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# Lower Yangtze drainage reorganization response to western Pacific Subduction


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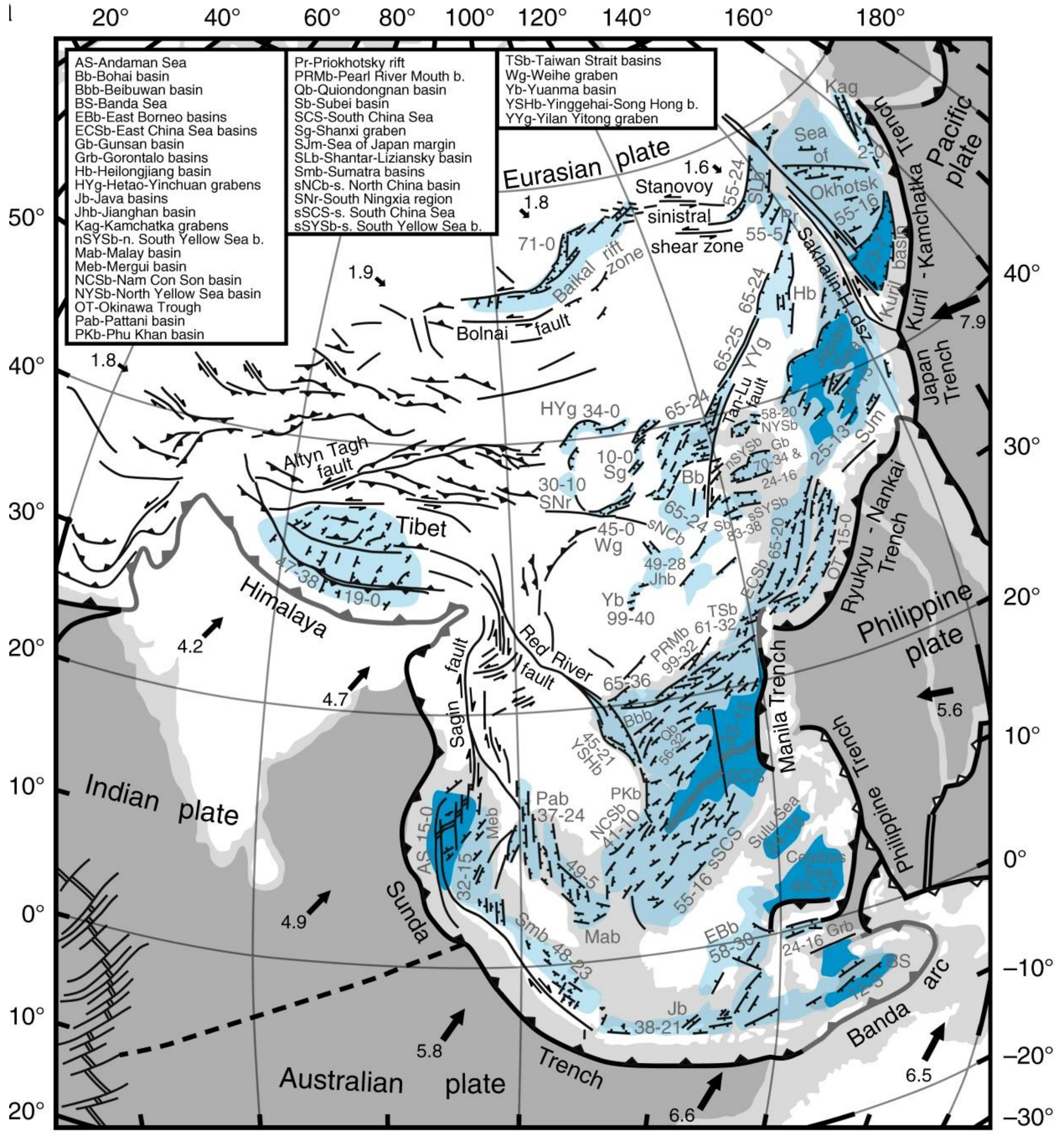
1. Introduction
2. Geological Background
3. Method and Result
4. Discussion

# East Asia Tectonics since ca. 50 Ma

- Far-field effects of the Indian–Eurasia collision were often invoked to explain the widespread East Asia lithospheric deformations (Tapponnier et al., 1982) , the opening of the marginal seas (Jolivet et al., 1994; Xu et al., 2014), and the through-going of the large rivers (Clark et al., 2004; Zheng et al., 2013)

- Some geological and geophysical investigations challenge this model and suggest that the Pacific Plate subduction beneath Eurasia plays an much more active role in East Asia lithospheric deformation during the Cenozoic (Northrup et al., 1995; Schellart and Lister, 2005; Yang et al., 2018; Schellart et al., 2019).

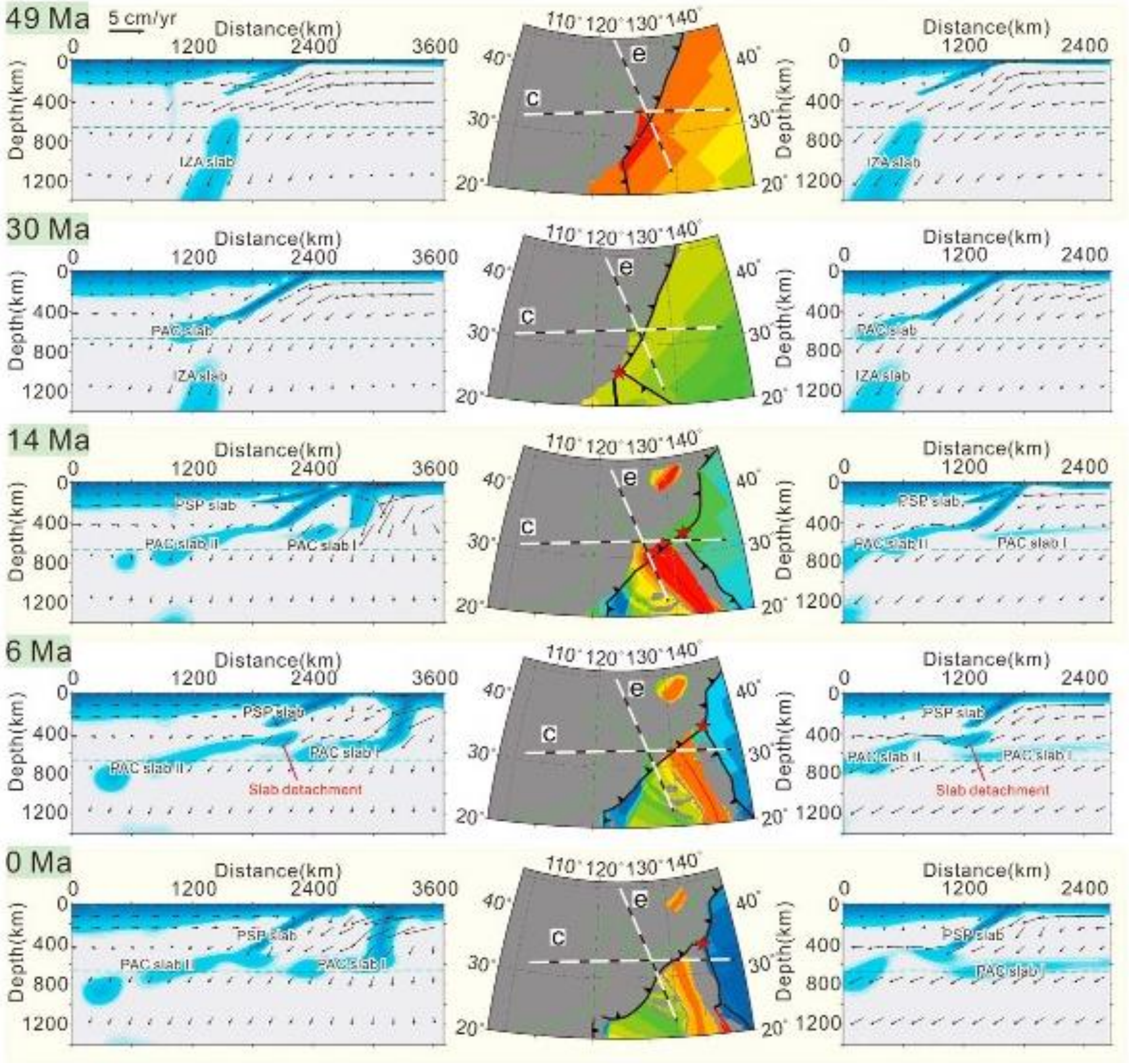



*Schellart et al., 2019, Nature Comm*

# Pacific Plate subduction

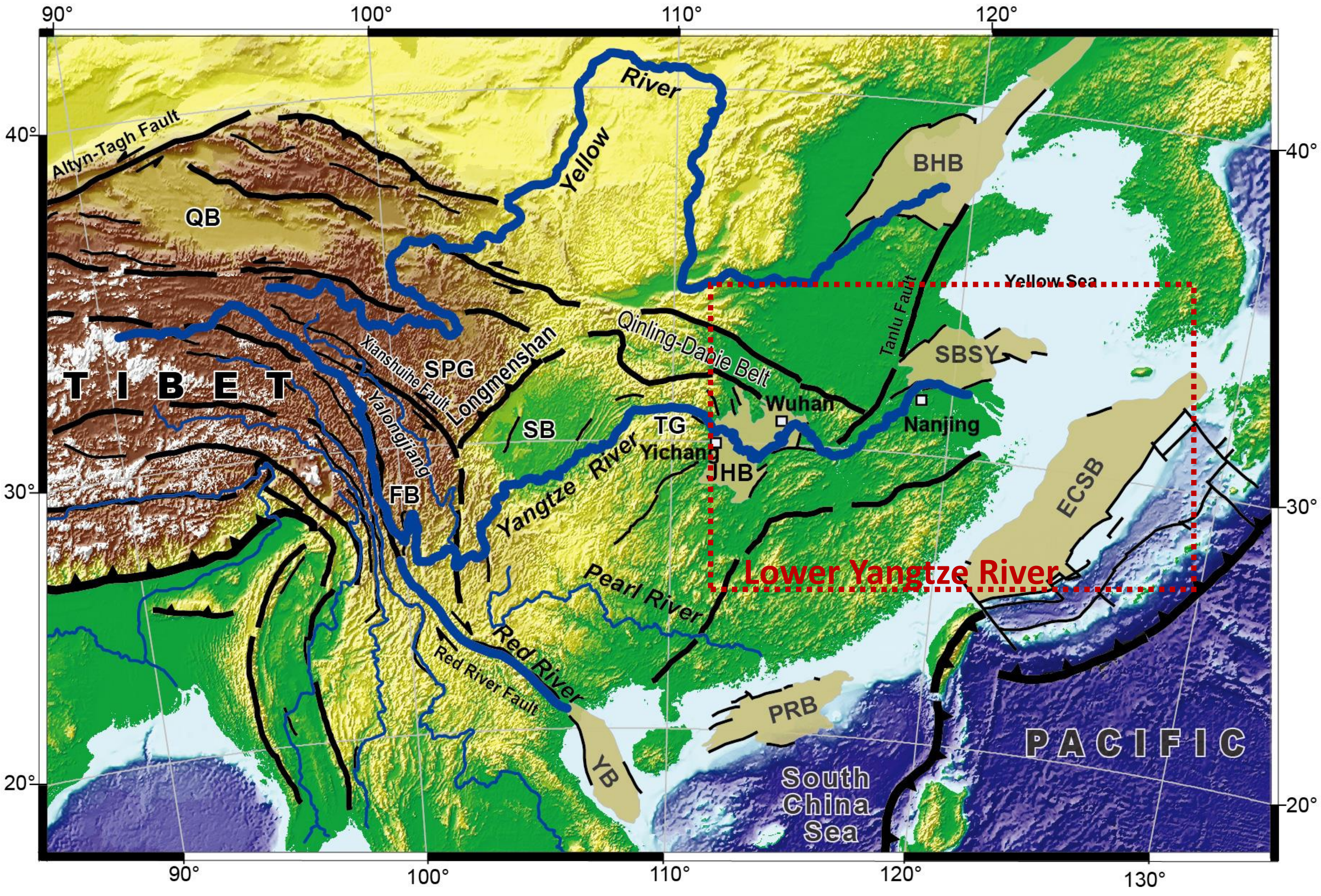
- Recent reconstruction of the plate motion in East Asia revealed the coupling relationship between the Pacific plate subduction and intracontinental tectonics (Liu et al., 2017b; Ma et al., 2019)

- The coupling relationship still lacks geological evidence and its bearing on earth surface processes remain largely unknown.




