



# Long-term Stability of the Potential Host Rocks in Taiwan: a Tectonic Perspective

**Wayne Lin**

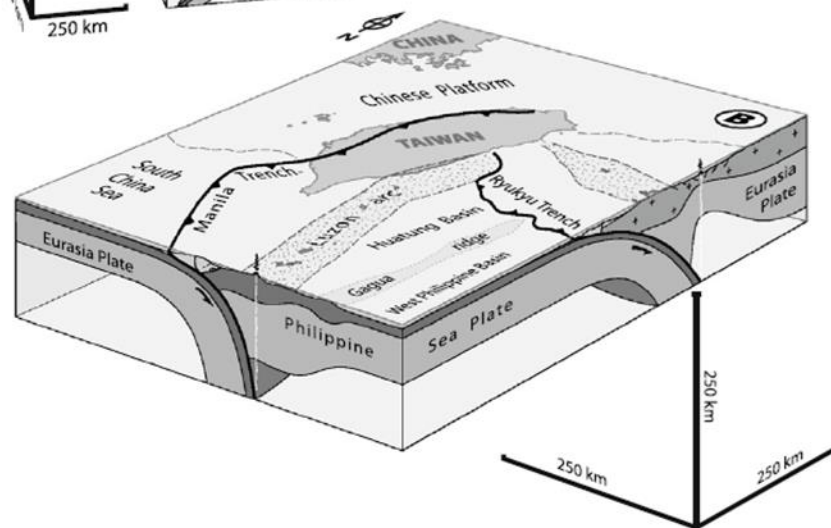
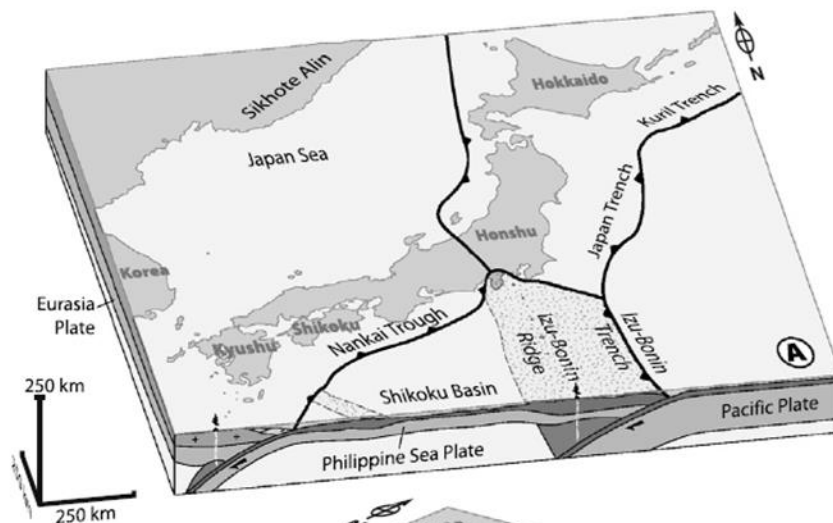
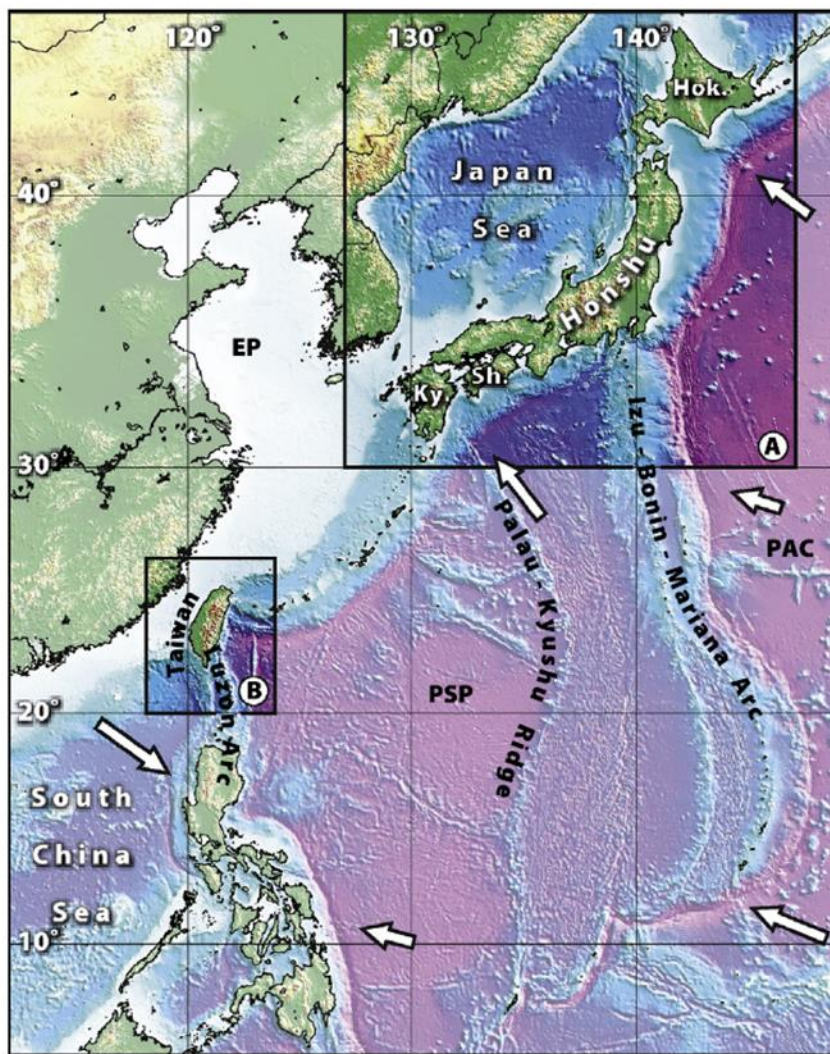
**2024/10/21**



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- **Long-term Stability for Geological Disposal**
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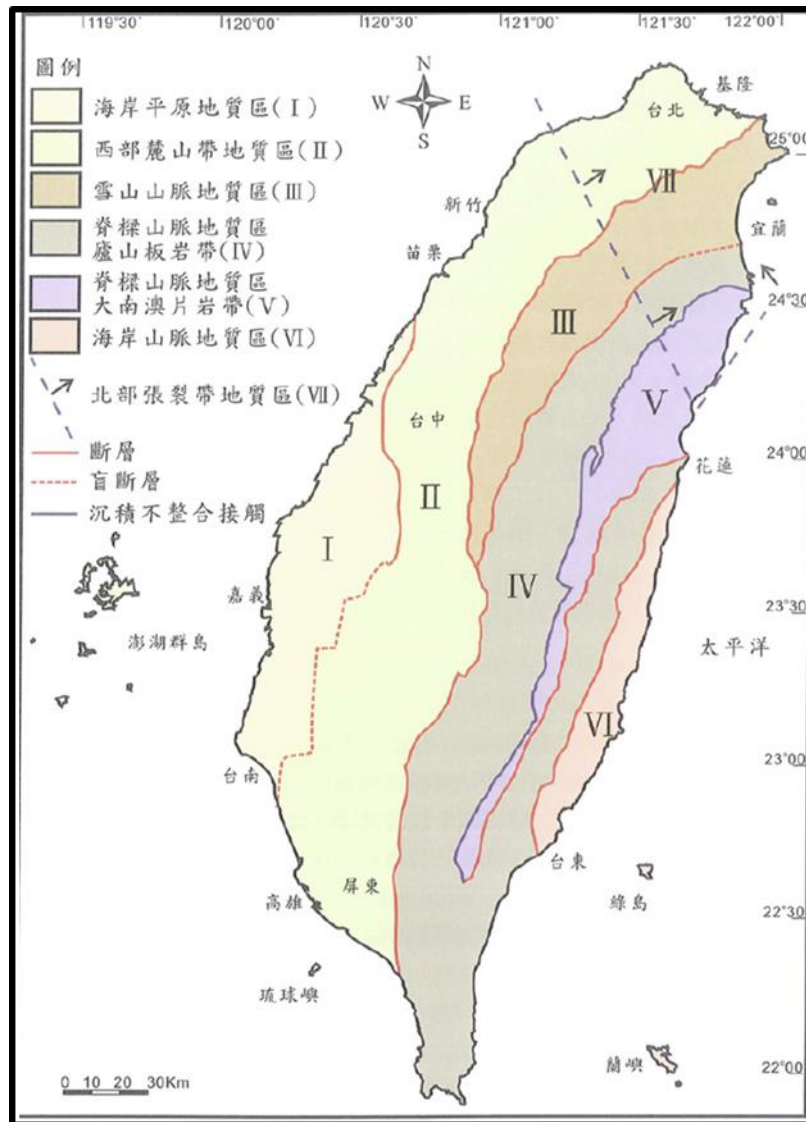
# Plate Tectonic Regime



(Lallemand et al., 2014)



# Geologic Provinces of Taiwan



Chen et al. (2016)



編製：陳學夏、柯啟昌、謝凱旋、孫偉、林偉雄、張鐵正、黃繼水、林啓文、陳政傑、楊錫勇、李光甫  
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繪圖：王俊華、李明鳳  
Drawn by: Jun-Hua Wang, Ming-Feng Lee

# Potential Host Rocks

## Considered for Geological Disposal

□ 3 different geological media were discussed before 2009

➤ **Granite rock:**

Off-shore Islands (K, W, M); Eastern Taiwan (H)

➤ **Mudstone rock:**

Southwestern, Central and Southeastern Taiwan

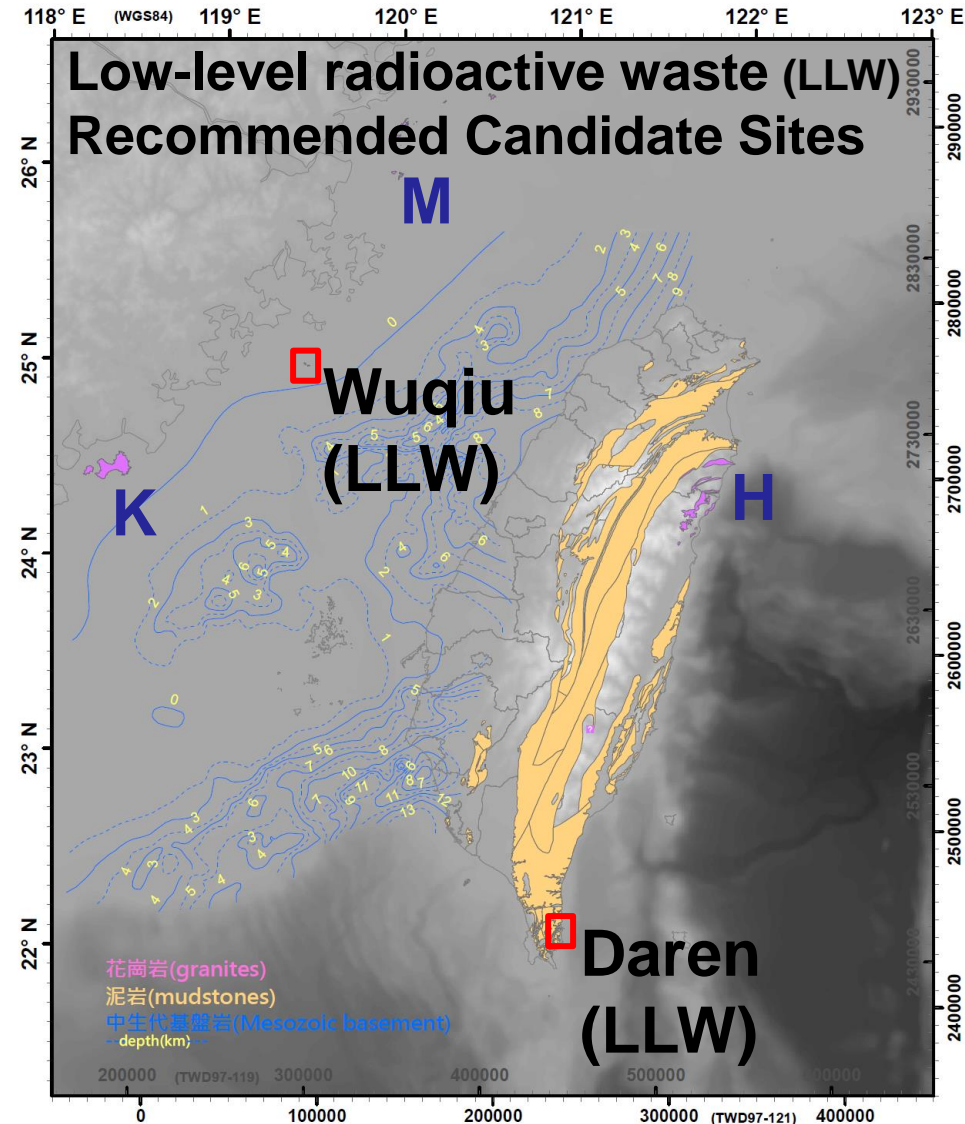
➤ **Mesozoic basement rock:**

Below seabed of Taiwan strait

□ Two recommended candidate sites for LLW disposal:

