

The Late Miocene Red River Submarine Fan in the Northwestern South China Sea: Characteristics and Exploration Significance*

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Abstract

Based on an integrated analysis of well log, core, and regional seismic data, a huge submarine fan is discovered at the boundary between the Yinggehai and the Qiongdongnan basins located in the northwestern South China Sea.

The fan, mainly formed during late Miocene (the Huangliu Period), is characterized by wedge-shaped oblique progradation configurations along depositional dip and bilateral downlapping geometries along strike. Analysis of seismic data shows that the fan has an area over 10,000 km² and a maximum thickness of over 2,000 m. Core and well log data from the YC35-1-2 well located in the distal side of the fan indicate that it mainly consists of sandy gravity-flow deposits in the lower part and interbedded sandstones and mudstones in the upper part. This, coupled with the fact that the study area during the Huangliu Period is bathyal, suggests that the fan is a sand-/mud-rich submarine fan with a sandy lower part up to 5,000 km².

Preliminary provenance analysis indicates that neither the Guiren Uplift to the west nor the Hainan Uplift to the north serves as the major source for the submarine fan. Facies analysis of the Huangliu Formation in the Yinggehai basin, in fact, suggests that the Red River is the major feeding river for the growth of the submarine fan. Therefore, the fan is named as the Red River submarine fan.

The integrated study shows that during late Middle Miocene a distinct shelf break was developed along and/or near the boundary between the Yinggehai and the Qiongdongnan basins under the affect of the Dongsha movement. Meanwhile, the tectonic event also leads to a large-

scale relative sea-level fall in the Yinggehai Basin. The Red River system, in response, shifted dramatically basinward towards the boundary between these two basins, resulting in the quick growth of the submarine fan.

The discovery of the Red River submarine fan provides important information for the uplift of the Tibetan Plateau and the evolution of Red River Fault Zone. It also points to a new direction for deepwater hydrocarbon exploration in the northern South China Sea.

