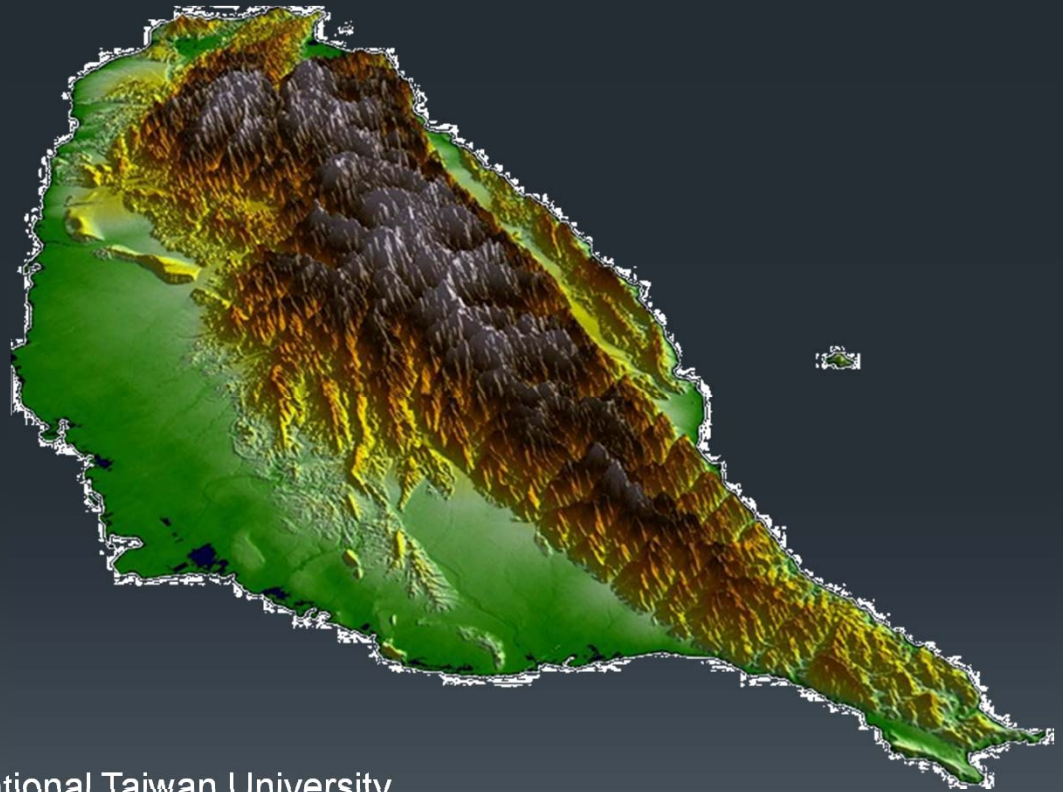


Shoreline Changes of Taiwan since the Last Glacial Maximum

末次最大冰期以來，臺灣海岸線變遷



Chen Wen-Shan

Department of Geosciences, National Taiwan University,

臺灣大學地質科學系

陳文山 教授

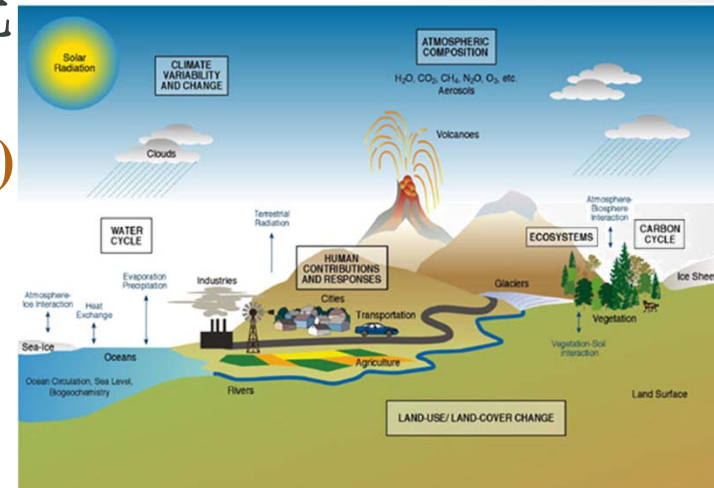
Outline

- **(1) Long term effects of climate changes**
長週期氣候變遷
- **(2) Pleistocene climate changes and sea-level fluctuations**
更新世氣候變遷與海面變動
- **(3) Sea-level rise since the Last Glacial Maximum (< 27,000 year BP)**
末次最大冰期以來 (< 27,000 year BP) 海面上升
- **(4) Tectonic deformation in Taiwan**
臺灣構造活動 (地殼變形)
- **(5) Shoreline changes in Taiwan since the Last Glacial Maximum**
末次最大冰期以來臺灣海岸變遷
- **(6) The relationship between archaeological sites and shorelines in the Late Holocene (< 5,000 year BP)**
5,000年以來考古遺址分布與海岸線的關係
- **(7) Asia mammal faunas migration in the glacial period**
冰河時期亞洲大陸動物遷移路線

(1) Long term effects of climate changes

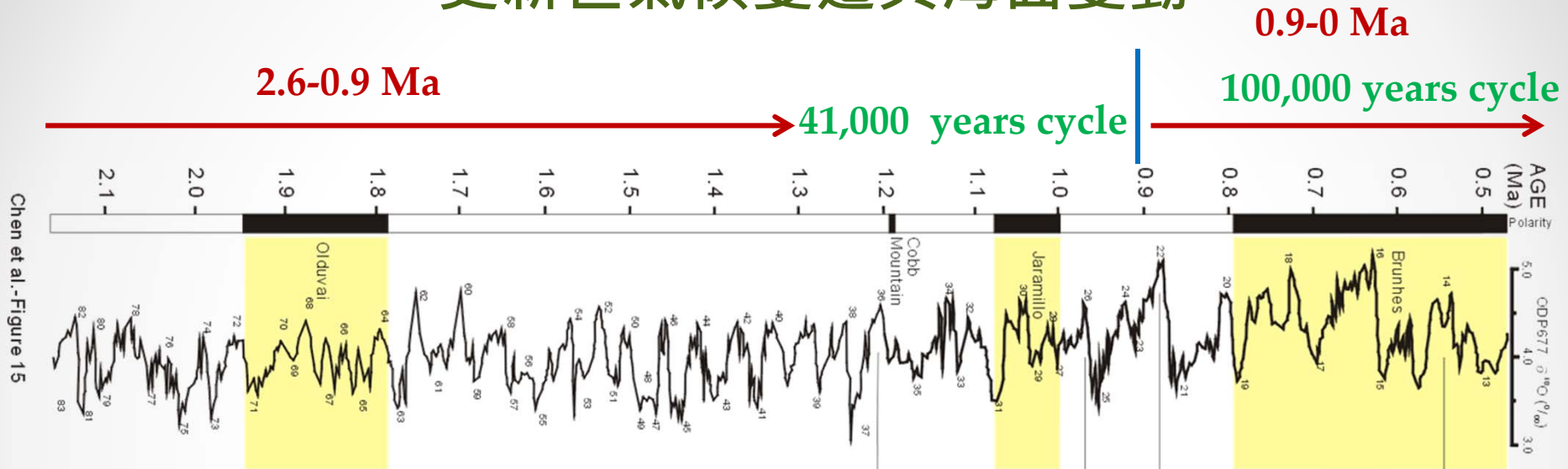
長週期氣候變遷

- **Long term**
- **1. plate tectonics 板塊運動 (百萬年)**
- **2. changes in planet orbits 行星軌道變化 (數十萬至數萬年)**
- **3. volcanism 火山作用 (數十萬至數十年)**
- **4. ocean conveyor circulation 海洋變化 (數十萬至數年)**
- **Short term**
- **solar activity 太陽活動 (數百至十一年)**
- **human activity 人類活動 (數百至數十年)**

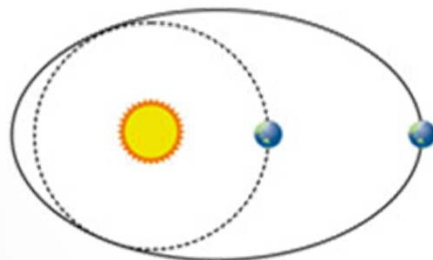


(2) Pleistocene climate changes and sea-level fluctuations

更新世氣候變遷與海面變動



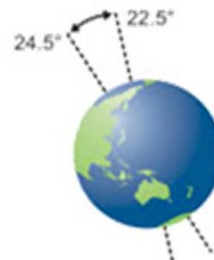
Milankovitch cycles 米蘭科維奇週期
changes in planet orbits



Eccentricity

偏心率

100,000 years

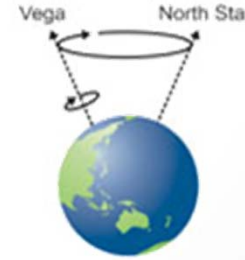


Obliquity

自轉軸傾斜角度

(22.5-24.5°)

41,000 years



Precession

自轉軸擺動角度

23,000 years

(3) Sea-level rise since the Last Glacial Maximum (< 27,000 year BP)

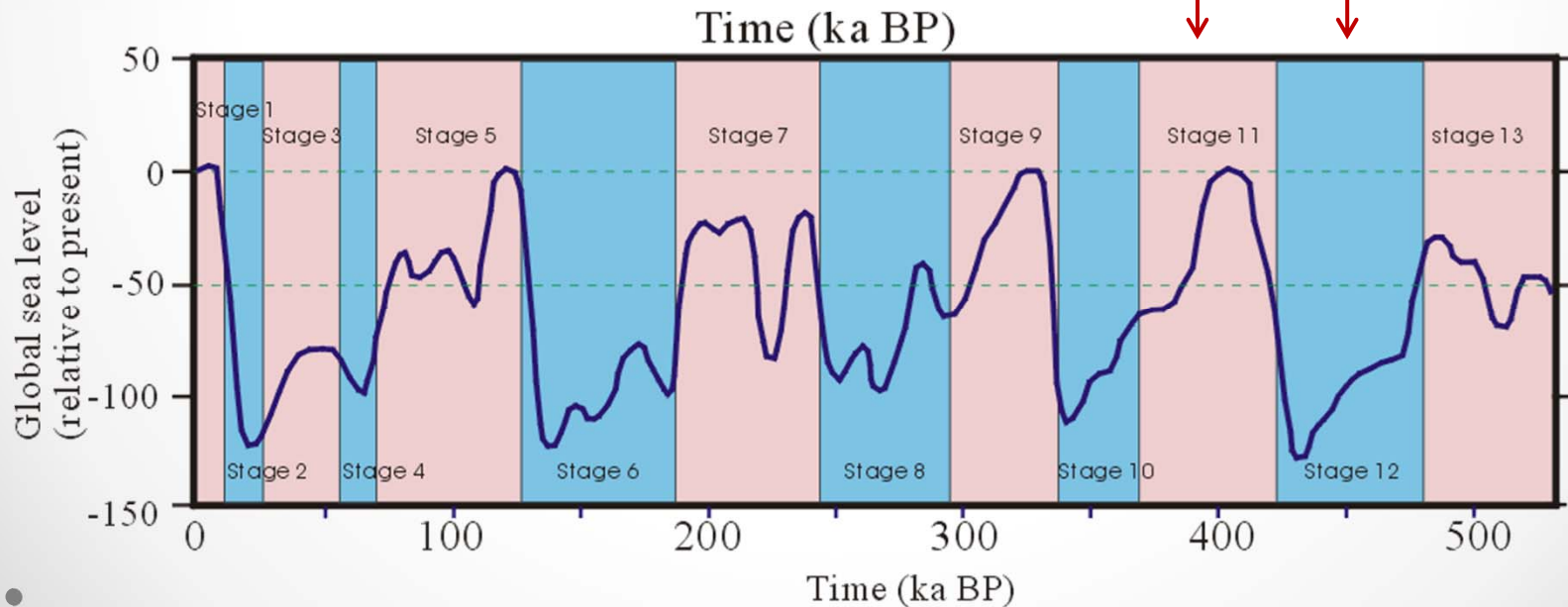
末次最大冰期以來 (< 27,000 year BP)海面上升

Late Pleistocene sea-level changes

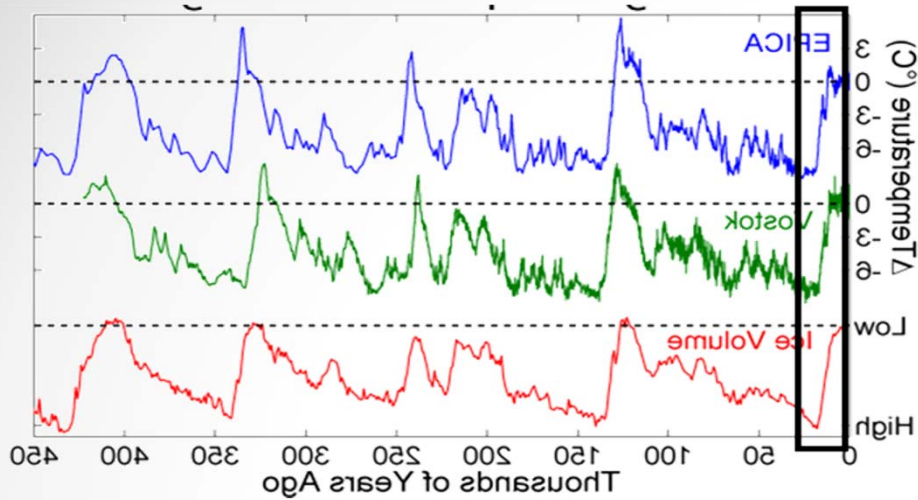
- 100,000-years eccentricity cycle prior to 0.9 million years ago

Interglacial period
間冰期 (暖)

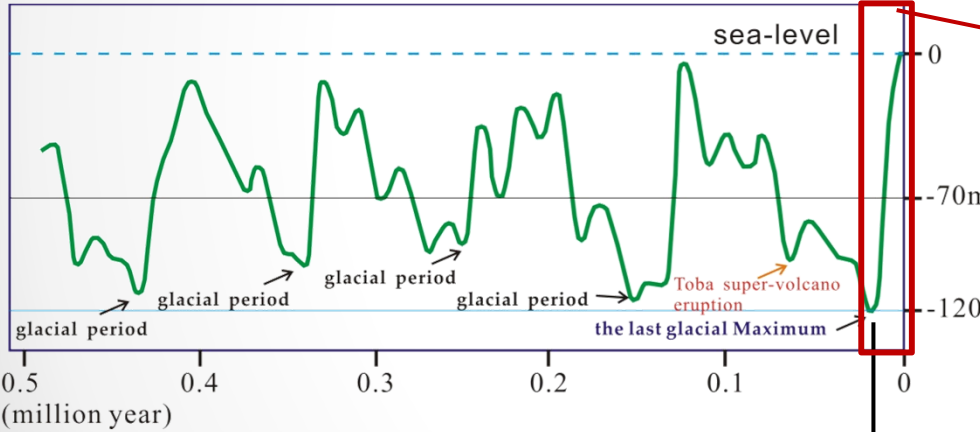
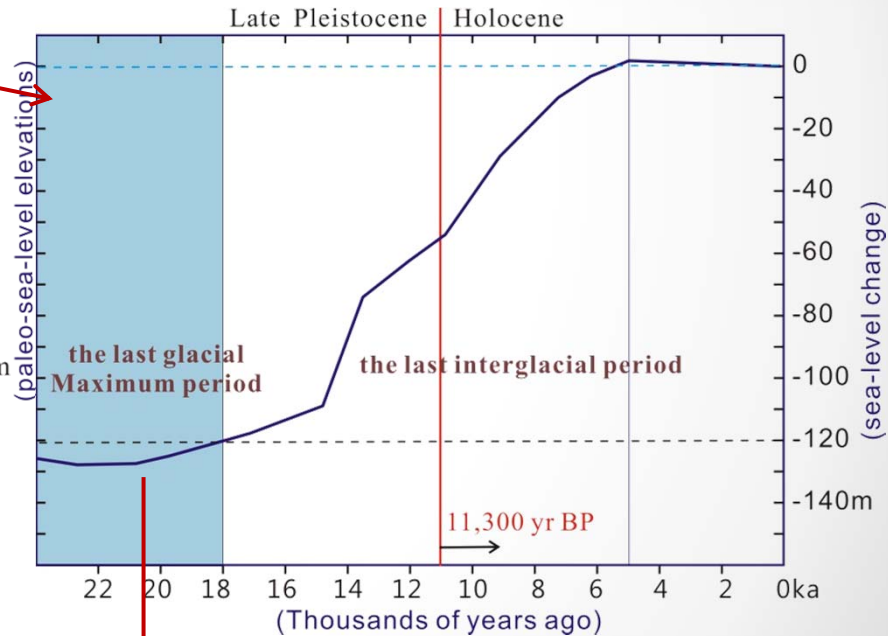
Glacial period
冰期 (冷)