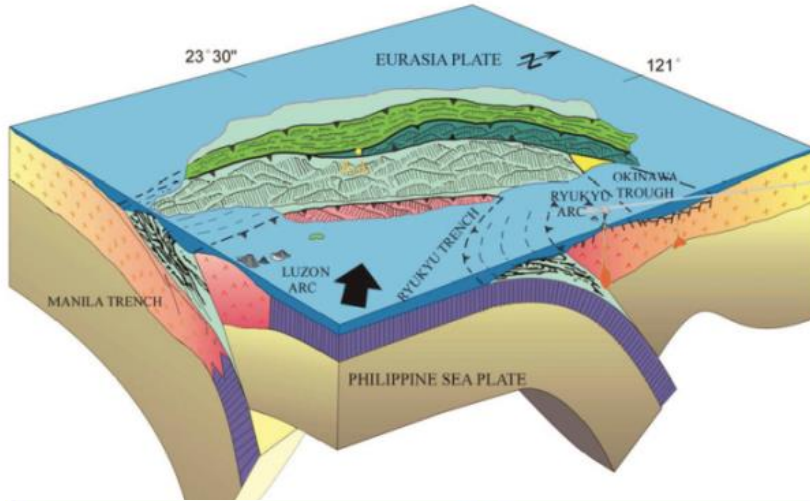
➤ **Wuqiu (granite)**

➤ **Daren (mudstone rock)**



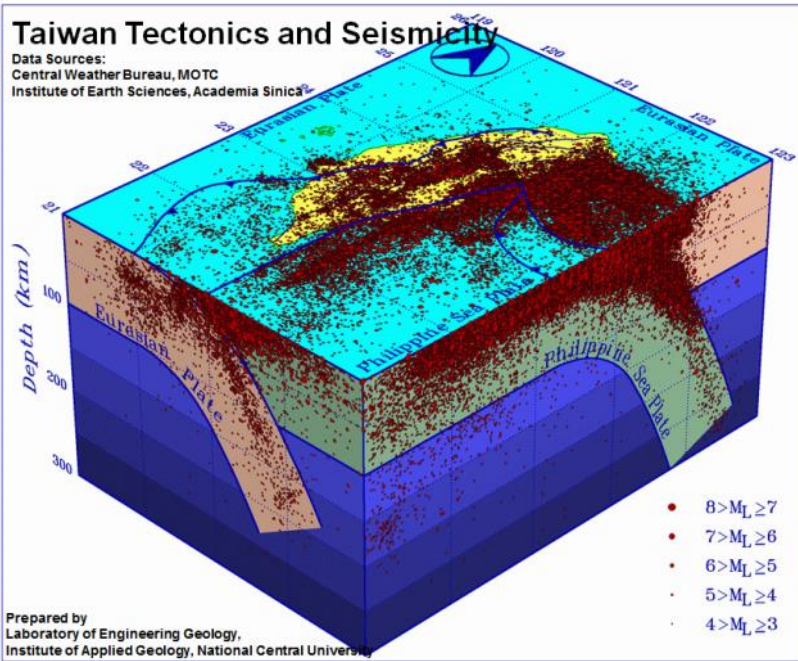


# Tectonic Setting of Taiwan

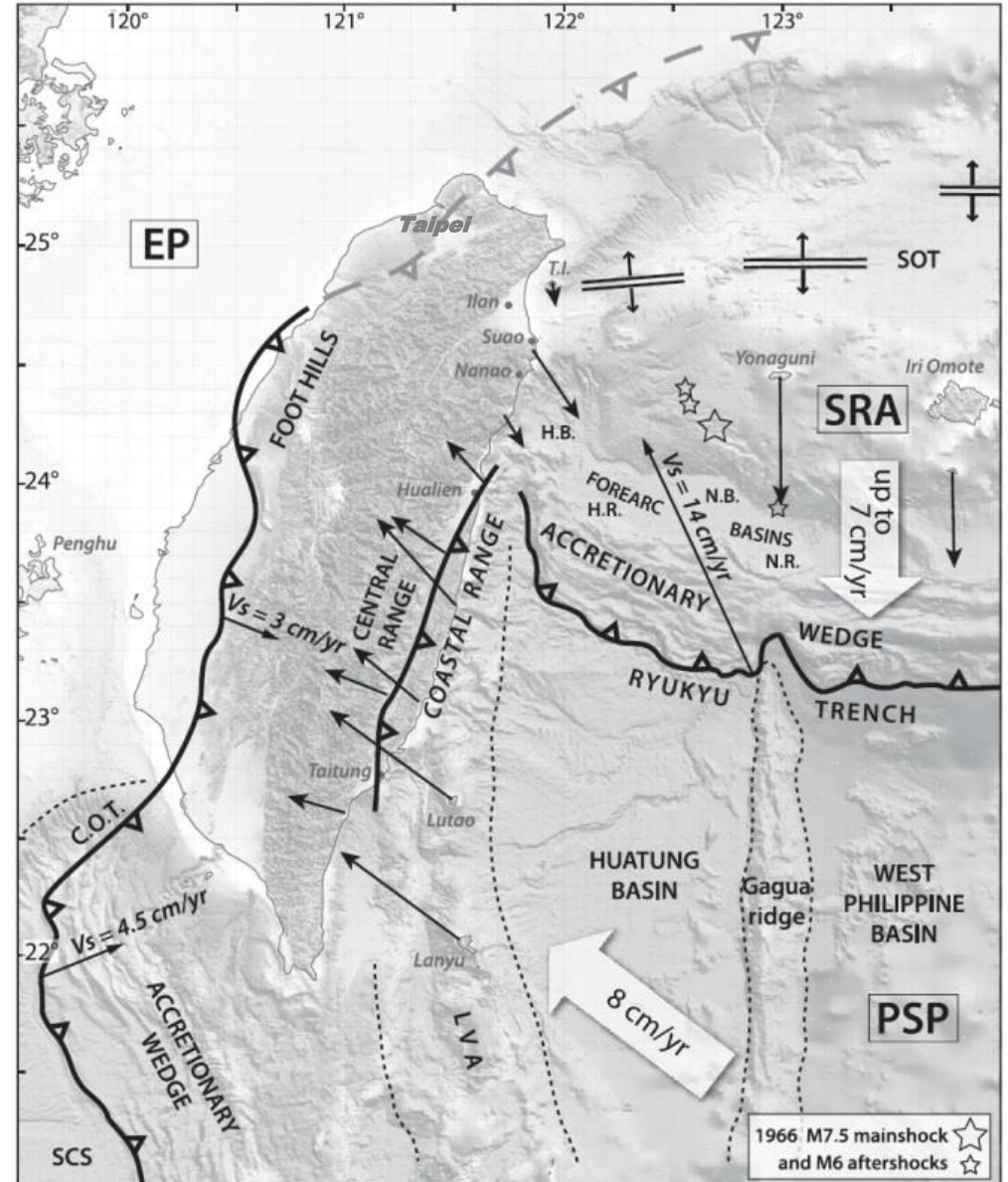


## Taiwan Tectonics and Seismicity

Data Sources:  
Central Weather Bureau, MOTC  
Institute of Earth Sciences, Academia Sinica



Prepared by  
Laboratory of Engineering Geology,  
Institute of Applied Geology, National Central University



# Long-term Stability of Statigraphy

Fig.2

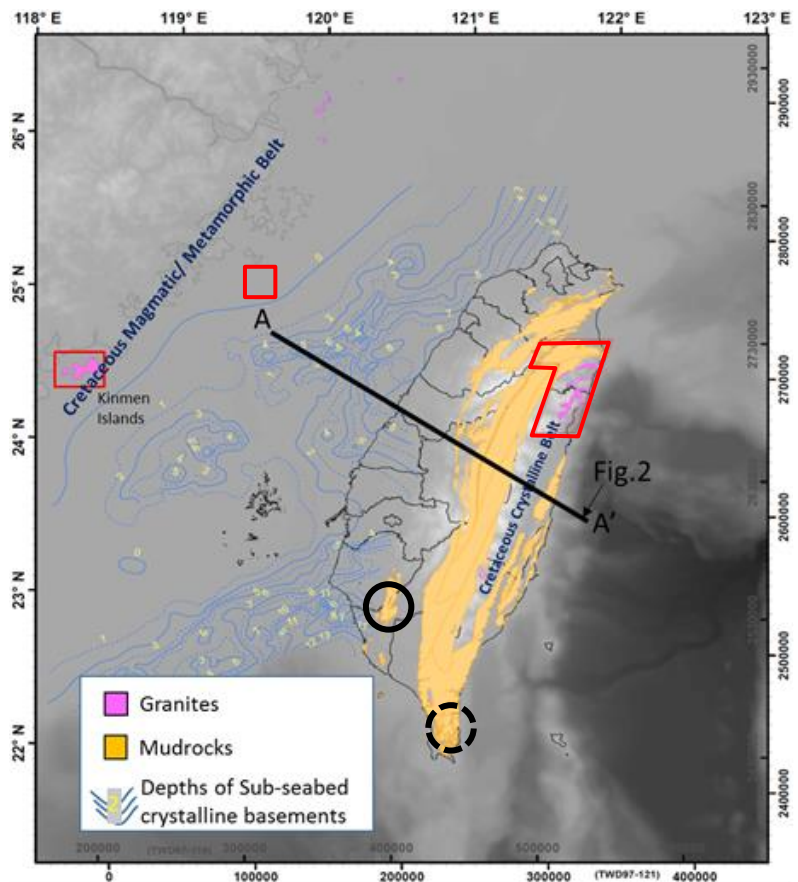
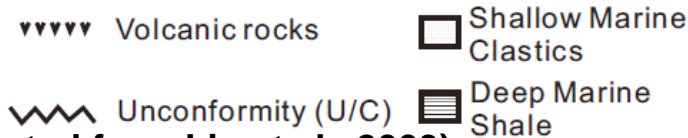
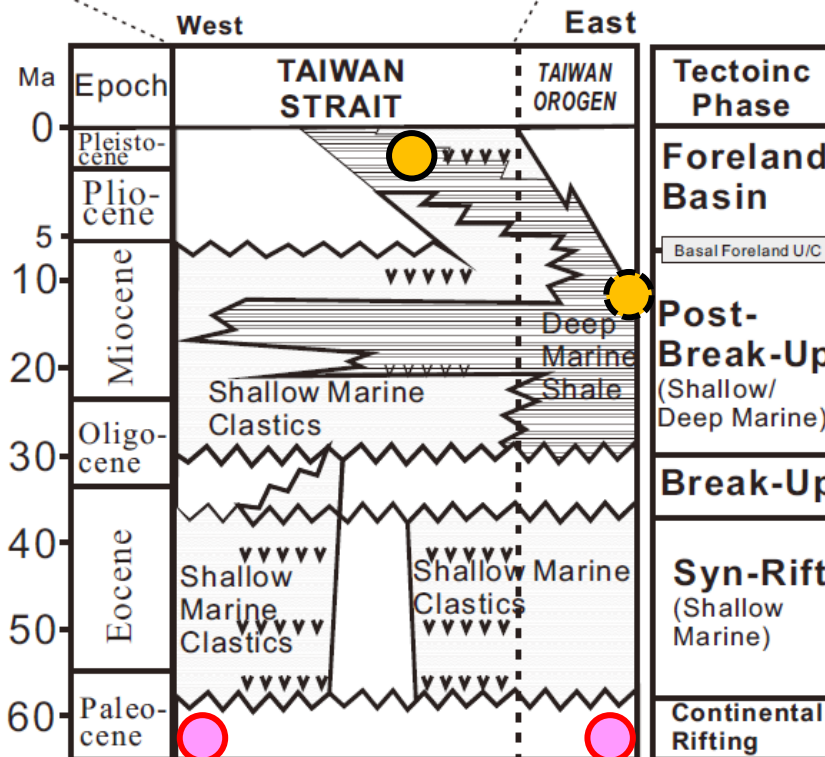
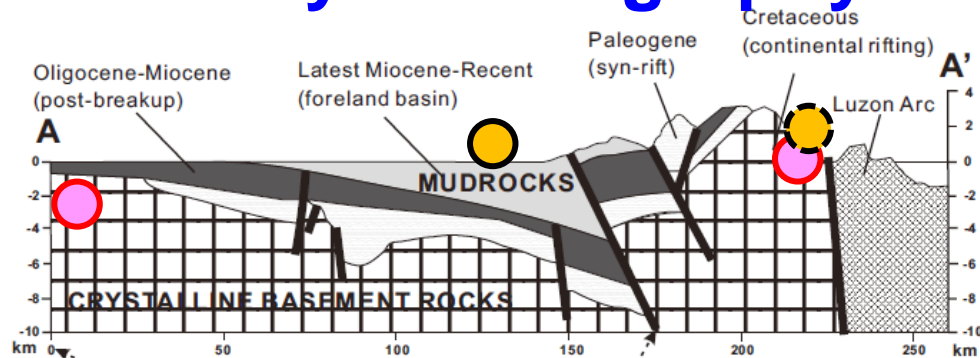


