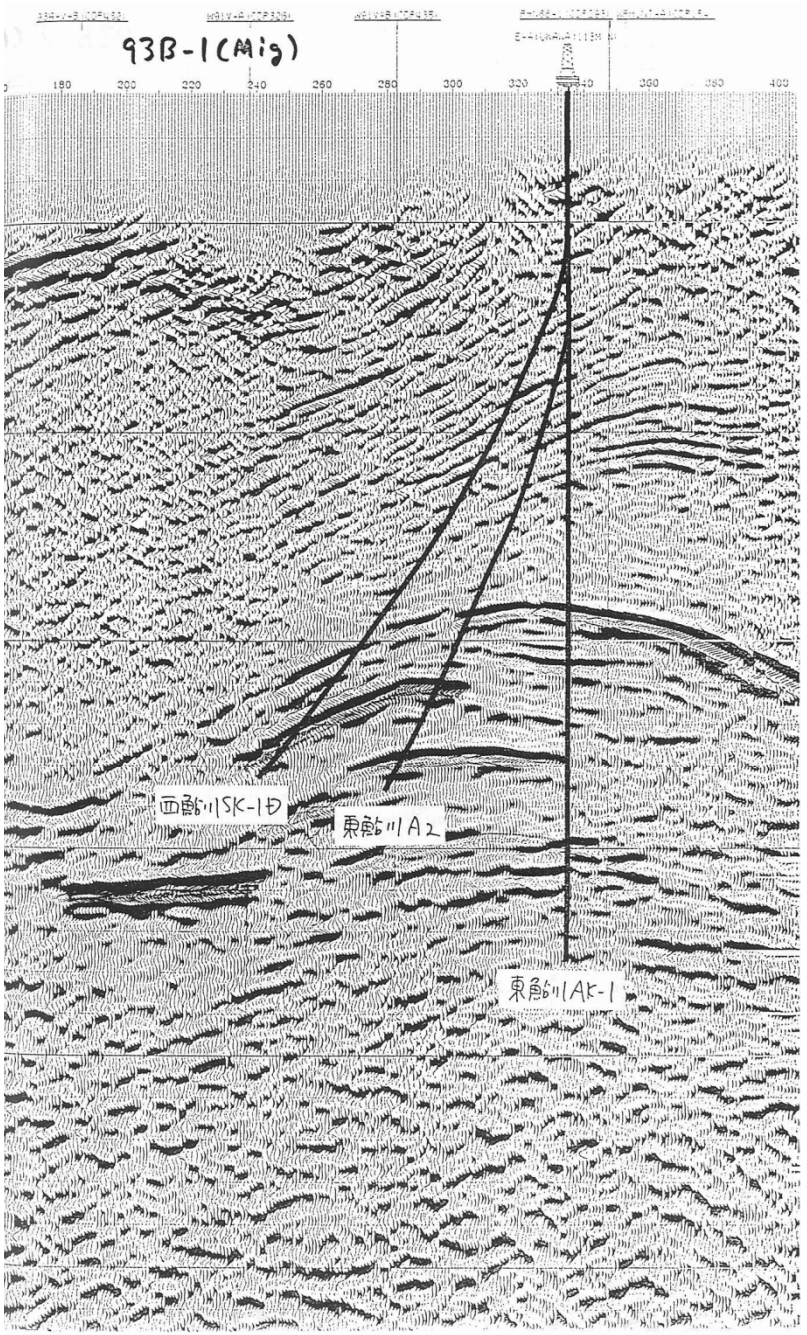
Cumulative Production by 2008			
Rhyolite Reservoir	Oil	Gas	
Yoshii-E Kashiwazaki	25 MMbbl	690 Bcf	1970-
Katakai-S Nagaoka	118	657	1984-