Ice age Temperature Changes



Sea-level Changes since 24,000 year BP



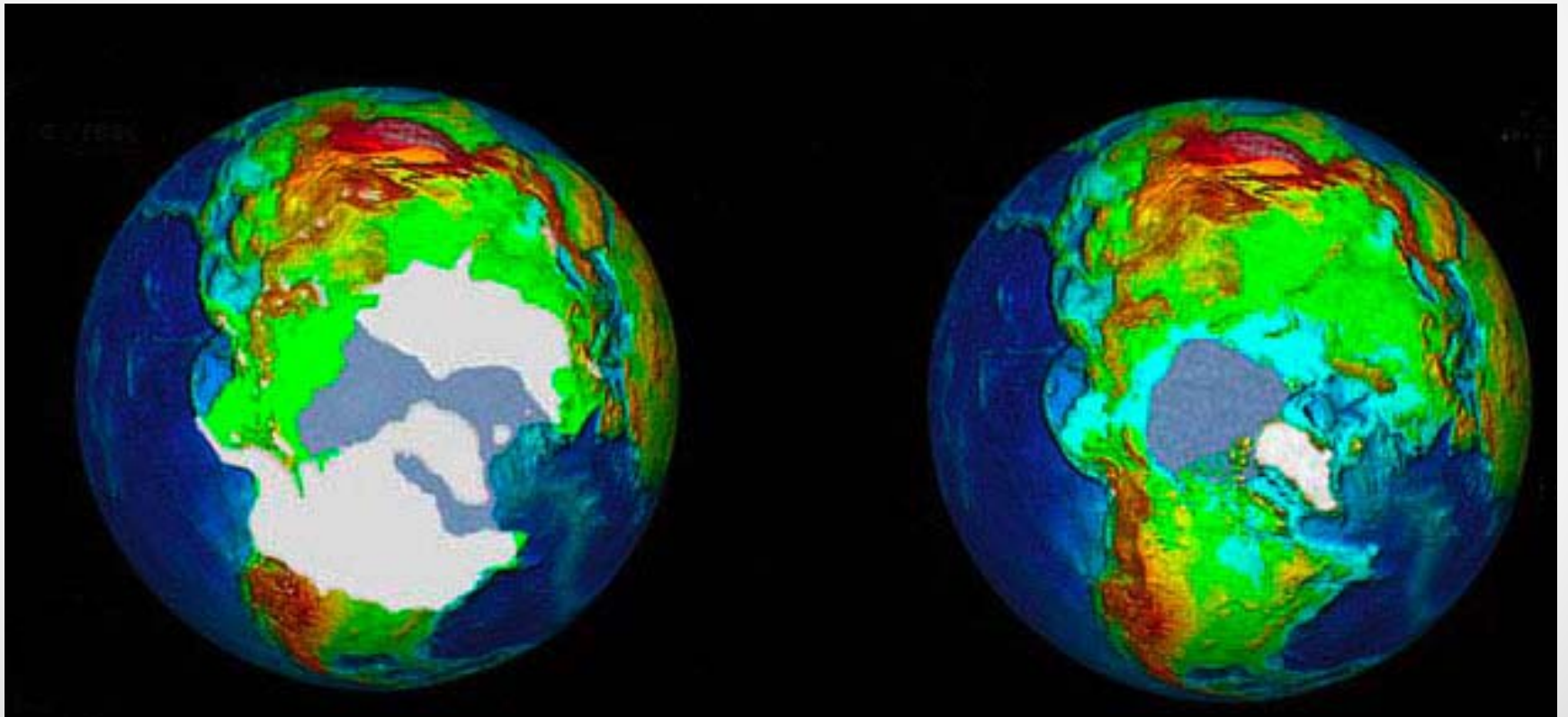
the Last Glacial Maximum (27,000-18,000 year BP)

Paleosea-level curve was based on marine terrace altitude.

Glacier coverage map

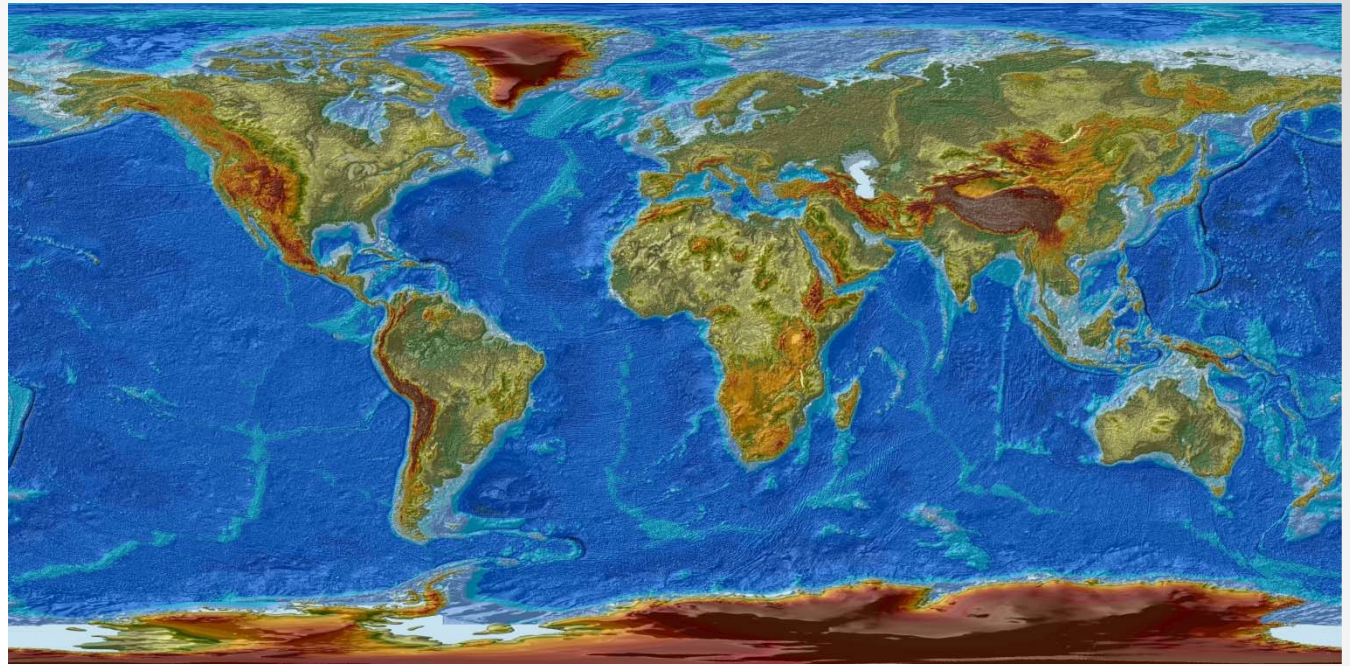
- 27,000-18,000 year BP
- the Last Glacial Maximum

Recent

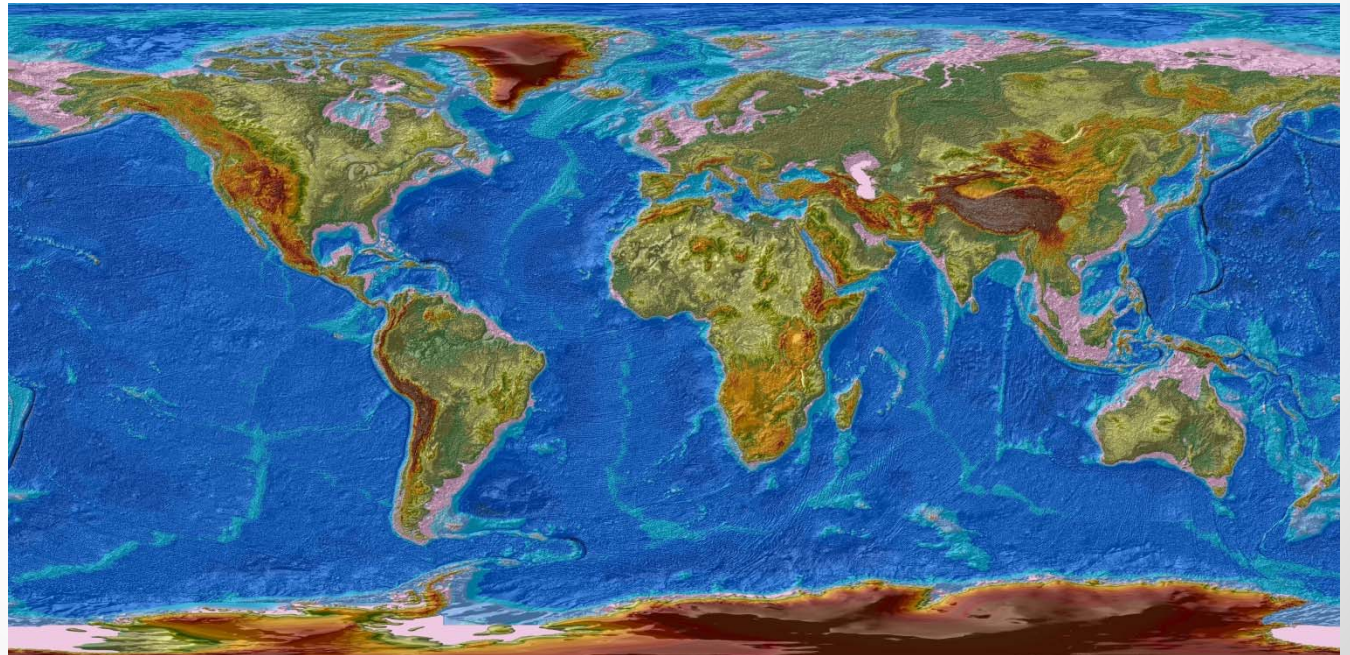


Global continent

Recent continent
map

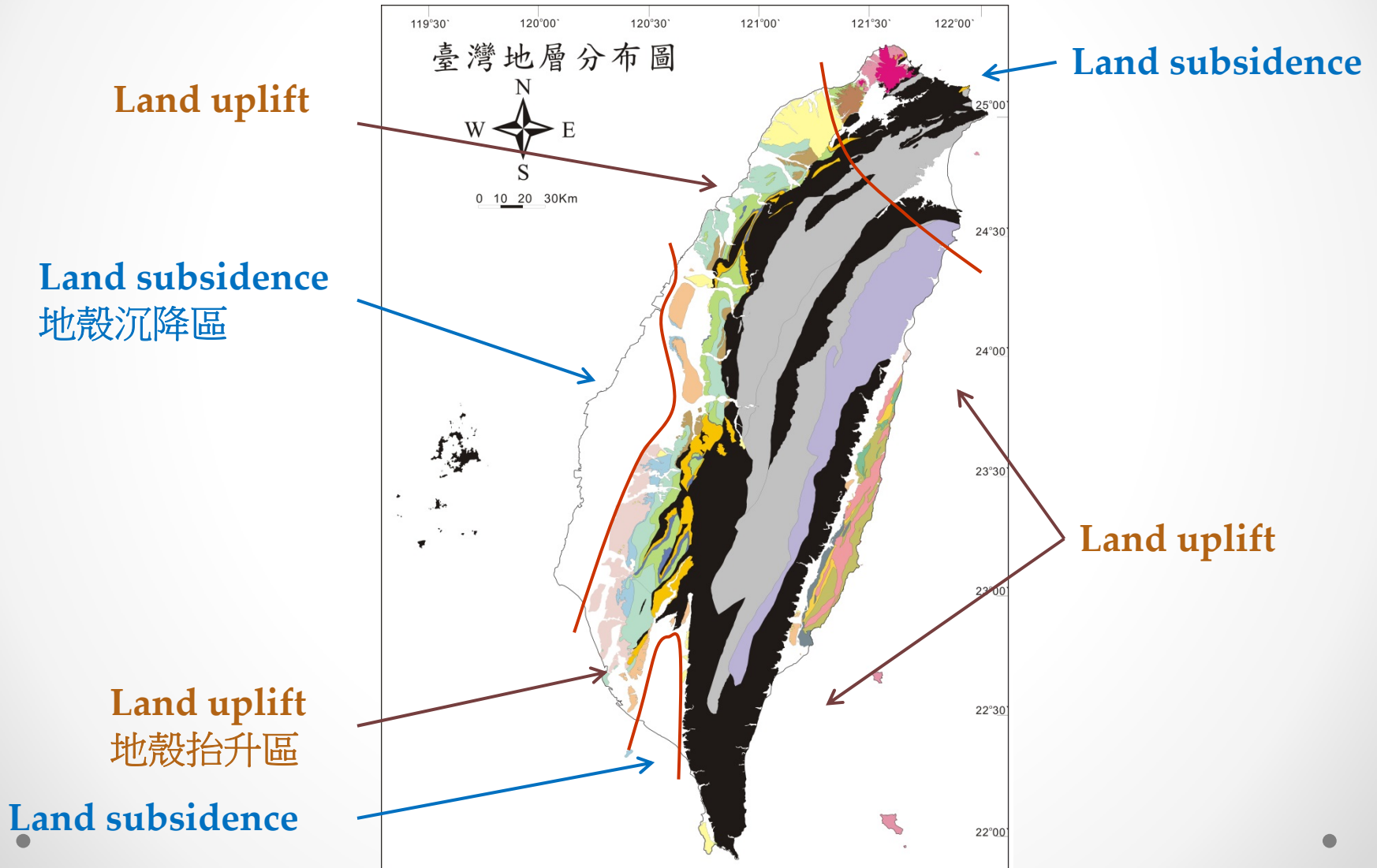


27,000-18,000 year
BP continent map
+ pink color area
Sea-level fall 120 m



(4) Tectonic deformation in Taiwan

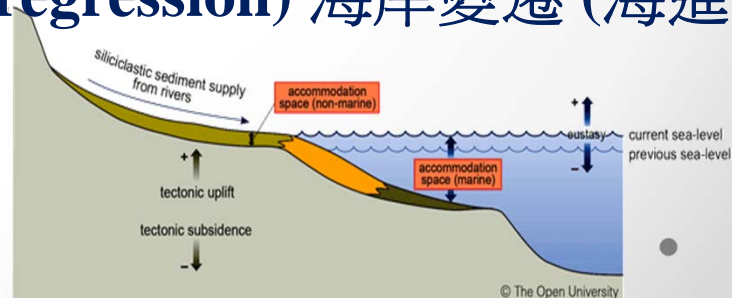
臺灣構造活動 (地殼變形)



(5) shoreline changes in Taiwan since the Last Glacial Maximum

末次最大冰期以來臺灣海岸變遷

- Effects of changes in depositional environment
沉積環境變遷因素
- **accommodation** (盆地沈積空間)
accommodation = tectonics + sea-level fluctuations + deposition
- (1) **Tectonics (uplift, subsidence)** —地殼升降活動
- (2) **Sea-level fluctuations (Climate changes)** 氣候變遷—海面變動
- (3) **Deposition** —沉積物堆積量
- ↓
- **shoreline changes (transgression and regression)** 海岸變遷 (海進, 海退)