*Ma et al., 2019, GRL*

# River Evolution in East Asia

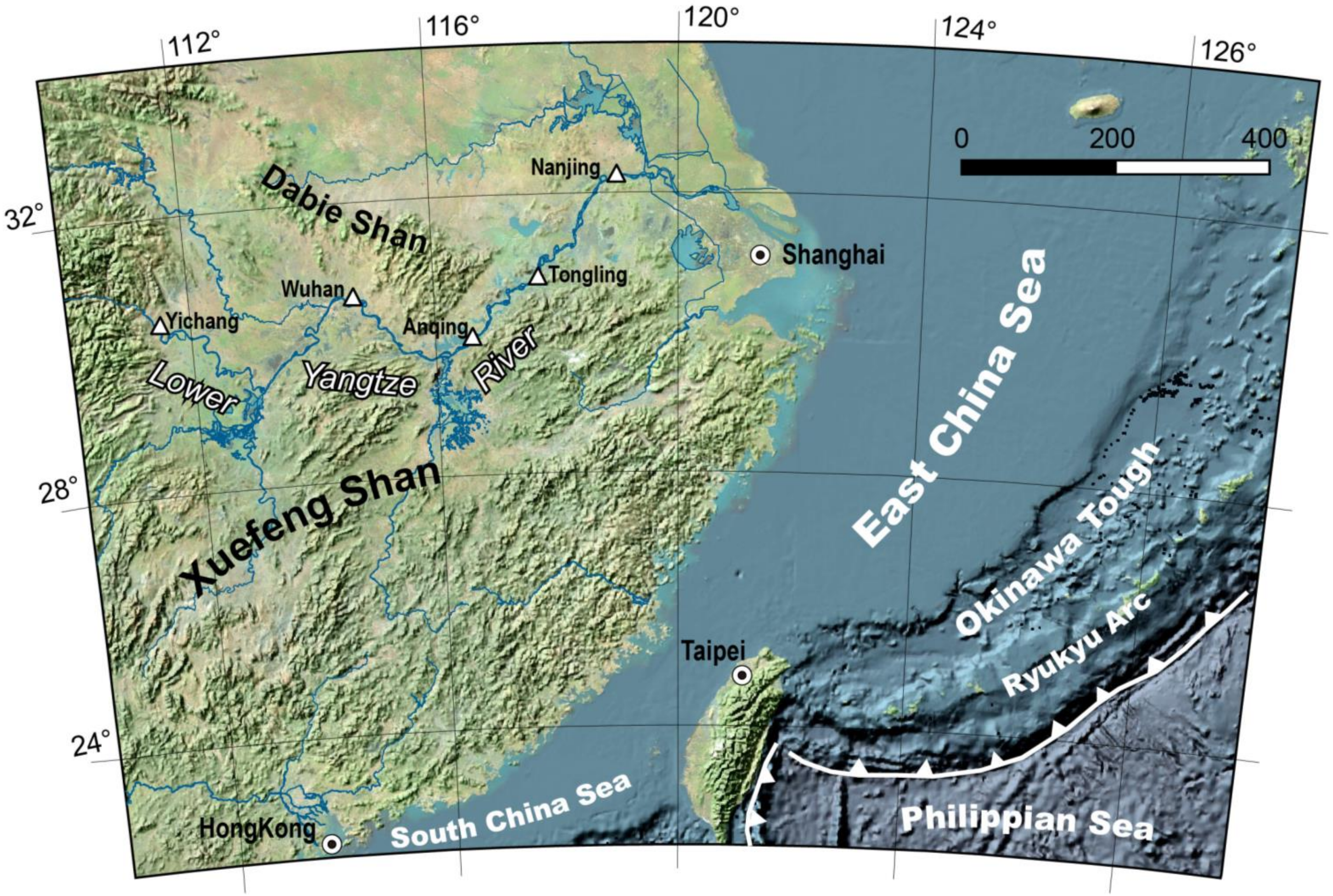



*Zheng et al., 2013, PNAS*

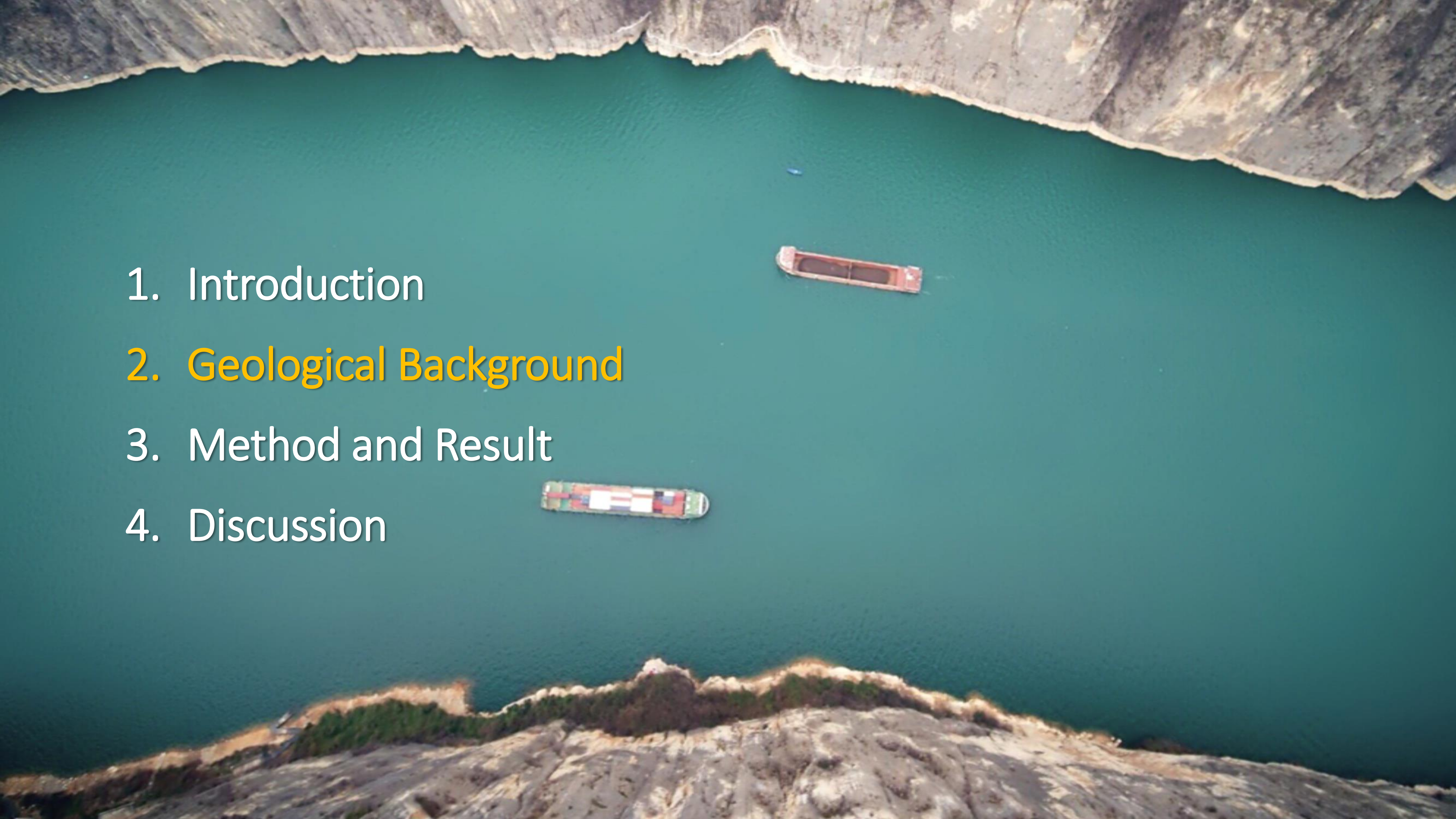
- As an overarching response to regional tectonic and climate, the integration of the Yangtze River provides a spectacular example to understand the interaction between the tectonic, climate and surface processes.

- Debate on the timing of the Yangtze integration has limited the further understand of these processes, with estimates ranging from 23 to 45 Ma (Richardson et al., 2010; Zheng et al., 2013), to a more recent initiation around 1 to 2 Ma (Yang et al., 2006; Shao et al., 2012)

# To understand the link between tectonic and river integration we study the Lower Yangtze River sedimentation (Yangtze Gravel)




- Lithofacies interpretation for Yangtze Gravel within 17 sections measured along the Lower Yangtze River at Yichang, Wuhan, Anqing, Tongling, and Nanjing.
- Regional chronostratigraphic correlation based on $^{40}Ar/^{39}Ar$ dating of the basalt layers as well as the newly found fossil woods and pollens.
- Provenance of the Yangtze Gravel using petrography and detrital zircon U-Pb chronology and compare them with the results of the Early Cenozoic sediments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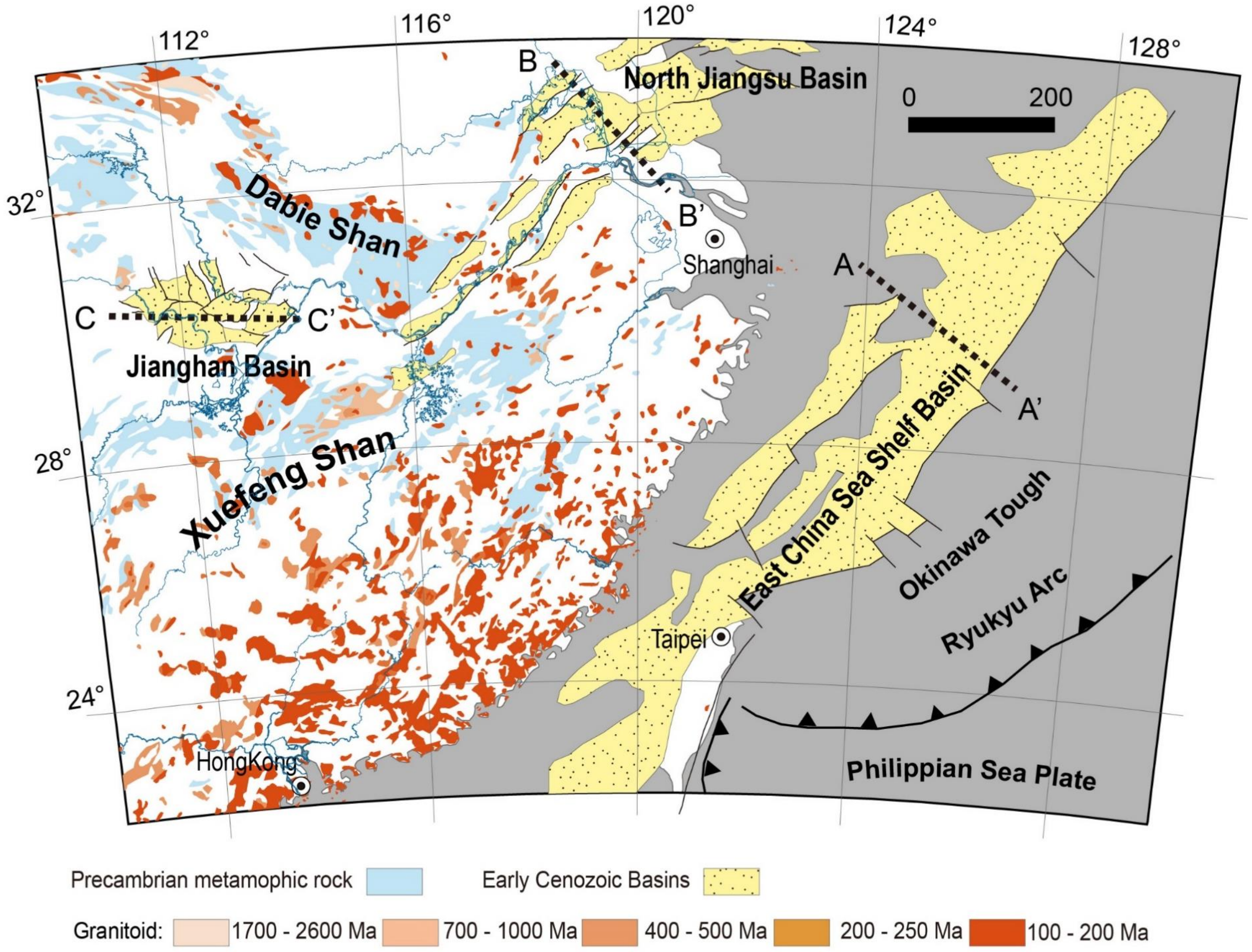
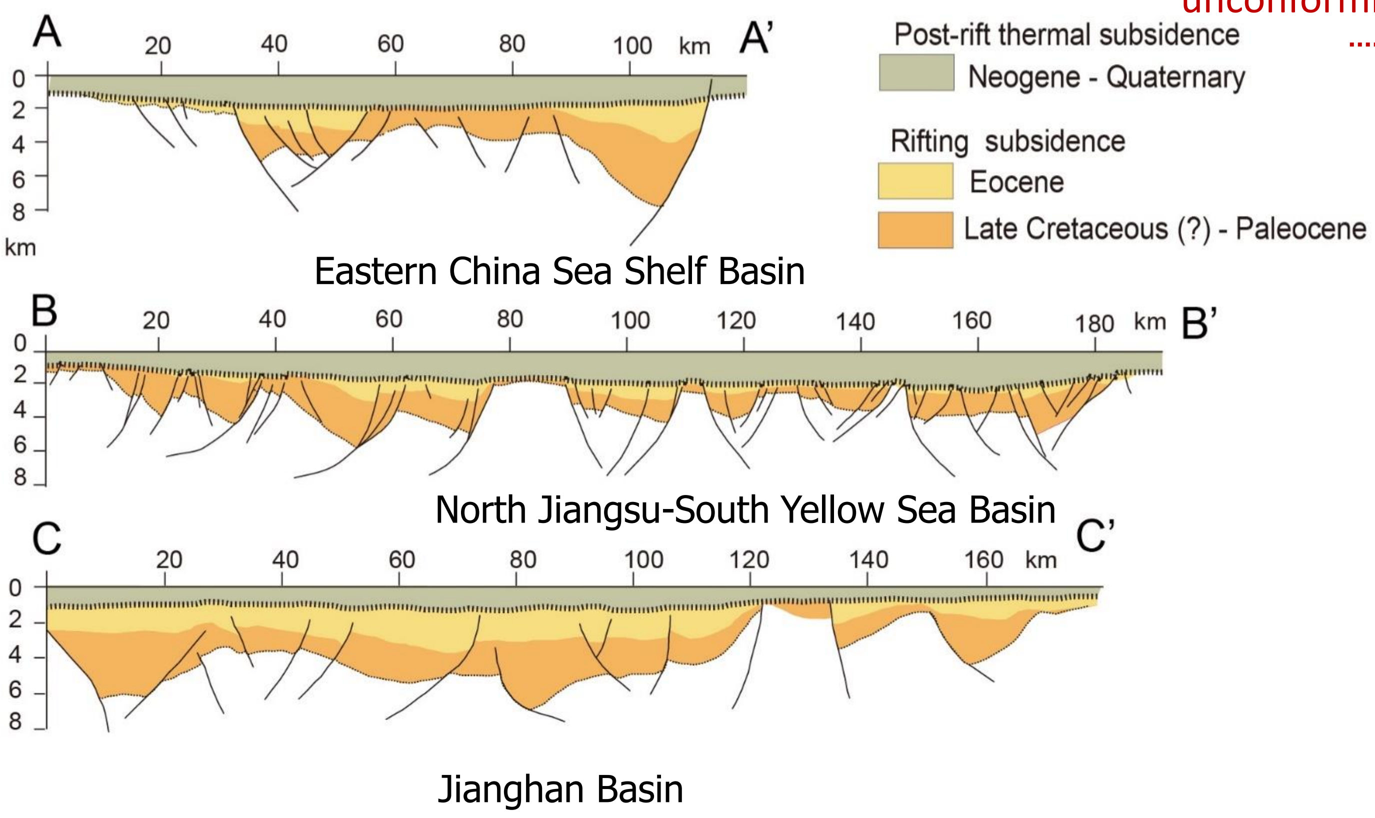
# Cenozoic basins in Lower Yangtze River area