- Intrusive Rock: Post rift stage
  Dolerite intruded into diatomaceous shale

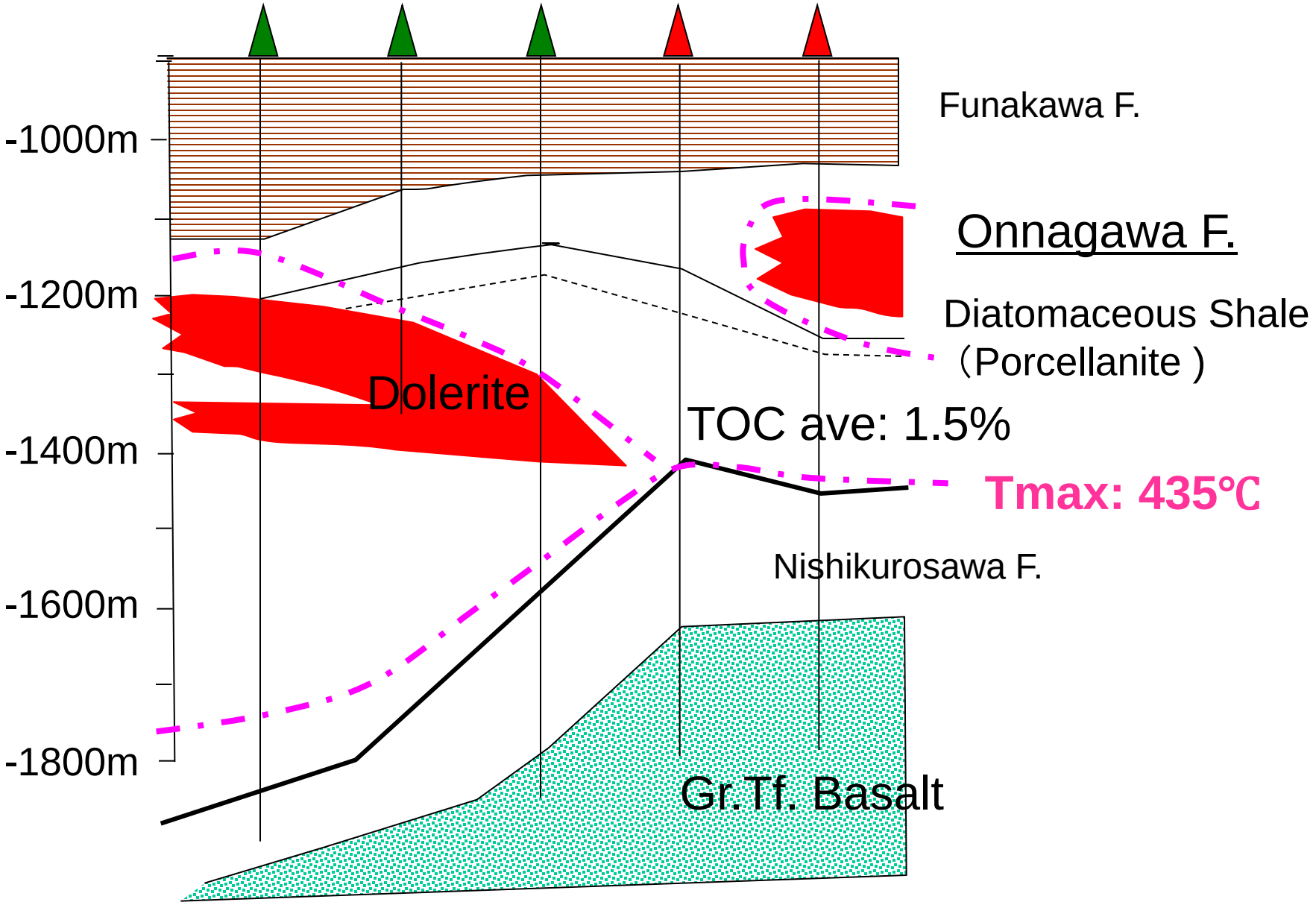
Ayukawa Oil and Gas Field



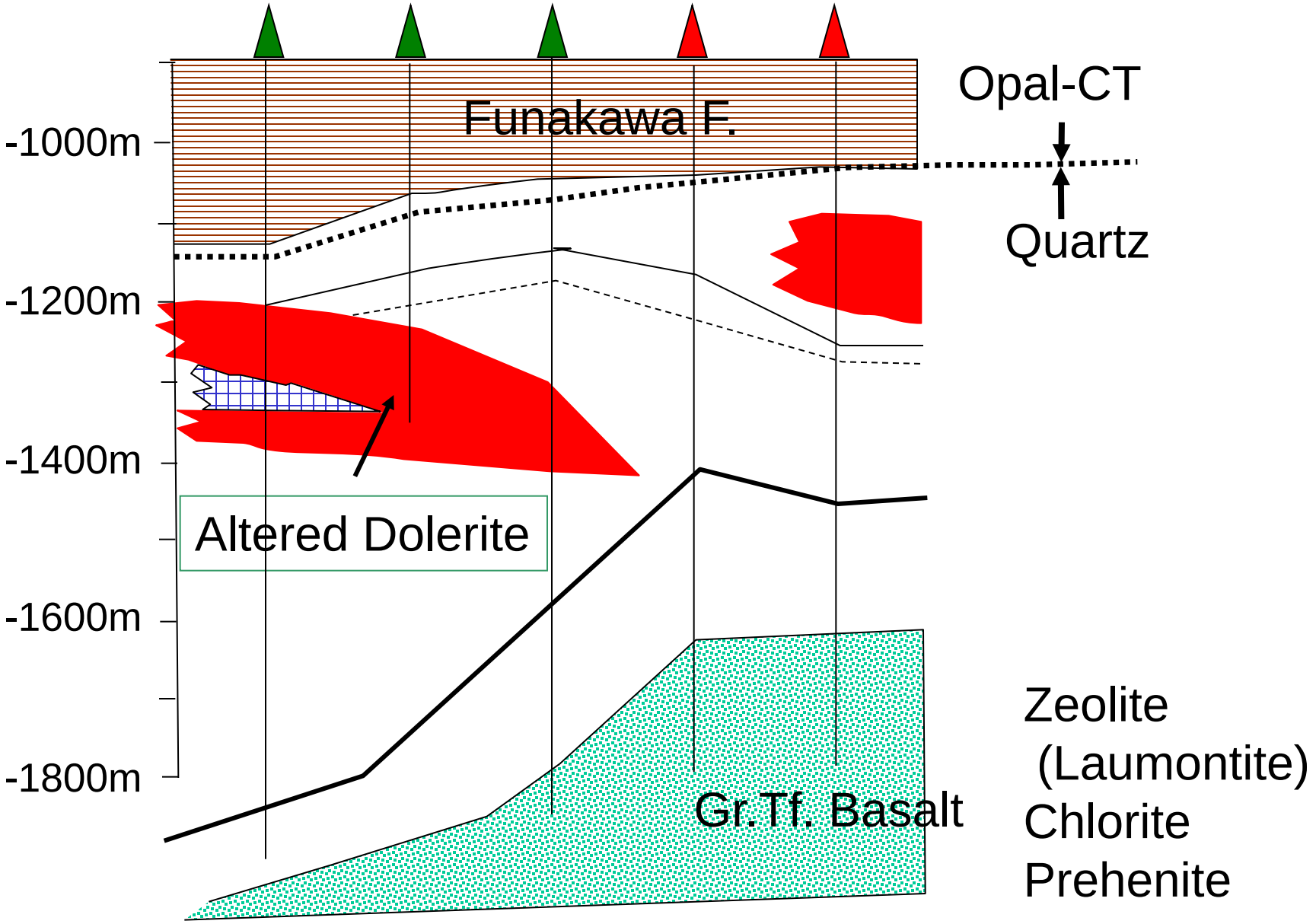

新鮎川A2


93B-1(Mig)
西鮎川SK-1H
東鮎川A2
東鮎川AK-1

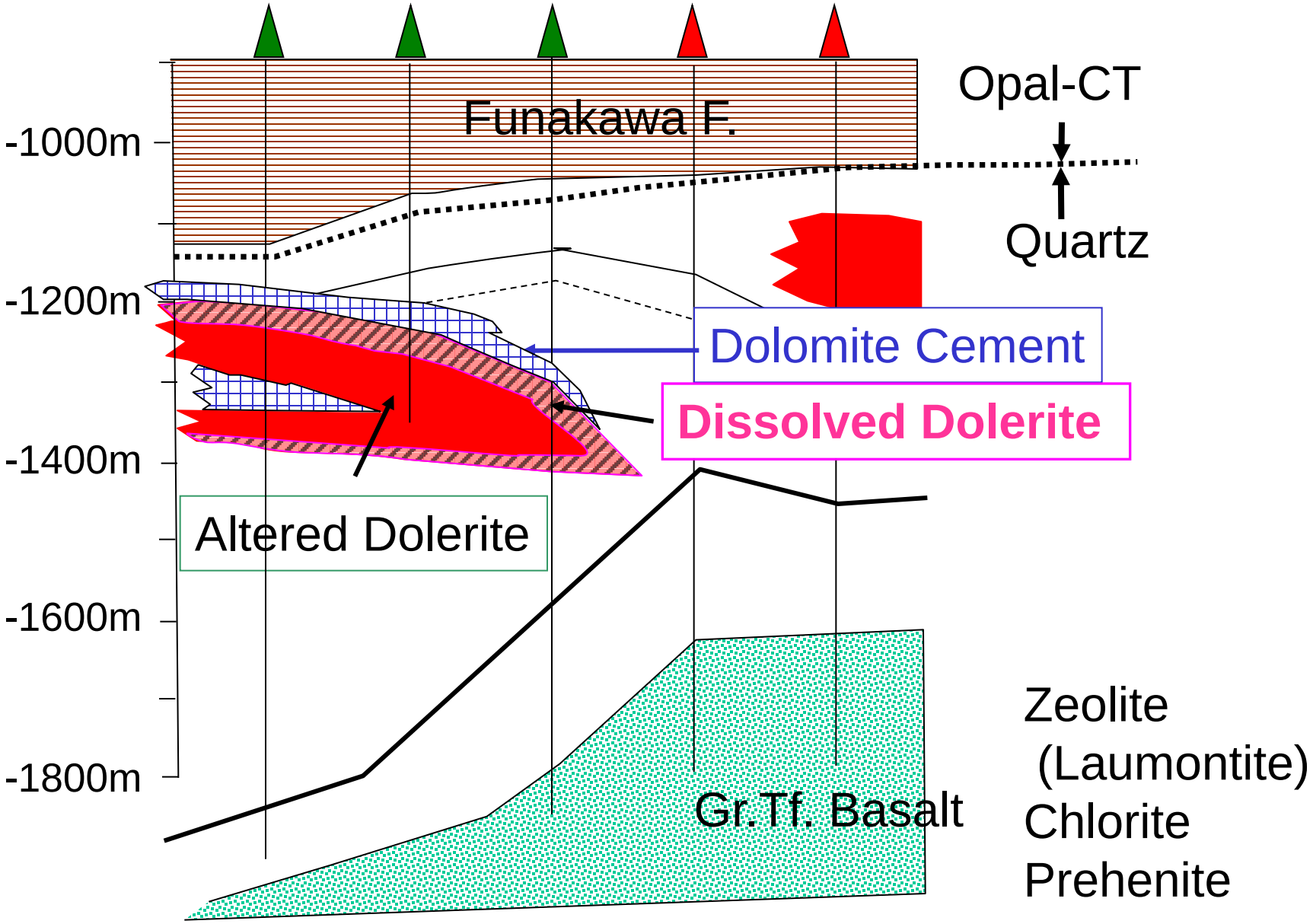
Ayukawa Field: Lithology

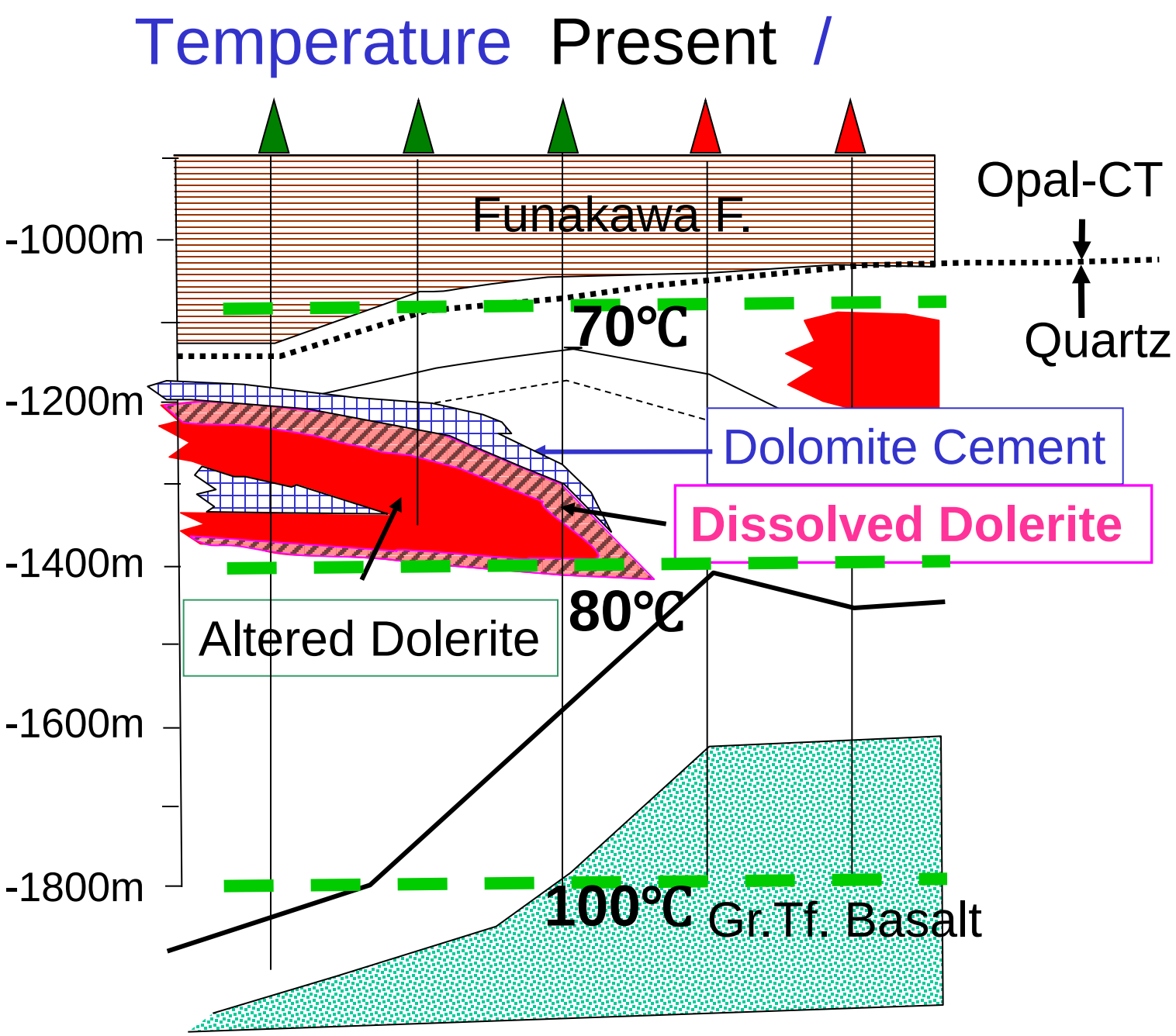