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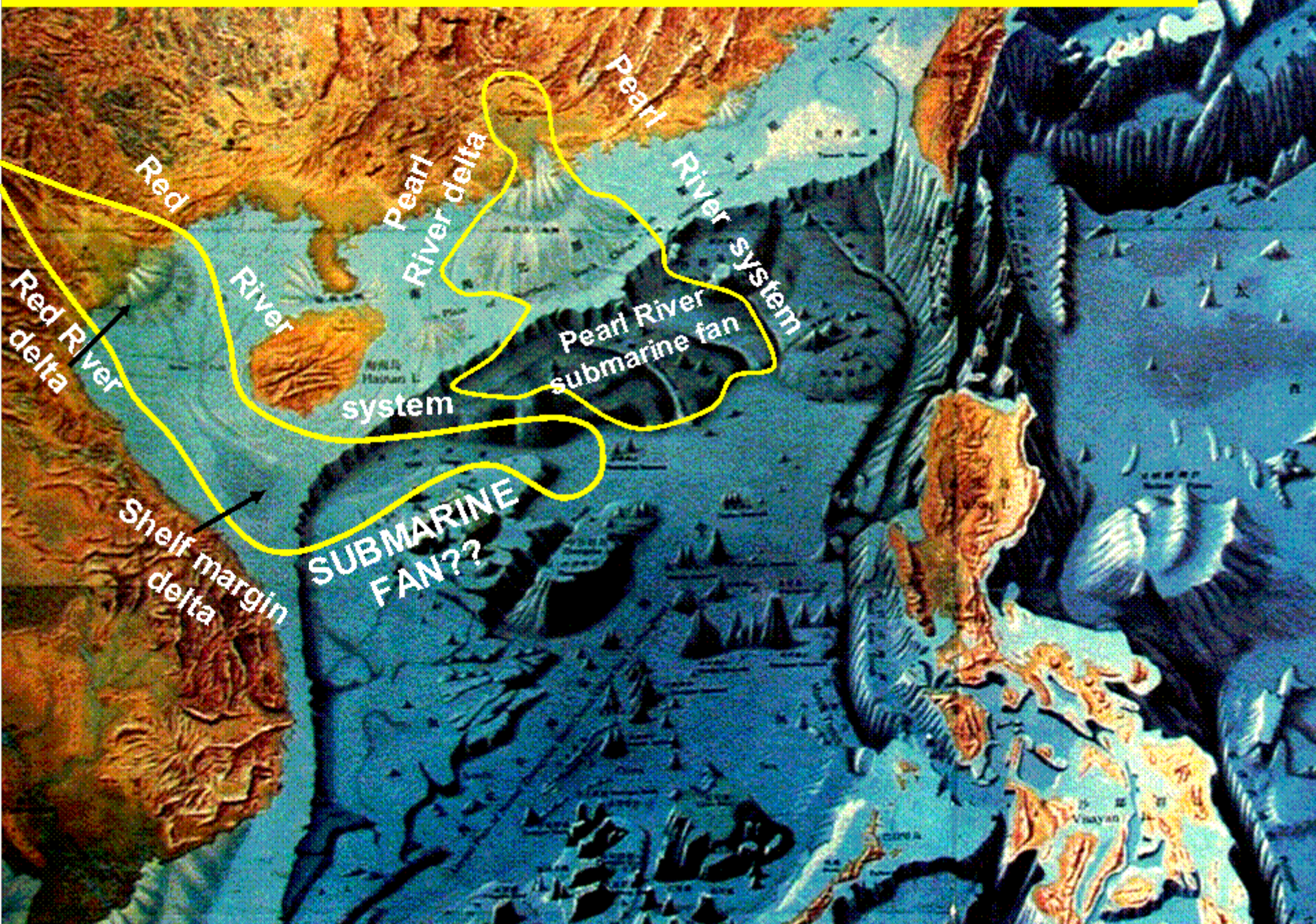
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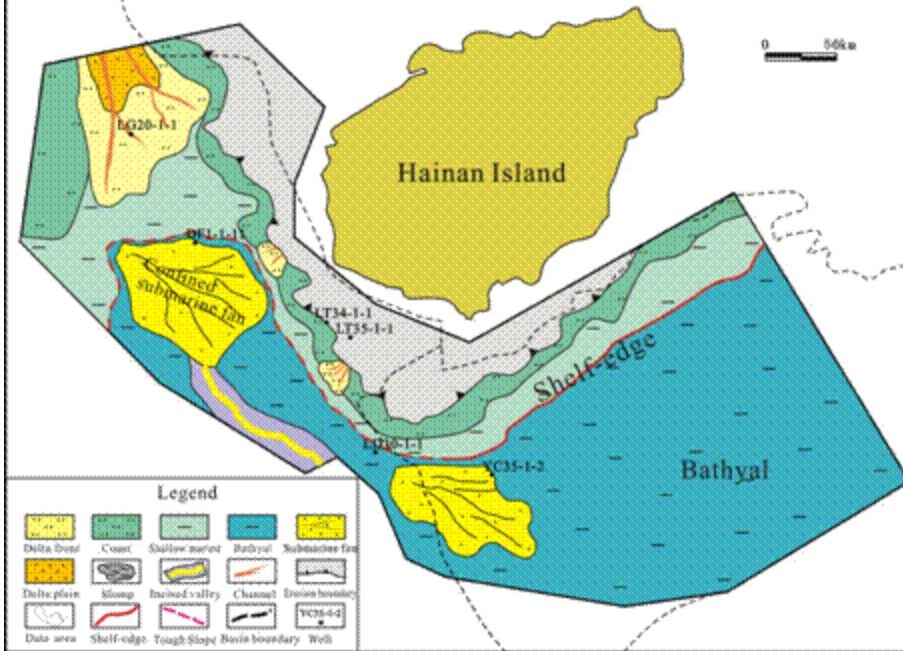