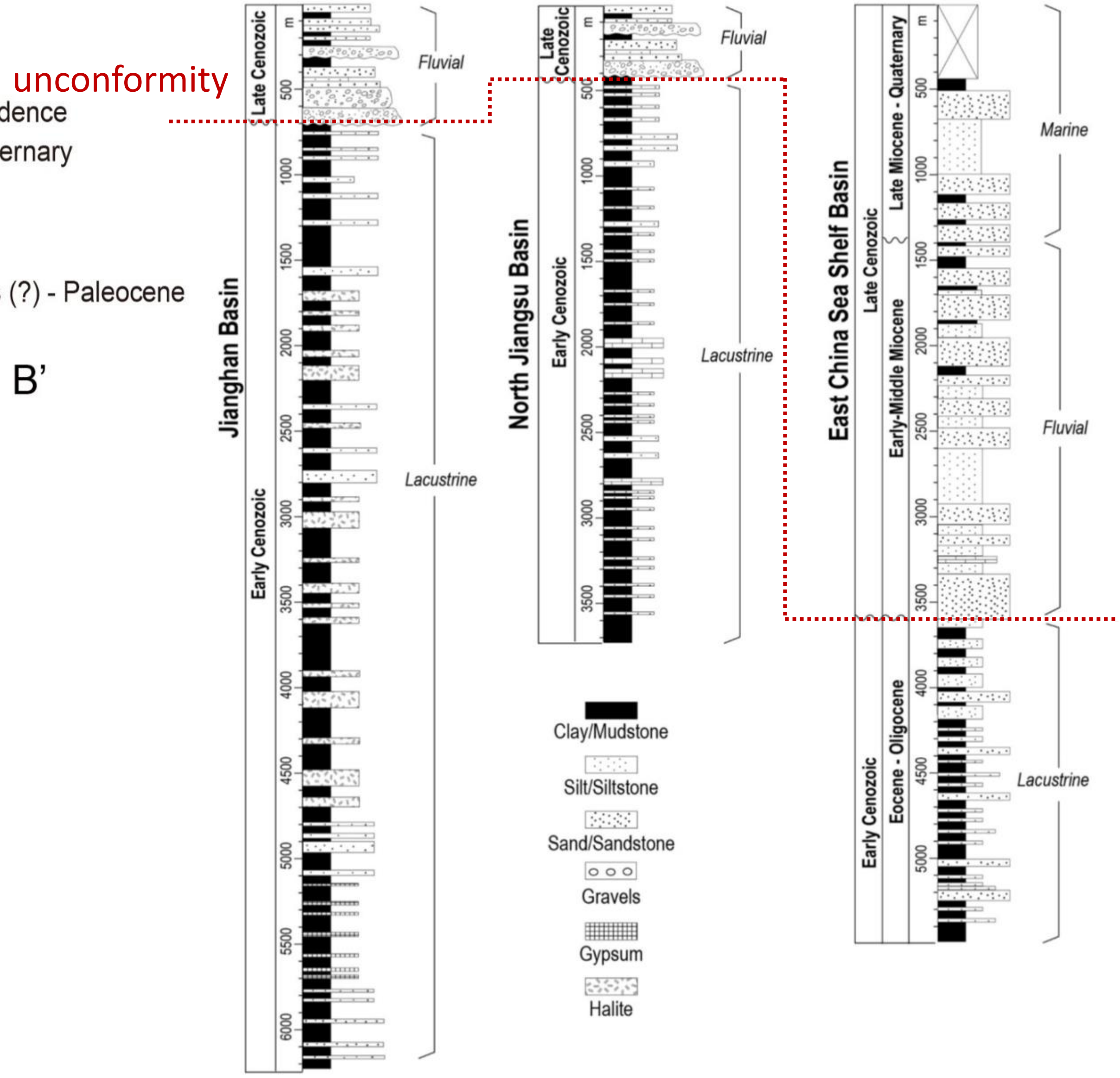



- The pre-Cenozoic basement in the Lower Yangtze area consists of an amalgam of Mesozoic orogenies (Precambrian metamorphic and Granitoid rocks ) and their foreland basins.

- Cenozoic Basins include Jianghan Basin, North Jiangsu-South Yellow Sea Basin, and East China Sea Shelf Basin, which consist of a series of grabens and half-grabens developed during the Late Cretaceous to Paleogene.

# Two-phase subsidence and depositional fills in Cenozoic basins




Based on petroleum exploration

*Dai, 1997; Zhang et al., 1989; Zhou and Yin, 1985*

# Late Cenozoic sedimentation at outcrops: Yangtze Gravel


- Sedimentary environment： Fan delta (e.g. Xiang et al., 2006) vs River (e.g. Zheng et al., 2013) ?
- Depositional ages： Pleistocene （e.g. Xiang et al., 2006） vs Pre-Miocene （e.g. Zheng et al., 2013） ?
- Provenance： Distal （Zheng et al., 2013; Yang et al., 2019） vs Proximal (Sun et al., 2017)?

**Pre-Miocene birth of the Yangtze River**

Hongbo Zheng[a,1], Peter D. Clift[b], Ping Wang[a], Ryuji Tada[c], Juntao Jia[d], Mengying He[e], and Fred Jourdan[f]

Quaternary sediment in the Yichang area: Implications for the formation of the Three Gorges of the Yangtze River

Fang Xiang [a,*], Lidong Zhu [a], Chengshan Wang [b], Xixi Zhao [c],

**Geochronology of detrital muscovite and zircon constrains the sediment provenance changes in the Yangtze River during the late Cenozoic**

Xilin Sun,*,† Chang'an Li,* Klaudia F. Kuiper,† Jietao Wang,‡ Yuntao Tian,§

**Provenances of Cenozoic sediments in the Jianghan Basin and implications for the formation of the Three Gorges**

Chaoqun Yang[a,b], Chuanbo Shen[a], Massimiliano Zattin[b], Wu Yu[a], Shaoxian Shi[a] and Lianfu Mei[a]

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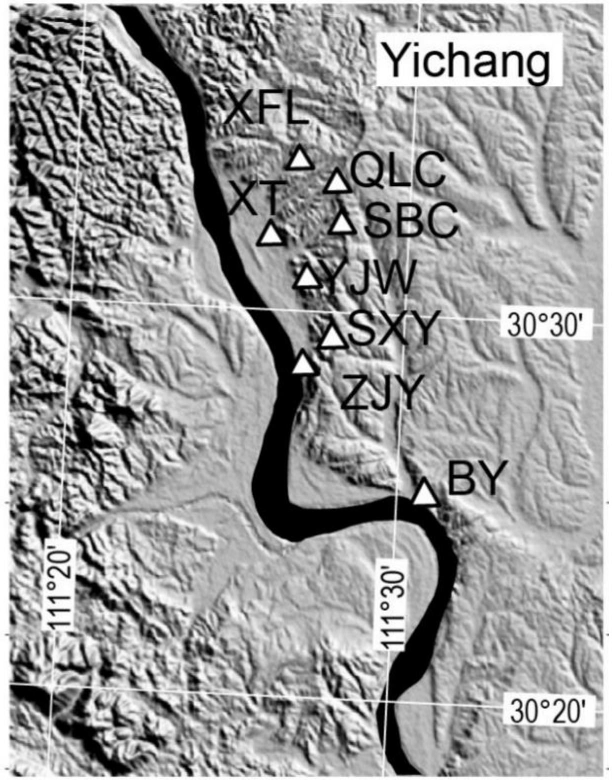
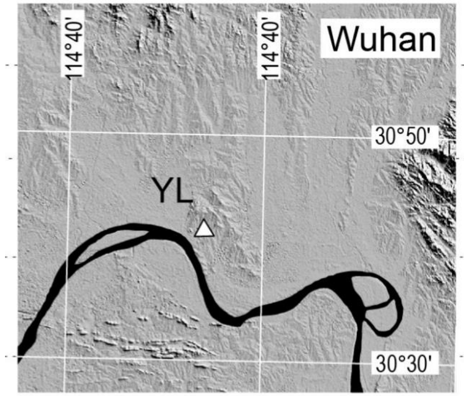
# Method

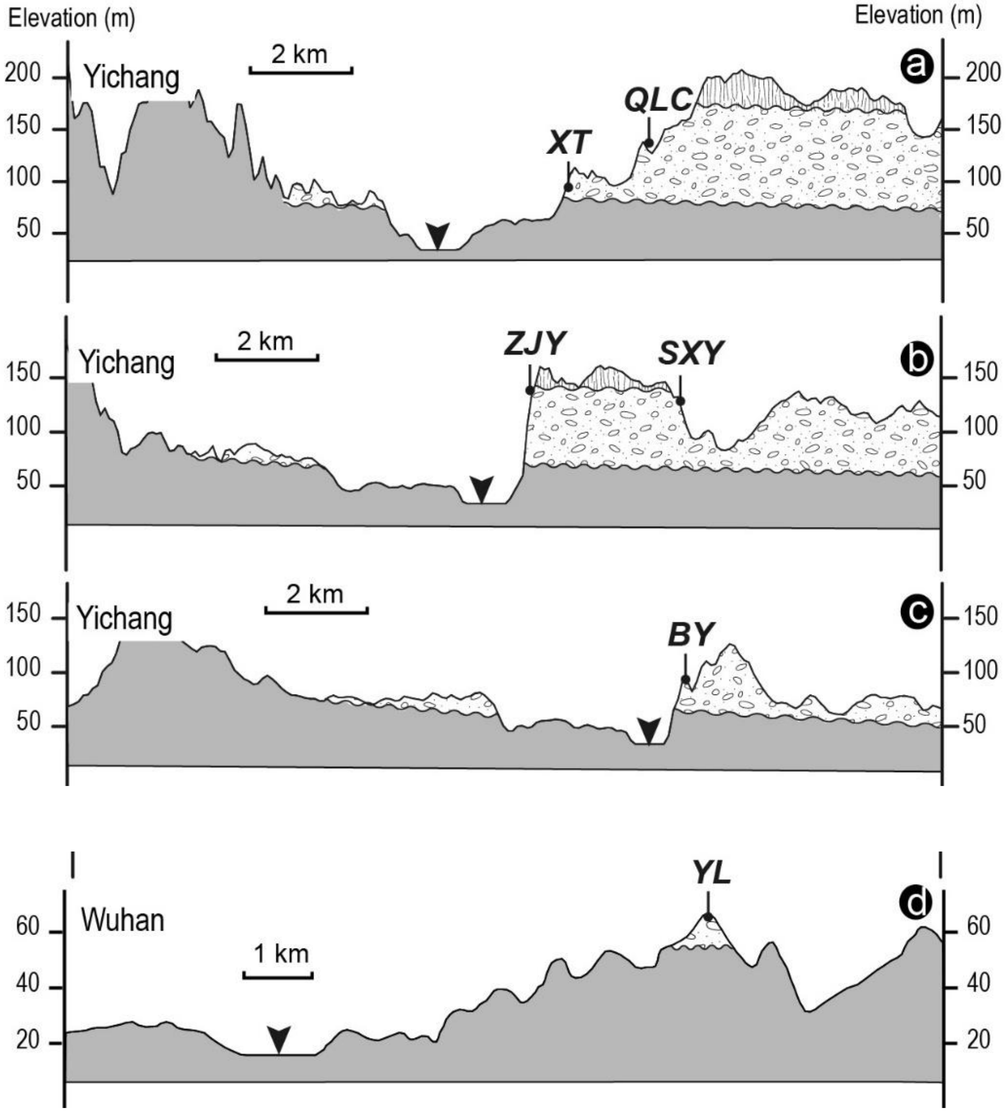
**Yangtze Gravel**

- **Sedimentology**
  - 17 sections measured
  - Geomorphology observation
  - lithofacies interpretation
- **Geochronology**
  - chronostratigraphic correlation
  - Ar/Ar dating of the basalt layers
  - Fossil woods and pollens
- **Provenance**
  - Clast composition
  - Heavy minerals
  - Zircon U-Pb Geochronology