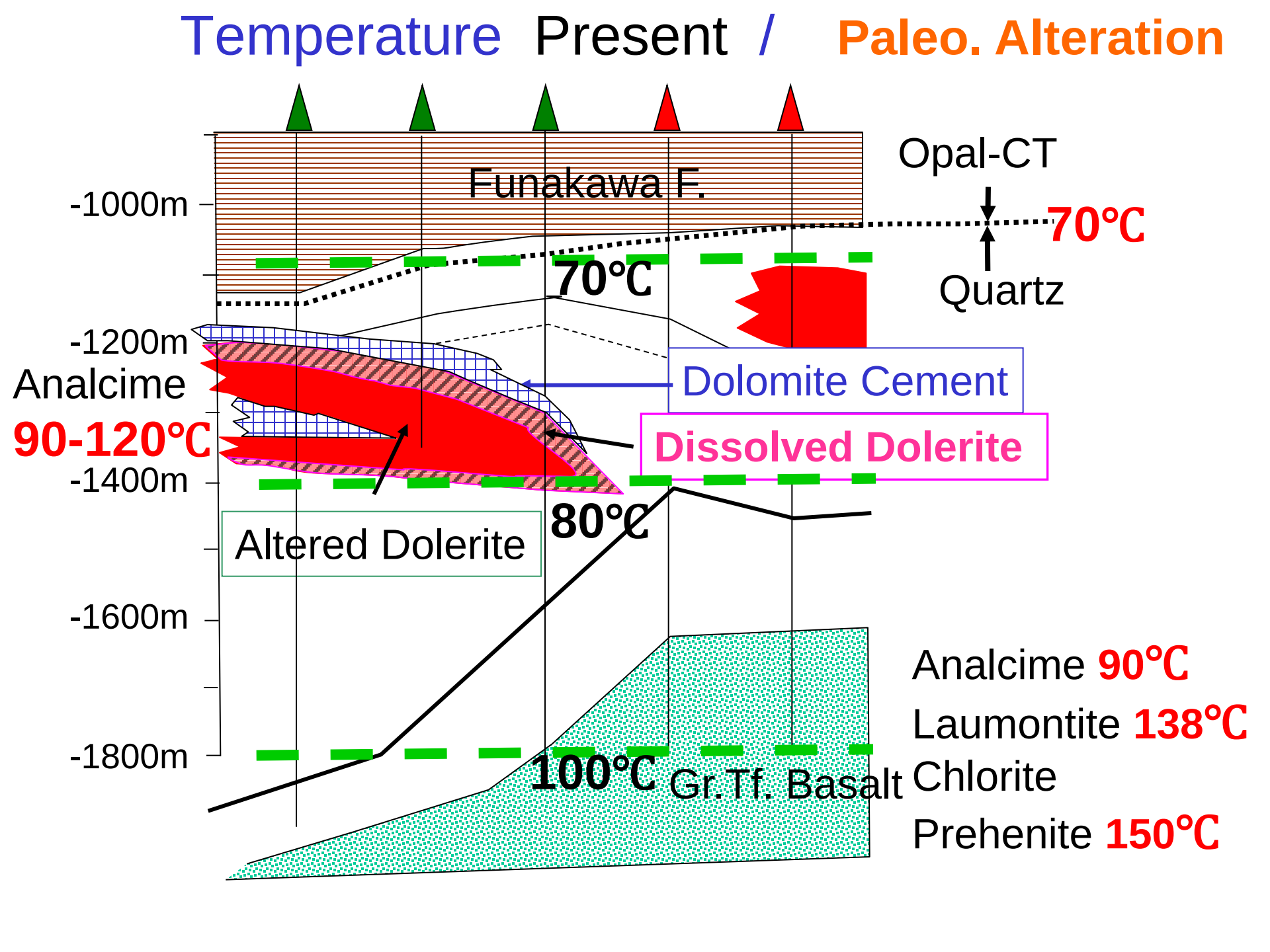
Alteration / Digenesis



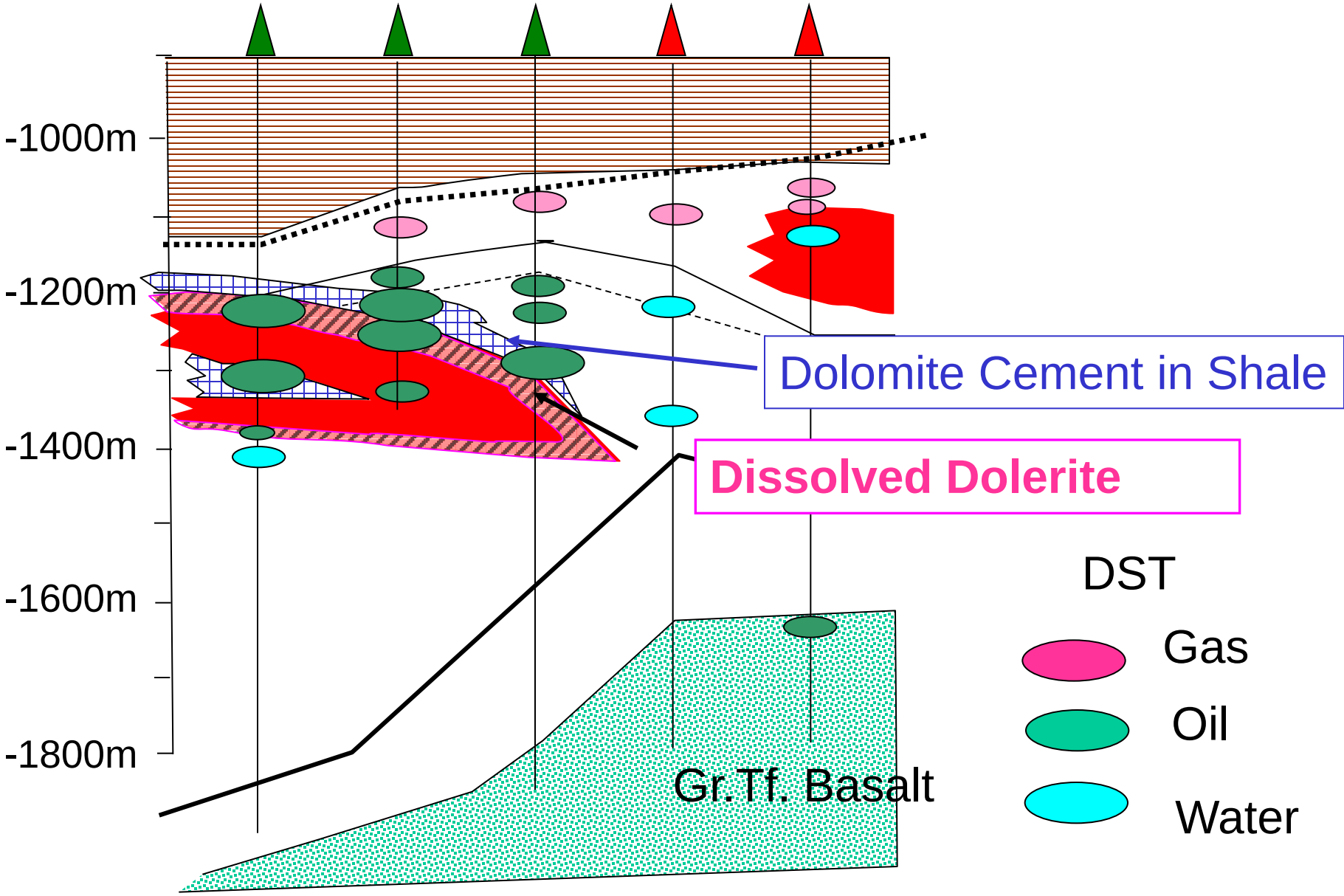
Alteration / Digenesis



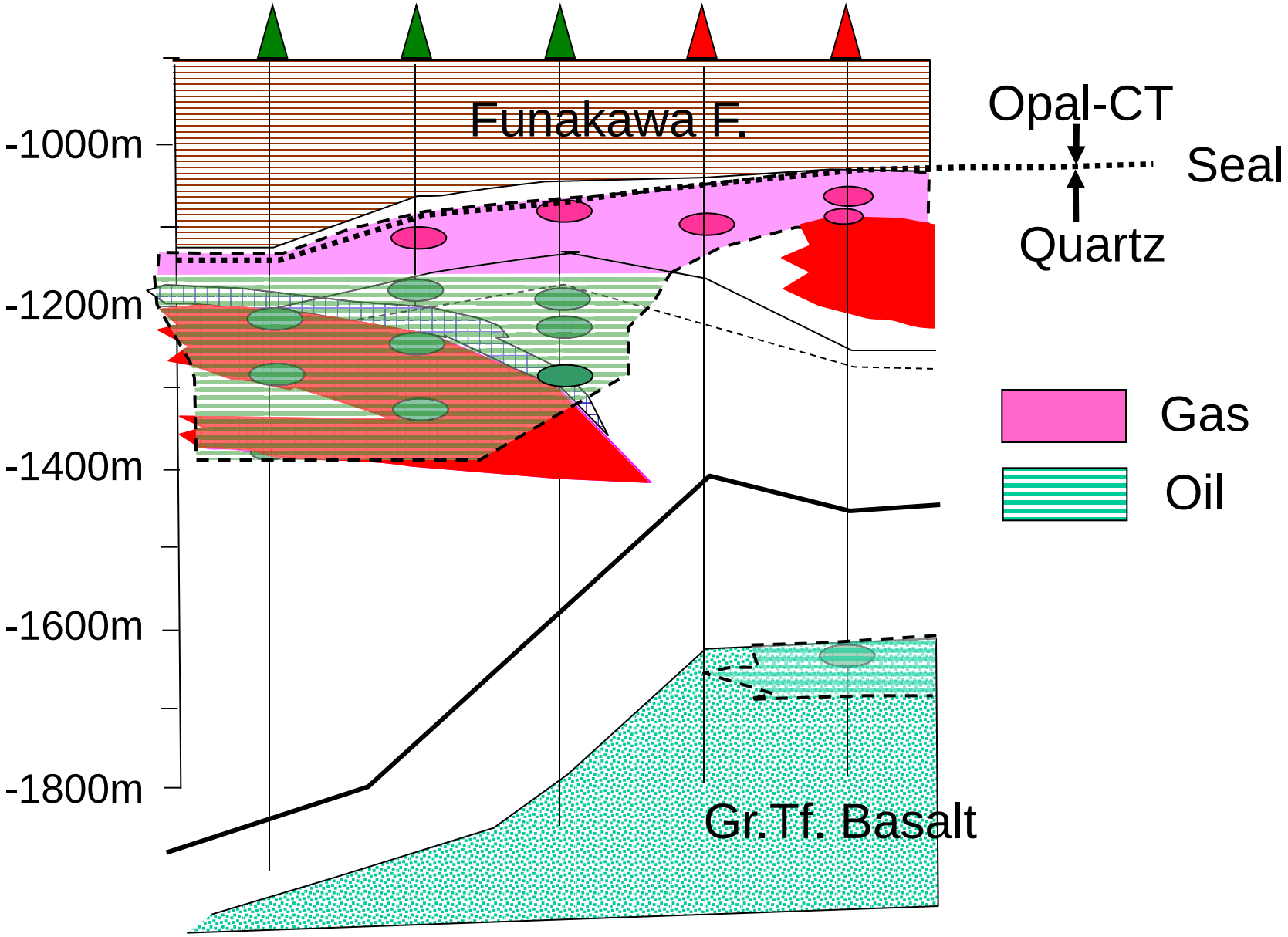

Temperature Present /
Funakawa F.
Opal-CT
Quartz
-1000m
-1200m
-1400m
-1600m
-1800m
70℃
Dolomite Cement
Dissolved Dolerite
80℃
Altered Dolerite
100℃
Gr.Tf. Basalt