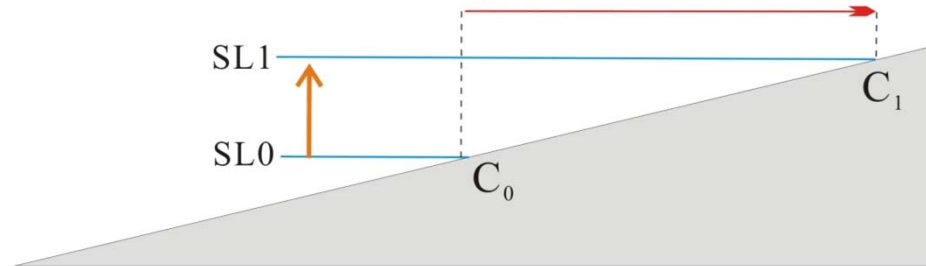
Accommodation = Tectonics + Sea-level fluctuations + Deposition

盆地沈積空間=地殼變動+海面變動+沉積物堆積量

accommodation increase with age (沉積空間增加)

$$V(\text{sea level} + \text{tectonics} + \text{deposition}) > 0$$

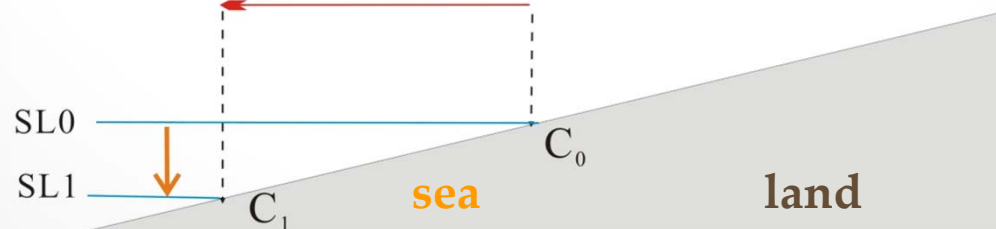
shoreline transgression, 海進



accommodation decrease with age (沉積空間減少)

$$V(\text{sea level} + \text{tectonics} + \text{deposition}) < 0$$

shoreline regression, 海退



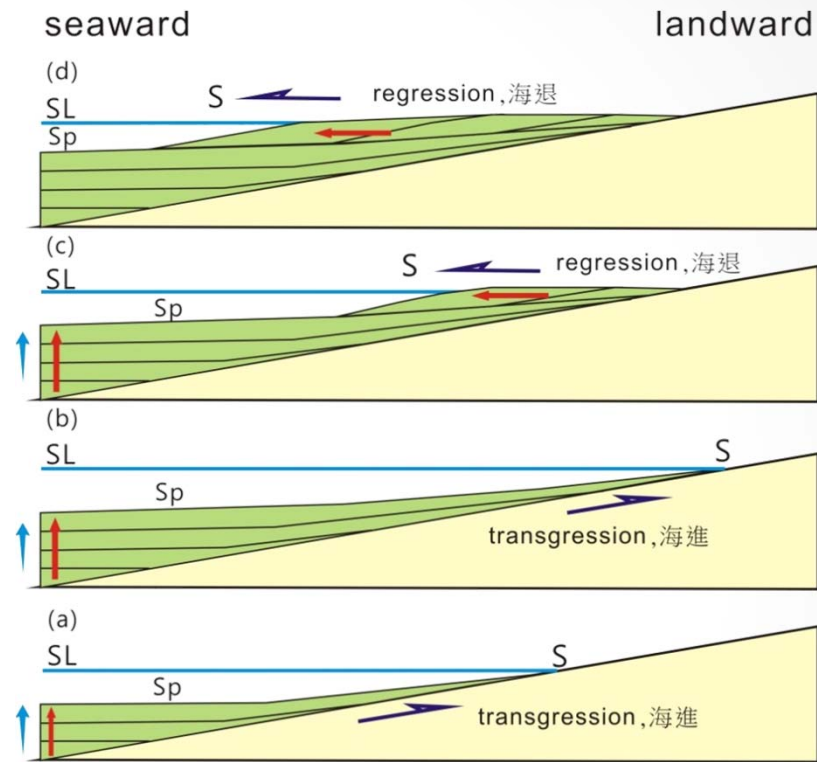
Shoreline changes since 18,000 year BP

(d) 6000-0 year BP

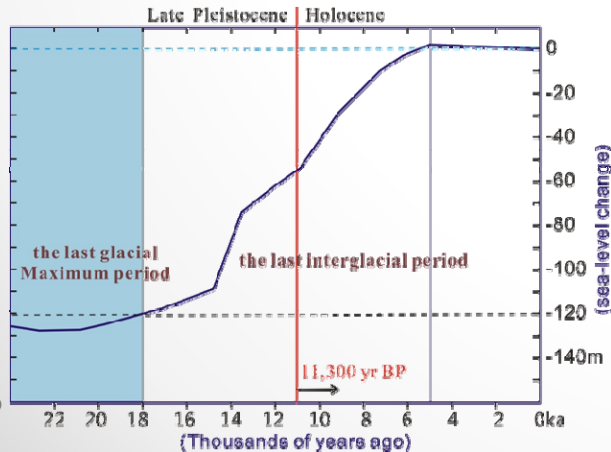
(c) ~ 9000-6000 year BP

(b) ~9000 year BP

(a) 18,000-9,000 year BP



SL: sea-level, 海面 S: shoreline, 海岸線 Sp: accommodation 沉積空間
 ↑ aggradation, 向上加積 ← progradation, 向外加積
 ↑ sea-level rise, 海面上升

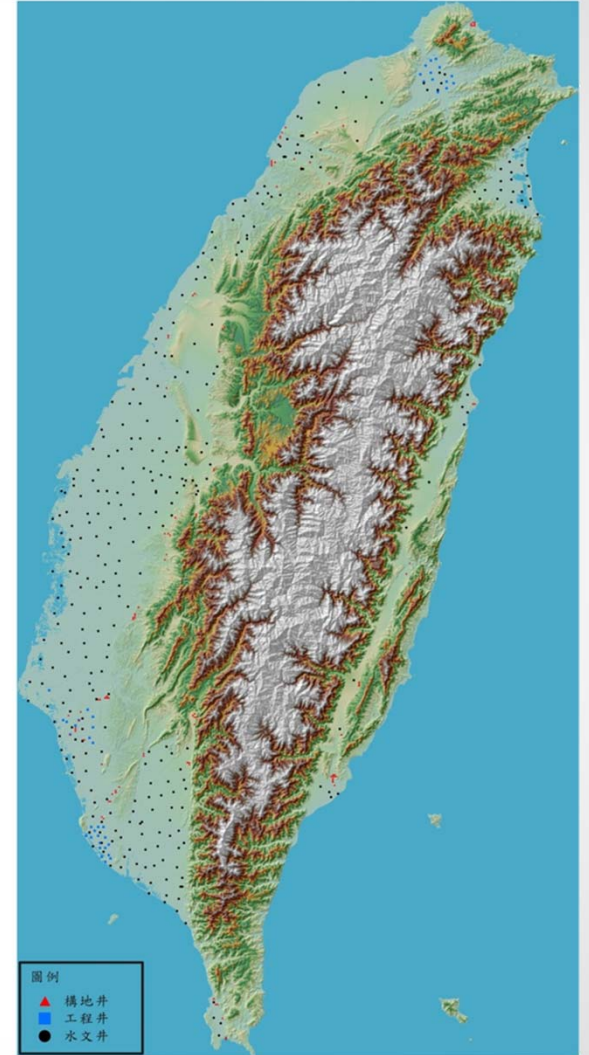


Borehole sites 鑽井地點

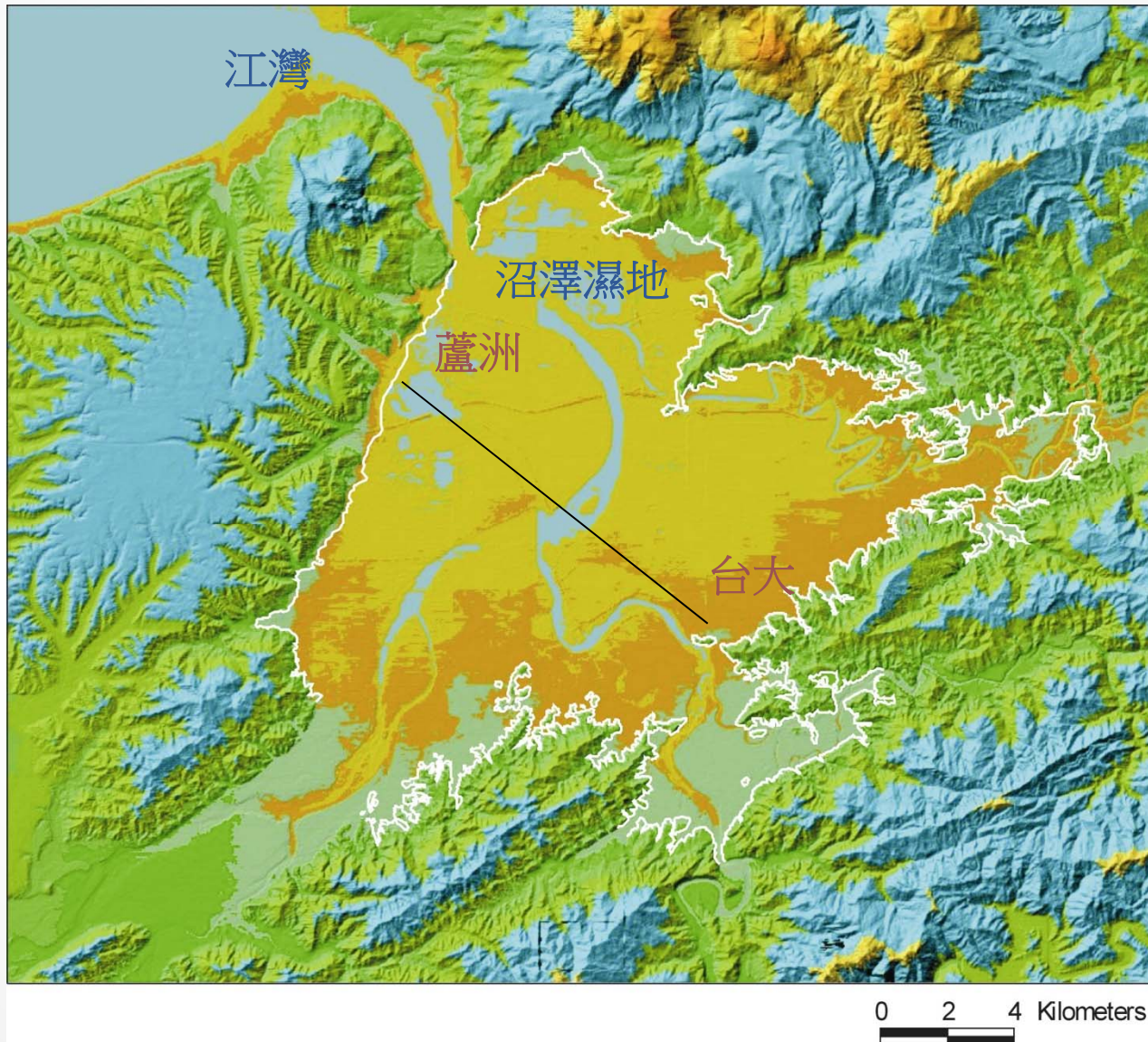
鑽井平台



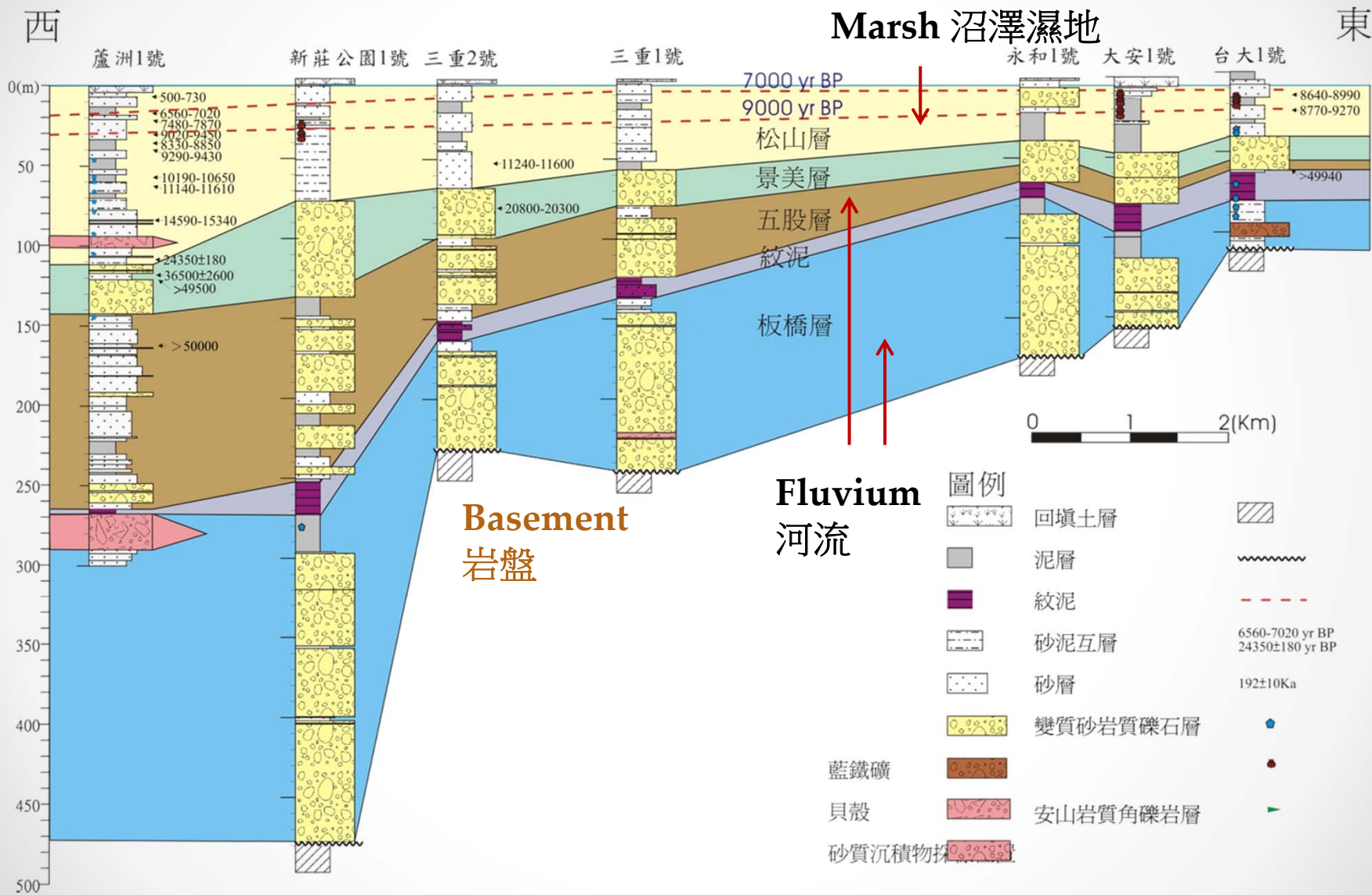
岩芯



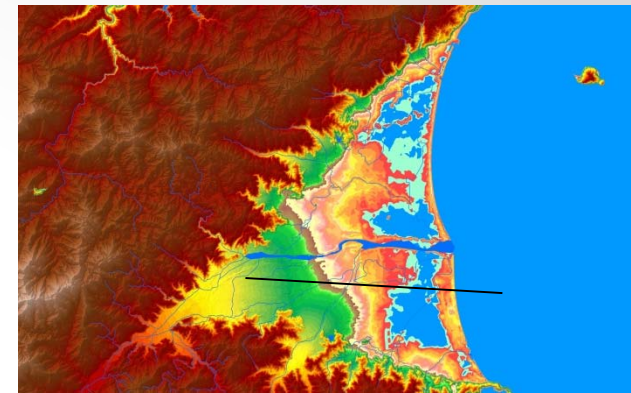
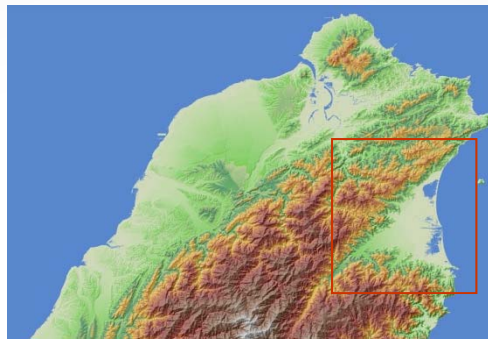
Taipei Basin 臺北盆地