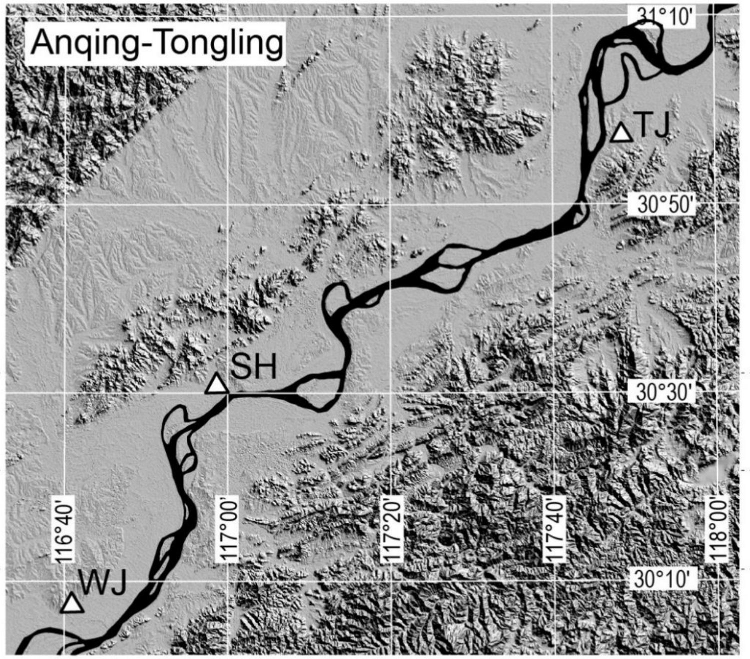
# Geomorphology observation at Yichang and Wuhan

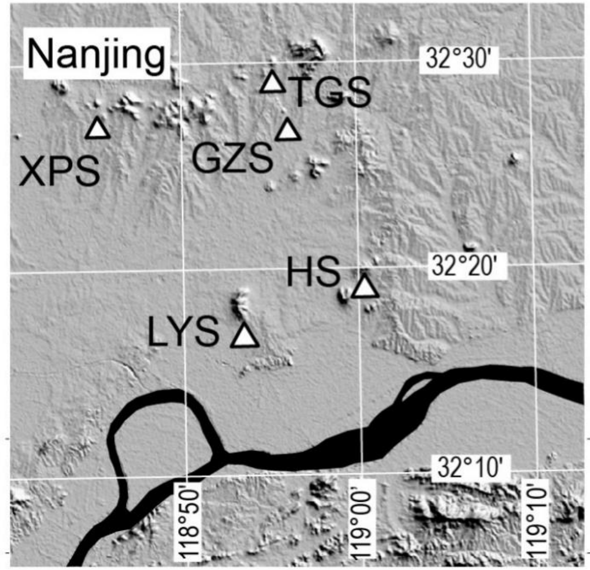


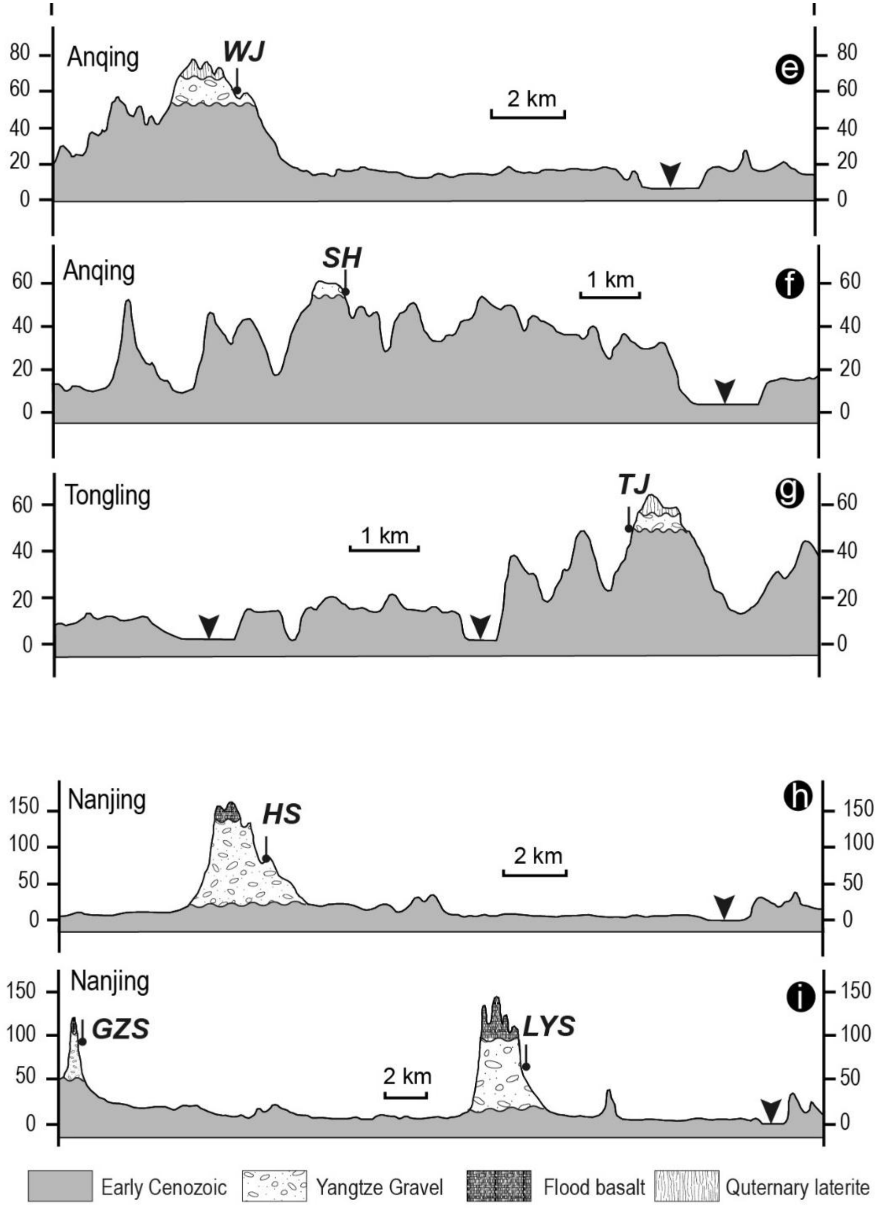



# Geomorphology observation at Anqing-Tongling and Nanjing

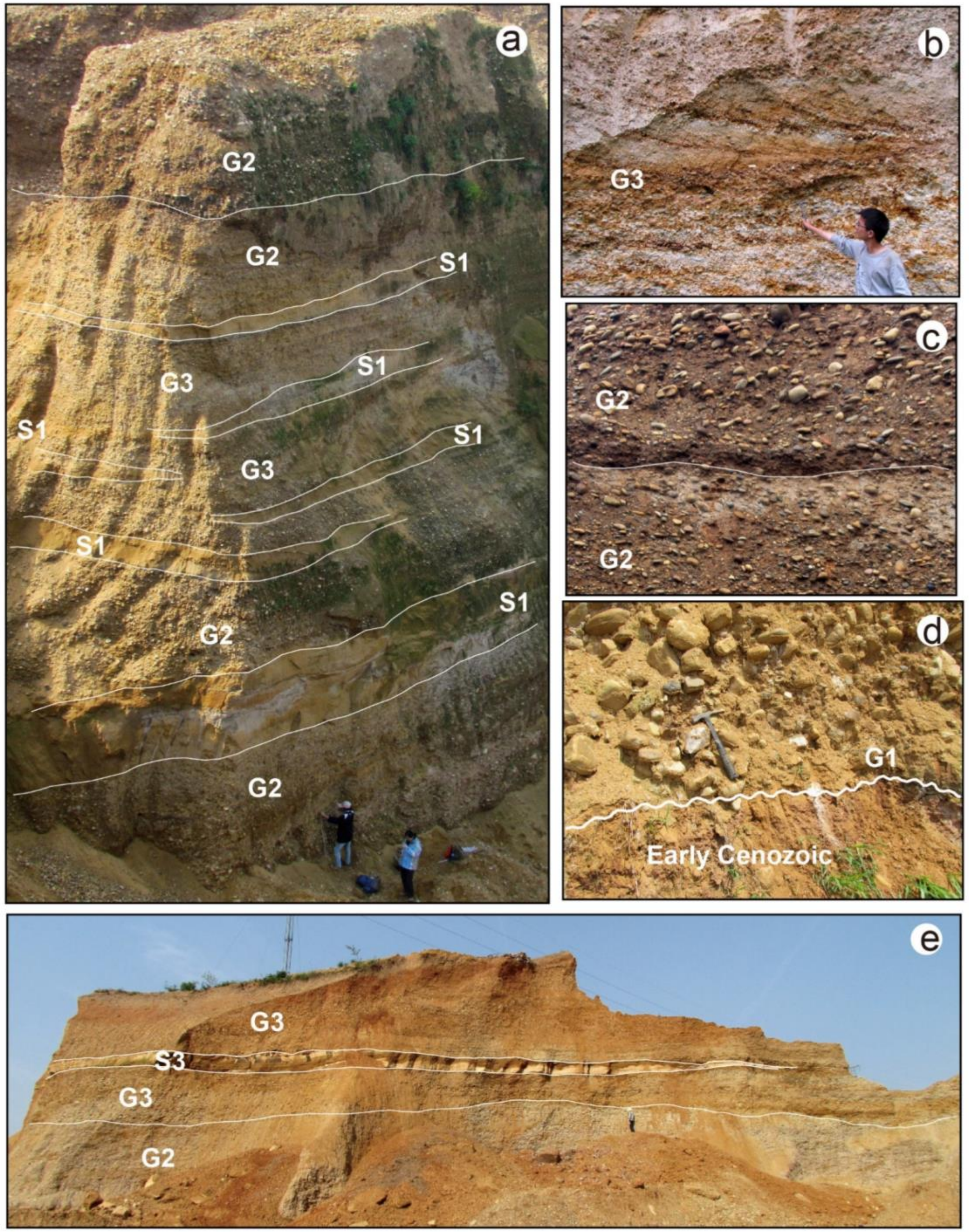


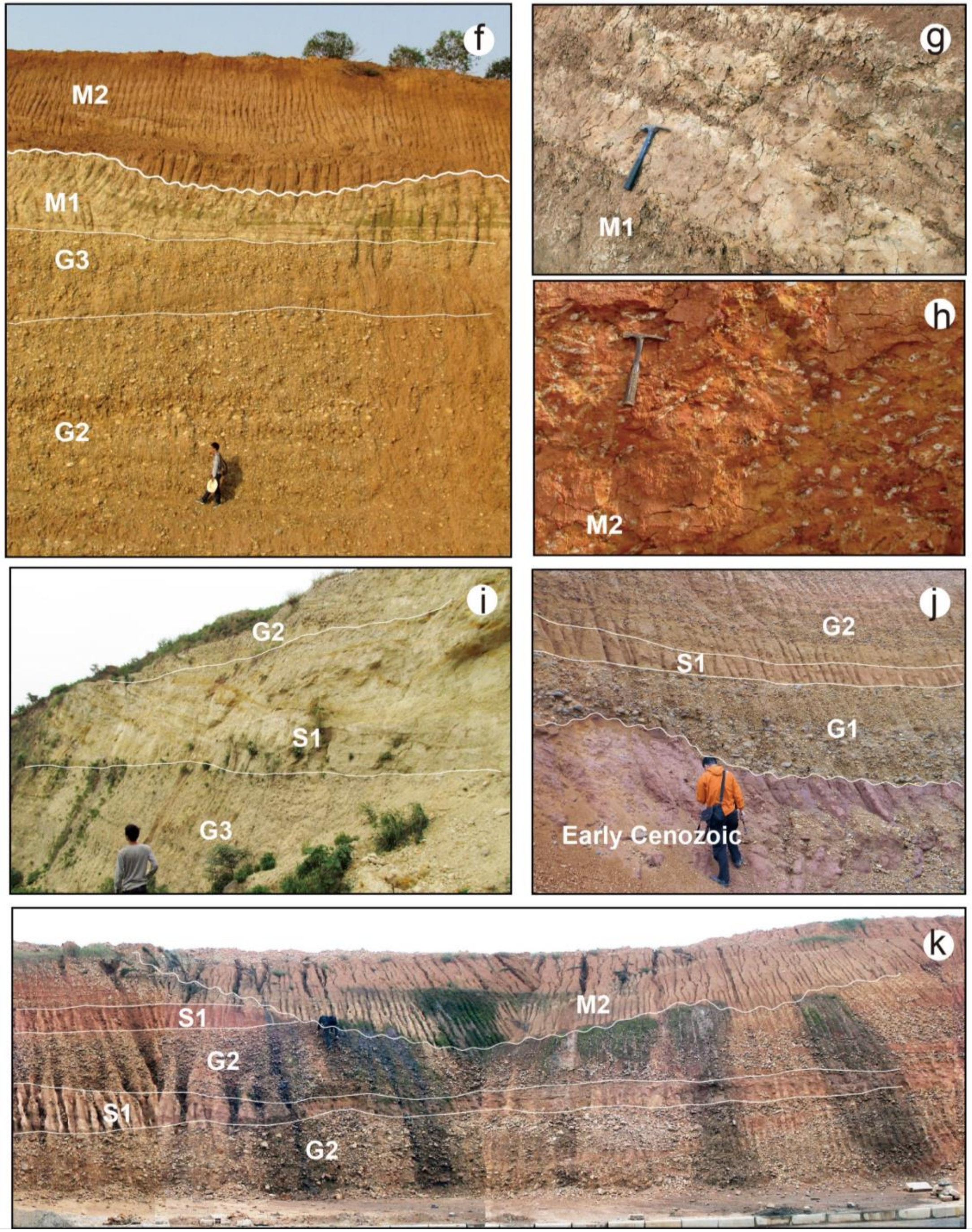
# Lithofacies at Yichang

| | Facies | Depositional environment |
|---|---|---|
| G1 | Massive poorly organized gravel | High-energy, high-discharge channel |
| G2 | Crudely beded gravel | High-energy channel, lateral accretion braid bar |
| G3 | Stratified sandy gravel | Channel with changing depositional energy, cross-channel bars, scour fill |
| S1 | Graded cross bedded sand | Channel, cross channel bars, scour fill,Transverse |
| S2 | Trough cross bedded sand | Sinuous-crested or linguoid dunes, channel, scour fill |
| S3 | Plane laminated sand | Bar top/sand flat, falling water stage in channel |
| M1 | Silt or Silty clay | overbank, abandoned channels |
| M2 | Laterite | Eolian dust |