Fig.1

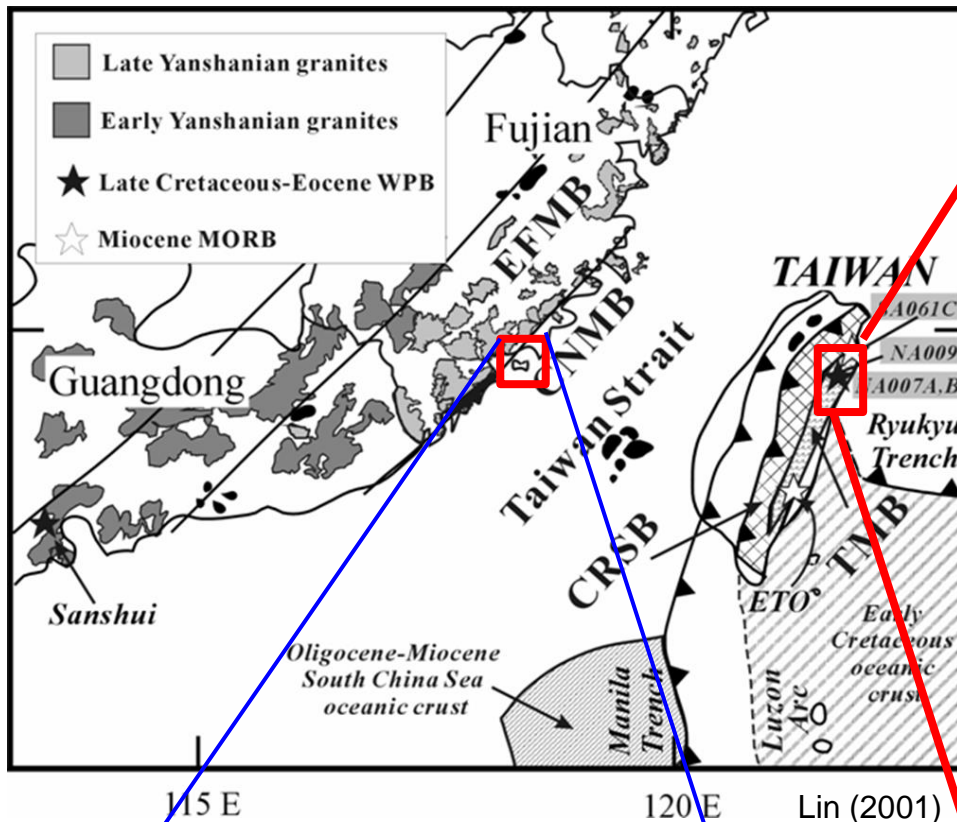


(Adopted from Lin et al., 2003)

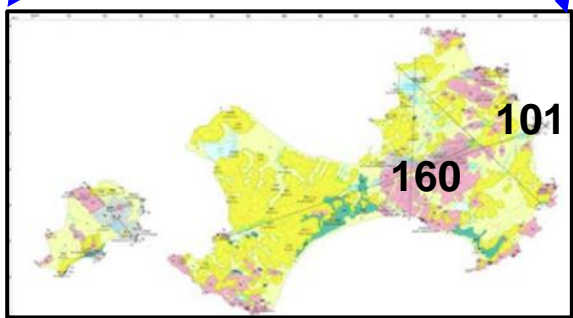




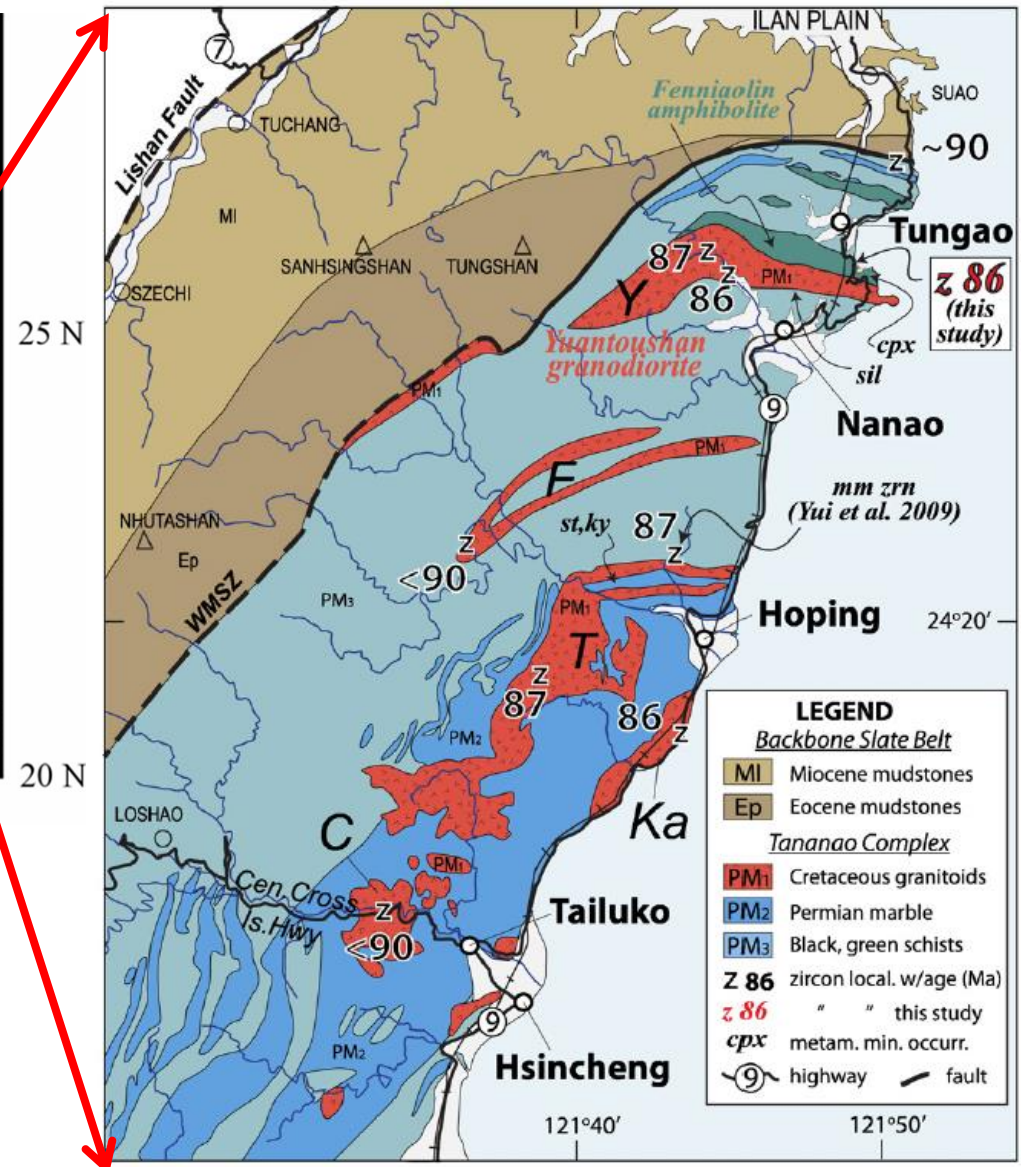
# Eurasian Continental Margin: Two Granitic Belts



Lin (2001)



Lin et al. (2011)



**LEGEND**

**Backbone Slate Belt**

- MI Miocene mudstones
- Ep Eocene mudstones

**Tananao Complex**

- PM<sub>1</sub> Cretaceous granitoids
- PM<sub>2</sub> Permian marble
- PM<sub>3</sub> Black, green schists

**Z 86** zircon local. w/age (Ma)

**z 86** " " this study

**cpx** metam. min. occur.

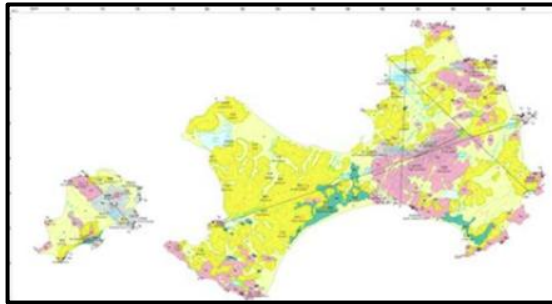
**9** highway **-** fault

Wintsch et al. (2011)

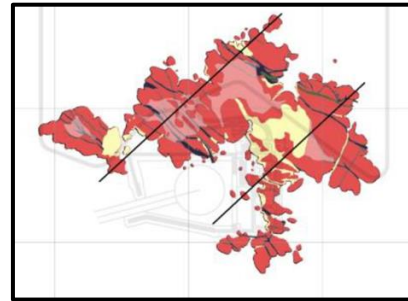


# Cretaceous Granitic Intrusions

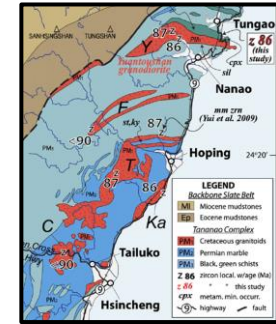
## K: Kinmen



## W: Wuqiu



## H: Eastern Taiwan

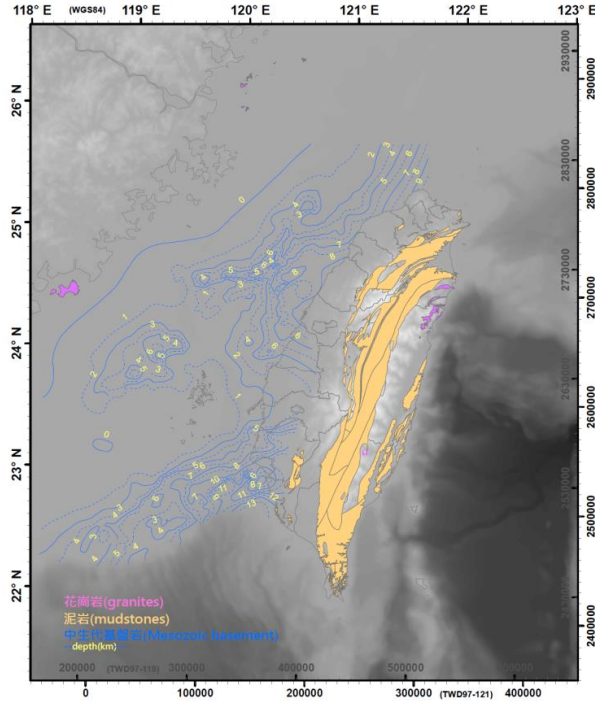




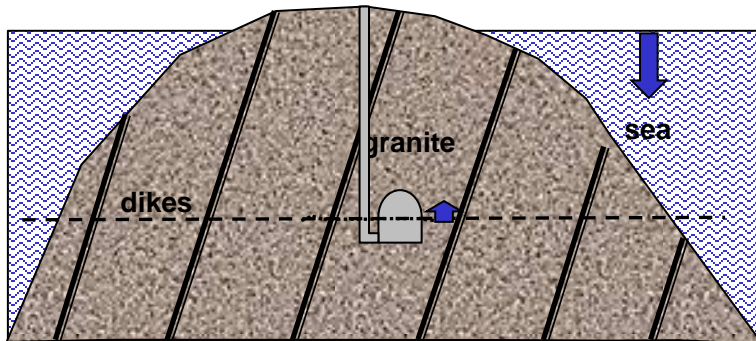
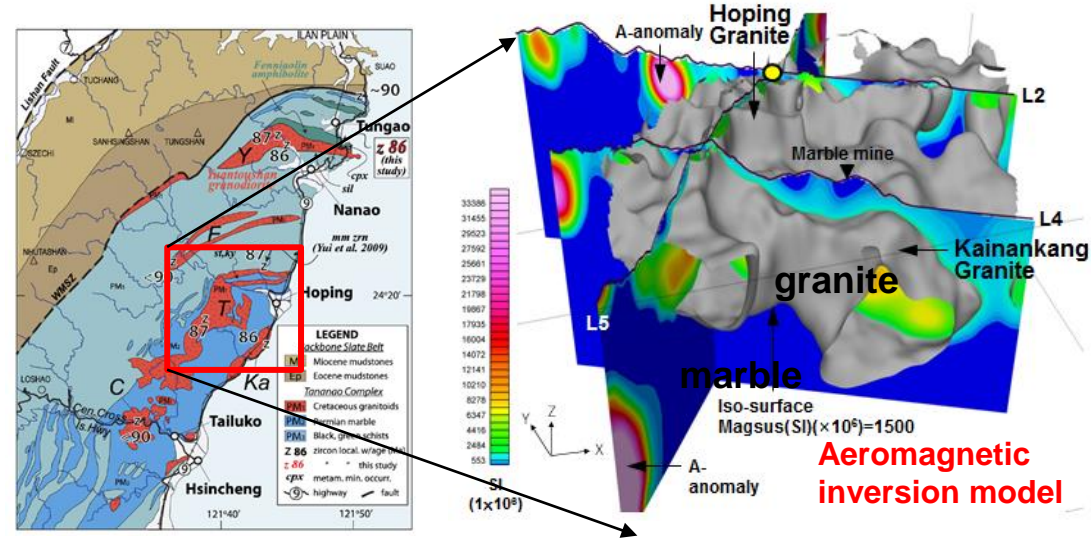
# Geological Disposal Concepts

## Granitic Host Rocks

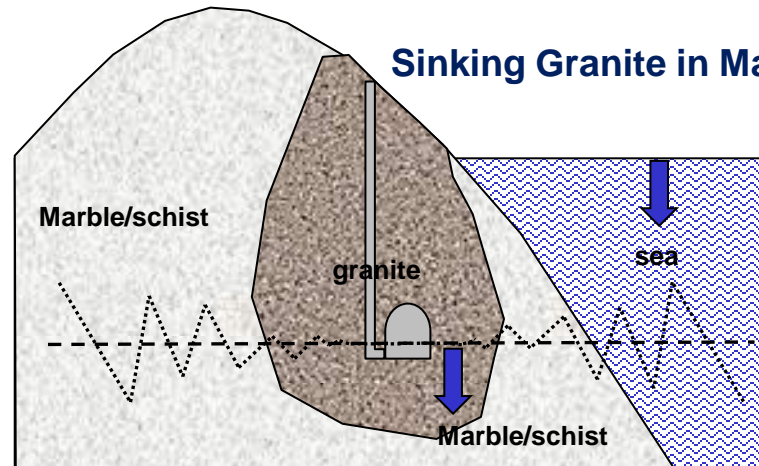
If waste disposal in a western off-shore island:  
Deep geological disposal in a granite rock mass