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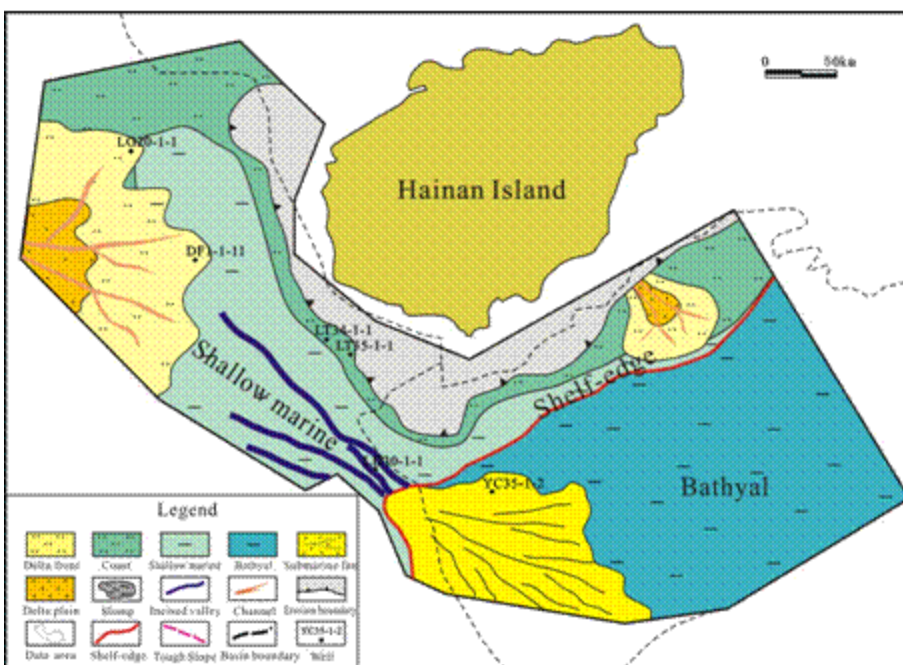
⑤ School of Energy Resources, China University of Geosciences, Beijing, China