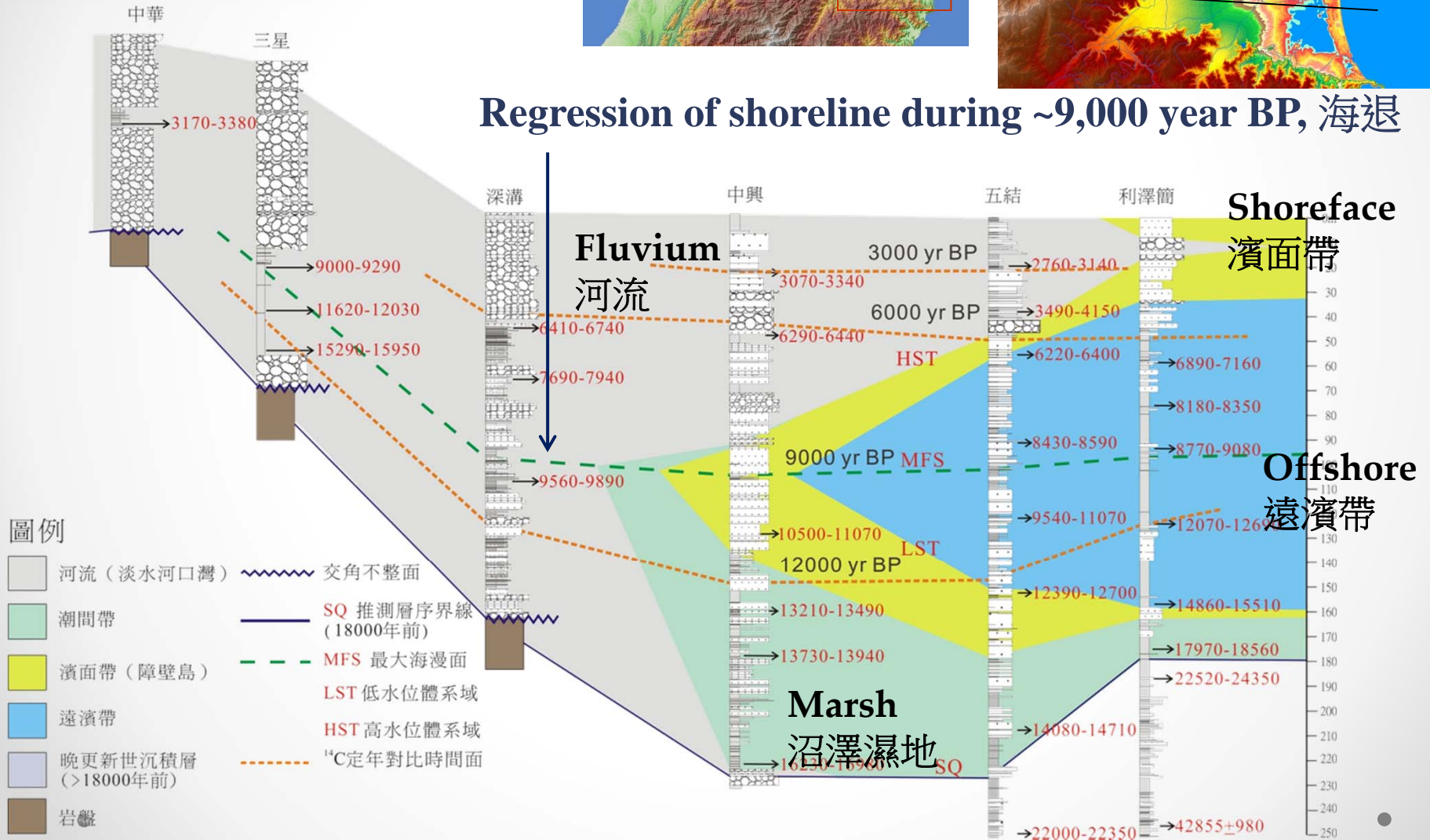
Taipei basin 臺北盆地



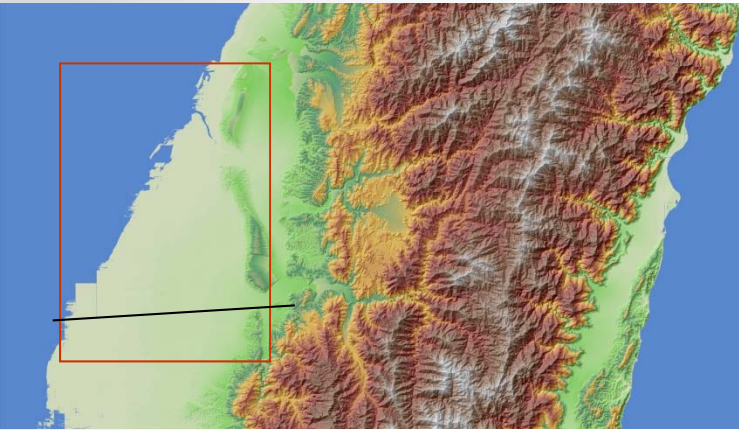
Ilan plain 蘭陽平原



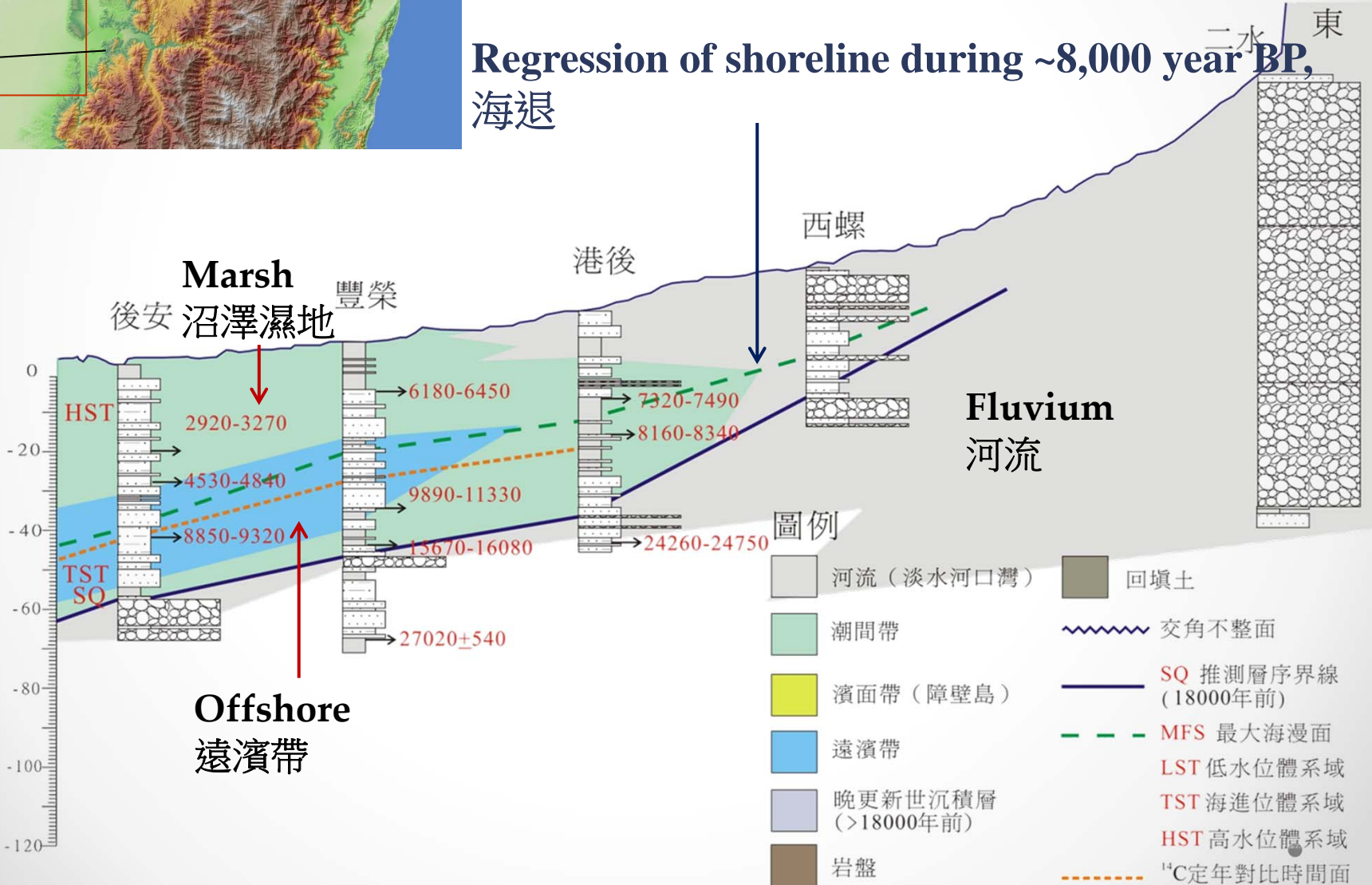
Regression of shoreline during ~9,000 year BP, 海退



Taichung-Changhua plain 台中-彰化平原



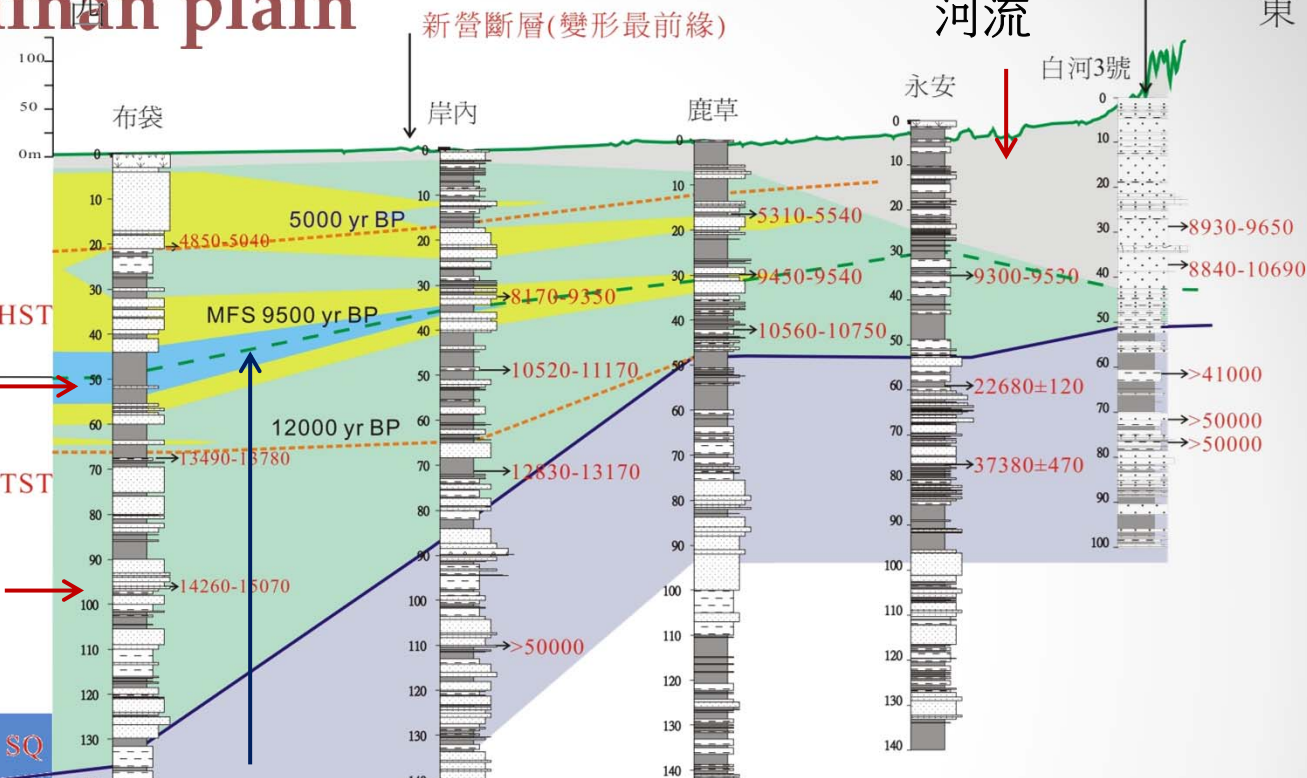
Regression of shoreline during ~8,000 year BP,
海退