Temperature Present / Paleo. Alteration
Funakawa F.
Opal-CT
70℃
Quartz
-1000m
70℃
-1200m
Analcime
90-120℃
Dolomite Cement
Dissolved Dolerite
-1400m
80℃
Altered Dolerite
-1600m
-1800m
100℃
Gr.Tf. Basalt
Analcime 90℃
Laumontite 138℃
Chlorite
Prehenite 150℃

Oil/Gas Test


-1000m
-1200m
-1400m
-1600m
-1800m
Dolomite Cement in Shale
Dissolved Dolerite
Gr.Tf. Basalt
DST
Gas
Oil
Water

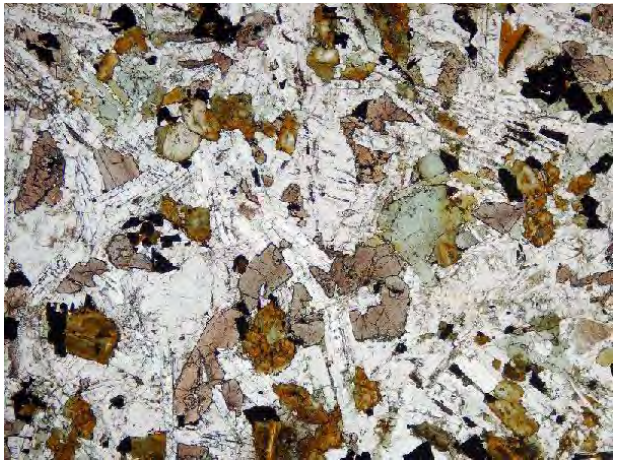
Oil/Gas Reservoir



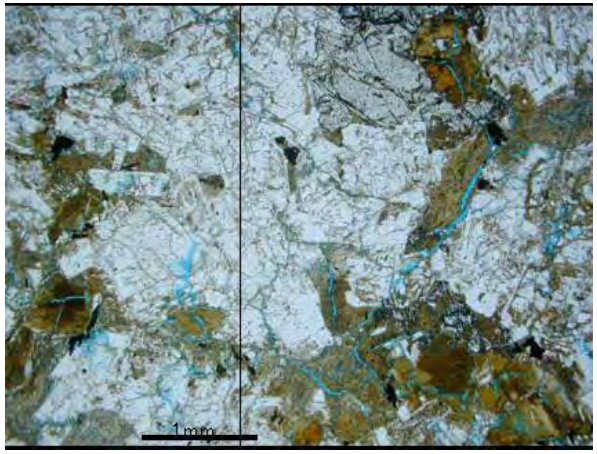
Dolerite Classification

Type		ϕ %	ϕ e %	K insitu	Color	Mafic
			>0.1 μ m			mineral
I	Fresh Dorelite	0-3	0		d.gray	Unaltered
II	Altered Dolerite	5-8	3-7	0.1md	gray	Clay
III	Dissolved Dorelite	15-25	9-11	1-10md	wihte	Dissolved