1. Is there submarine fan in front of the Red River delta?

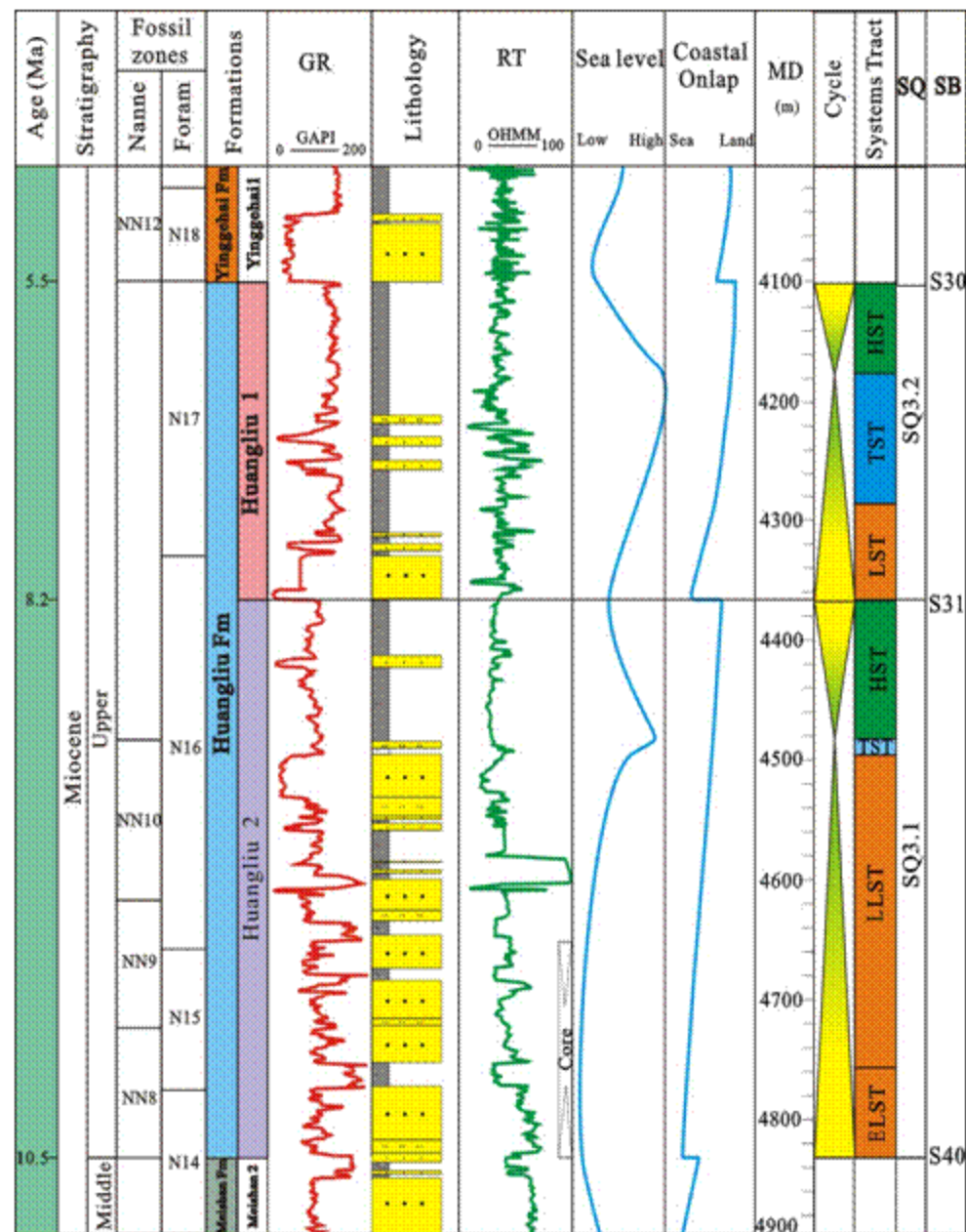




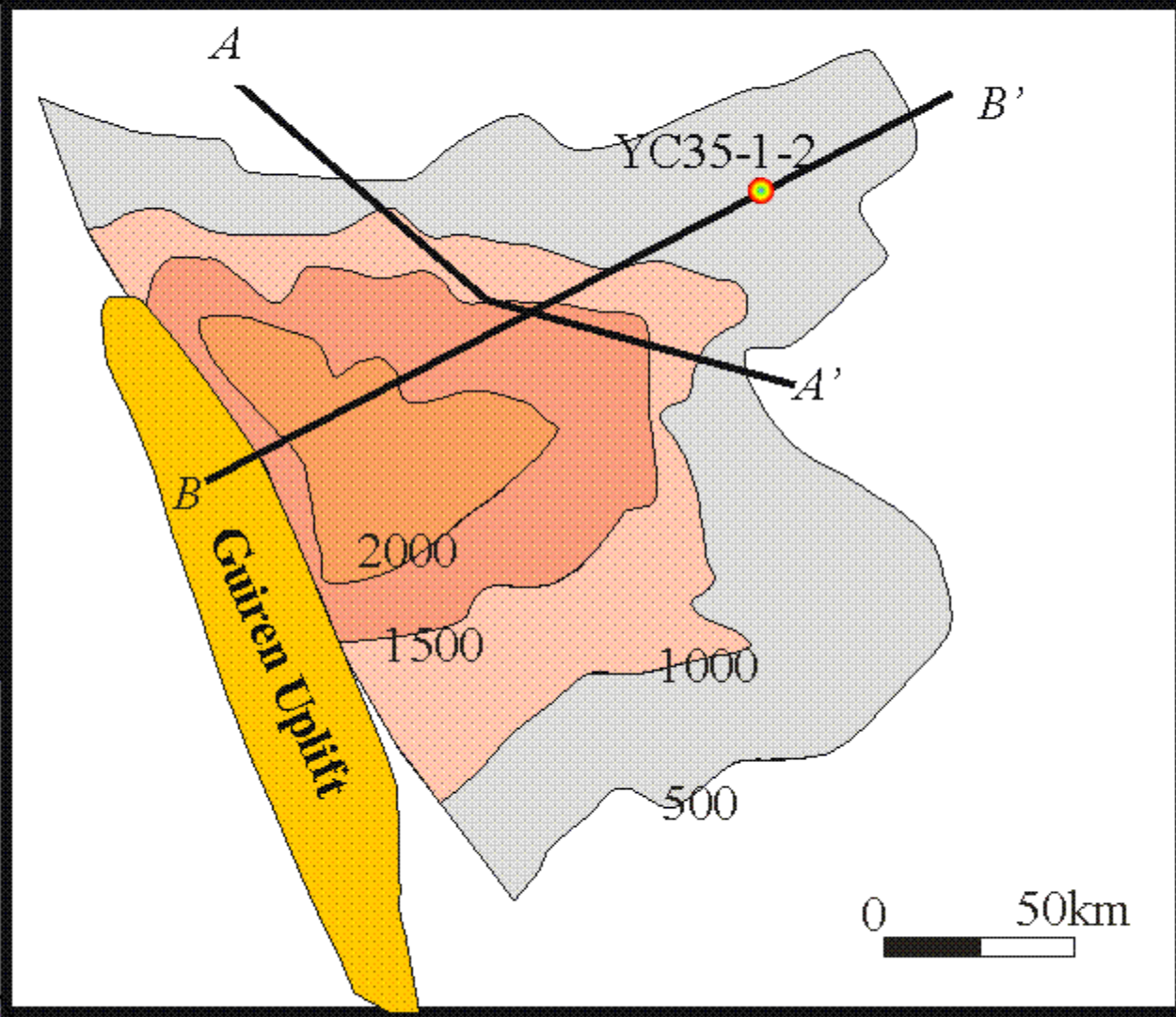