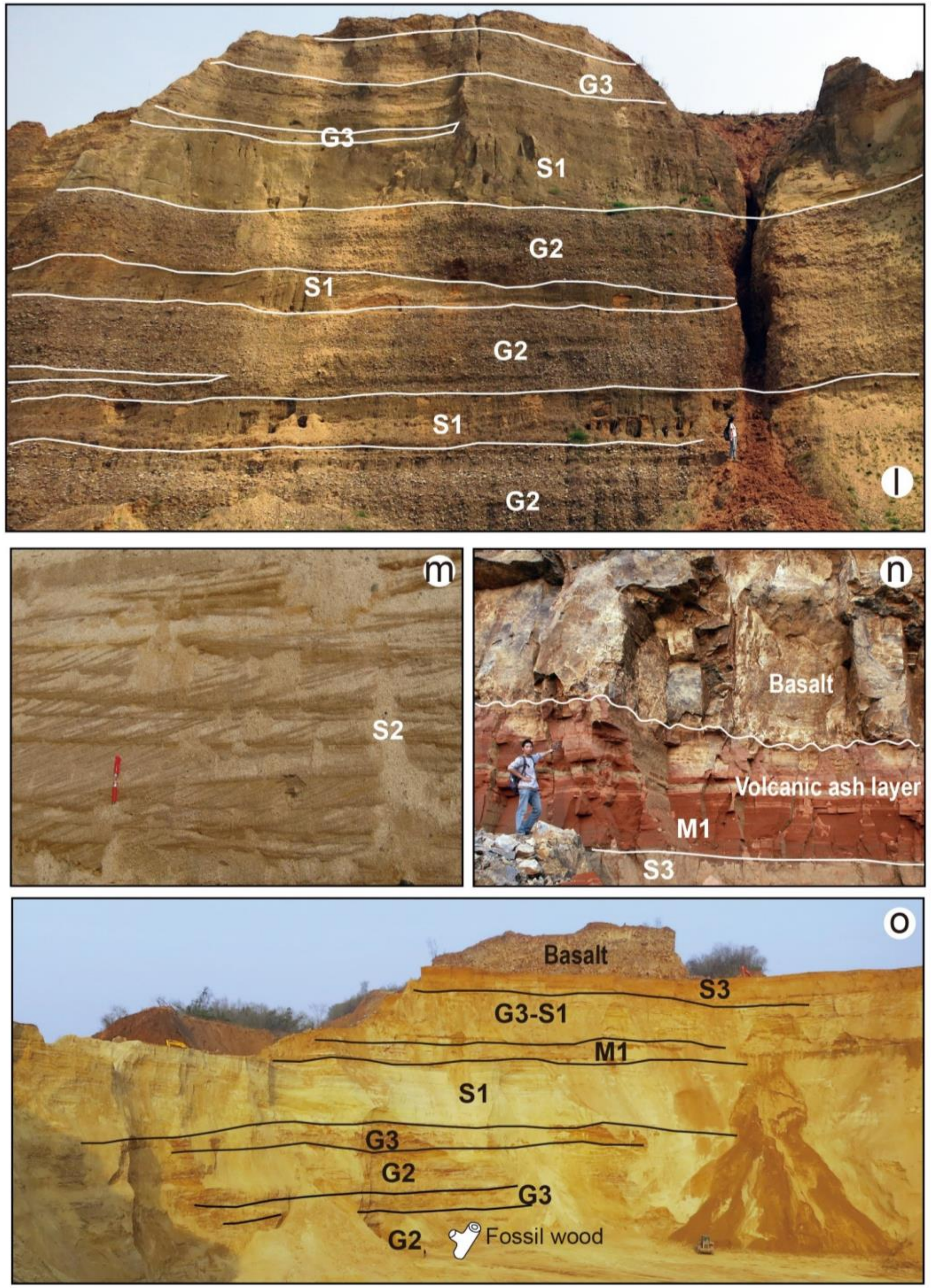
# Lithofacies at Yichang and Anqing-Tongling

| | Facies | Depositional environment |
|---|---|---|
| **G1** | Massive poorly organized gravel | High-energy, high-discharge channel |
| **G2** | Crudely beded gravel | High-energy channel, lateral accretion braid bar |
| **G3** | Stratified sandy gravel | Channel with changing depositional energy, cross-channel bars, scour fill |
| **S1** | Graded cross bedded sand | Channel, cross channel bars, scour fill,Transverse |
| **S2** | Trough cross bedded sand | Sinuous-crested or linguoid dunes, channel, scour fill |
| **S3** | Plane laminated sand | Bar top/sand flat, falling water stage in channel |
| **M1** | Silt or Silty clay | overbank, abandoned channels |
| **M2** | Laterite | Eolian dust |

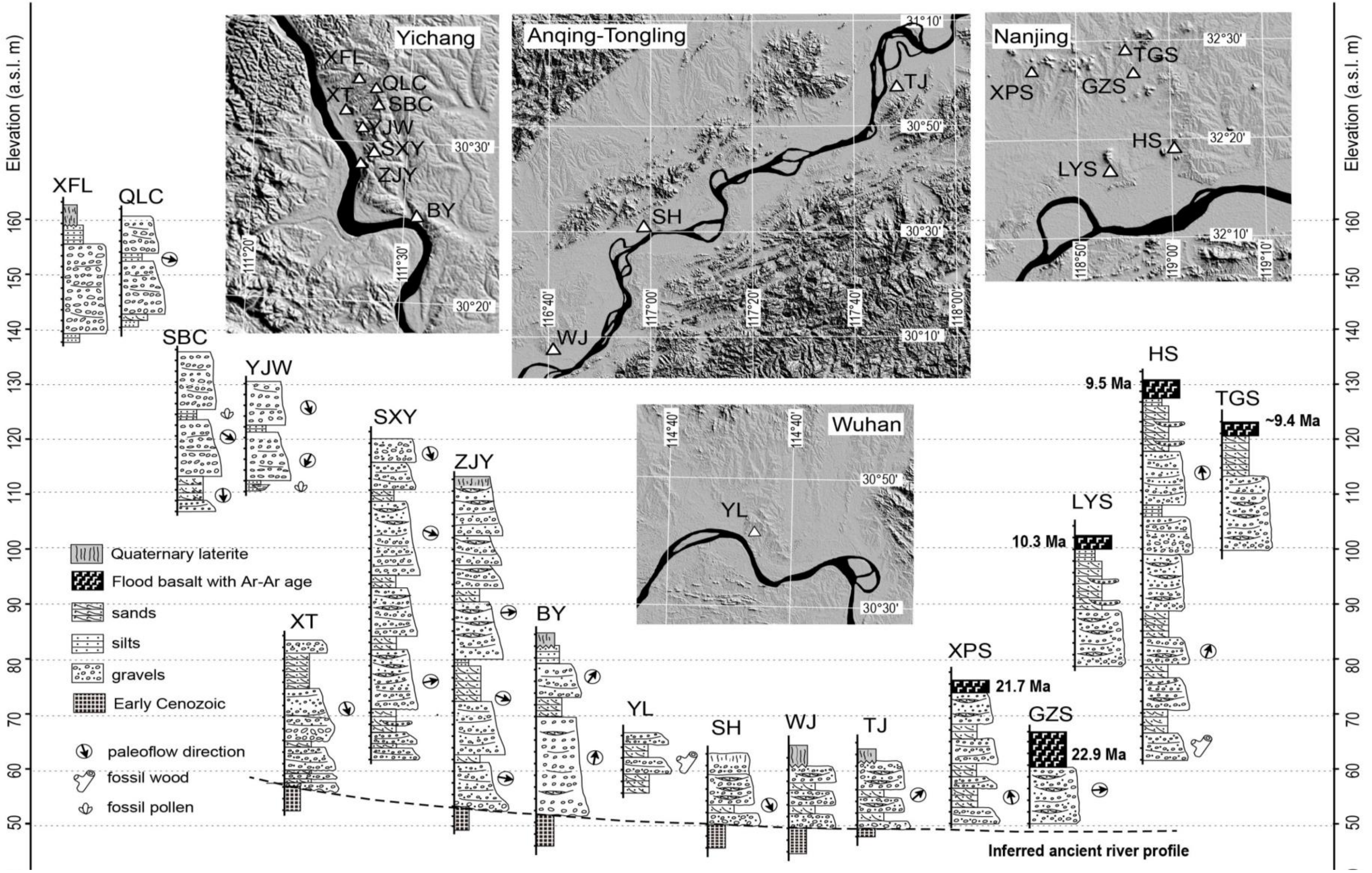


# Lithofacies at Nanjing

| | Facies | Depositional environment |
|---|---|---|
| **G1** | Massive poorly organized gravel | High-energy, high-discharge channel |
| **G2** | Crudely beded gravel | High-energy channel, lateral accretion braid bar |
| **G3** | Stratified sandy gravel | Channel with changing depositional energy, cross-channel bars, scour fill |
| **S1** | Graded cross bedded sand | Channel, cross channel bars, scour fill,Transverse |
| **S2** | Trough cross bedded sand | Sinuous-crested or linguoid dunes, channel, scour fill |
| **S3** | Plane laminated sand | Bar top/sand flat, falling water stage in channel |
| **M1** | Silt or Silty clay | overbank, abandoned channels |
| **M2** | Laterite | Eolian dust |

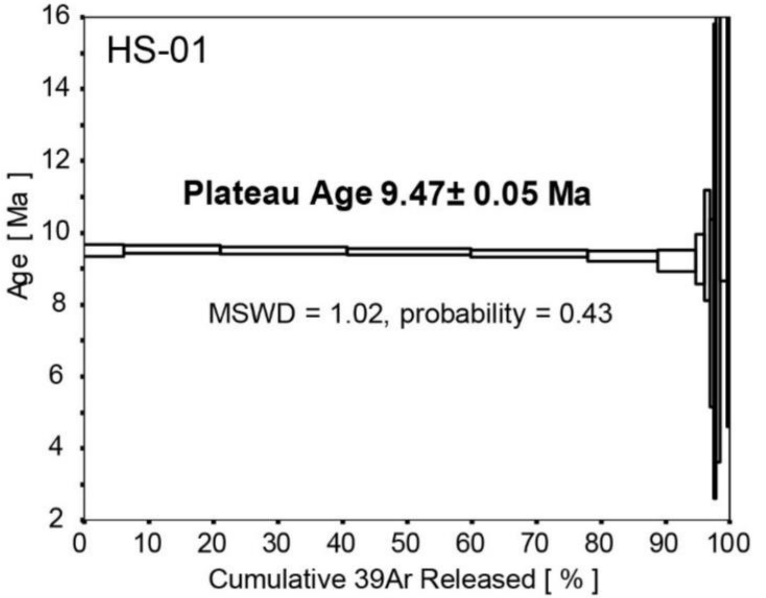


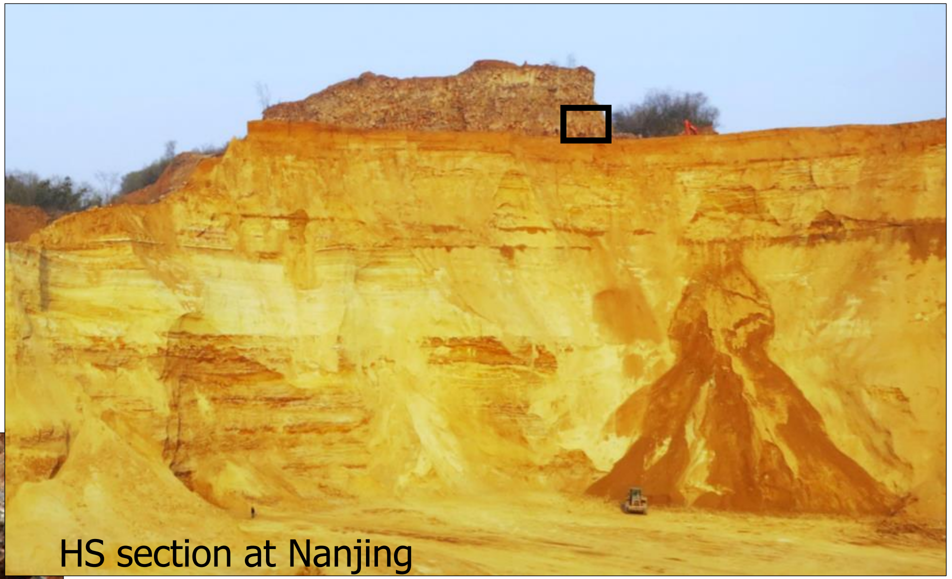
# Sedimentary environment interpretation