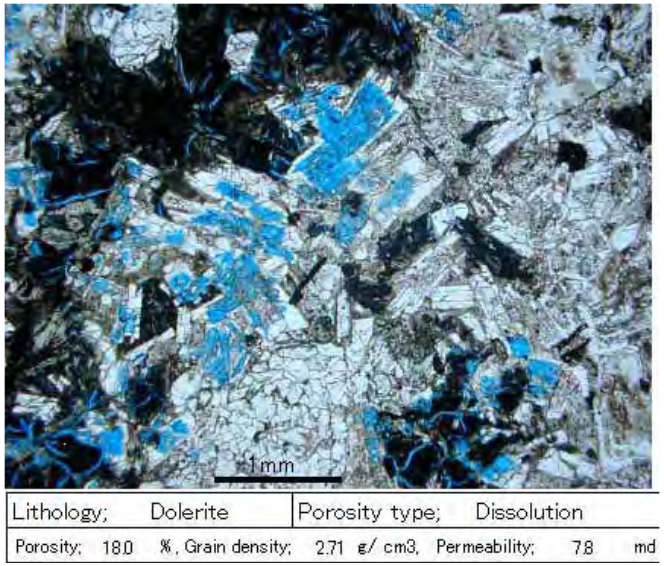
Fresh, Unaltered



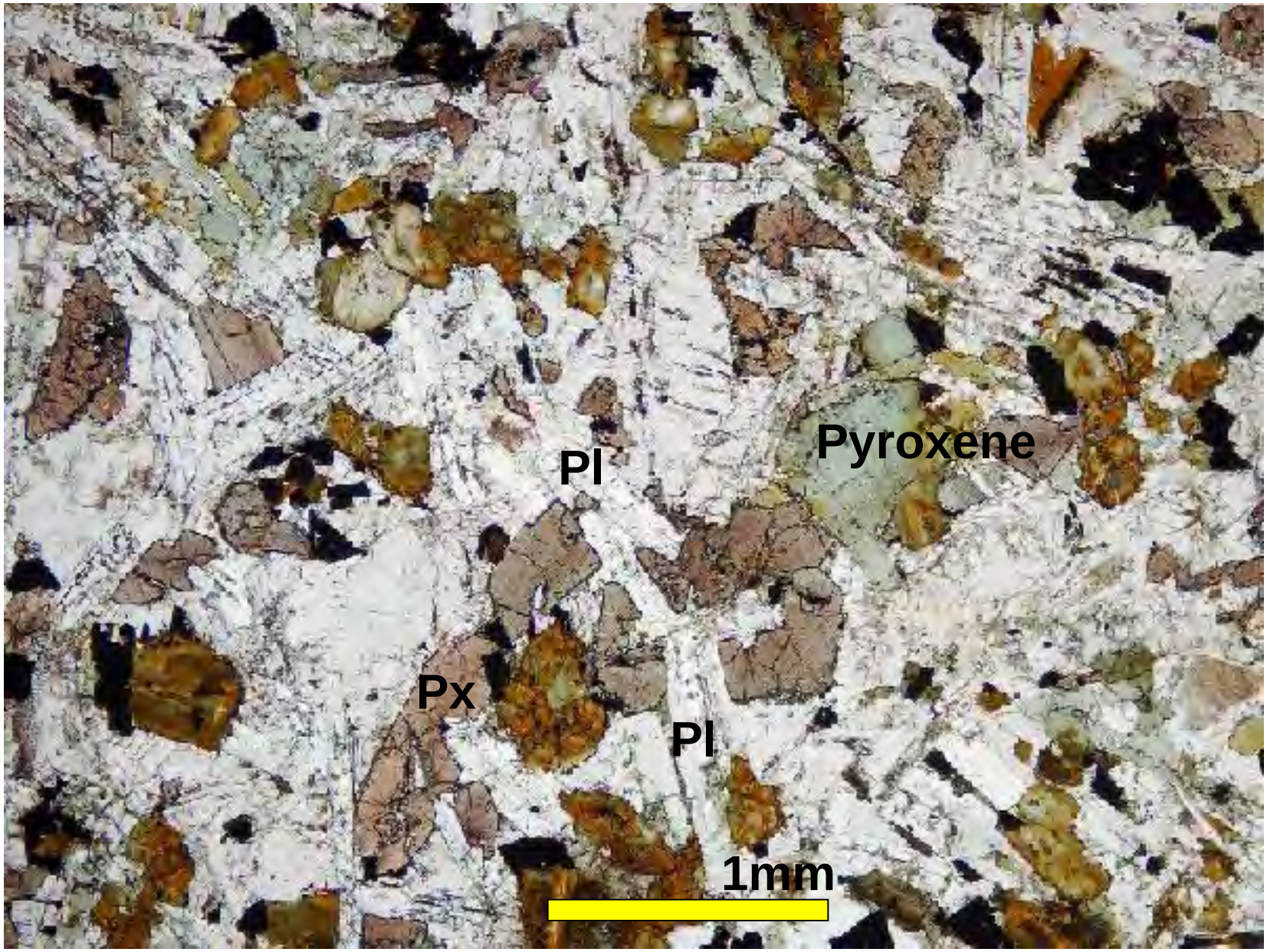
Altered



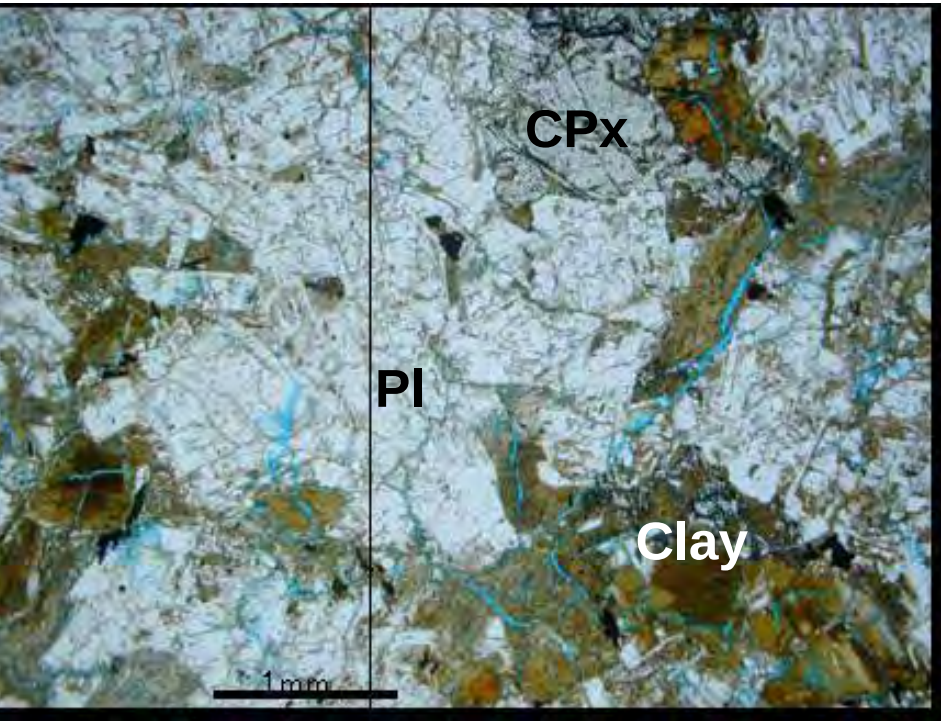
Dissolved

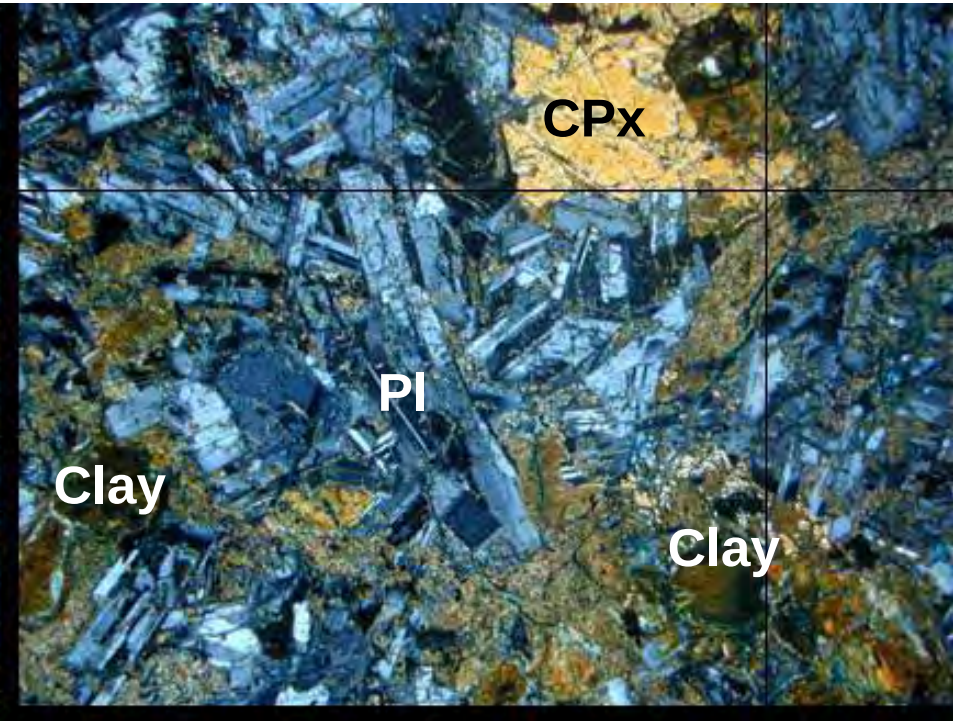


Fresh Dolerite

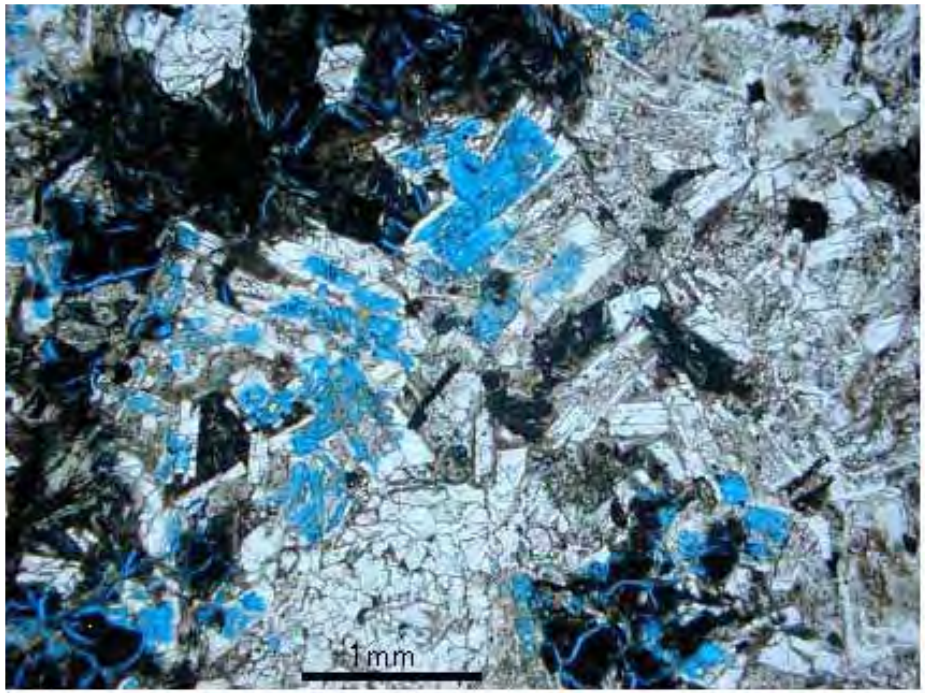


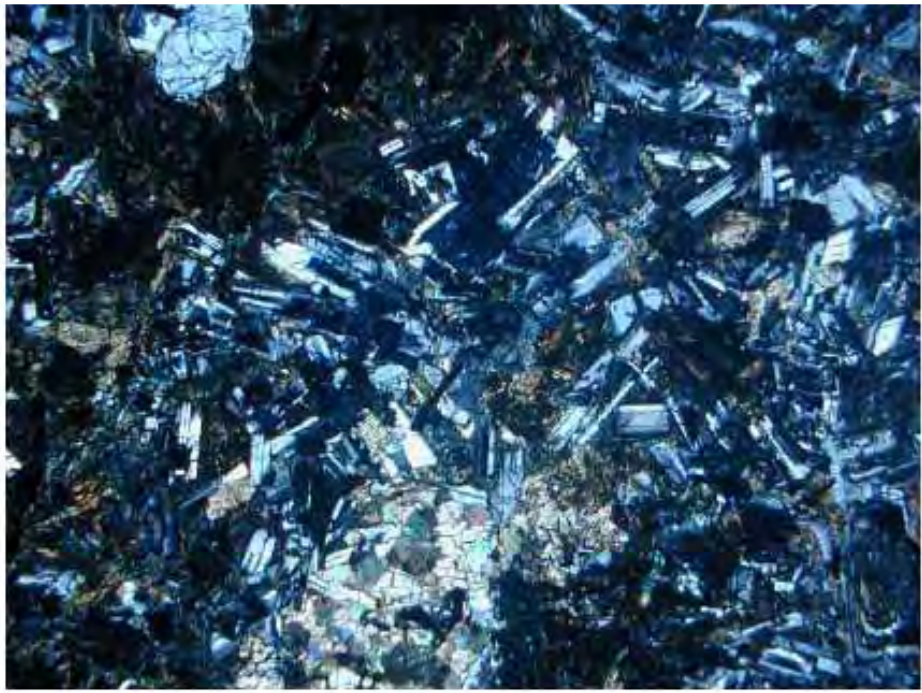
Altered Dolerite





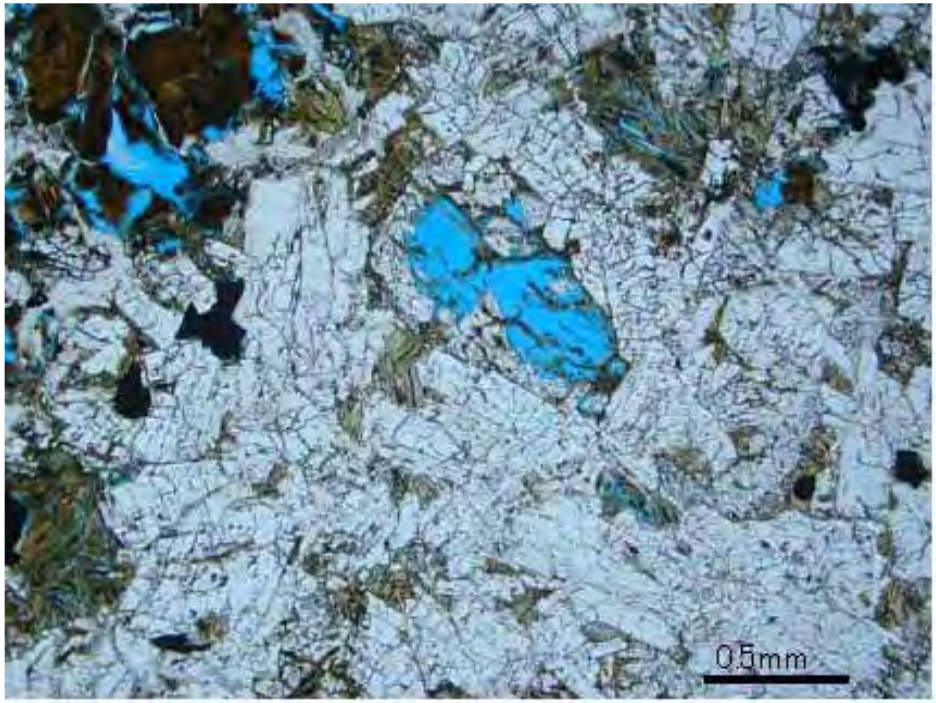
Dissolved Dolerite

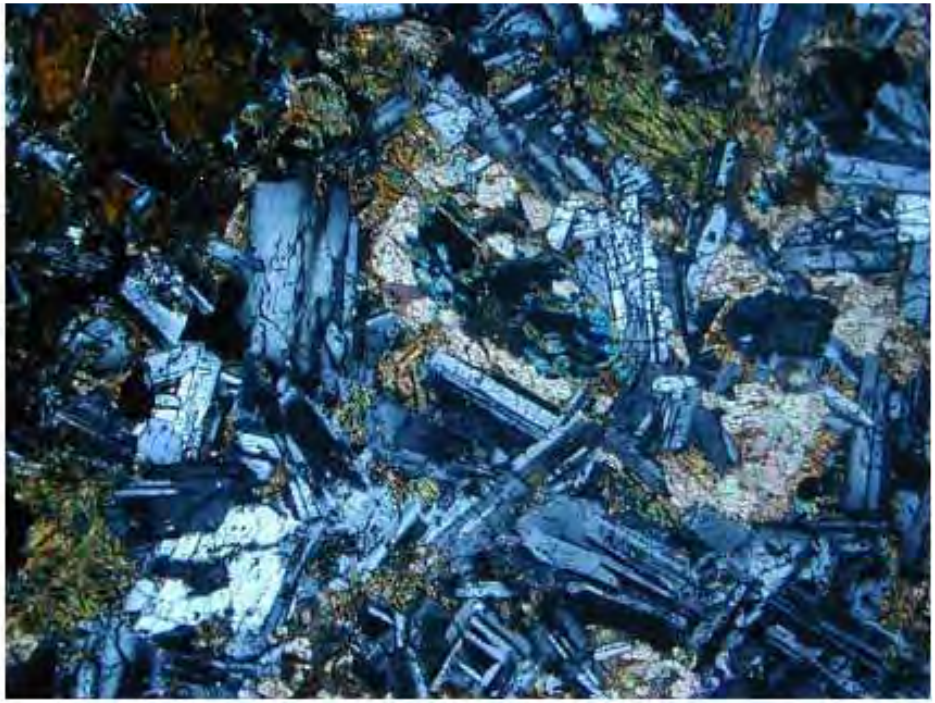




Lithology;	Dolerite	Porosity type;	Dissolution
Porosity; 18.0 %, Grain density; 2.71 g/ cm3, Permeability; 7.8 md			