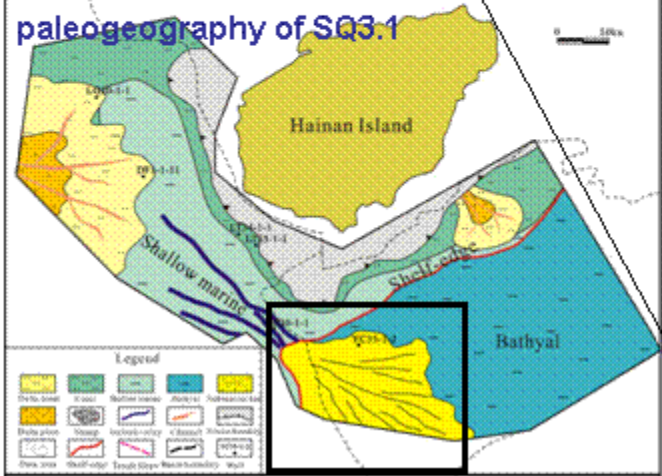
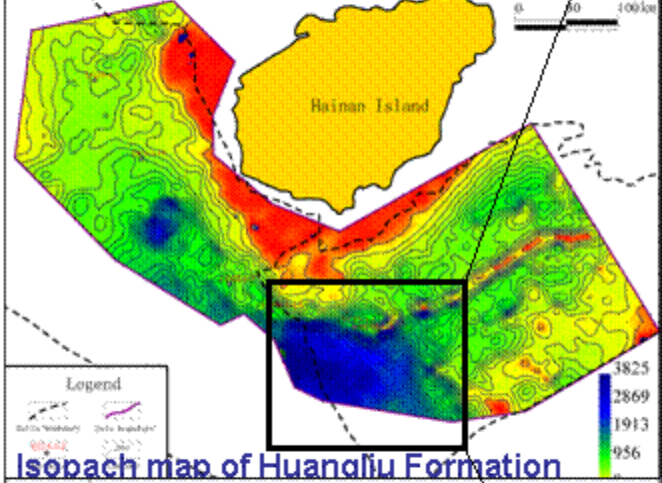
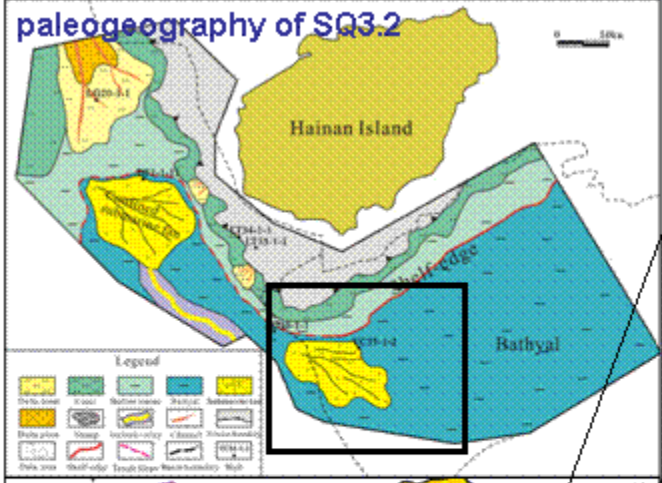
Paleogeography of SQ3.2(Upper Huangliu Formation)