Yunlin-Chiayi-Tainan plain 雲嘉南平原

Fluvium
河流

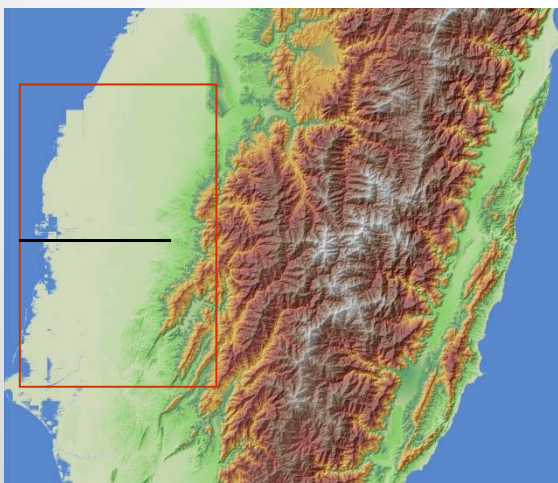
東



Offshore
遠濱帶

Marsh
沼澤濕地

Regression of shoreline during ~9,500 year BP,
海退

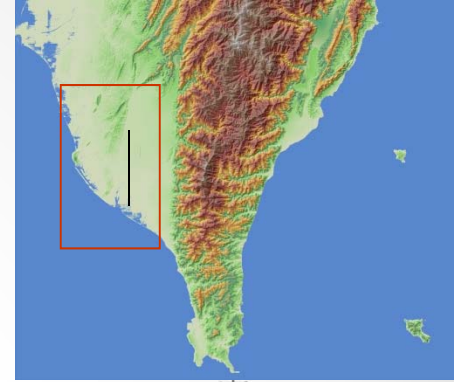


圖例

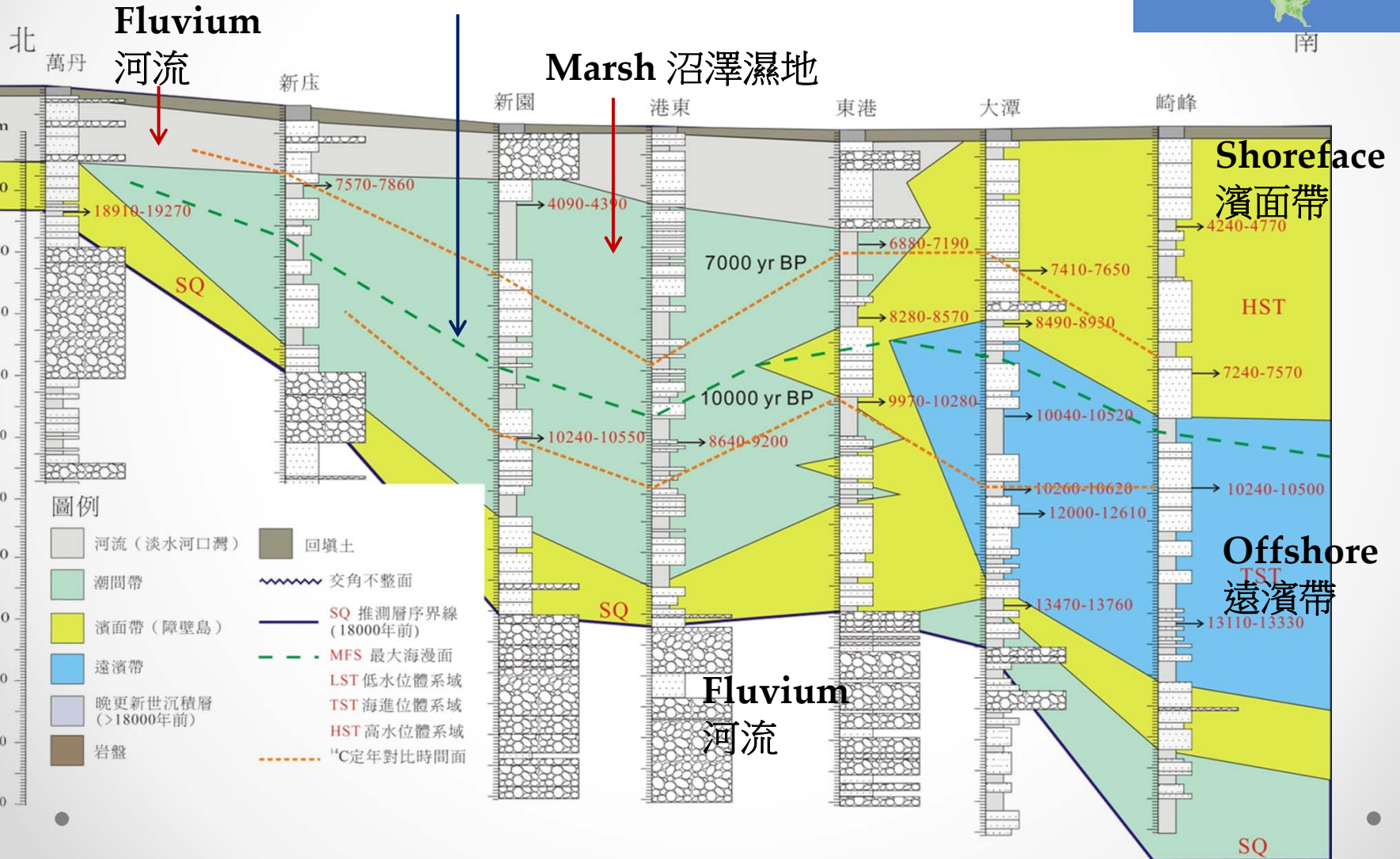
- 河流 (淡水河口灣)
- 潮間帶
- 濱面帶 (障壁島)
- 遠濱帶
- 晚更新世沉積層 (>18000年前)
- 岩盤
- 回填土
- 交角不整面
- SQ 推測層序界線 (18000年前)
- MFS 最大海漫面
- LST 低水位體系域
- TST 海進位體系域
- HST 高水位體系域
- ¹⁴C定年對比時間面

Pingtung plain 屏東平原

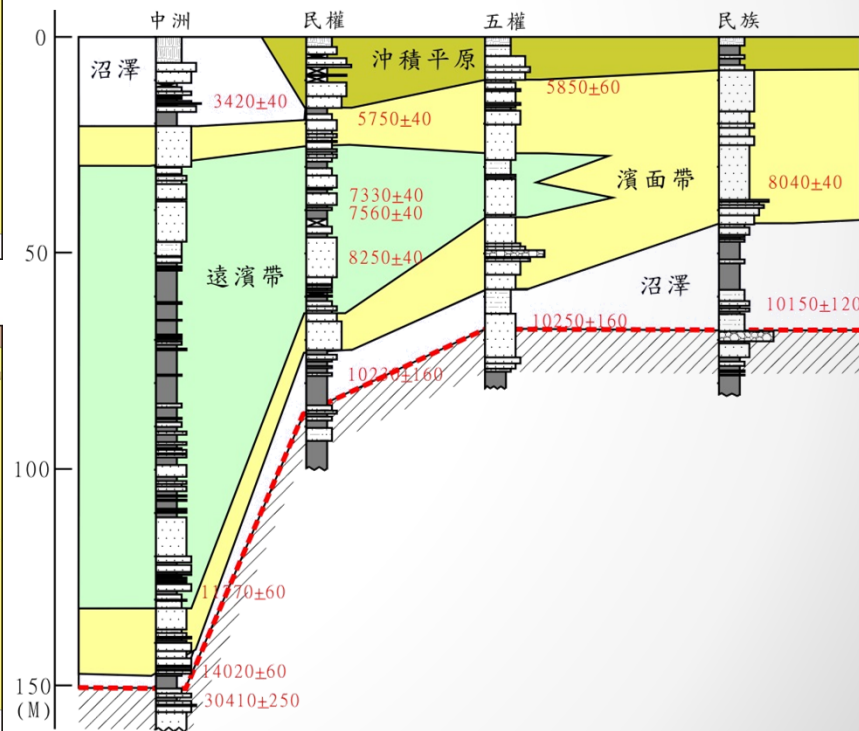
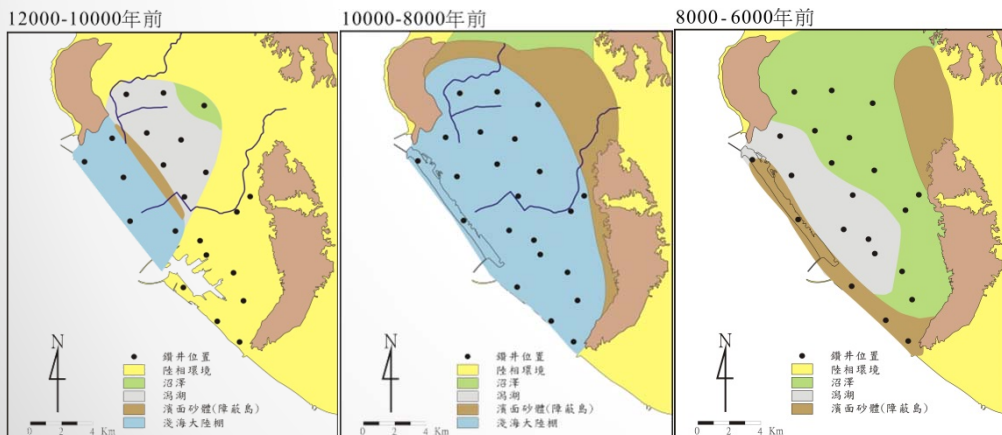
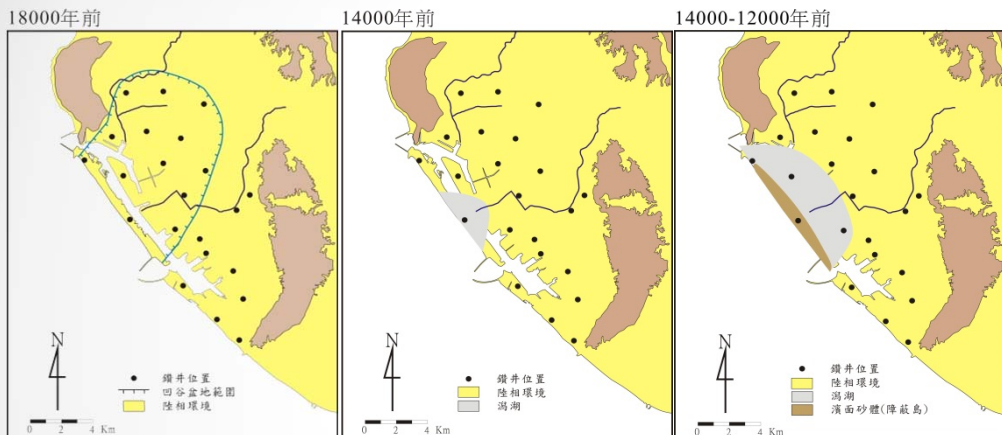
Regression of shoreline during ~9,000 year BP, 海退



南



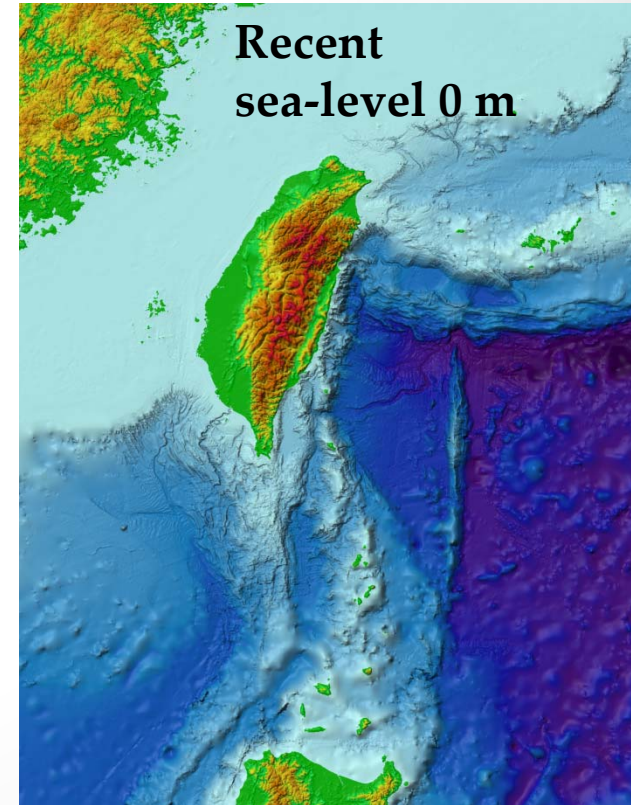
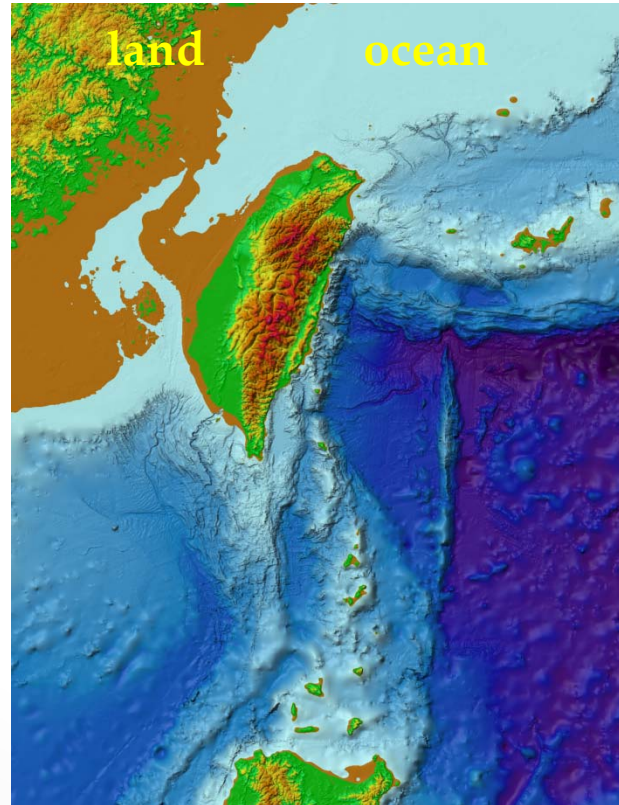
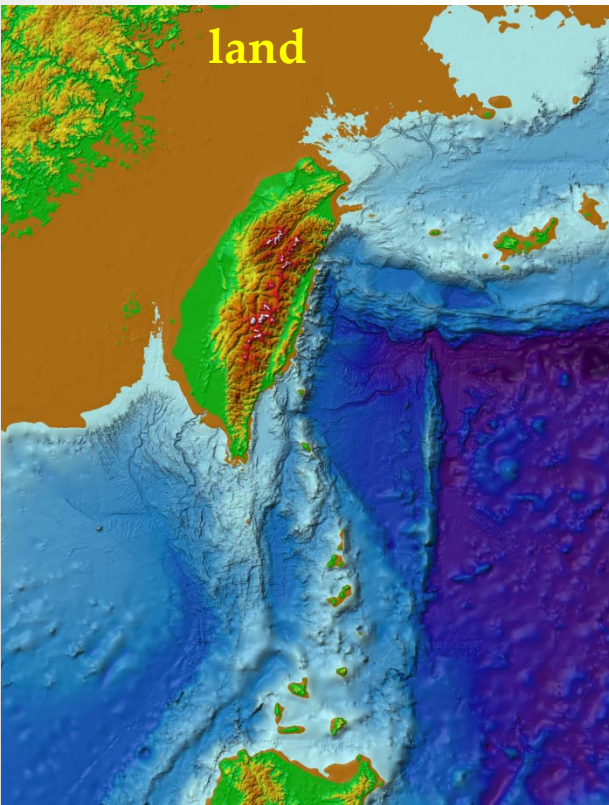
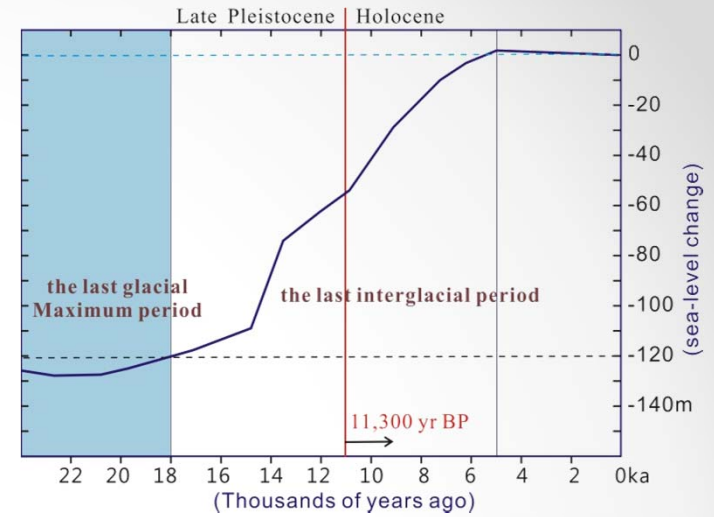
Kaohsiung plain 高雄平原