If waste disposal in eastern Taiwan:  
Deep geological disposal in a sinking granite rock mass with chemical buffer of huge surrounding marble/schist



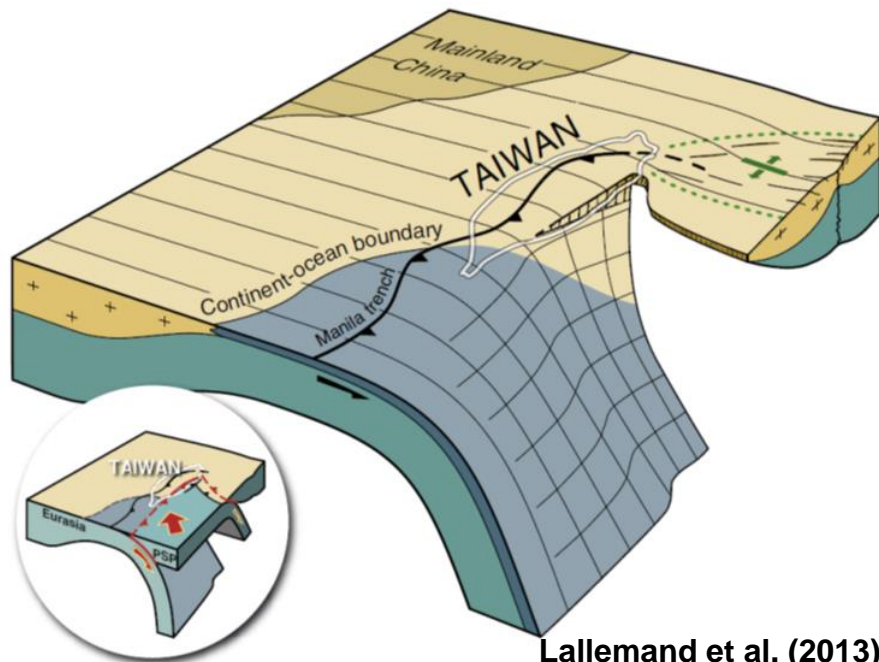
## Sinking Granite in Marble/schist





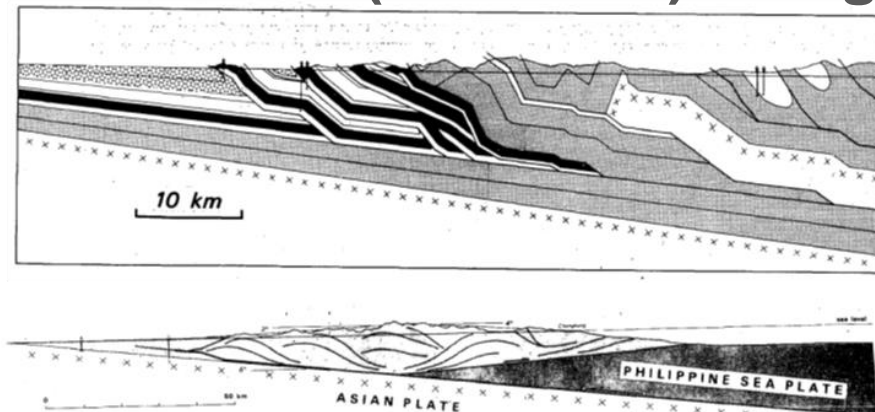
# Recent Tectonic Regime: Previous Studies

## ◆ Subducted continental crust

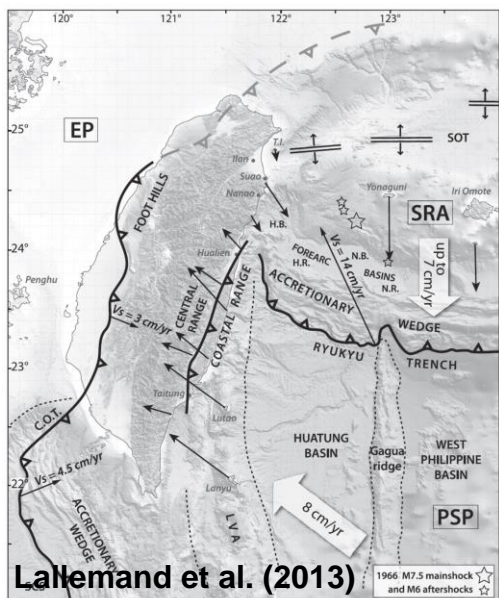


Lallemand et al. (2013)

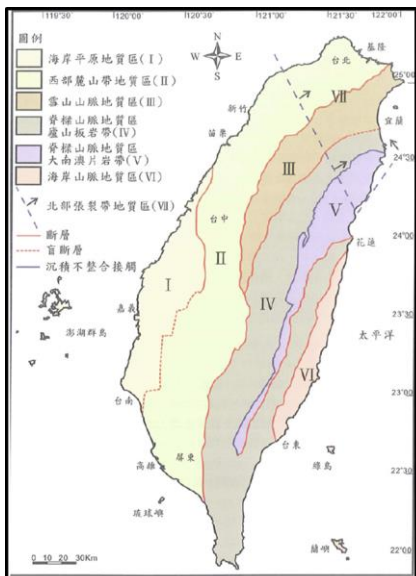
## ◆ Continental (bulldozer) Wedge



Suppe (1981)

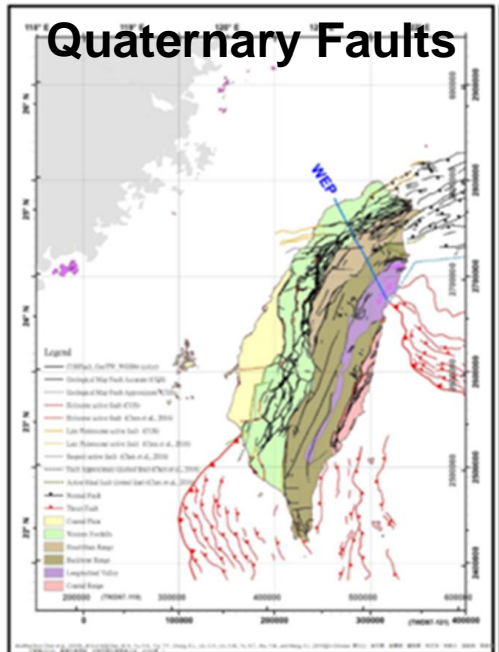


Lallemand et al. (2013)



Chen et al. (2016)

## Quaternary Faults



## Active Faults

經濟部中央地質調查所

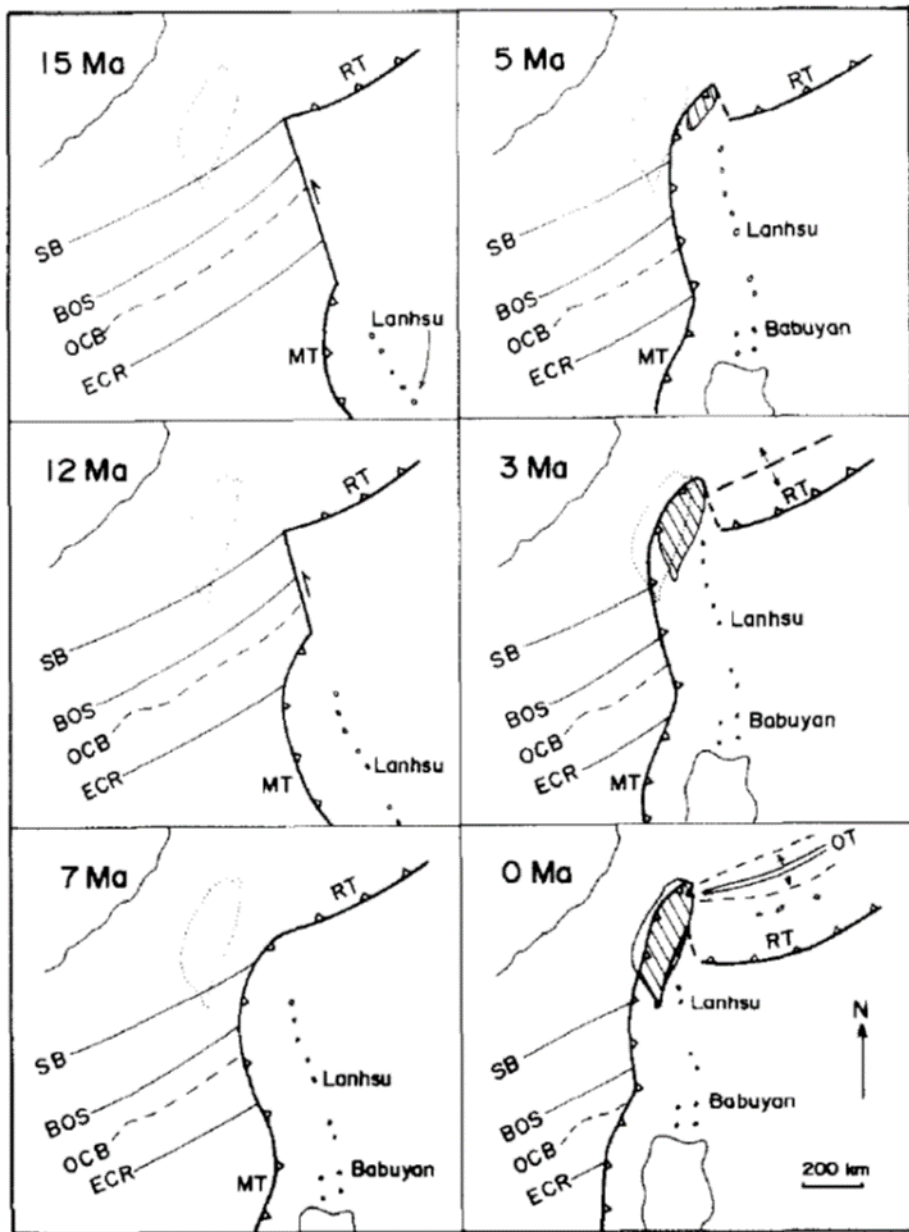
中華民國110年 (2021)

圖例  
第一類活動斷層  
(虛線為推測或隱伏部分)  
第二類活動斷層  
(虛線為推測或隱伏部分)  
1900-2020年發性地震震中位置  
6.0以上的震央位置  
M規模 < 7  
T規模 ≤ 8.3

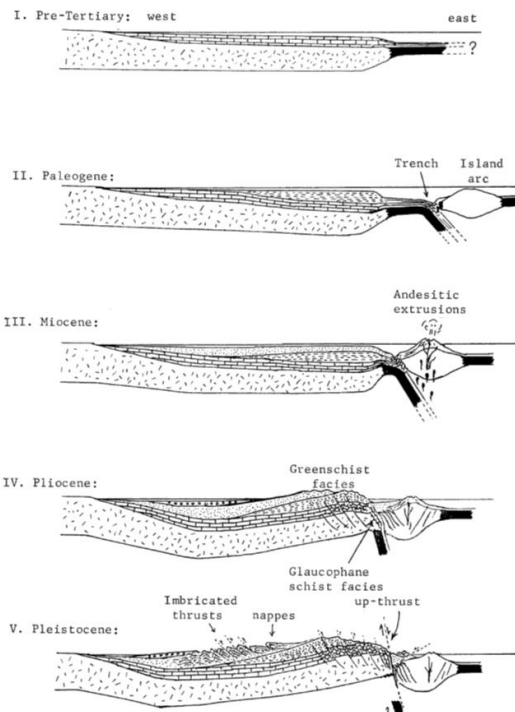
林保文、劉承志、周景雄、林燕慈 編繪



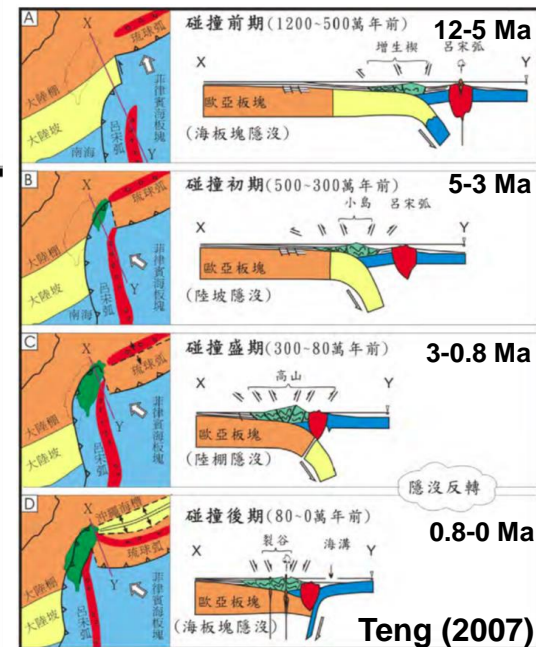
# “Arc-Continent Collision” Models



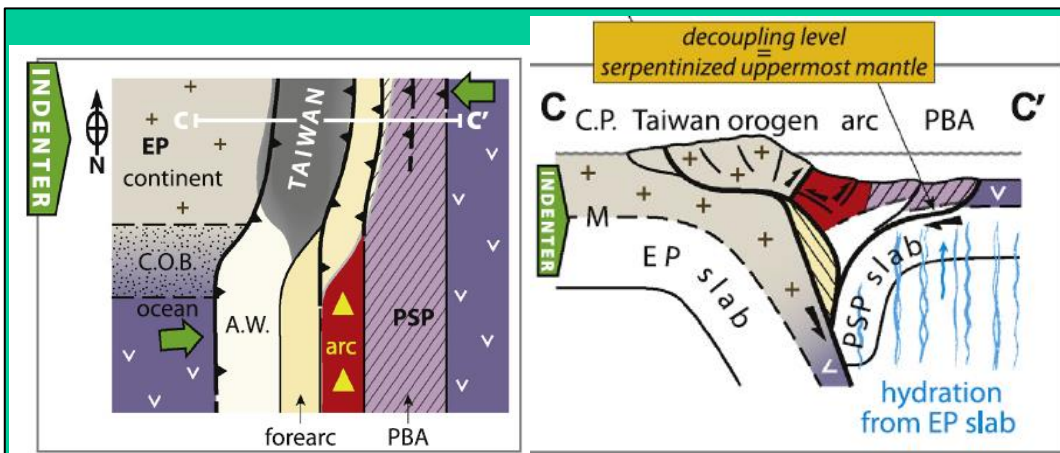
Teng (1990)