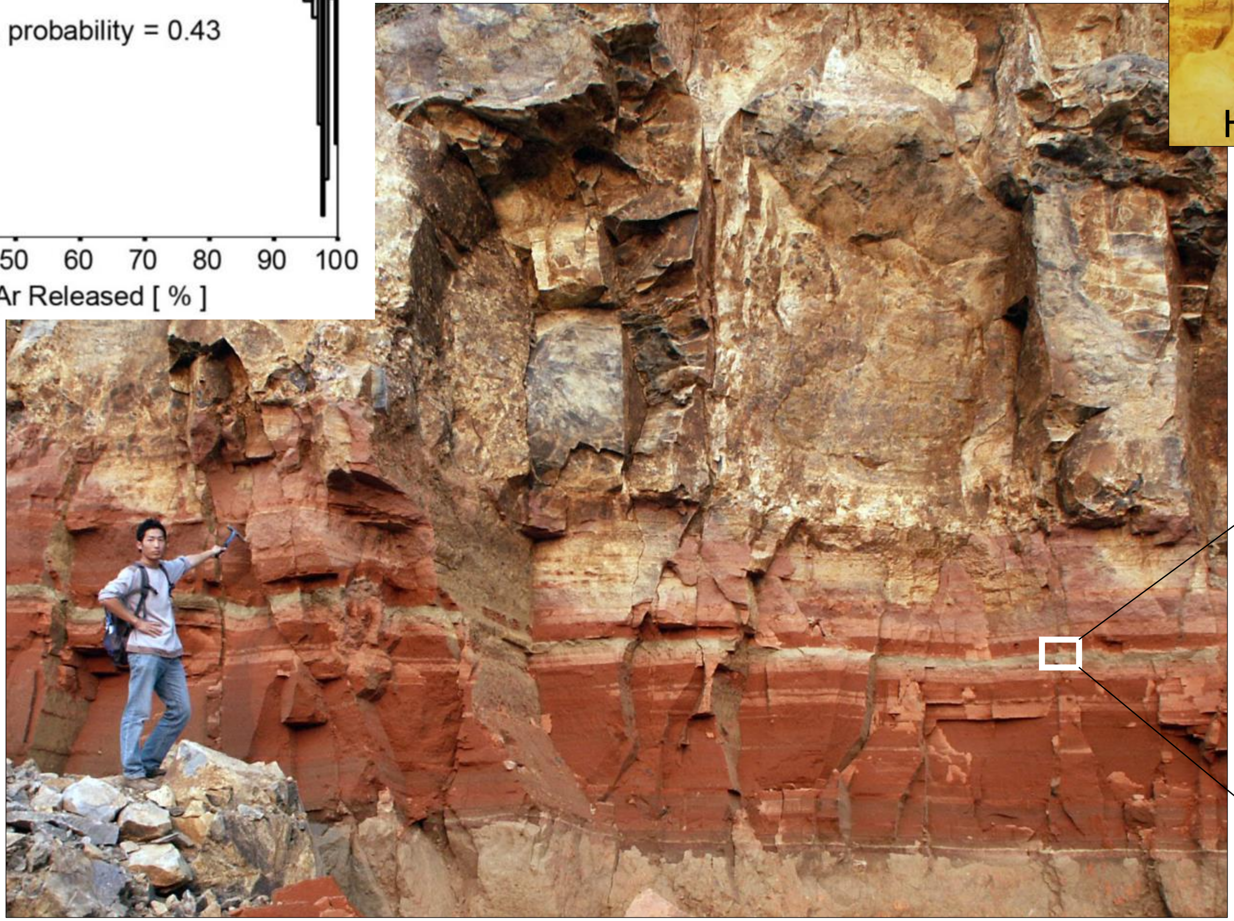



- Yangtze Gravel contains many features of braided streams with predominance of coeval channel-bar and channel-fill deposits within laterally continuous channel-belt sections.
- We interpret that Yangtze Gravel might have been deposited in a braided alluvial system, but not in an alluvial fan or fan-delta environment as proposed by Xiang et al. (2007).

# New Age constraint： Basalt $^{40}Ar/^{39}Ar$ dating



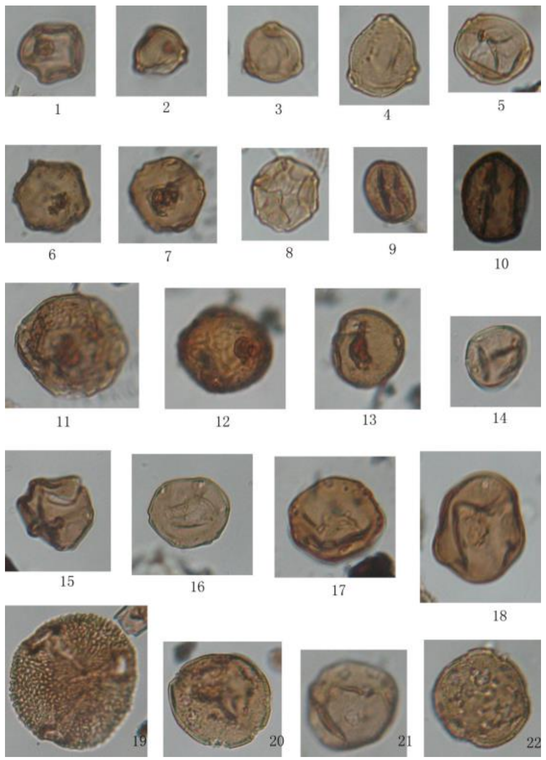
# Fossil Woods and Pollens

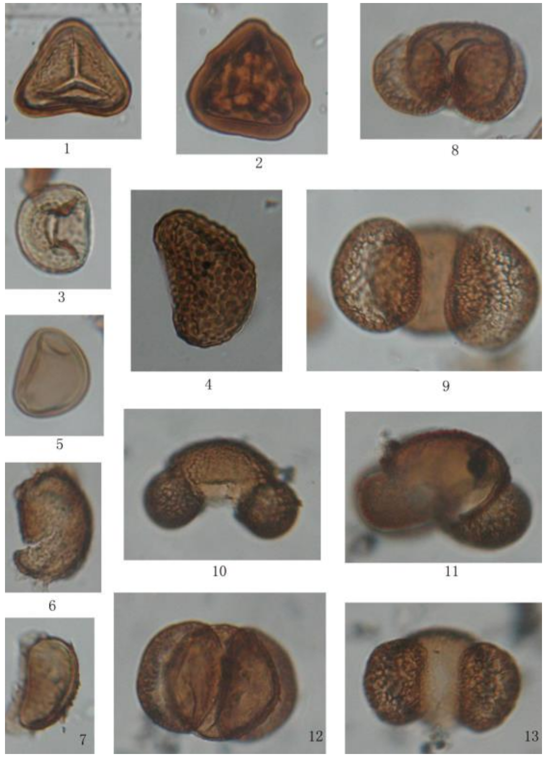
*HS-1 and HS-2: Agathoxylon sp.*

*HS-3: Cf. Careyoxylon sp. of the Terminariaceae*

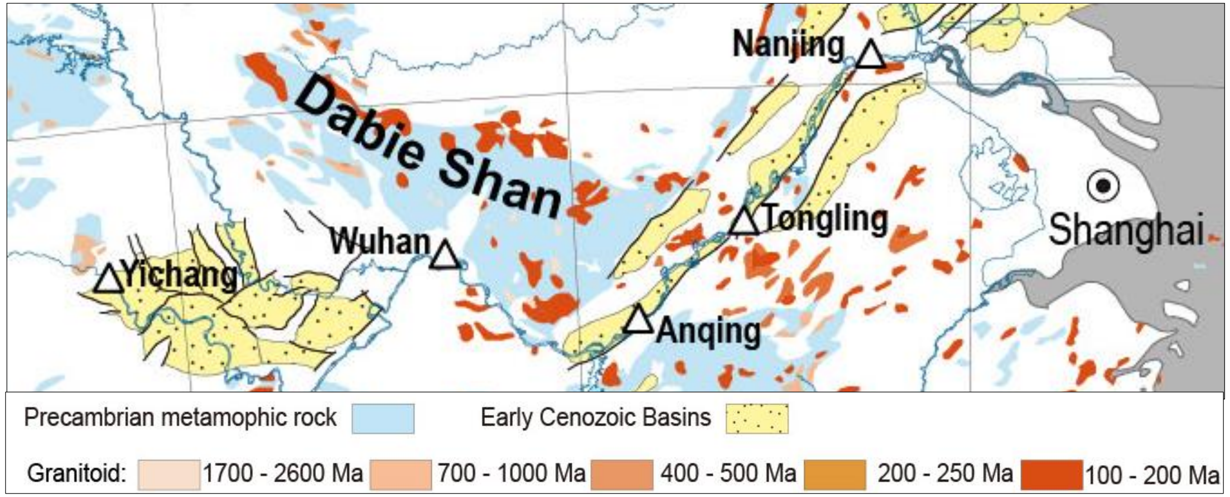
*HS-4: Bishofia sp. of the Euphorbiaceae*

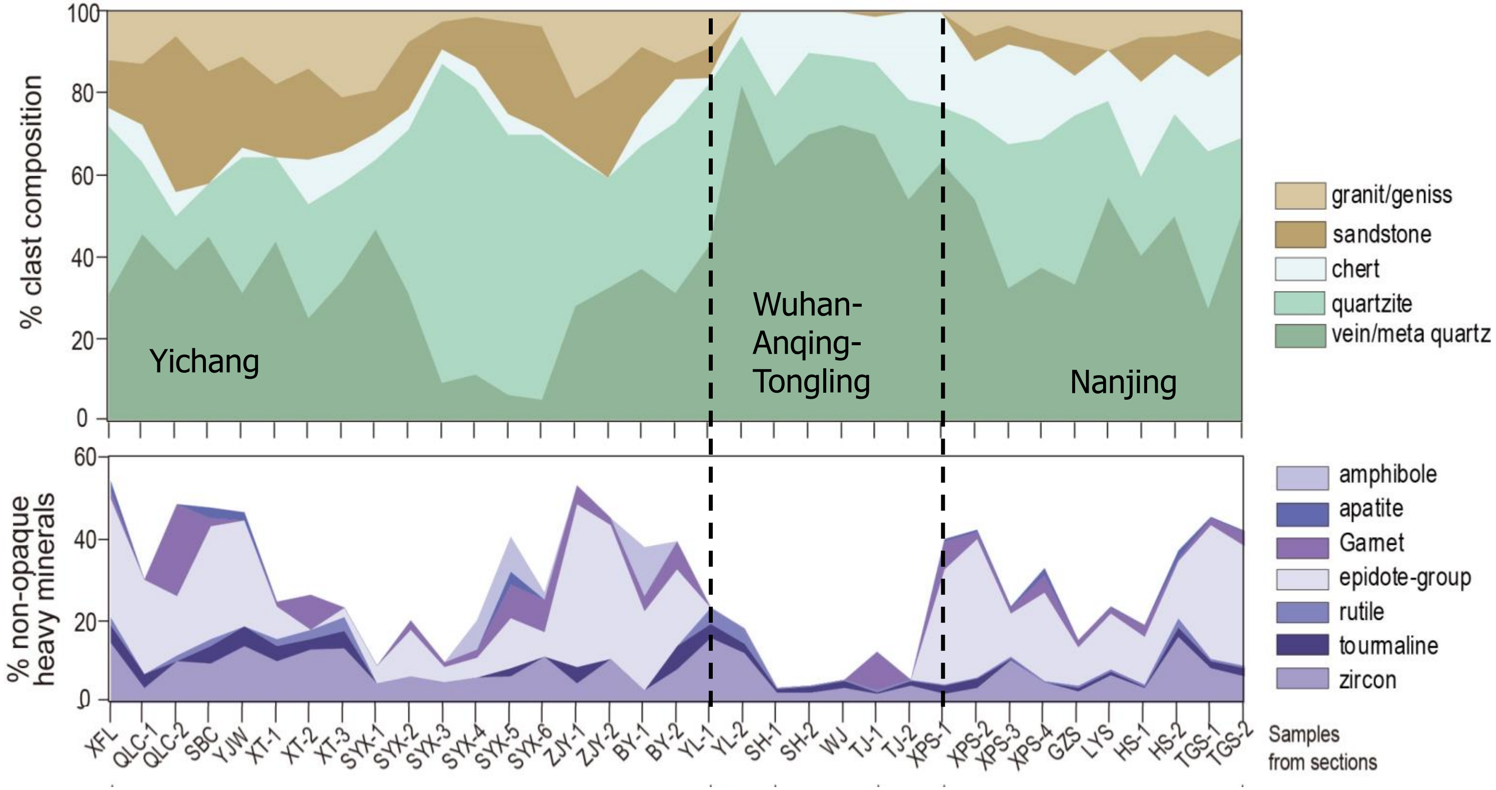
*Pinus* (22%), *Picea* (22%), *NAP*(19%) and *Tsuga* (13.6%) , with significant occurrence of Quercus (3.4%), *Ulmus* (5.5%), *Alnus* (2.8%), *Betula* (2.7%), *Liquidenbar* (4.3%) and *Juglans* (3.1%) and minor ocurrence of *Patracarya* and *Carya*.