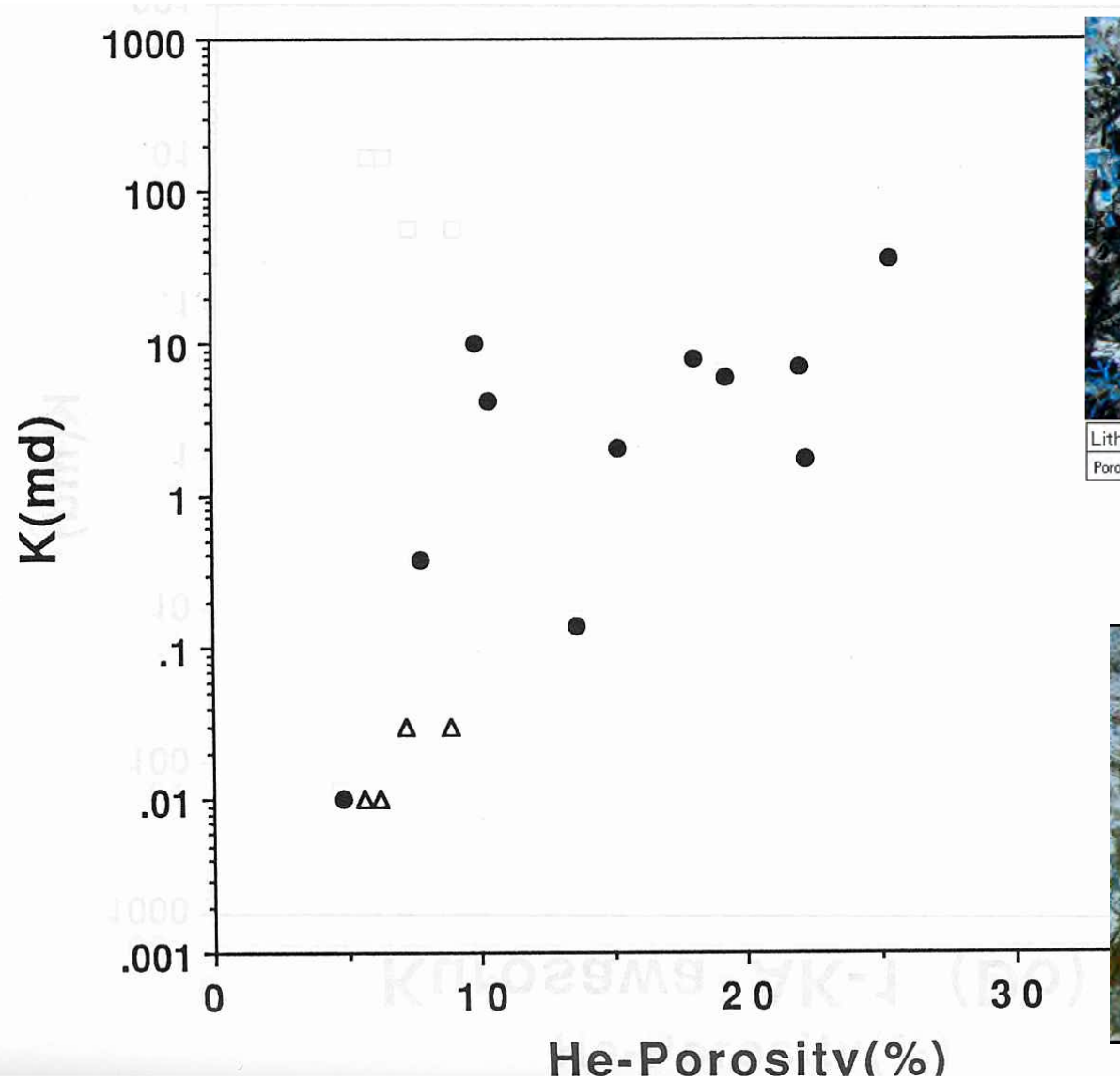
Dissolved Dolerite



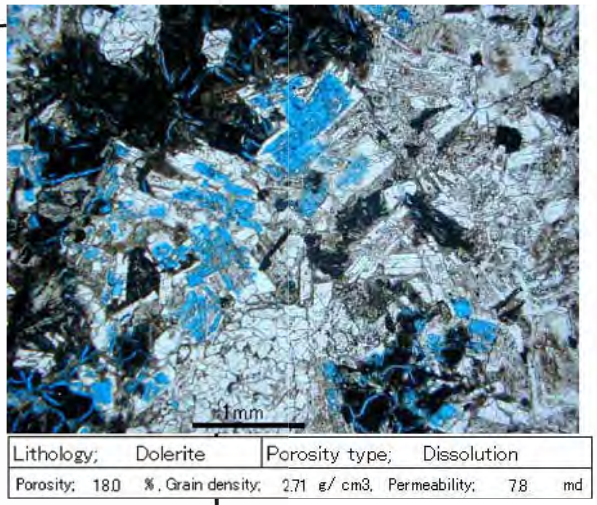


Lithology; Dolerite	Porosity type; Dissolution
Porosity; 19.0 %, Grain density; 2.75 g/ cm3, Permeability; 6.0 md	

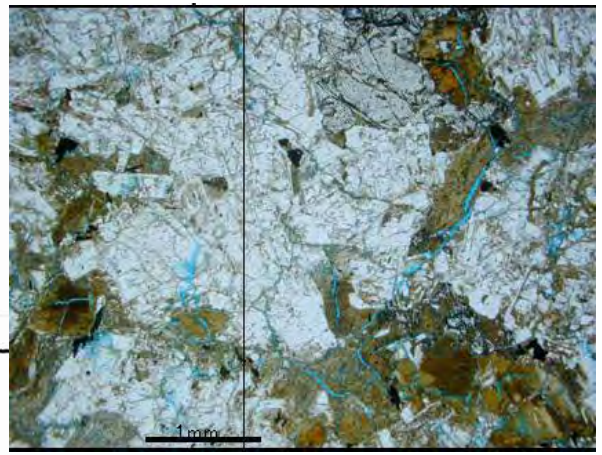
Dolerite Core Porosity-Permeability



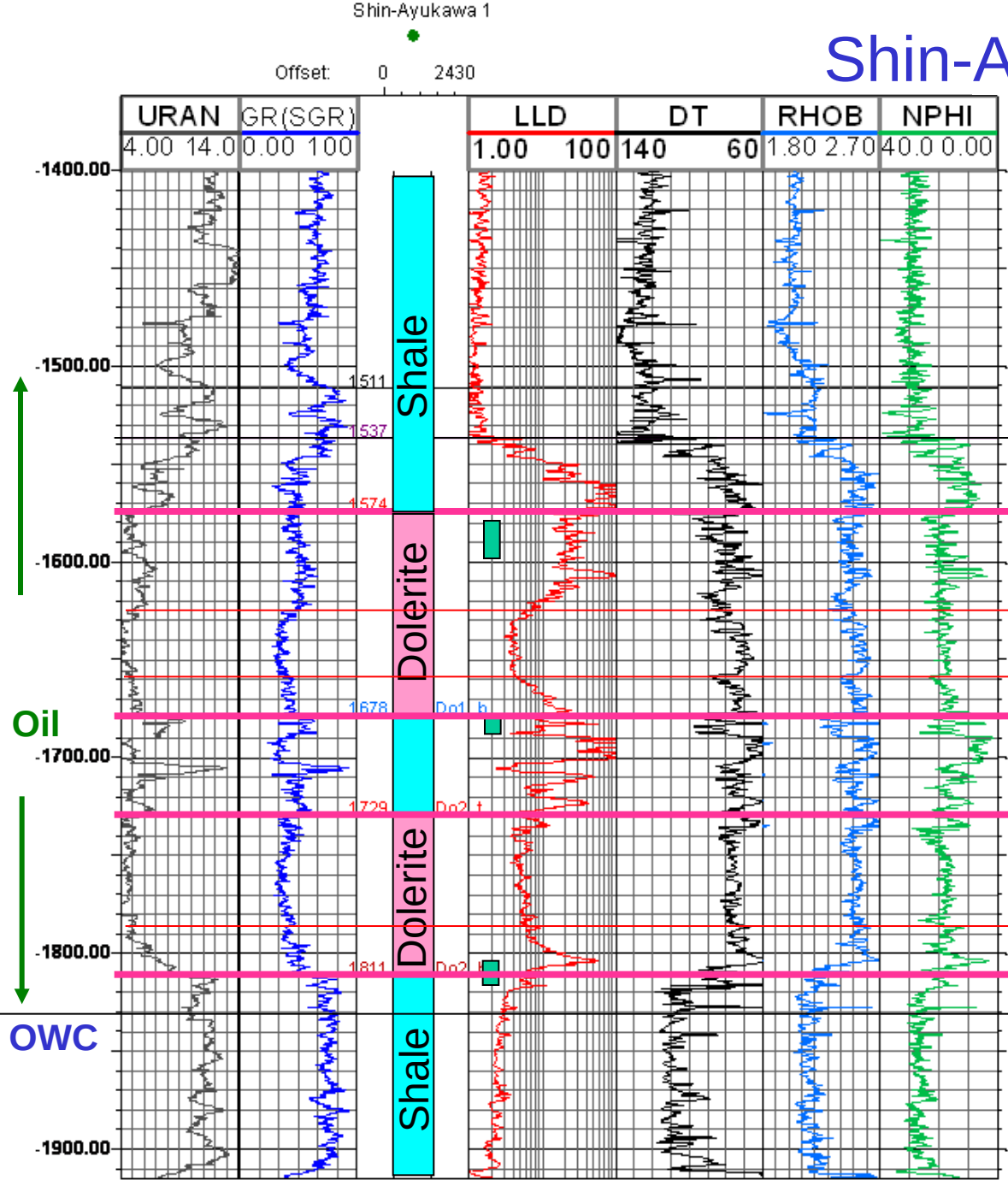
Dissolved Dolerite



Altered Dolerite



Shin-Ayuakawa AK-1



Shale (Porcelanite)