Cai (1972)



Teng (2007)

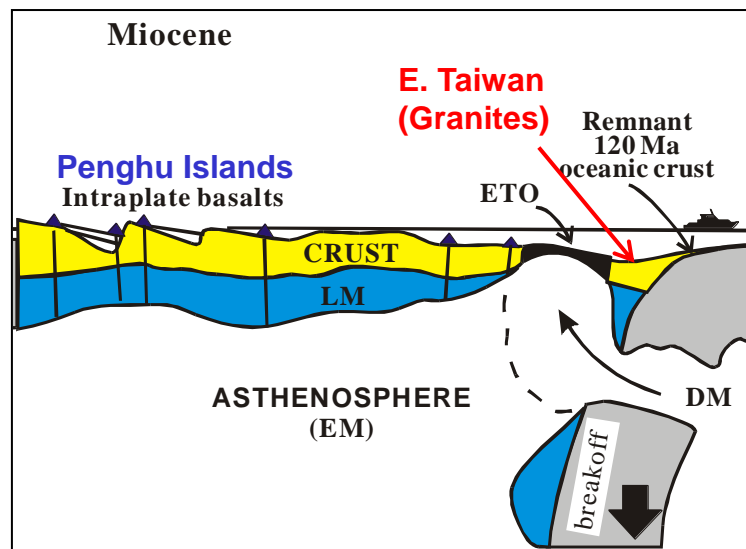
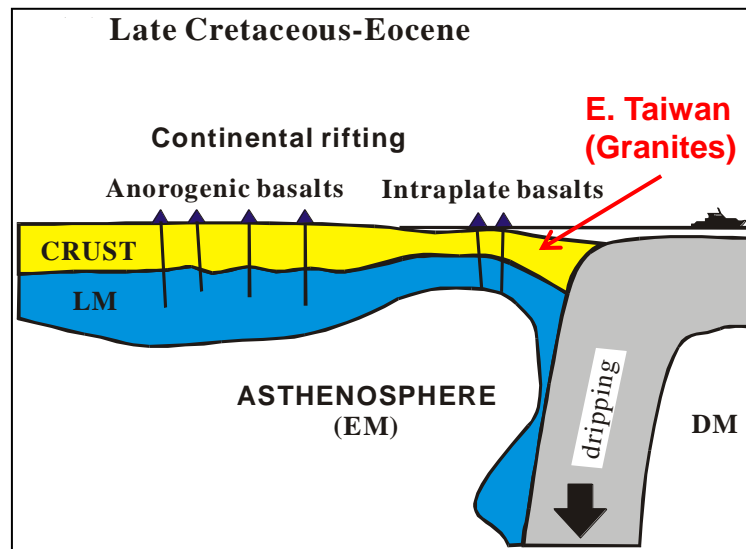
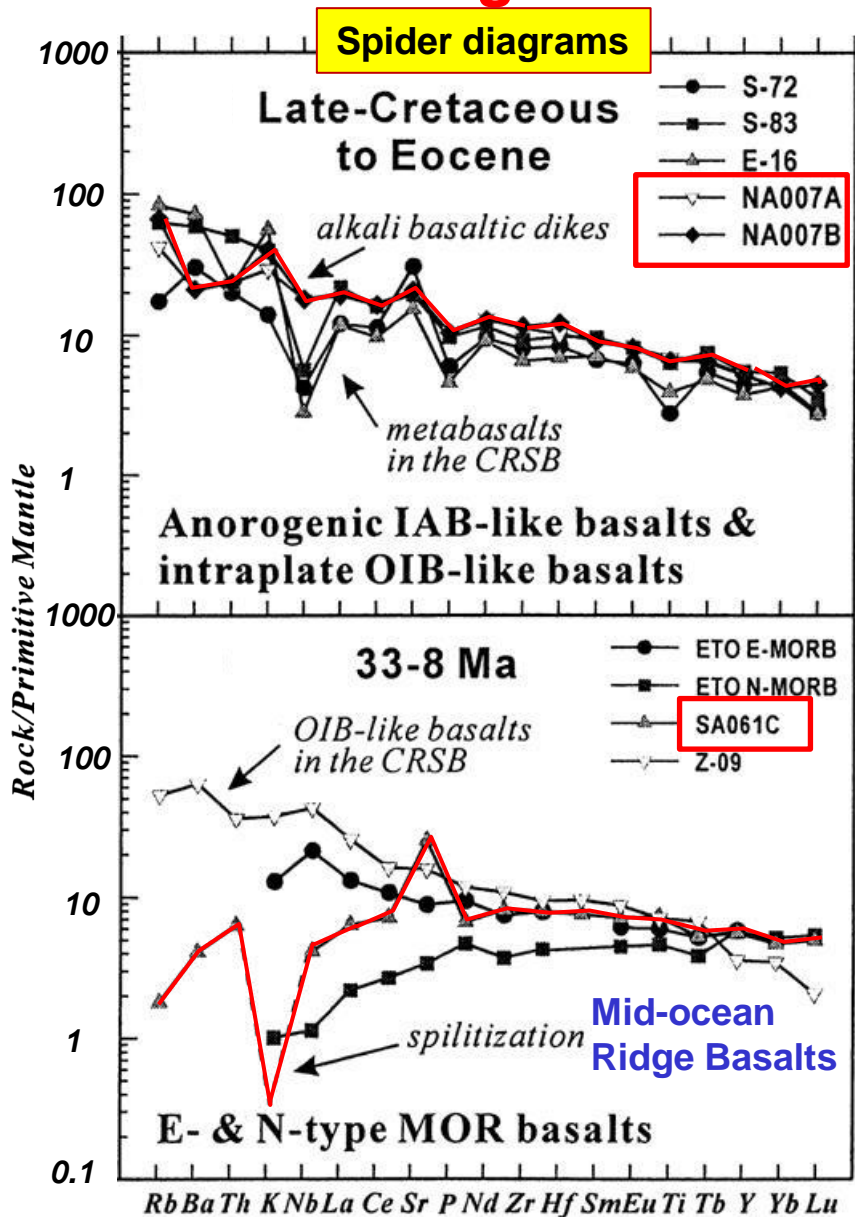


Lallemand et al. (2014)



# Magmatotectonic Constraints on Tectonics

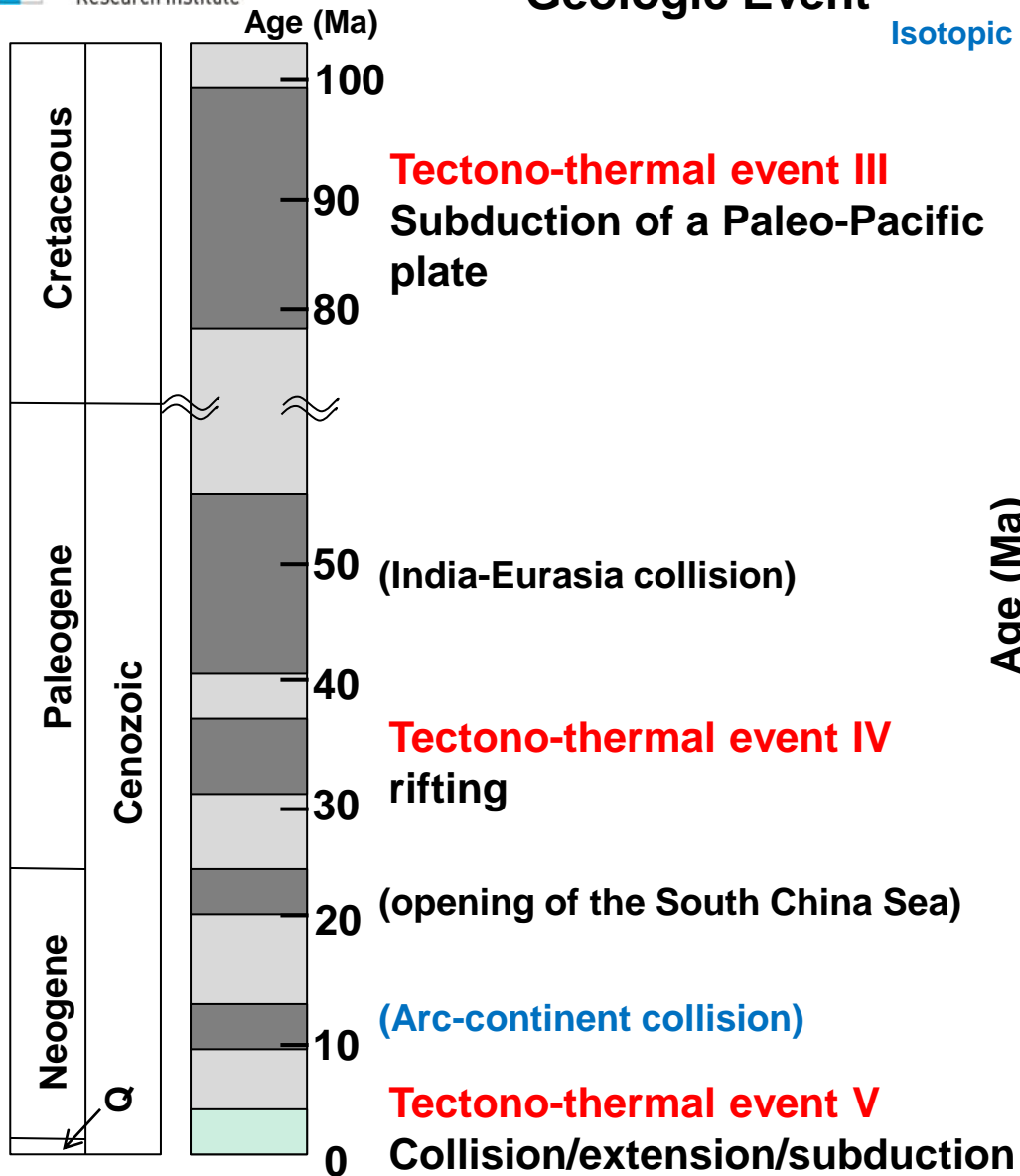
## Before Arc-Continent Collision



Lin, W. (2001); Yui et al. (1994); Chung and Sun (1992)