# Clasts and Heavy Mineral Composition



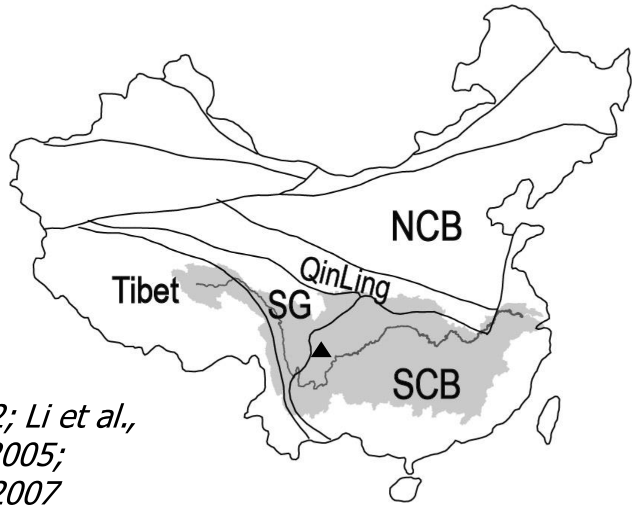




Clasts: Proximal source

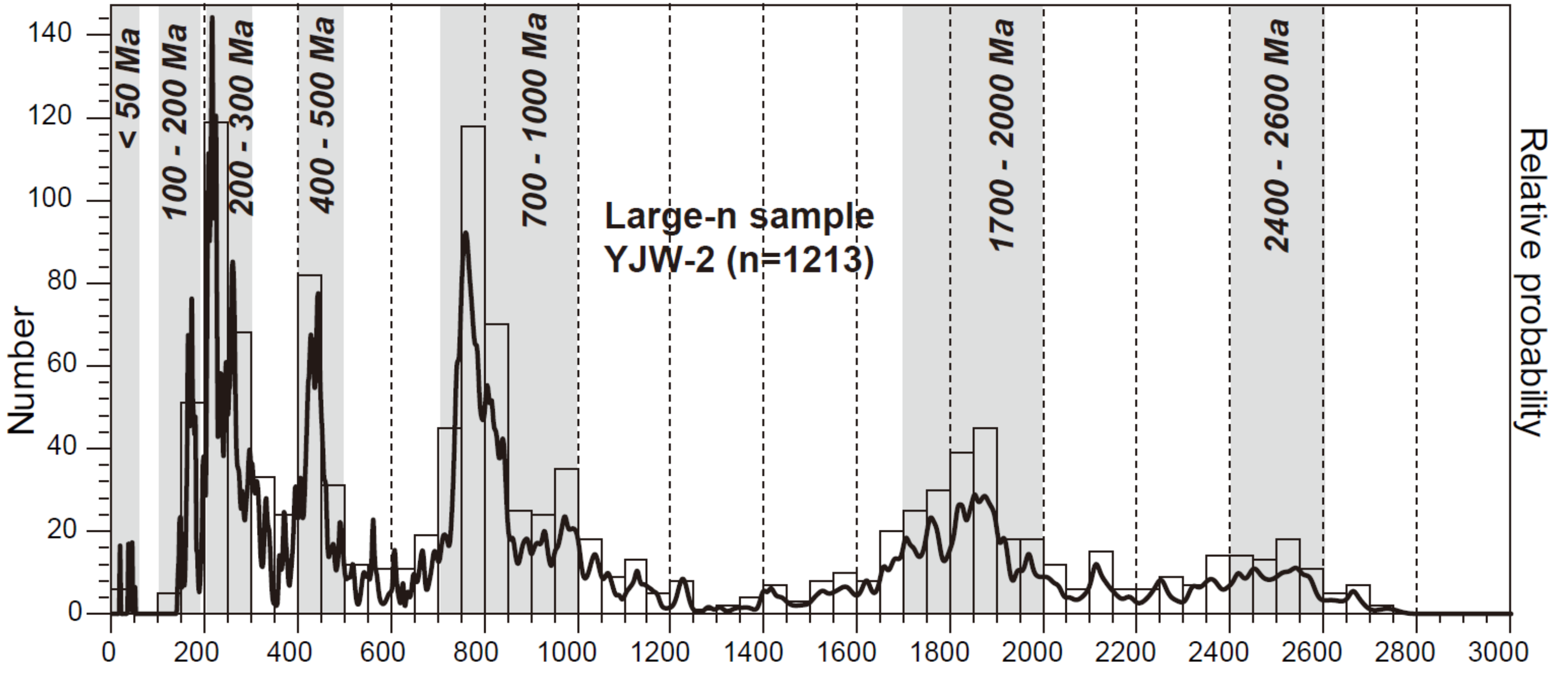
Heavy mineral: Proximal + Distal sources

# Large-*n* Detrital Zircon Geochronology

100–200 Ma: Qinling + South China Block
200–300 Ma: Qinling + Songpan-Ganzi + South China Block
400–500 Ma: Qinling
700–1000 Ma: South China Block
1700–2000 Ma: South China + North China Block
2400–2600 Ma: North China Block

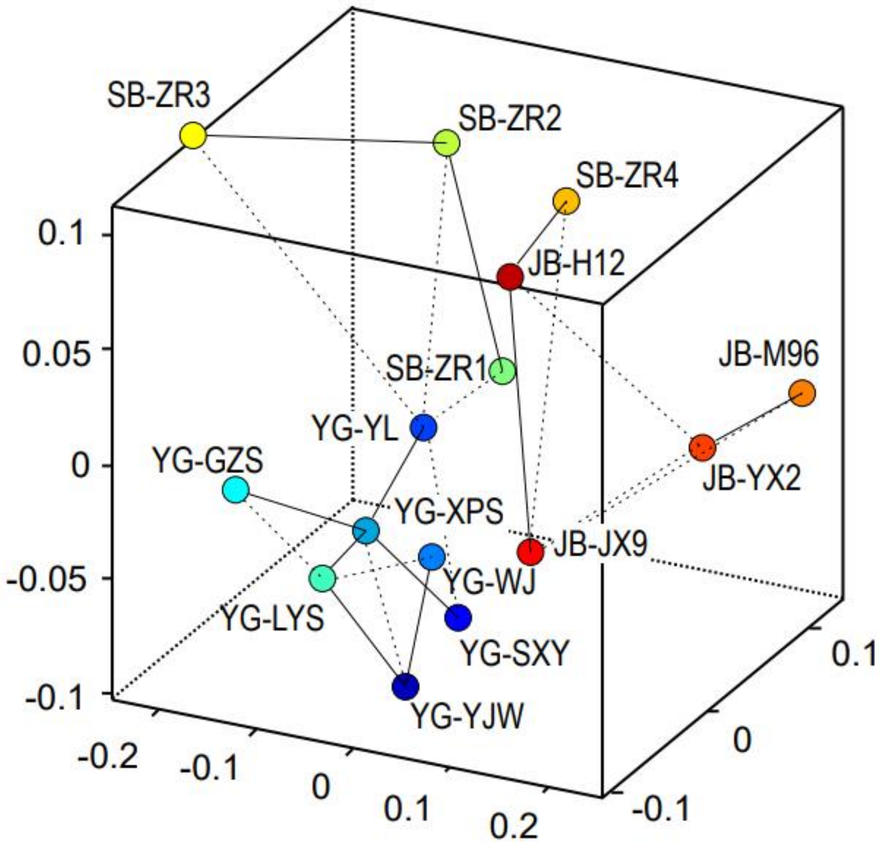



*Kusky and Li, 2003; Wilde et al., 2002; Li et al., 2003; Gao et al., 2011; Wang et al., 2005; Ratschbacher et al., 2003; Li and Li, 2007*

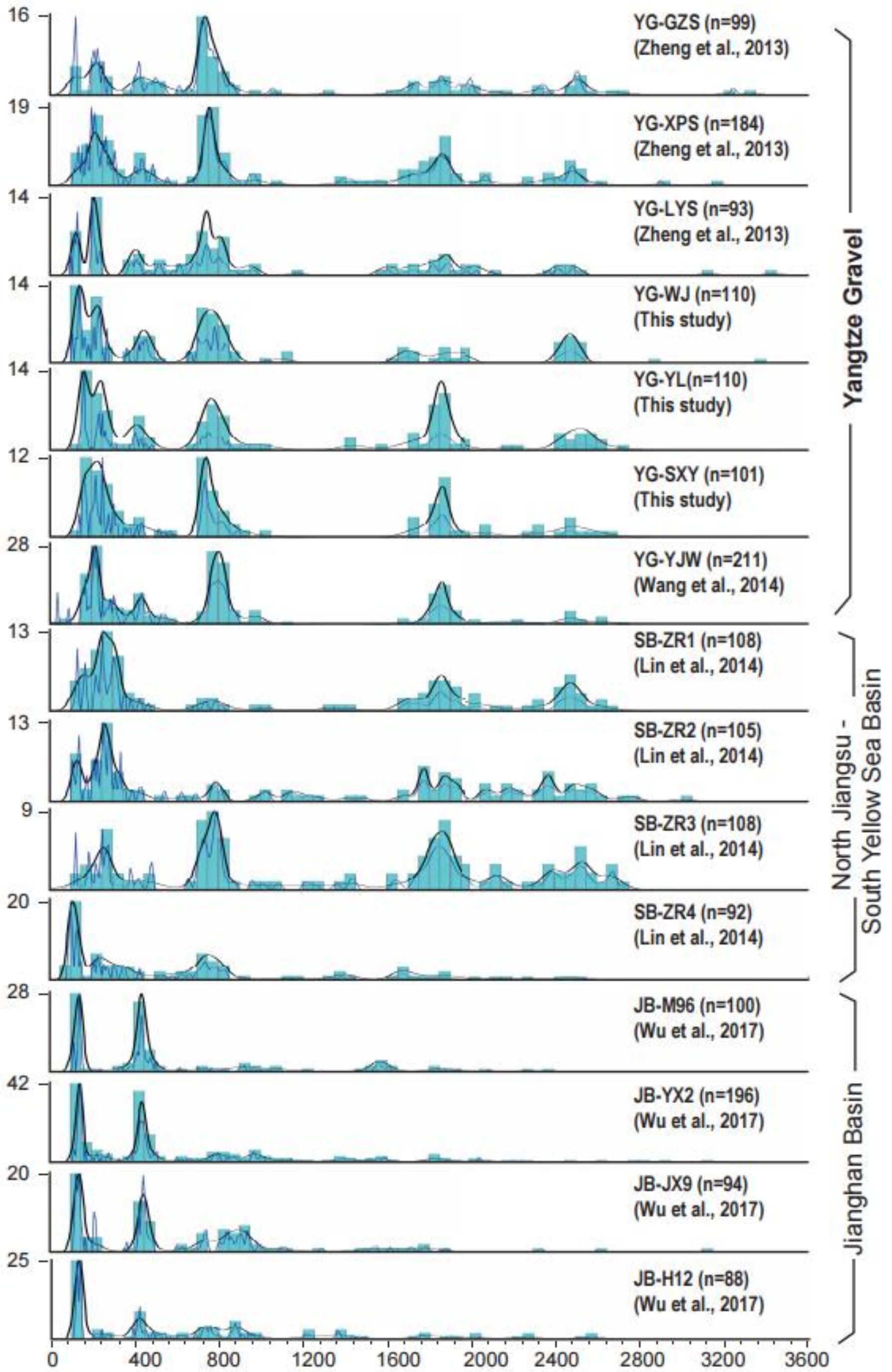



Tibet (6 grains): Distal Sources

# Comparison of the U-Pb age spectra




3D-MDS




KDE and PDP

## Late Cenozoic

Similarity in age spectrum of these detrital zircons may reflect the similar erosion pattern during the deposition of the Yangtze Gravel.

## Early Cenozoic

Changes in zircon spectra between Jianghan and North Jiangsu-South Yellow Sea Basin through Early to Late Cenozoic represent the changes in their provenances probably as a result of drainage reorganization.