Dolomitized Shale

Dissolved Dolerite — Type III

Altered Dolerite — Type II

Dissolved — Type III

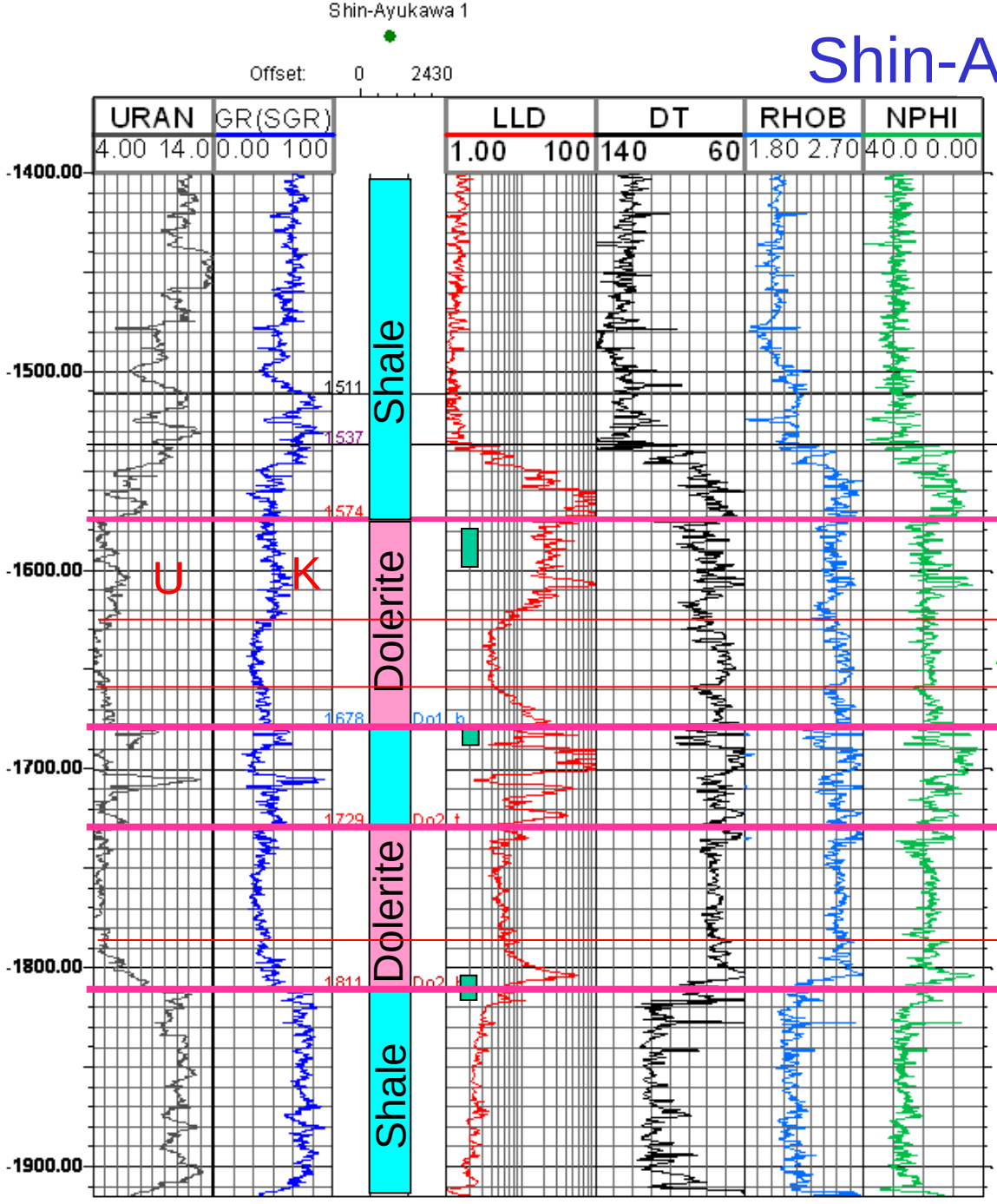
Dolomitized Shale

Altered Dolerite — Type II

Dissolved — Type III

Shale

Shin-Ayuakawa AK-1



Shale

Dolomite CMT

Dissolution

Alteration

Dissolution

Dolomite CMT

Alteration

Dissolution

Shale

$MgCa(CO_3)_2$

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

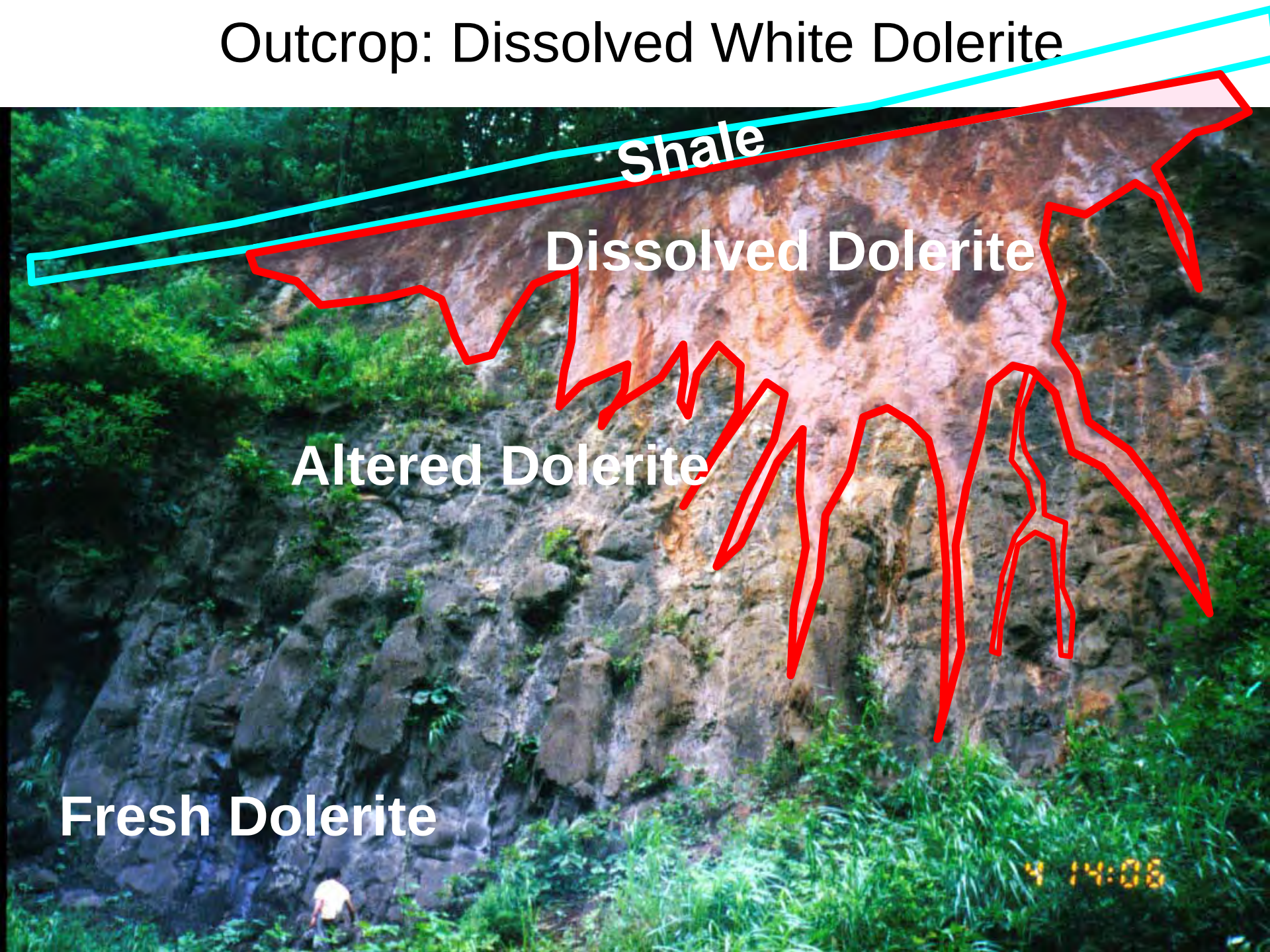
K^+

K-fd

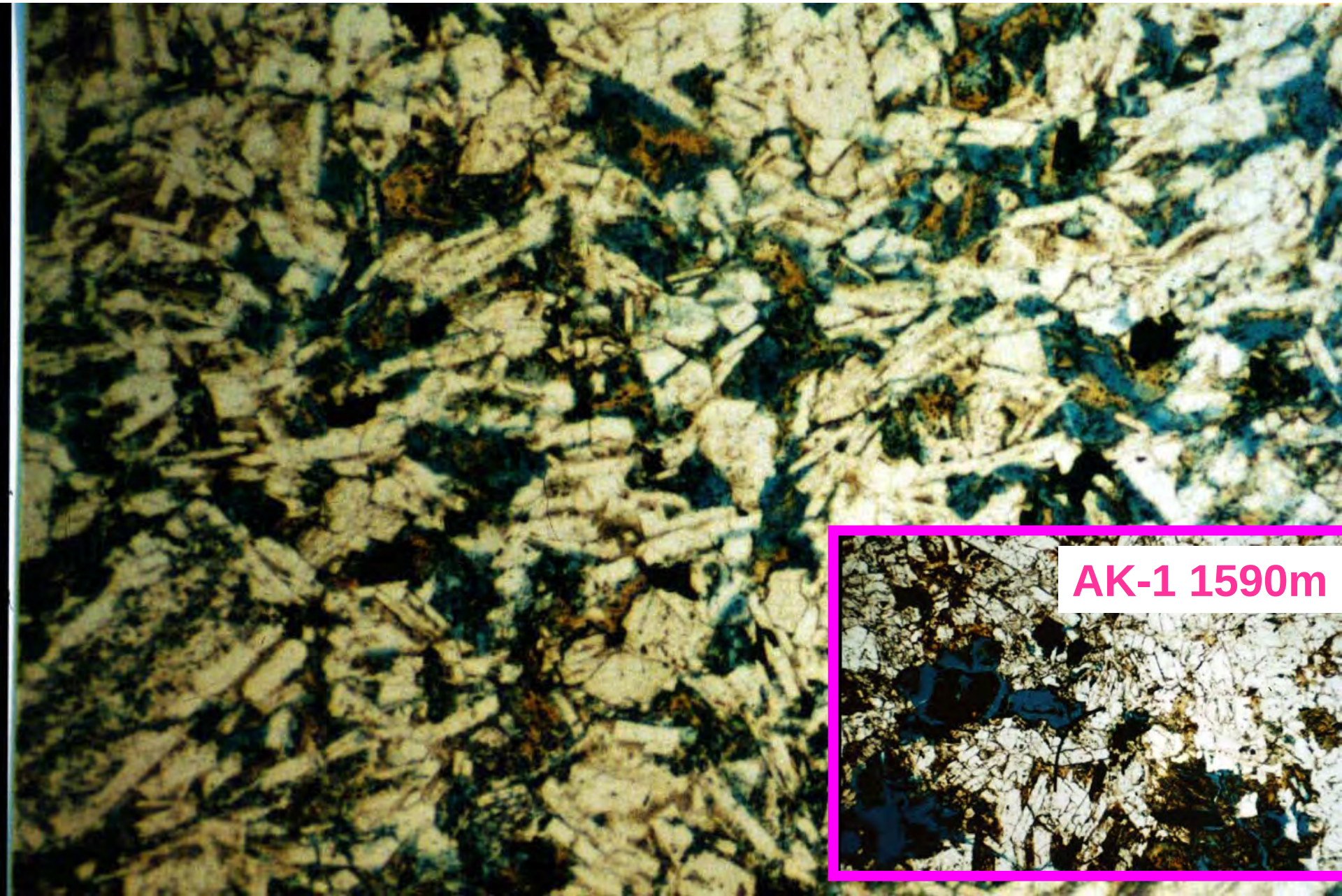
Pyroxene → Clay

Outcrop: Dissolved White Dolerite

Outcrop: Dissolved White Dolerite

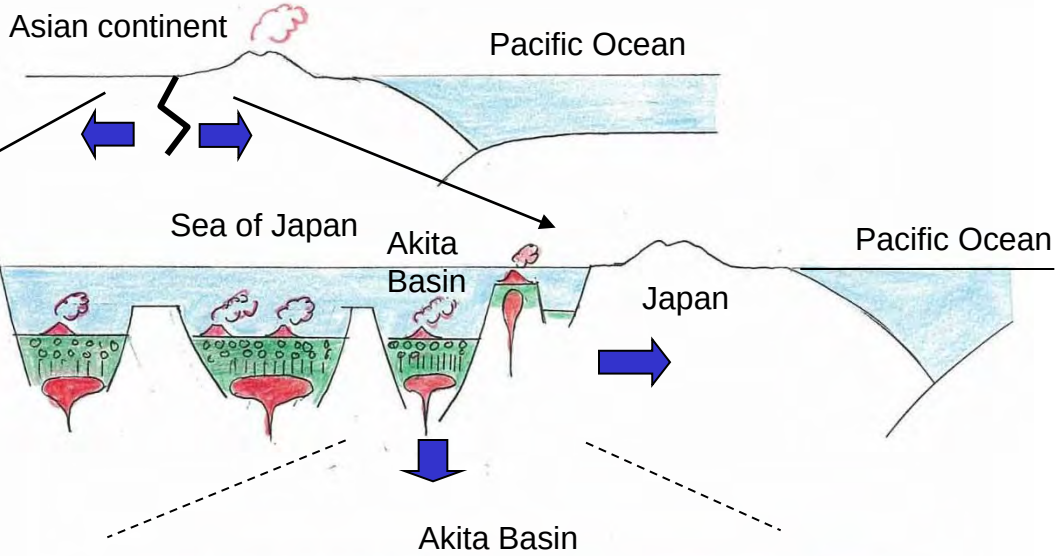


White Dolerite: Outcrop

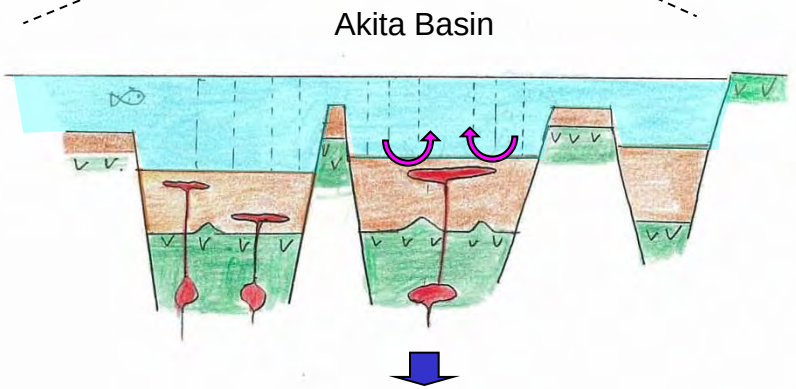


Outcrop: Dissolved White Dolerite

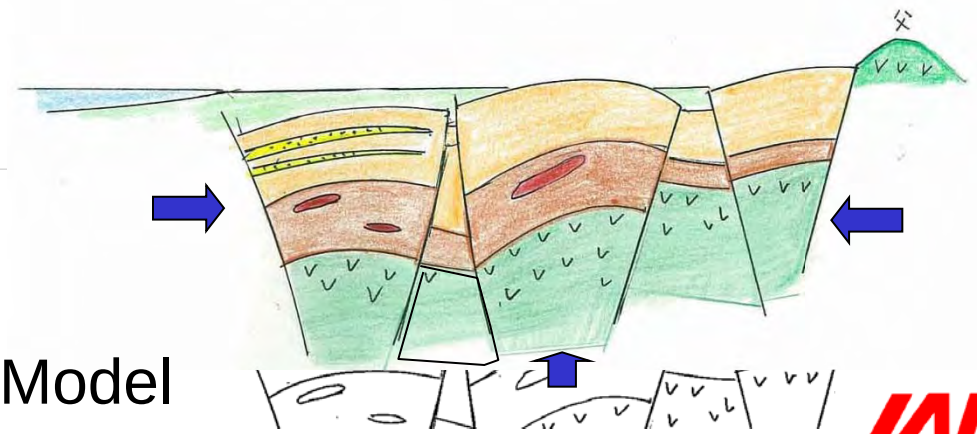
: Andean type margin



Opening of the Sea of Japan
Back-arc basin initiates
Submarine Volcanism.
Hydrothermal Alteration
(Ocean Floor Metamorphism)
Reservoir (Dissolution) Clay, Au, Ag



: Post Rift
Subsidence.
Diatom-siliceous sediments.
Anoxic environments: Source
Dolerite intrusion / Hydrothermal Altera



: Inversion
Fold