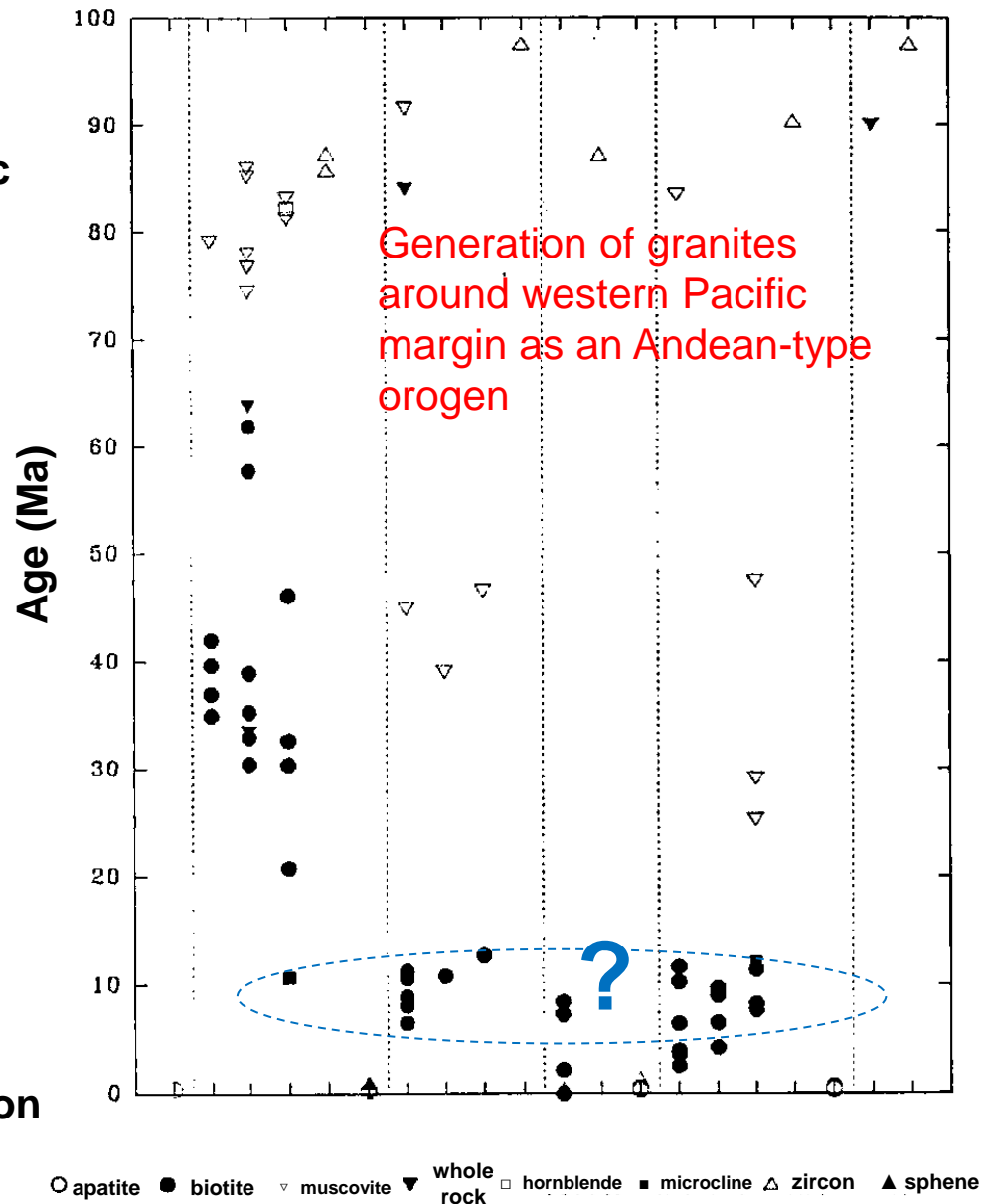


# Geologic Event



# Granitic bodies (crystalline basement)

Isotopic dating FT Sr K Ar Pb FT Sr K Ar Pb Sr Pb FT Sr K Ar Pb FT Sr Pb

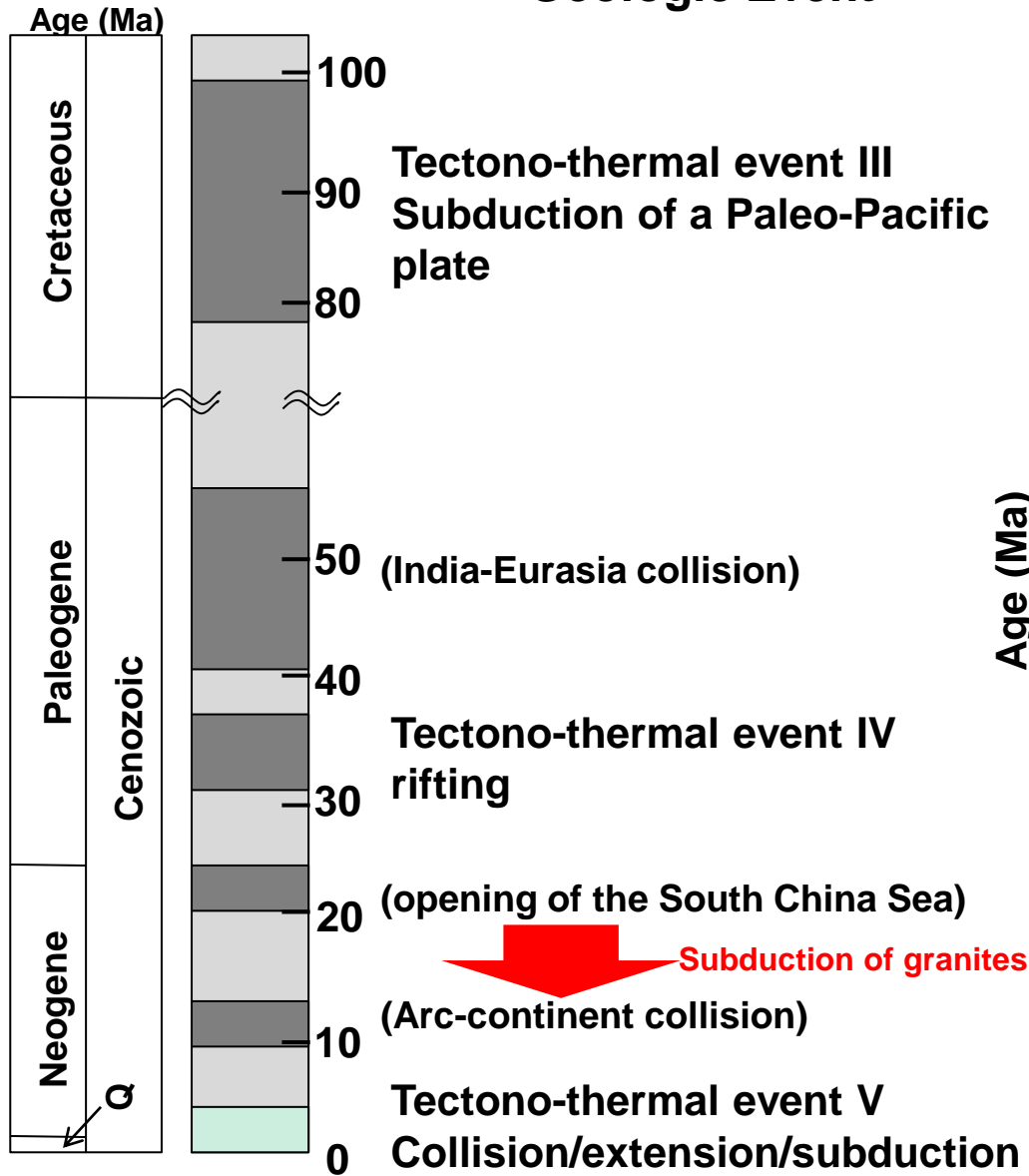


(Lan et al., 2008)

(Wang and Lan 1995)



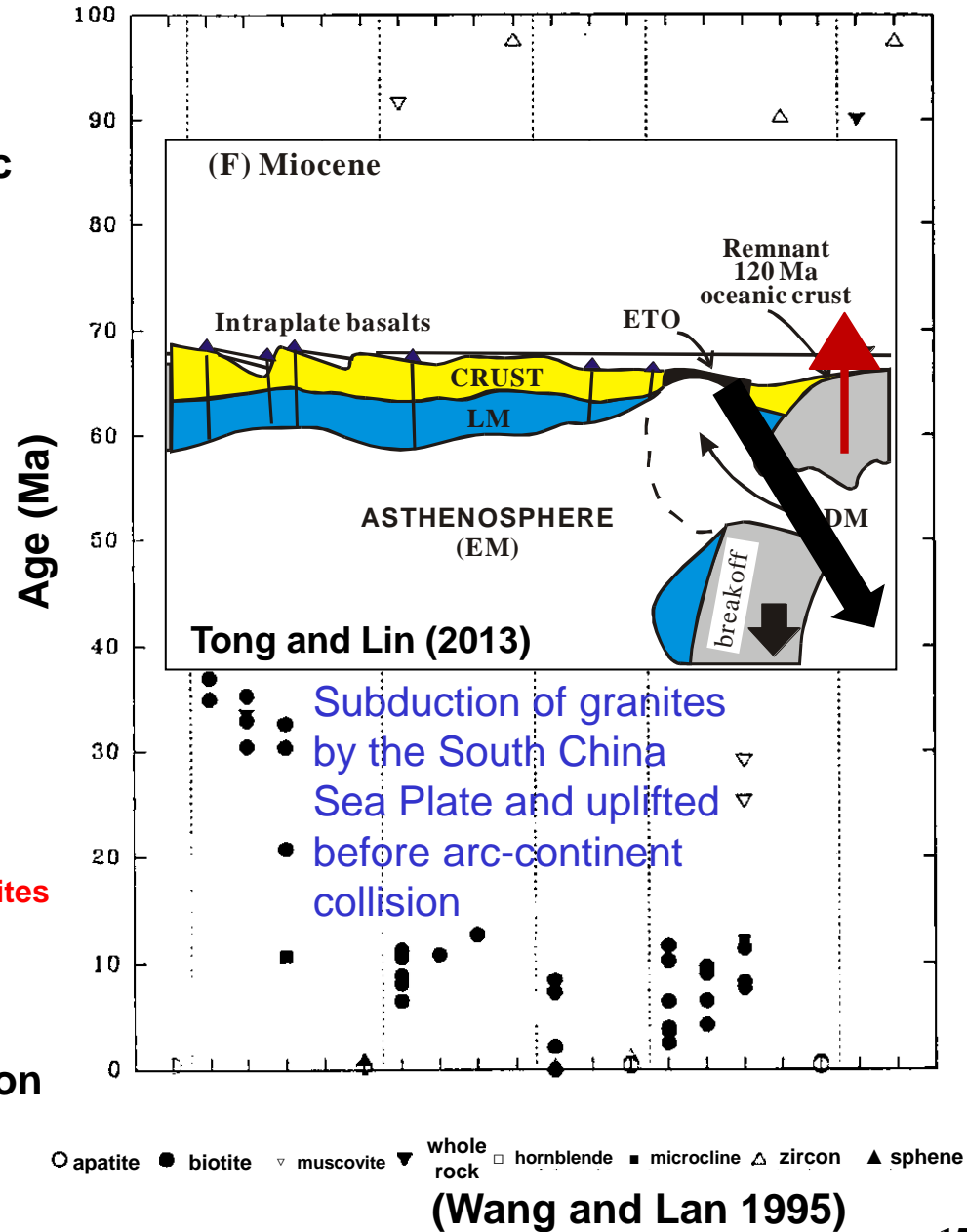
# Geologic Event



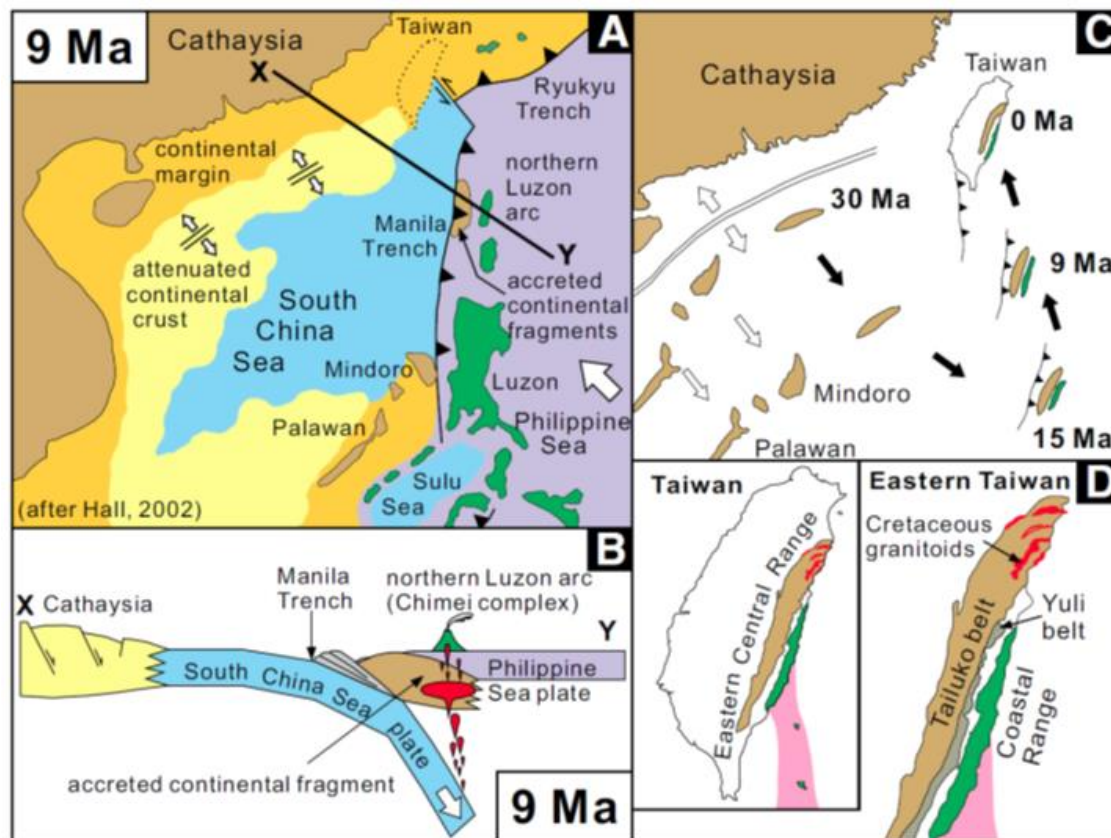
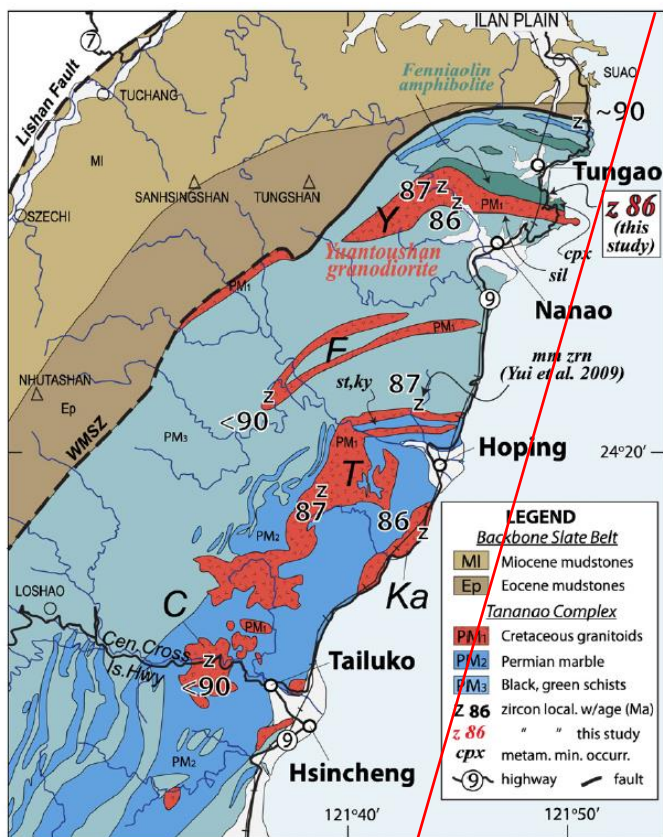
(Lan et al., 2008)