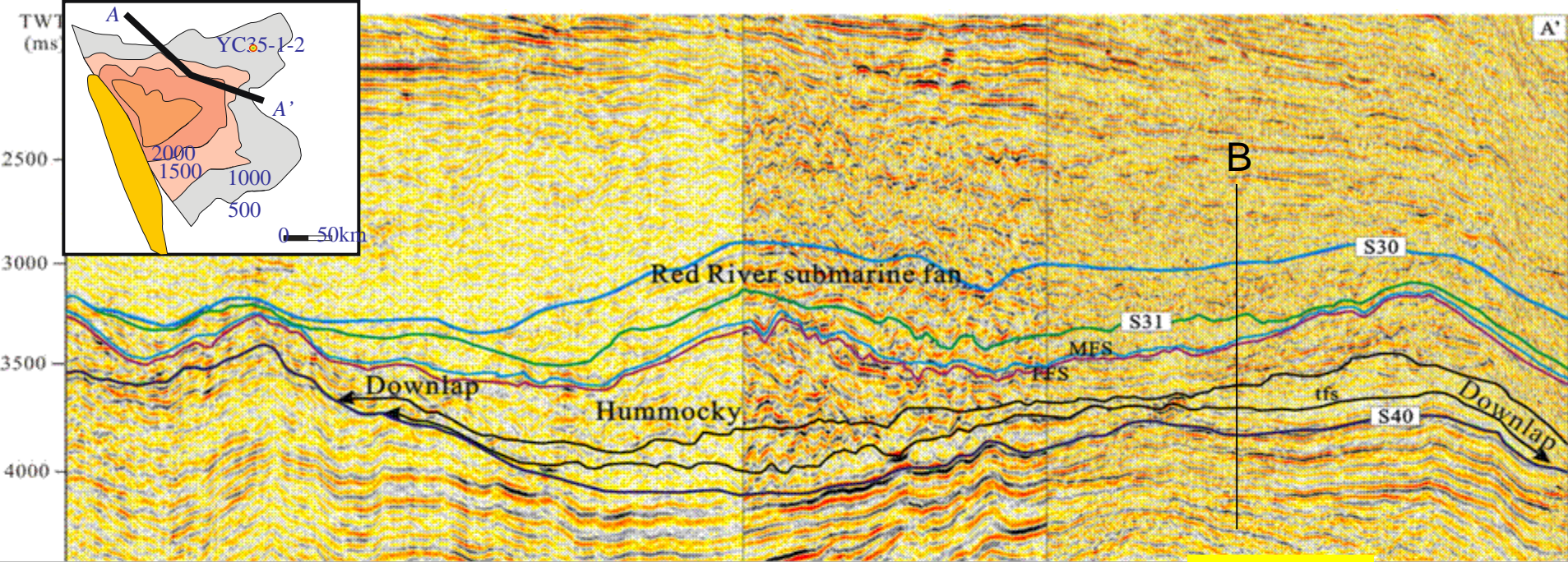
Paleogeography of SQ3.1(Lower Huangliu Formation)