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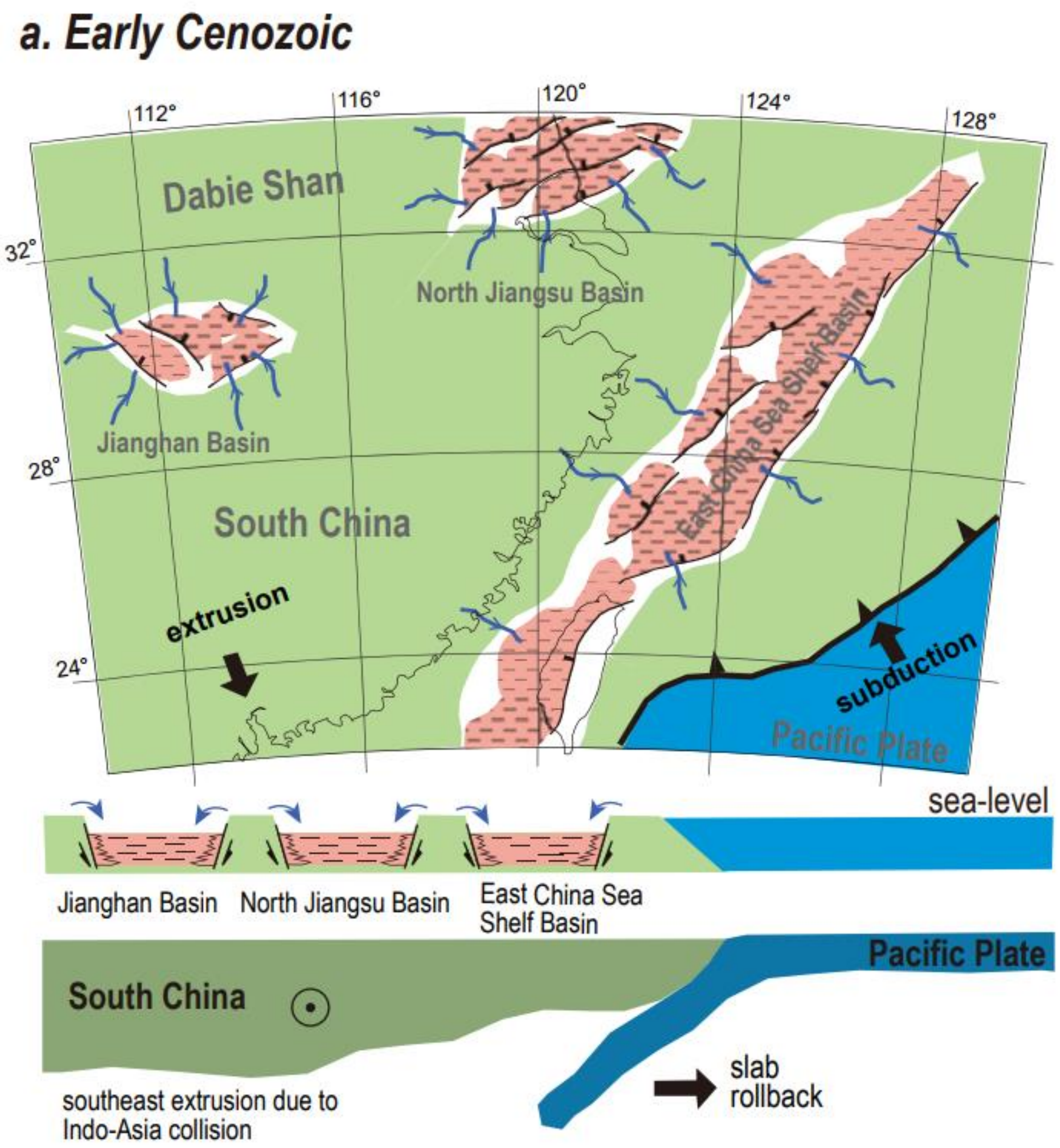
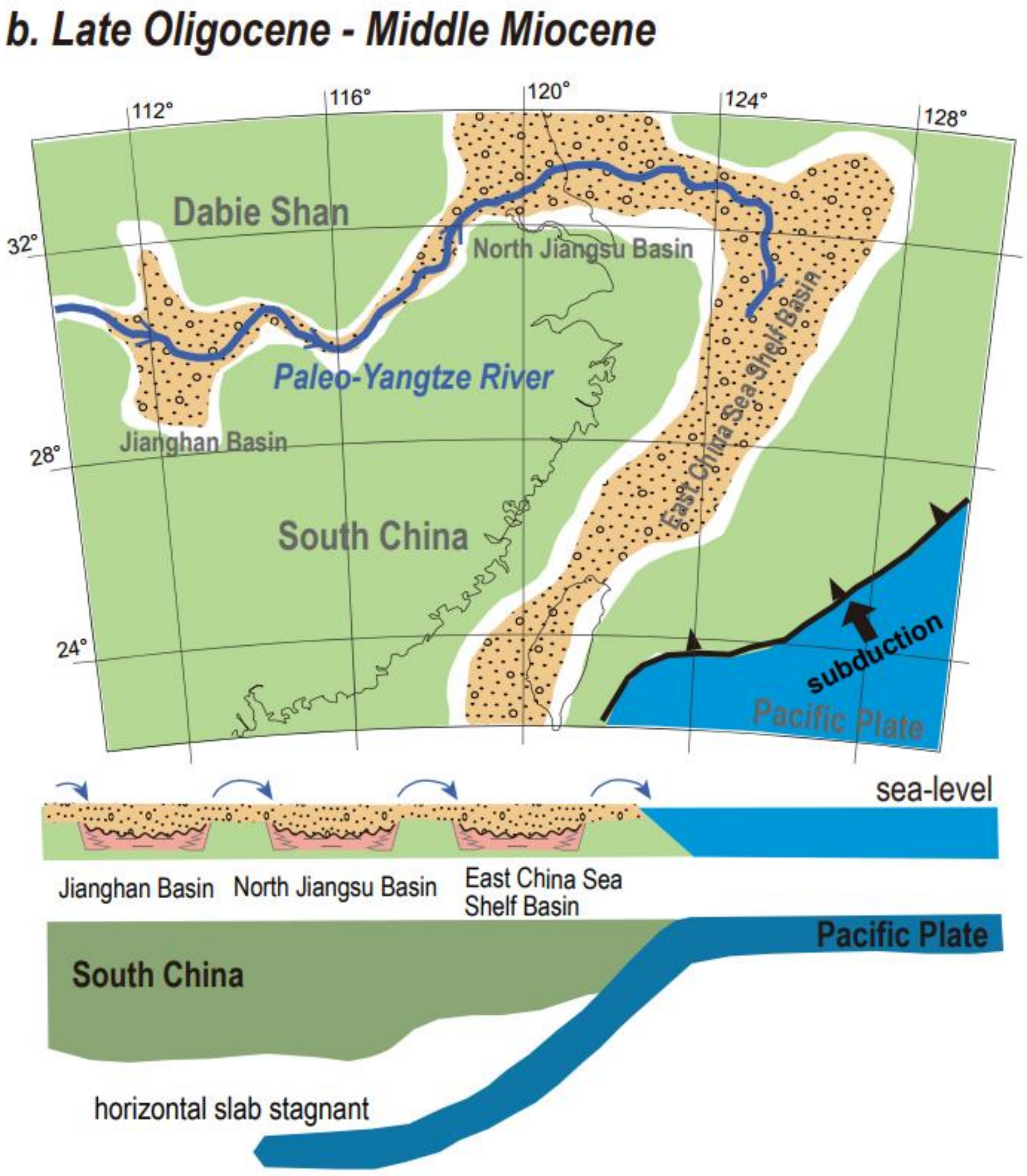



- Extensional deformation generally started from latest Cretaceous to Palaeocene, even earlier than the Indo-Asia collision (Ren et al., 2002). The rollback of the subducting Pacific slab is an appealing mechanism to explain back-arc extension in East Asia, including the formation of these extensional basins (Schellart and Lister, 2005; Schellart et al., 2019).

- Early Cenozoic basins were generally composed by several northeast–southwest striking grabens or half grabens with isolated subsidence centers. Alluvial and fluvio-lacustrine deposition filled most of the grabens and half grabens across the Jianghan Basin (Teng et al., 2019), North Jiangsu- South Yellow Sea Basin (Yi et al., 2003) and East China Sea Shelf Basin (Zhu et al., 2019).

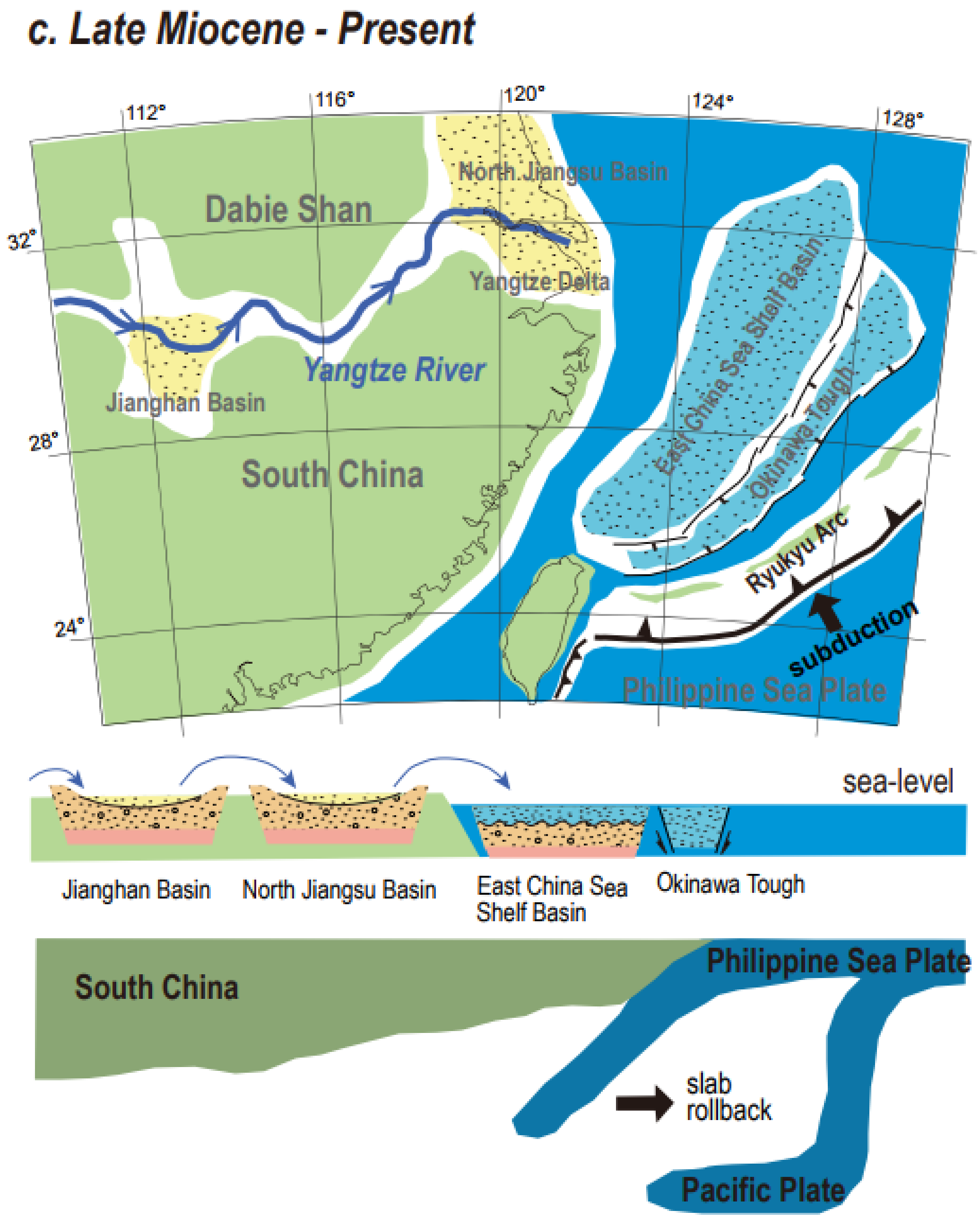
- The spectacular difference on detrital zircons between modern Yangtze (or Yangtze Gravel) and Early Cenozoic sediments (Yang et al., 2019 and this study) indicate that a through-going river had not yet been formed during this time period.




- Extensional basins enter a period of tectonic quiescent since early Oligocene, when the horizontal Pacific slab entered the mantle transitional zone. The maximum stagnant duration of the horizontal Pacific slab is ca. 20 Ma (Ma et al., 2019), which might significantly cause the dynamic subsidence for sediment deposition. (Liu et al., 2017; Zhu et al., 2019)

- River drainage networks and resulting sedimentation are sensitive to dynamic subsidence and that rivers tend to flow toward maximum subsidence, leading to regional unconformities and continental-scale reorganization of fluvial networks (e.g. Chang and Liu, 2019; Ding et al., 2019).

- An eastward-flowing Lower Yangtze River was formed since Late Oligocene or Early Miocene. It might flow across the North Jiangsu basin into the East China Sea Shelf Basin or even further south to Taiwan (Zhang et al., 2017).




- The westward subduction of the Philippian Sea Plate at Ryukyu Arc lead to back-arc extension of the Okinawa Trough probably at 9-6 Ma (Miki, 1995; Sibuet et al., 1998). As a result, the subsidence center migrated eastward from the East China Sea Shelf Basin to the Okinawa Trough, accompanied by the inception of the marine deposition in East China Sea Shelf Basin.

- The widespread flooding of the southeast China occurred in this period and caused the formation of the present-day shoreline and the development of the Yangtze Delta (Chen and Stanley, 1995). The oldest sediments of Yangtze Delta was dated to ca. 3.2 Ma (Jia et al., 2010), indicating that the delta was formed much later than the Lower Yangtze River and can hardly be used to trace the river history.

# TAKE-HOME MESSAGE

1. We recognized an ancient braided alluvial system based on lithofacies of Yangtze Gravel across the Lower Yangtze River area. The new $^{40}Ar/^{39}Ar$ dating of the overlying basalt and fossil-based stratigraphic correlation, suggest an early-middle Miocene age for these sediments.
2. This ancient Lower Yangtze River is supported by petrography and detrital zircon U-Pb geochronology results which show similar provenance and erosion pattern as the present-day Yangtze River.
3. The results allow us put the Lower Yangtze River evolution in the Cenozoic pictures of the western Pacific subduction and build a link between tectonic and earth surface processes.