# Granitic bodies (crystalline basement)

Ki Y F T C Ka  
FT Sr K Ar Pb FT Sr K Ar Pb Sr Pb FT Sr K Ar Pb FT Sr Pb

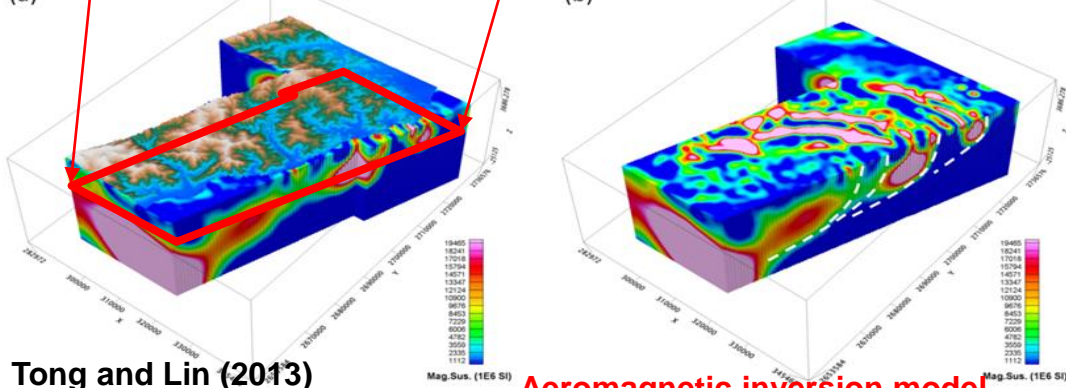


# "Continent-Microcontinent-Arc Collision" Model



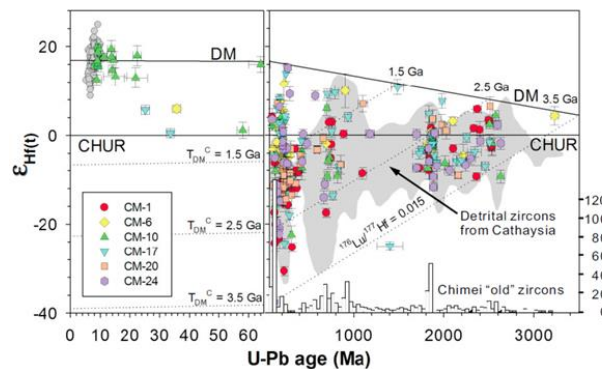
Shao et al. (2015)

## (a) The Sea Plate beneath the Microcontinent



Tong and Lin (2013)

Aeromagnetic inversion model



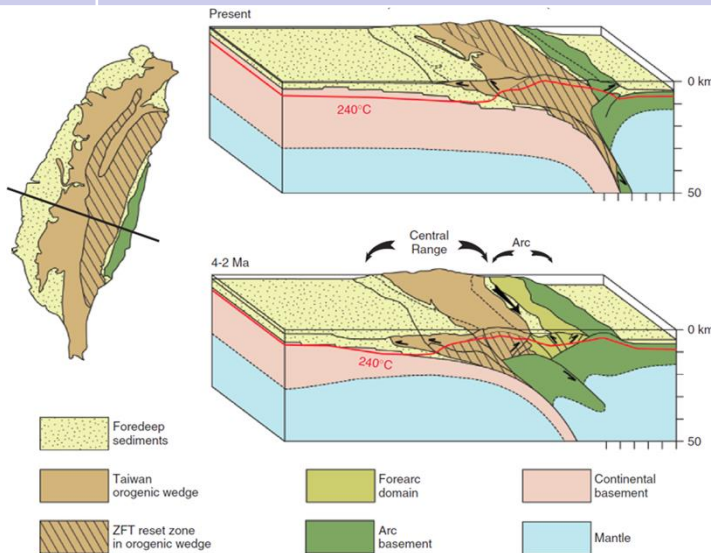
Old zircons  
in the Luzon  
Arc  
volcanics

Shao et al. (2015)

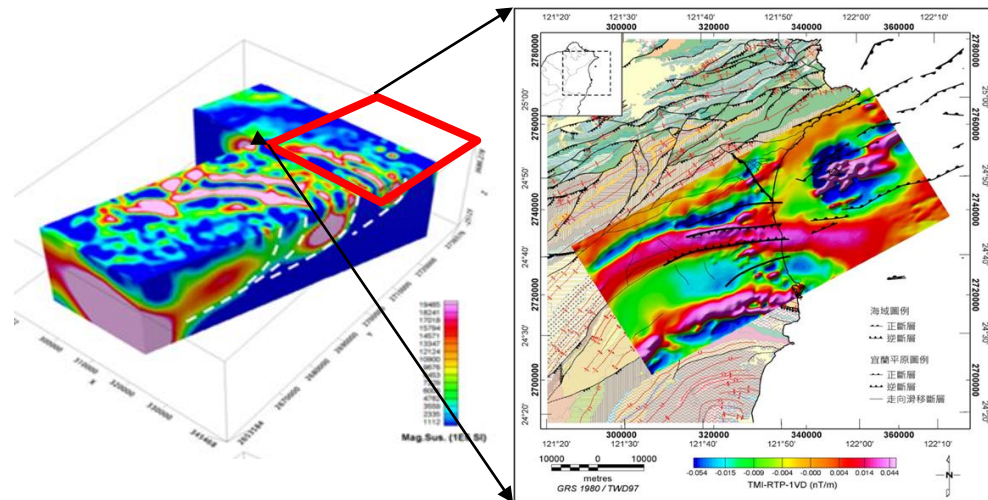


# Long-term Stability by Tectonics

Granites in E. Taiwan	Arc-Continent (Oblique) Collision	Arc-Microcontinent-Continent Collision
5-2 Ma	Mountain building in from N to S;	Mountain building by accretion of micro-continent and/or volcanic arcs;
2 Ma	Mountain collapse/rapid uplifting in the granitic/metamorphic belt;	Subsiding/rapid cooling in the granitic/metamorphic belt during the initial subduction of the Philippine Sea Plate
1 Ma-present	Extensional setting due to westward migration of Okinawa Trough	Extensional setting due to westward migration of Okinawa Trough



Kirstein et al. (2009)

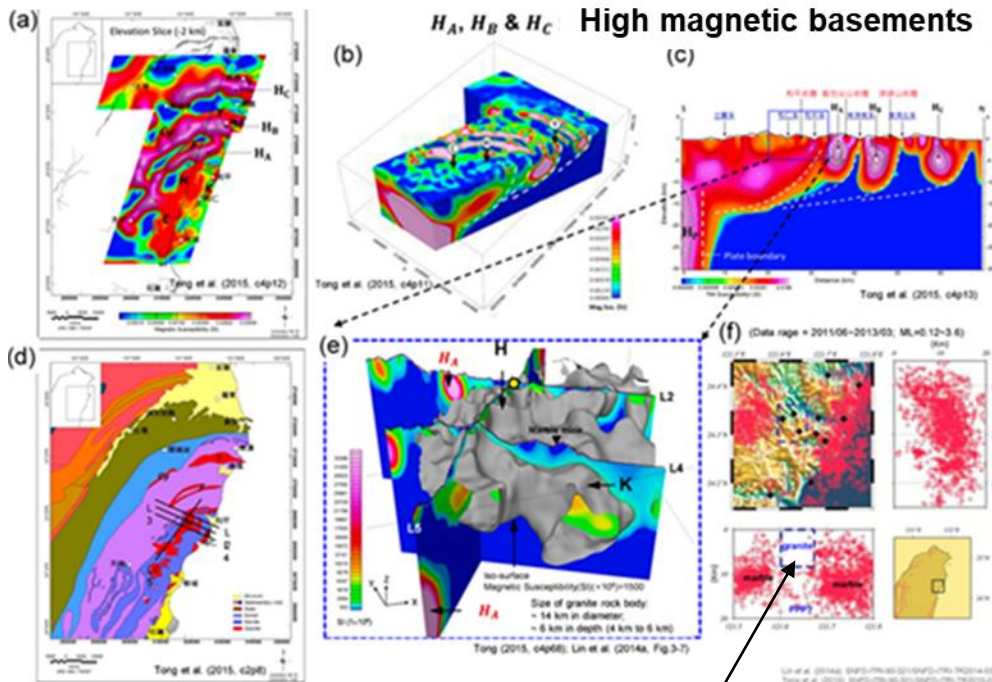


Tong et al. (2013)

# Structrual Characterization and Suitability

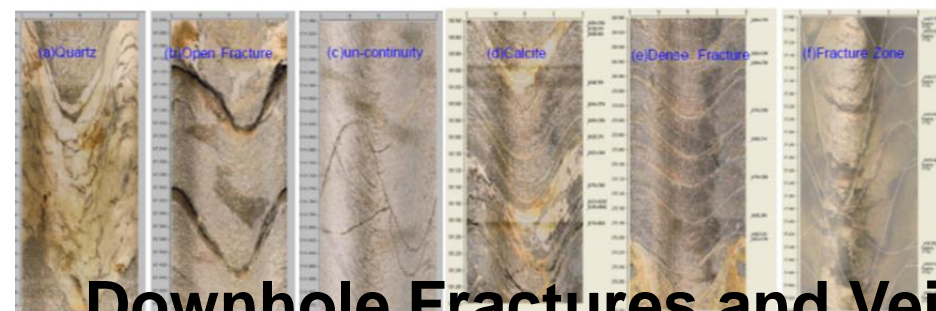
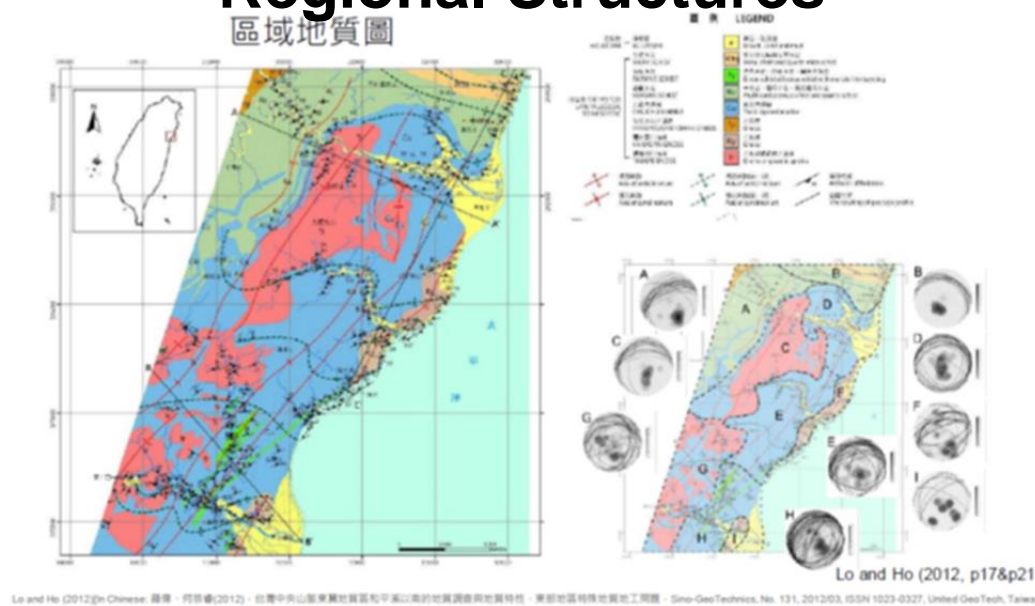
## Regional Structures