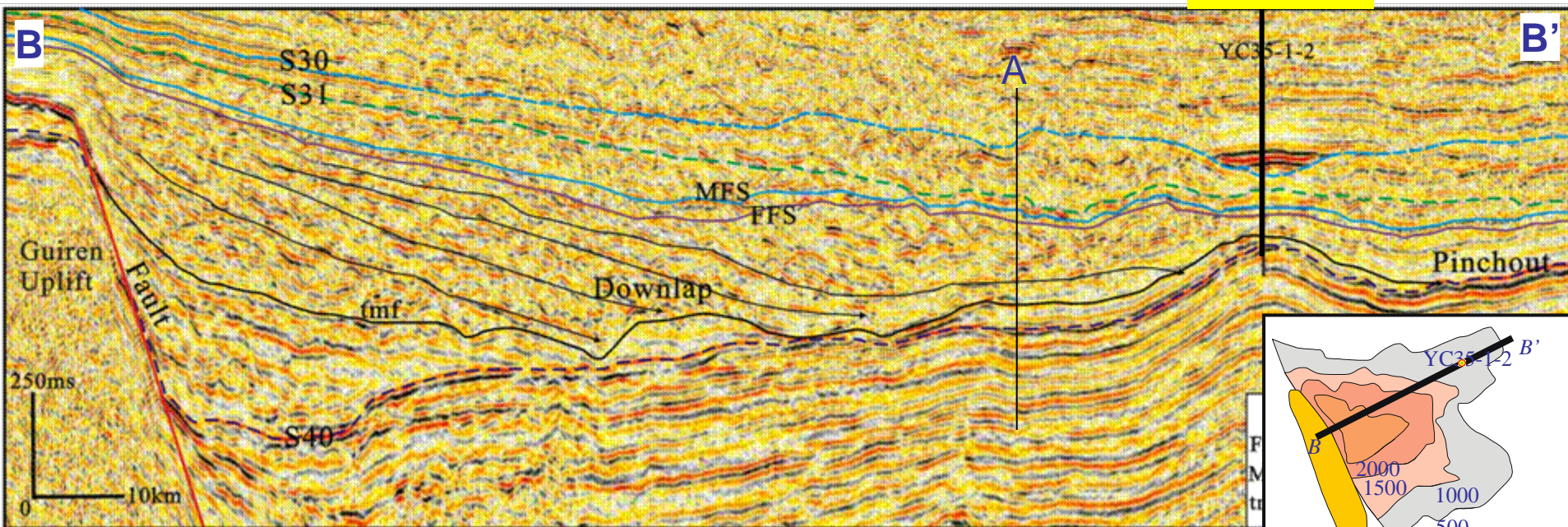
2. Characteristics of the submarine fan



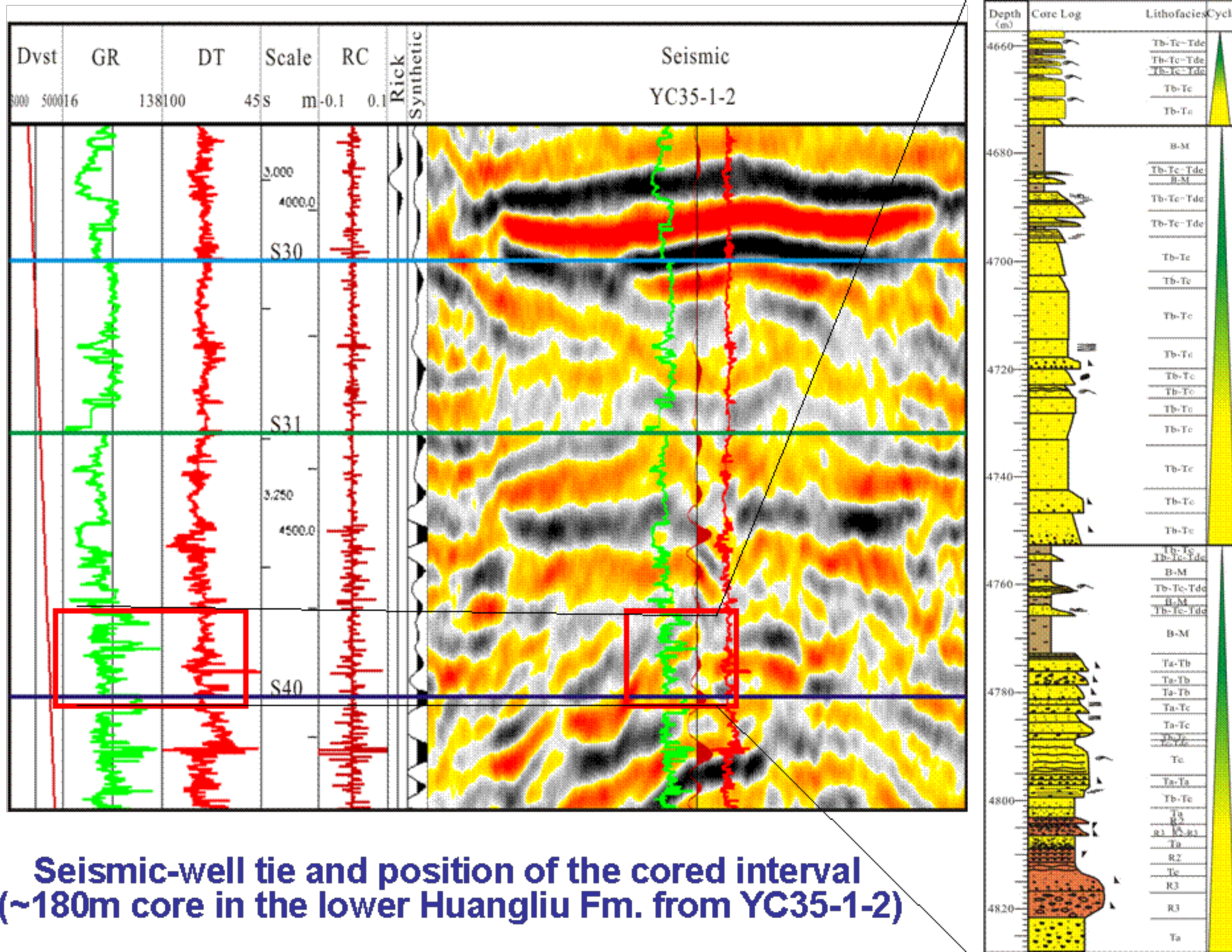
Isopach map of the Red River submarine fan shows that it thins out toward the margins