Source Maturation and Expansion
Oil and Gas accumulation

Akita Basin Development Model

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Discussion

- Most dolerite are fresh, not dissolved!
- What controls dolerite alteration?
- Alteration Temperature
  - Zeolite mineral thermometer
  - Analcime 90℃＜Thomsonite < Laumontite 138℃
- A large amount of hydrothermal fluid circulation.
- Continuous Supply of Seawater and Heat.
- Dolerite intrusion Near sea-bottom

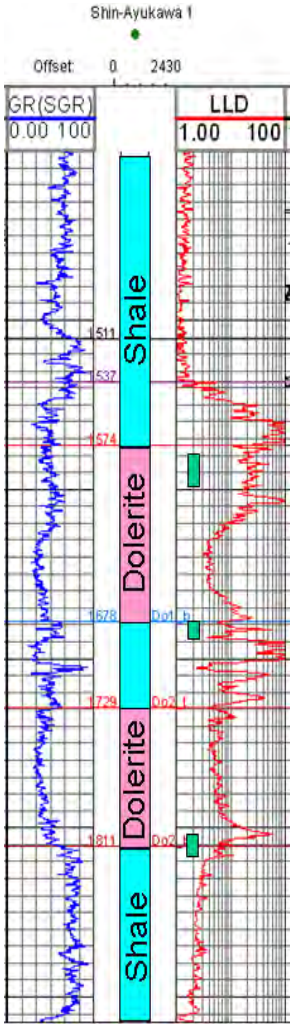
  and heat from Magma chamber.

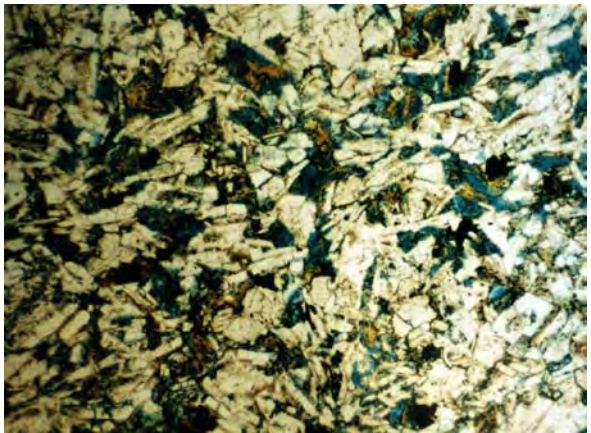
Summary

1. Altered sheeted dolerite dykes form important oil reservoir in the Ayukawa oil field where secondary porosity has been created by dissolution of pyroxene and plagioclase.

2. Heat from dolerite and circulation of seawater hydrotheramlly altered the dolerite and surrounding sediments at the post-rift stage of the Akita back-arc basin.

3. We expect similar dolerite reservoir to be discovered in other rift basin where early submarine volcanic activities existed.





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