### Geophysical Surveys:

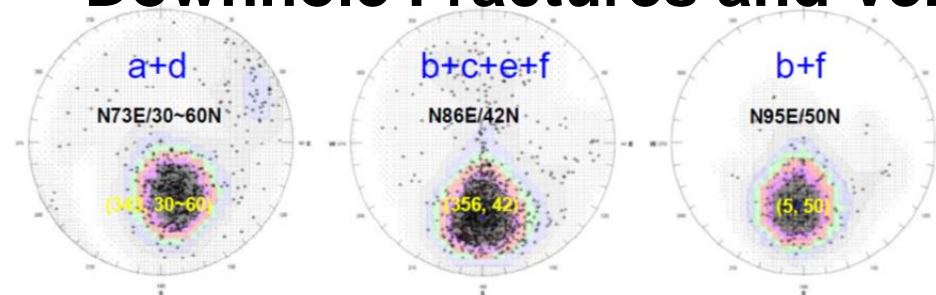


**Aseismic zone**

區域地質圖



### Downhole Fractures and Veins

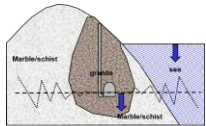






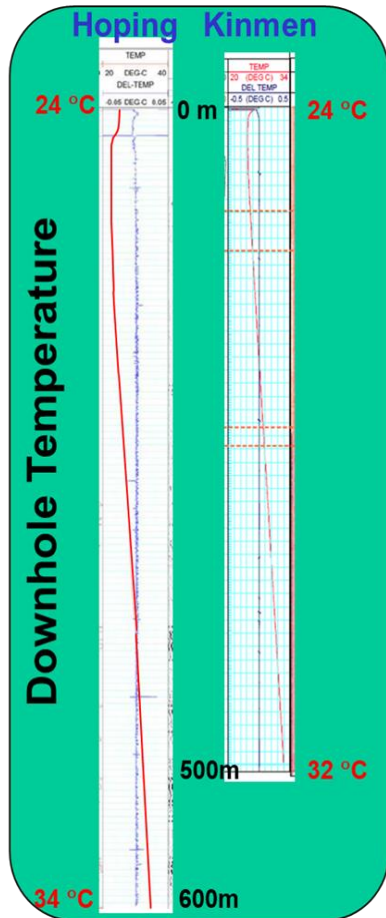
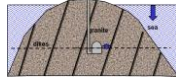
# Evolutionary Thermal History

Regional geothermal  
gradients: **<20°C/km**



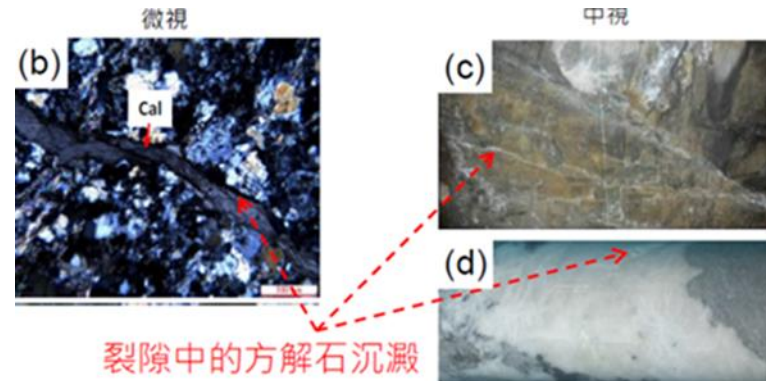
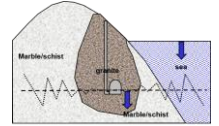
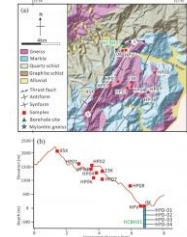
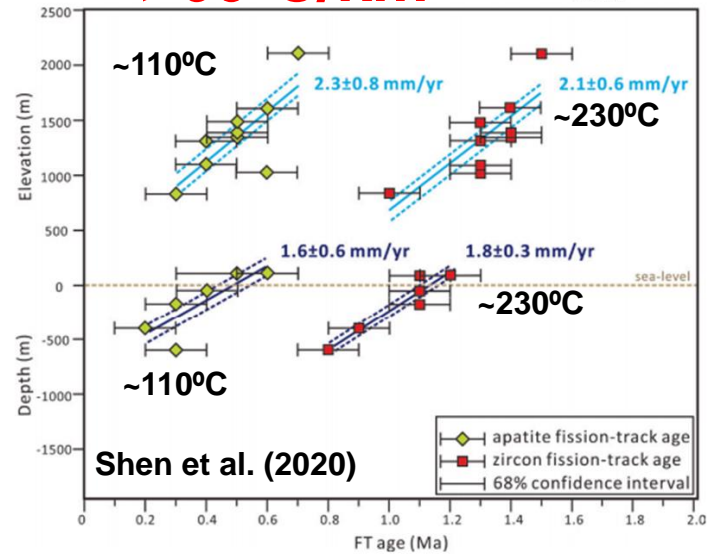
H

K



(a) Paleo-thermal Cooling  
History

**>60°C/km**

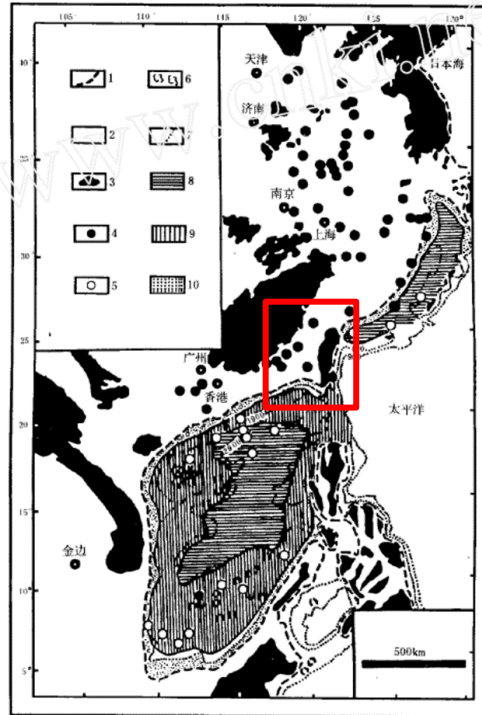
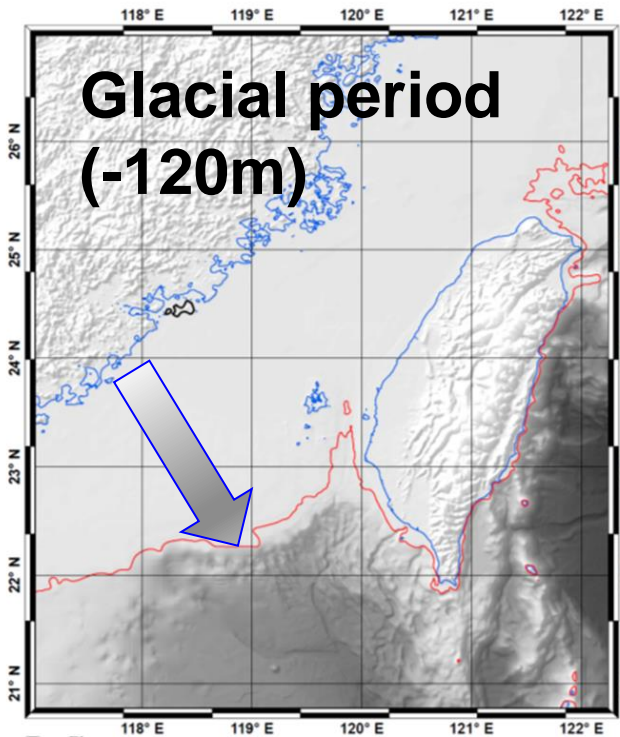


**Carbonate Sealing**



# Climate and Sea-level Changes

## If Host Rock = Granite



Variations of Sea level in the last 900 thousand years

- ◆ Global : +10 m to -130 m
- ◆ Taiwan: +7 m to -120 m

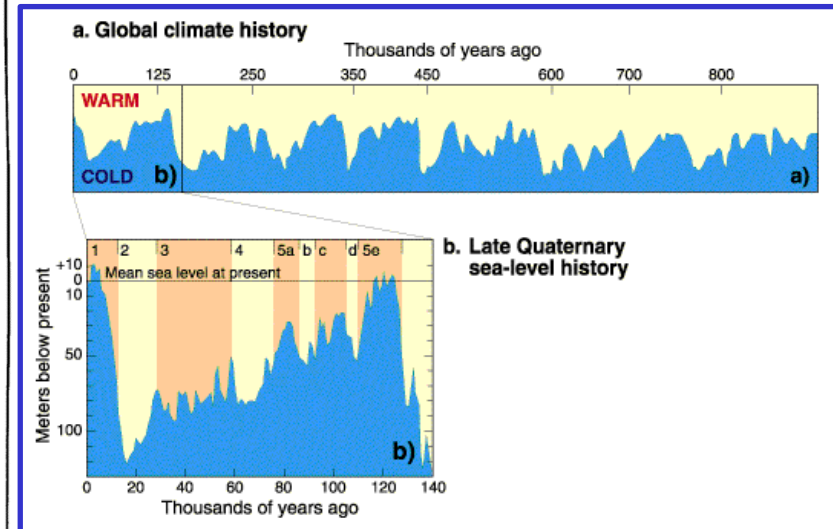
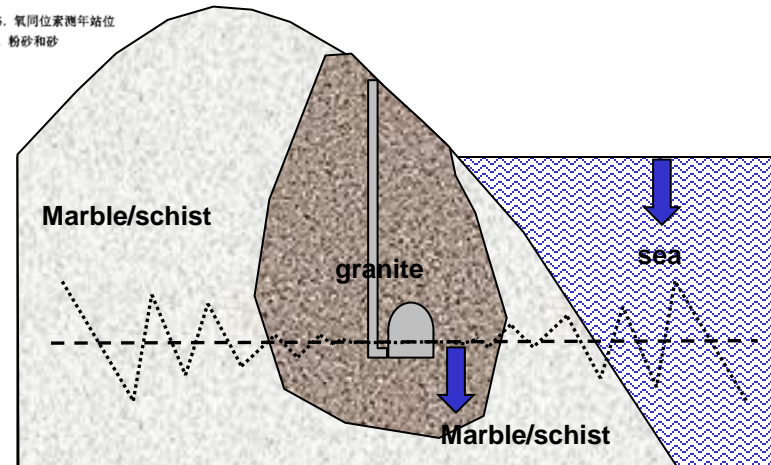
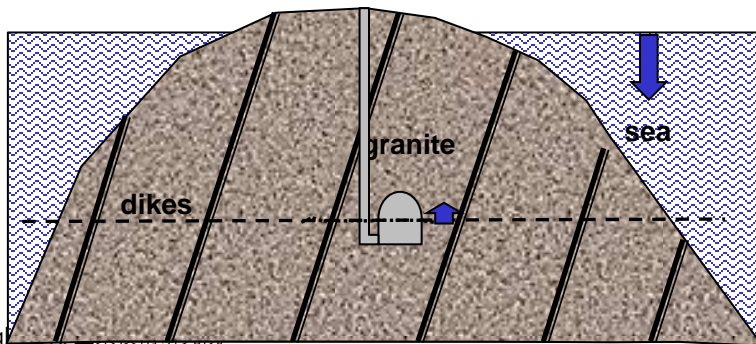


图1 中国海末次盛冰期低海面时古地理略图

1. 海岸线
2. 平原 (<300m)
3. 山地 (>300m)
4.  $^{14}\text{C}$  测年站位
5. 氧同位素测年站位
6. 珊瑚礁
7. 等深线 (m)
8. 粘土
9. 含钙粉砂质泥
10. 粉砂和砂

Xie et al. (1996)







# Conclusion: A Comparison of Long-term Stability

Potential Repository Host Rocks		Granites		Mudstones	Mesozoic basement
		Western offshore islands	Eastern Taiwan	Southwestern Taiwan	Taiwan Strait to Western Taiwan
Lithology		Granite/Granite-Gneiss	Granite/Granite-Gneiss	Siltstone/Mudstone	Volcanic/Meta-sedimentary rocks
Age		100-140 Ma	80-90 Ma	1-2 Ma	60 Ma
Stability based on geo-history	Tens-of-million-year scale	13 Ma (Coastal environment)	10 Ma (Deep sea)	Shallow sea or coastal environment	10 Ma (Coastal environment)
	Million-year scale	Tiny crustal movement (Coastal environment)	6.5-3.5 Ma (Rapid uplifting and mountain building)	6.5-3.5 Ma (Rapid subsidence)	Tiny crustal movement (Penghu Islands in Taiwan Strait); Rapid subsidence (Mesozoic basement beneath Western Taiwan at depths > 2000m)
			(High geothermal gradient with carbonate-quartz vein sealing)	3.5~0.5 Ma (Subsidence)	
			1.5 Ma (Extensional subsidence and rapid cooling)	0.5 Ma (Rapid uplifting)	
Tens-of-thousand-year scale	(Diffusive fault zones)	(Slowly subsidence)	Active Faults	No movement since 5 ka (Penghu Islands)	
Tectonic setting		Within Plate	Continental Margin	Continental Margin	Within Plate
		Extensional	Compressional transition to extensional	Compressional	Extensional
		(Far away deformation front)	(Deformation Zone with carbonate sealing)	(Deformation front)	(Far away deformation front)
Seismicity		Aseismic	Aseismic (Need further investigation)	Seismic zone	Aseismic
Active faults		(Need further investigation)	(Need further investigation)	Intensive seismicity	None
Sea-level/climate changes (-120 m to +7m related to the current sea level)		Sea-level rise → island; Sea-level drop → land	Sea-level rise → land; Sea-level drop → land	Sea-level rise → beach; Sea-level drop → land	Sea-level rise → island; Sea-level drop → land



Suitable/favorable



unsuitable/unfavorable



**Thanks for Your Attention!**