18,000年前之後，全球氣候逐漸暖化，海面上升，臺灣海峽逐漸淹沒；約5,000年前海面達到現今位置，不再大幅度變動。

27,000-18,000 year BP
sea-level -120 m

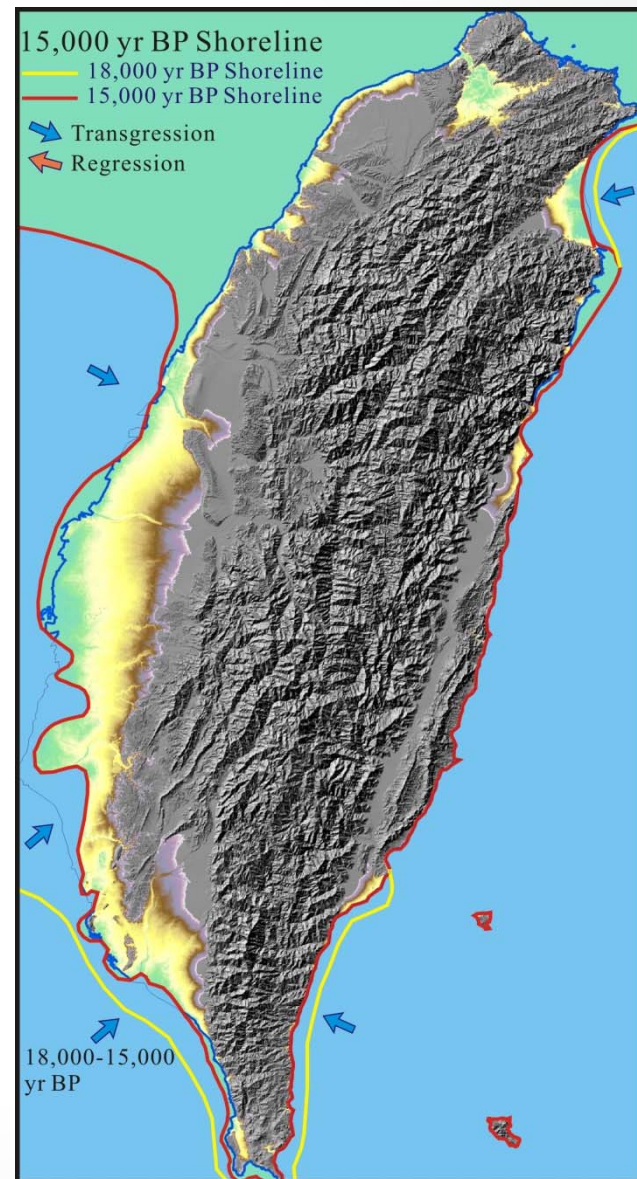
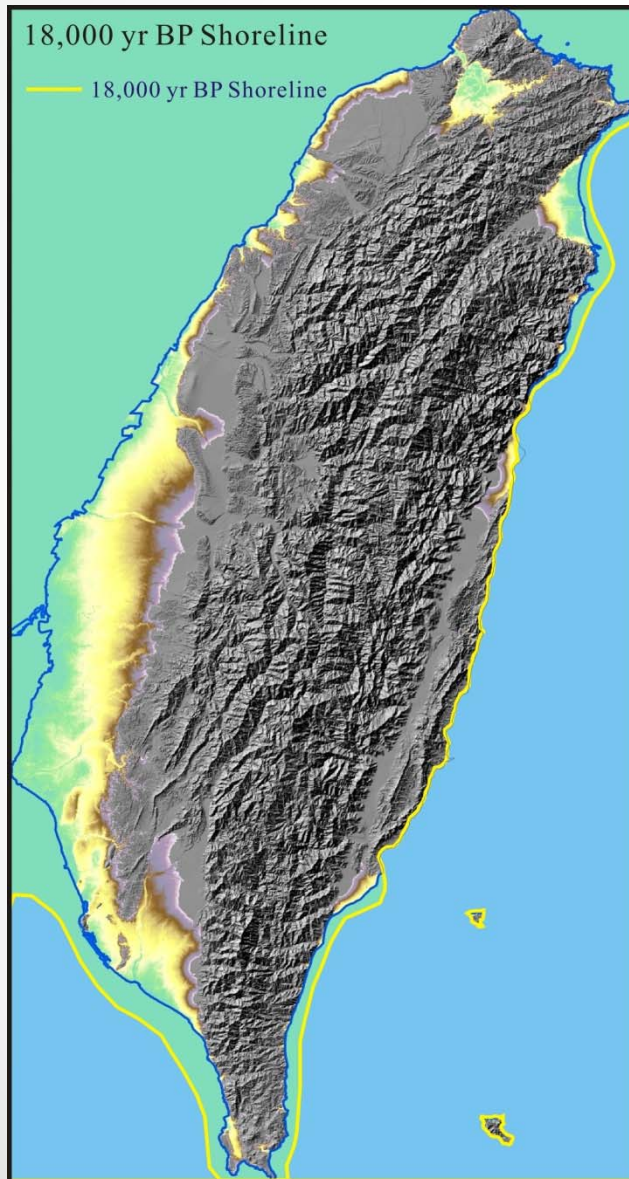
11,000 year BP
sea-level -60 m



Shoreline (yellow line) at 18,000 year BP

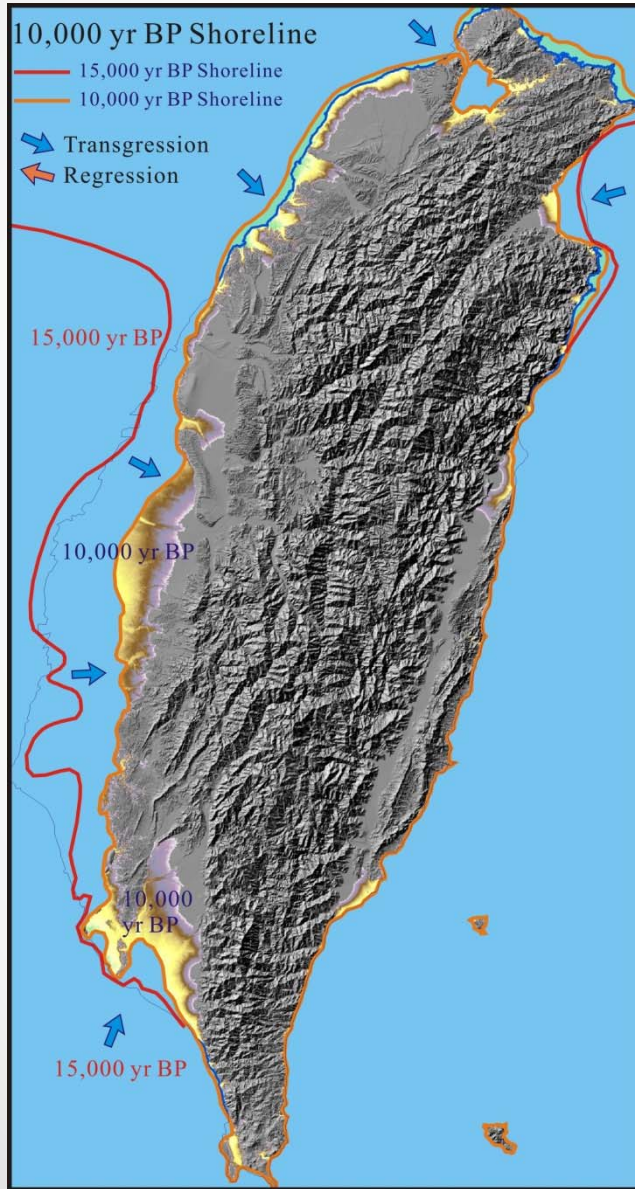
Shoreline (red line) at 15,000 year BP

Shoreline transgression



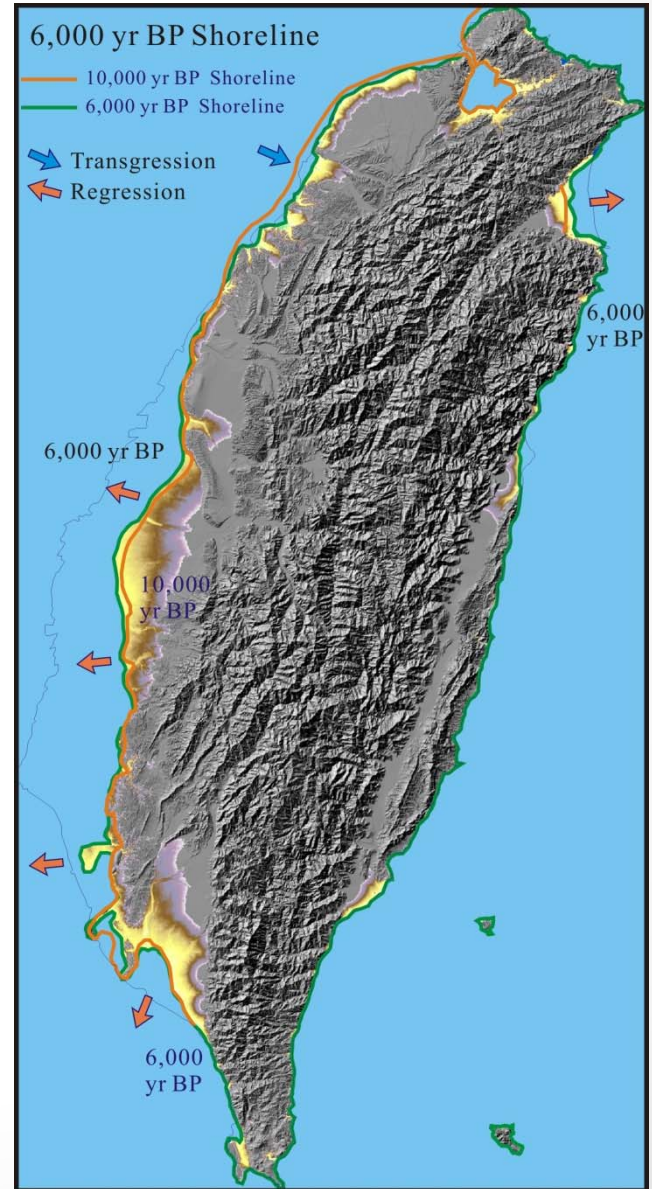
Shoreline (orange line) at 10,000 year BP

Shoreline transgression



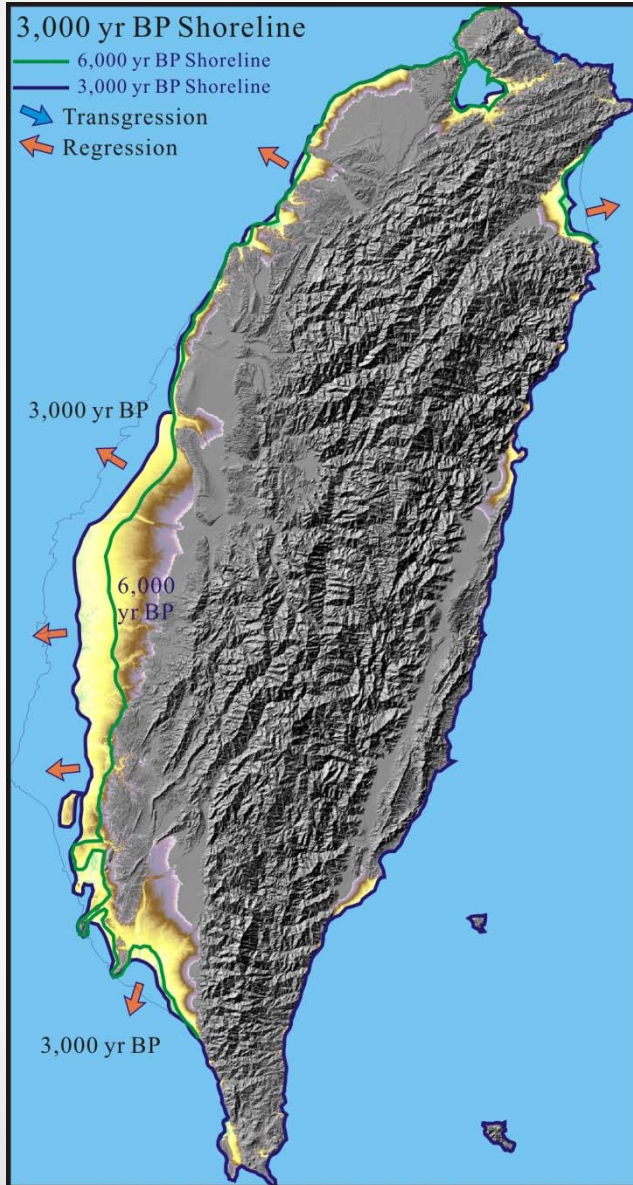
Shoreline (green line) at 6,000 year BP

Shoreline regression (9,500-8,000)

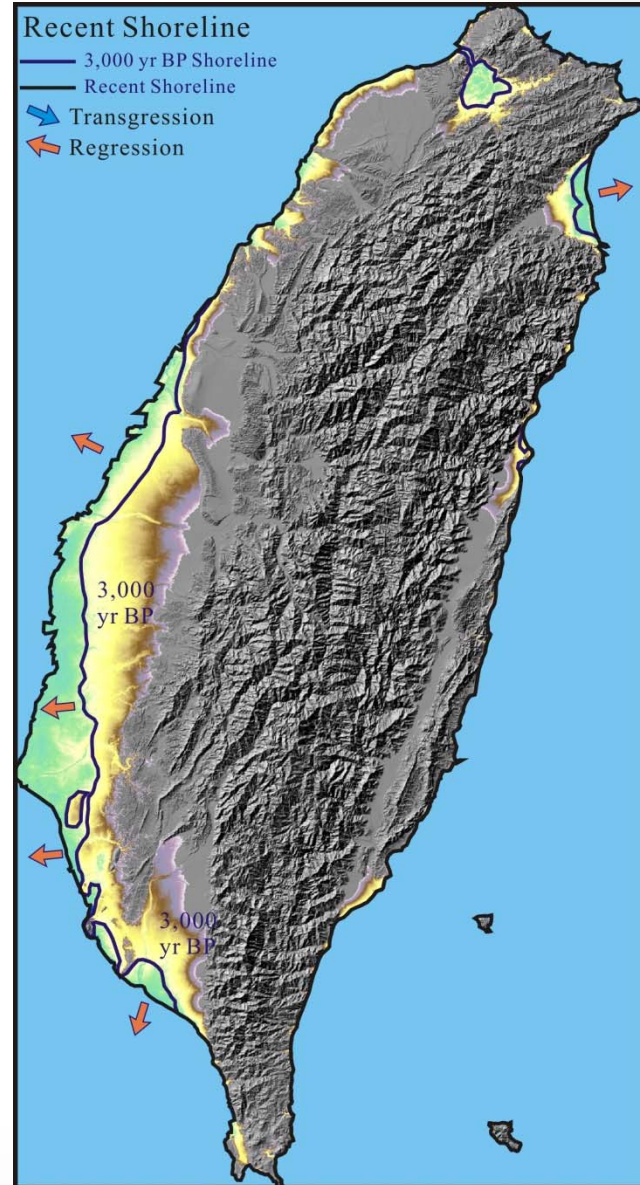


Shoreline (blue line) at 3,000 year BP

Shoreline regression



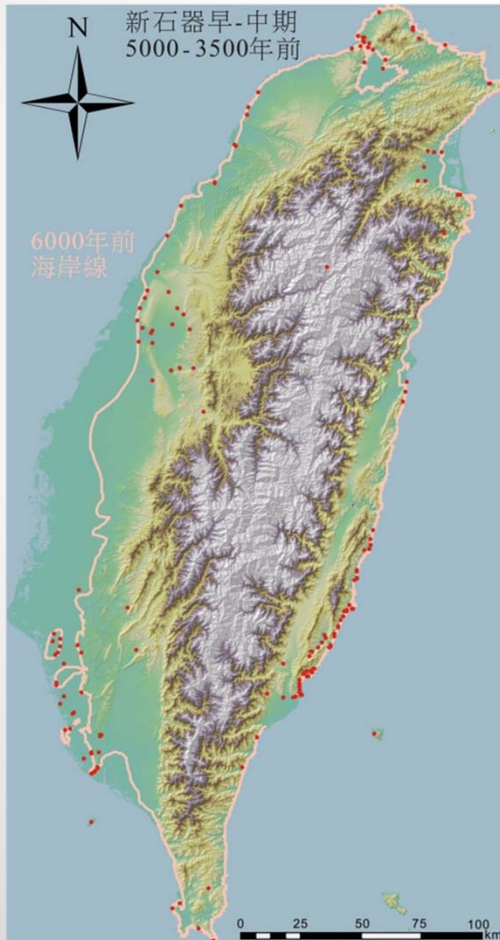
Recent Shoreline (black line)



(6) The relationship between archaeological sites and shorelines in the Late Holocene (< 5,000 year BP)

5,000年以來考古遺址分布與海岸線的關係

5,000-3,500 year BP



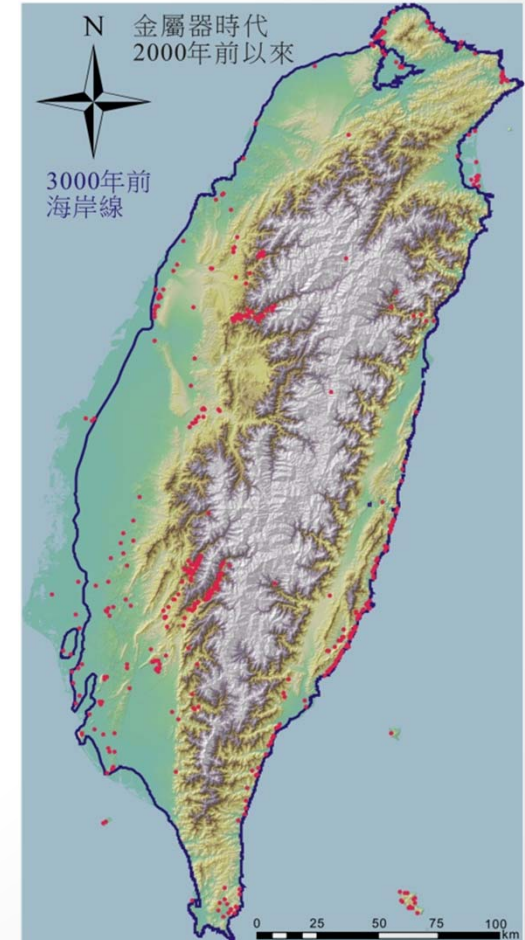
Neolithic Culture

3,500-2,000 year BP



Neolithic Culture

2,000-400 year BP



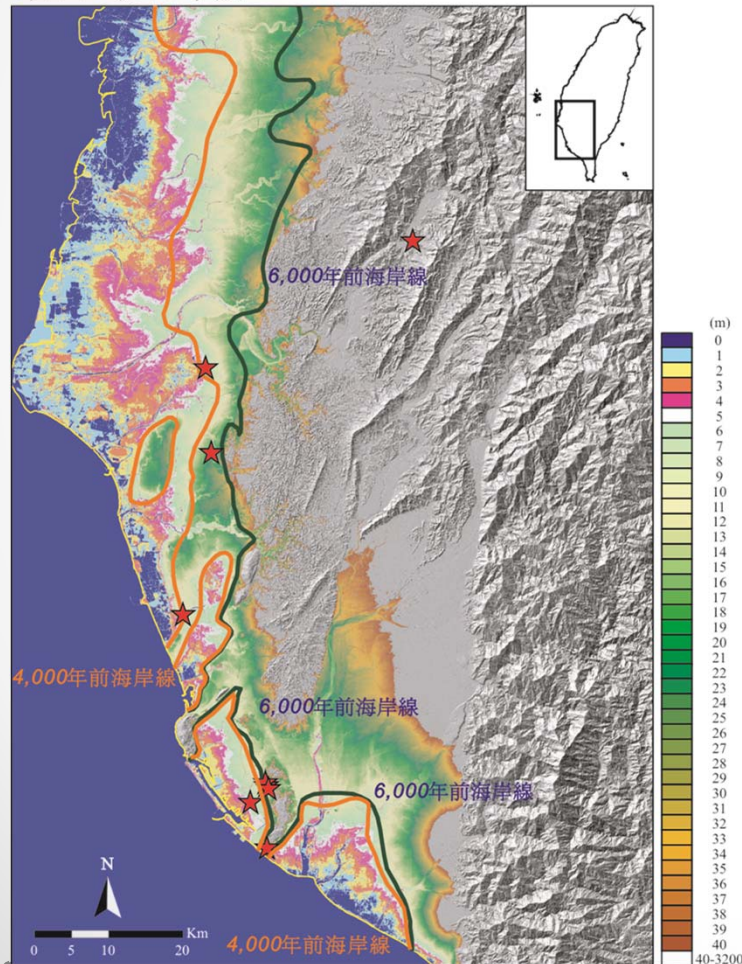
Metal Culture

archaeological sites and shorelines in the Chianan coastal plain 新石器時代人類與嘉南平原的海岸關係(5,000-400年前)

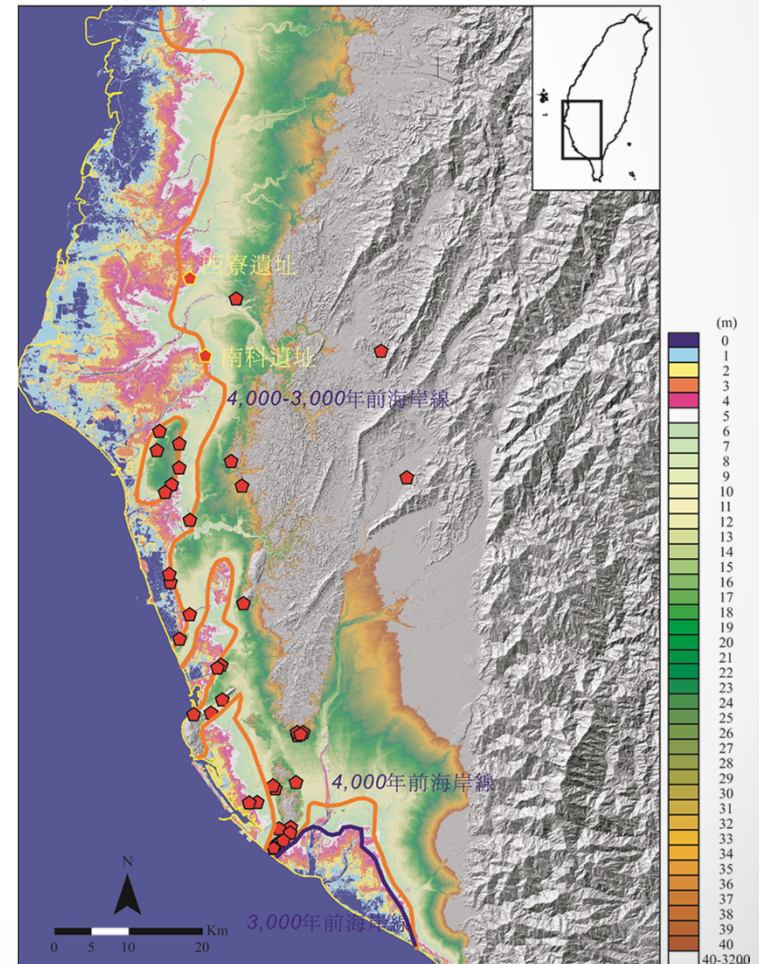
6,000-4,000 year BP Neolithic Culture

4,000-3,000 year BP Neolithic Culture

6,000-4,000年前

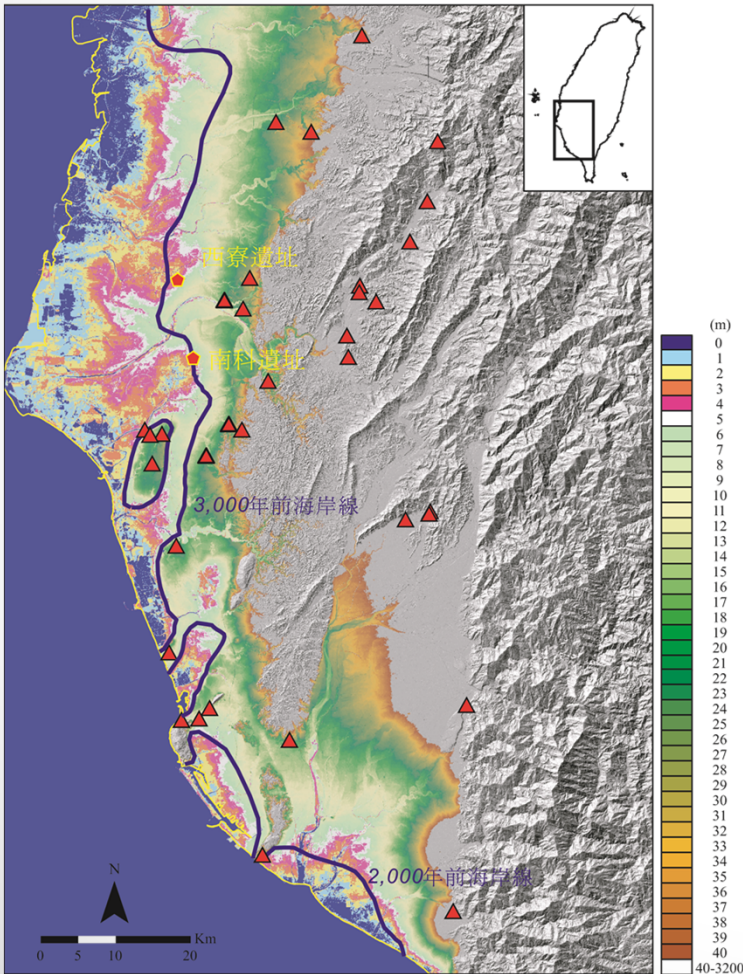


4,000-3,000年前



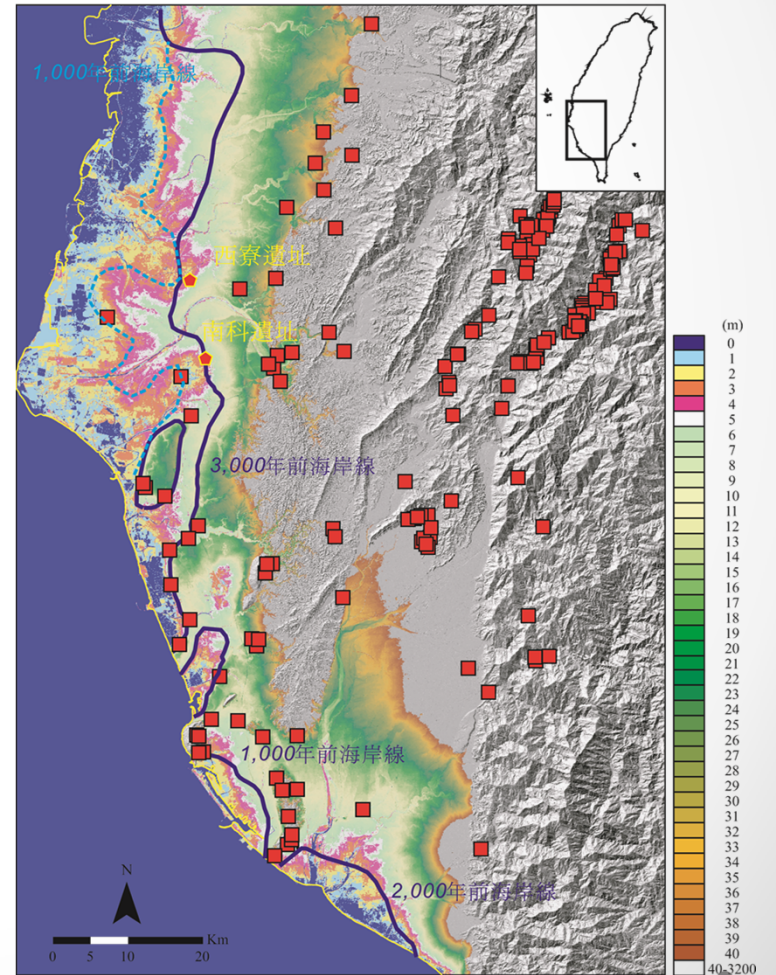
3,000-2,000 year BP Neolithic Culture

3,000-2,000年前



2,000-400 year BP Metal Culture

2,000-400年前

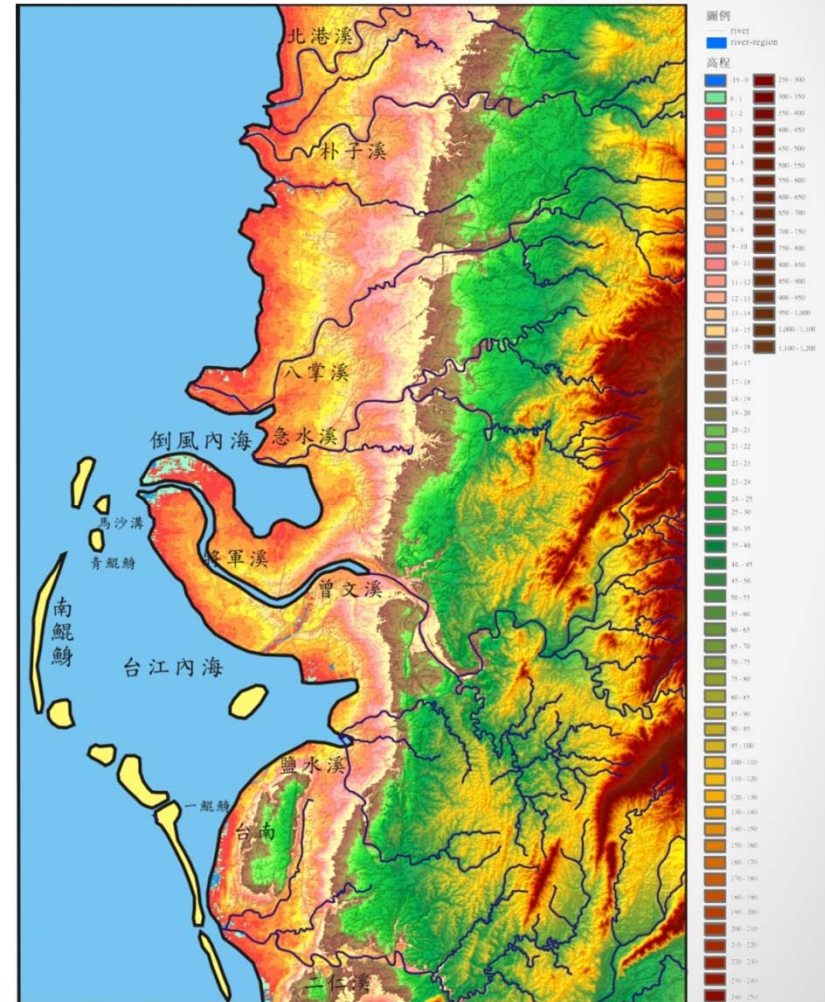
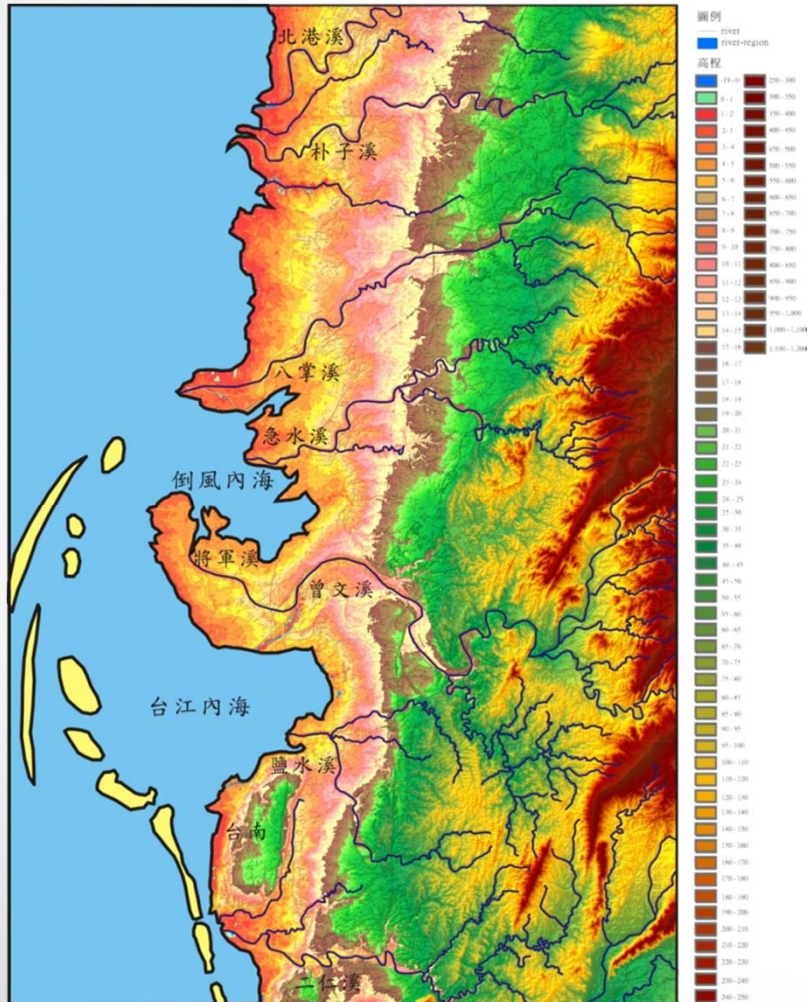


Historical shoreline map (< 400 year BP) in the Chianan coastal plain

歷史時期嘉南平原海岸變遷(400年以來)

17 century

18 century



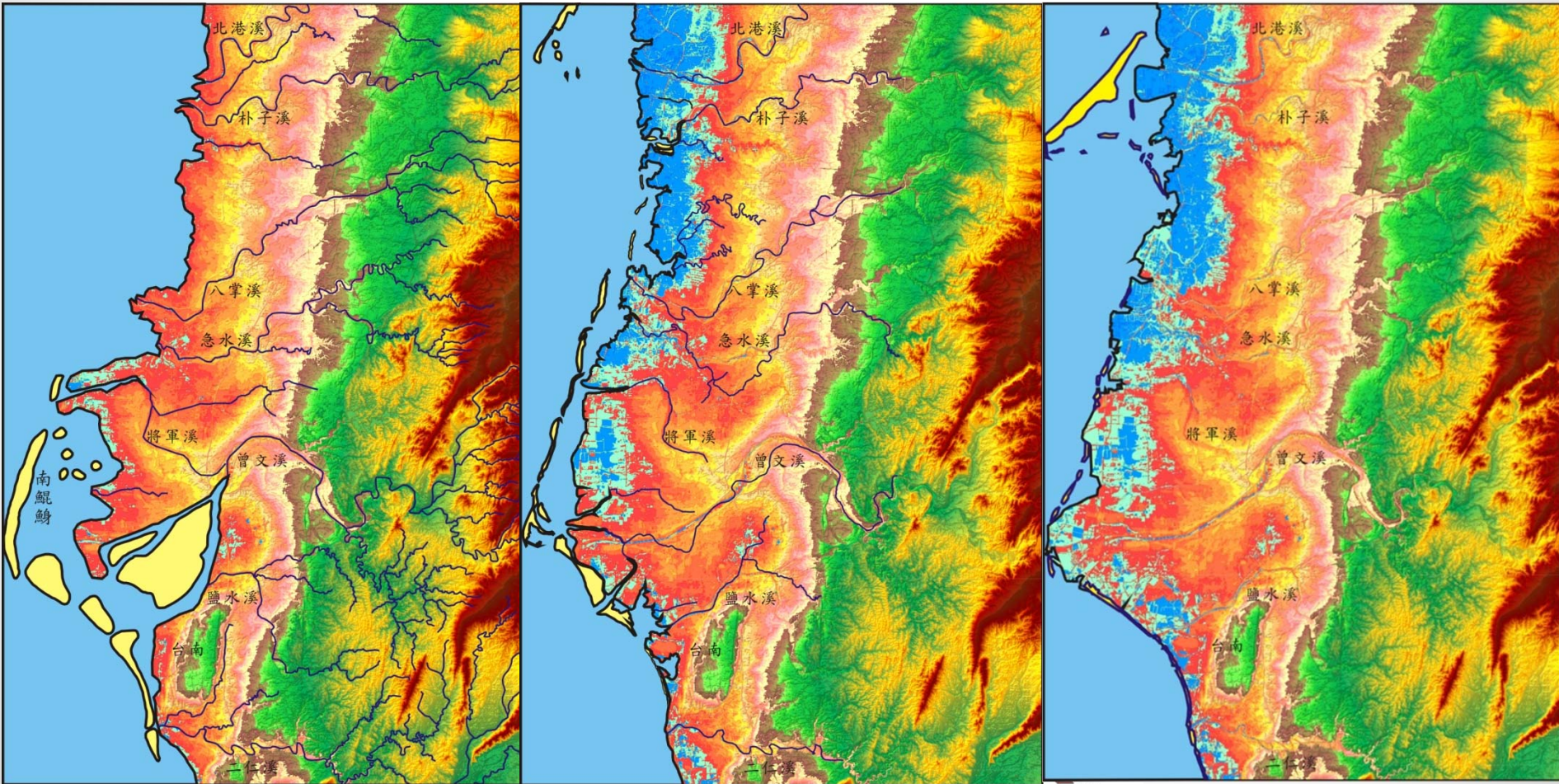
Historical shoreline map (< 400 year BP) in the Chianan coastal plain

歷史時期嘉南平原海岸變遷(400年以來)

19 century

Early 20 century

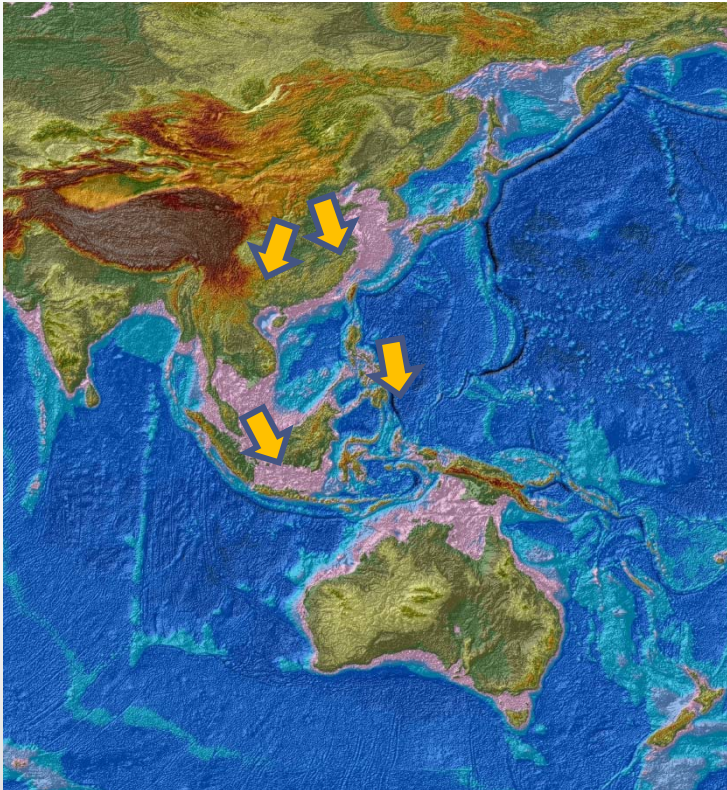
21 century



Tseng-wen river diversion by storm in 1823 DC,
西元1823年颱風造成曾文溪改道

(7) Asia mammal faunas migration in the glacial period 冰河時期亞洲大陸動物遷移路線

- 1. 朝南遷移至中南半島-馬來半島-印尼
- (Migration route 1: **Indochina-Malayan-Indonesia**) ◦
- 2. 朝東南遷移至東南沿海地區(臺灣-菲律賓-新幾內亞)
- (Migration route 2: **Taiwan-Philippines- Papua New Guinea**)



冰河時期海面下降, 亞洲大陸與臺灣之間形成陸橋, 華北動物與人類朝南遷移至當時的海岸地帶。

Asia mammal faunas
and human migration routes

2百萬年前 (2 million years ago)

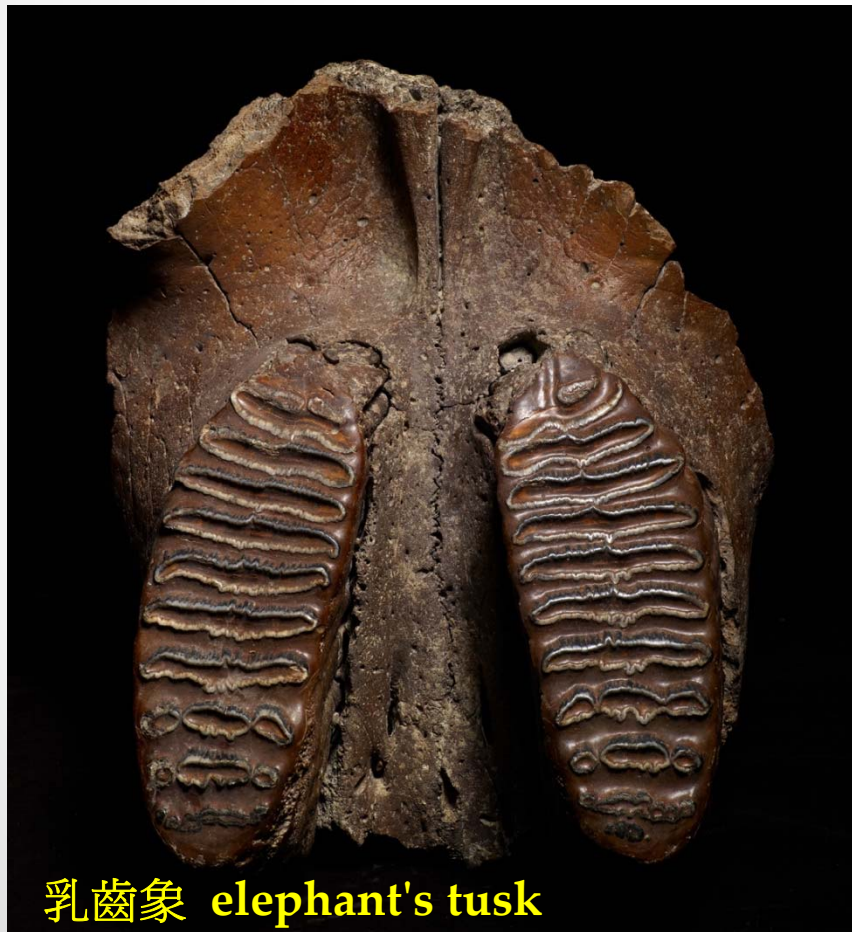


臺灣更新世地層中發現一乳齒象、劍齒象、犀牛、野牛、豬。

"Penghu fauna"

澎湖海溝動物群

About 40,000-10,000 year BP, 4萬-1萬年前



Human (Austronesian) migration route

南島語族的遷移路線

臺灣可能是南島語族的發源地
Taiwan as an origin location for the Austronesians

- 八仙洞遺址 (Basian Cave archaeological site)
- 臺灣最早的舊石器時代遺址
- 27,000-15,000 year BP

news and views

Taiwan's gift to the world

Jared M. Diamond

Study of the giant Austronesian language family tells us a great deal about the history of Pacific peoples and boatbuilding, as well as about Aboriginal Australia.

We humans are defined and fascinated by our languages. Especially intriguing are the 1,200 or so languages of the Austronesian language family, possibly the largest family among the 6,000 languages of the modern world¹. Until the European colonial expansion spread Indo-European languages far and wide after AD 1492, Austronesian was the most widely distributed family, spoken across a realm spanning 26,000 km from Madagascar in the west to Easter Island in the east (Fig. 1).

Austronesian history has been difficult to reconstruct, however, because there are no preserved samples of writing in any Austronesian language until about AD 670, by which time the family's expansion was nearly complete. A reanalysis of Austronesian languages by Robert Blust² strengthens the identification of the first Austronesian waystation, illuminates archaeological findings



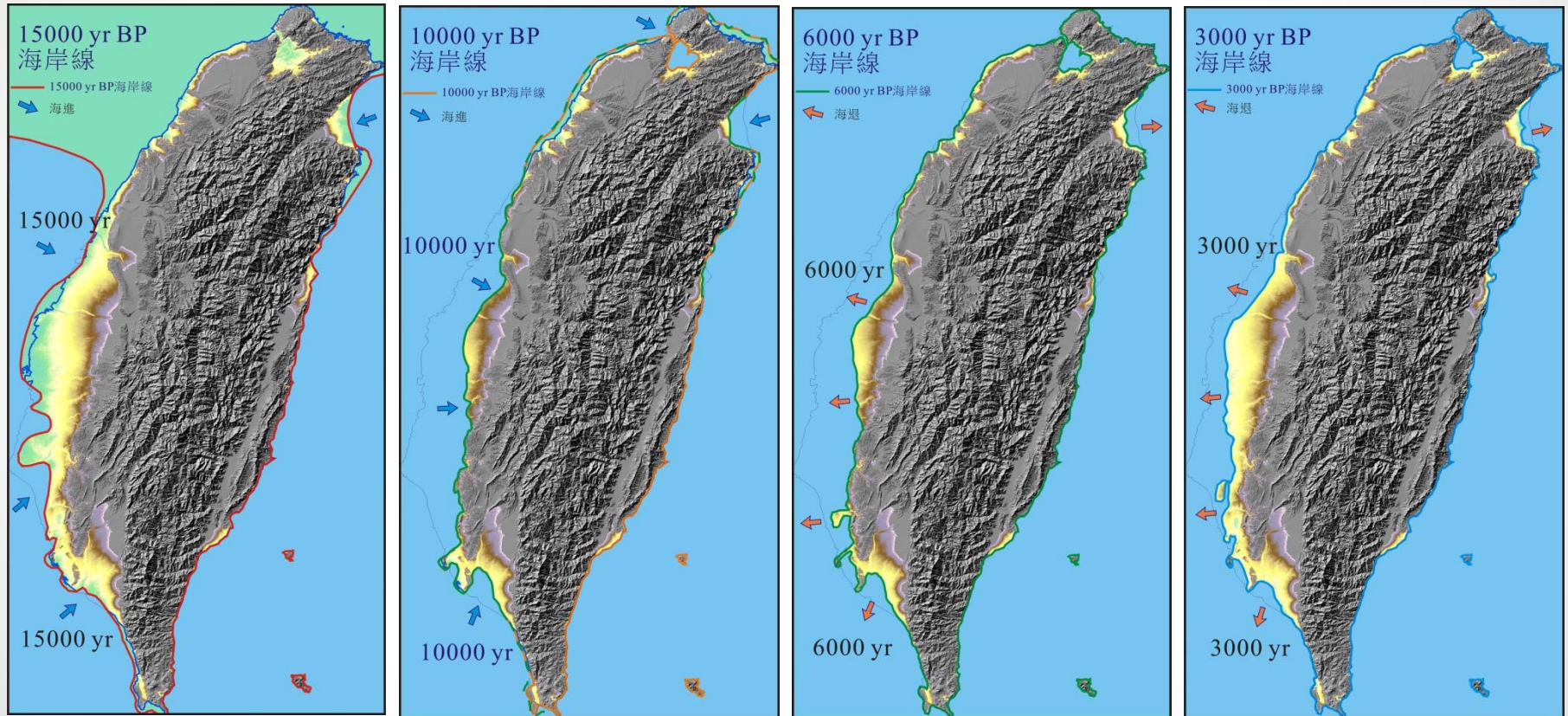
Figure 1 The geographical span of Austronesian languages. This language family encompasses all languages spoken on all Pacific islands from Sumatra in the west to Easter Island in the east, except for the Papuan languages of New Guinea and a few adjacent islands. They are also spoken in Madagascar and in mainland Malaysia. From the work² discussed here, it turns out that of the ten subgroups of Austronesian languages, nine are confined to Taiwan (red circle), and that all Austronesian languages outside Taiwan belong to the tenth subgroup (green), which includes Polynesian languages (dark green; only a few of the hundreds of Polynesian islands are shown here). (Redrawn from ref. 1.)

Nature (Diamond, 2000)



謝謝指教

Thanks for your attention



15,000年前以來海岸平原變遷