On the strike line, the fan has mound-shaped, bilateral downlapping reflections **YC35-1-2**



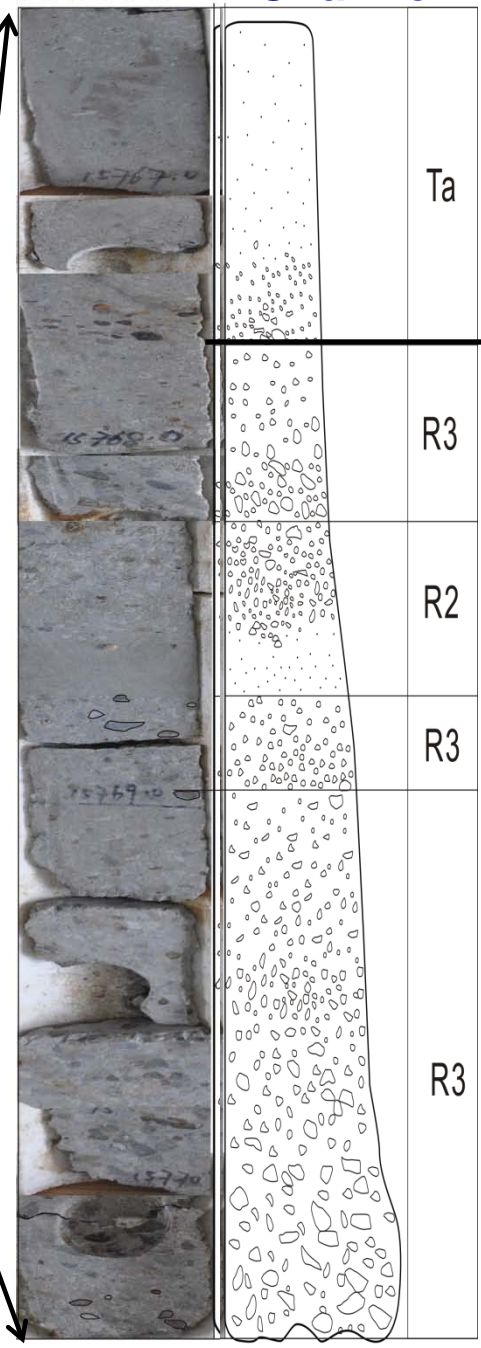
On this dip line, it shows wedge-shaped, progradational reflections



Channel

Ta

Composite, normal, inversely graded pebbly sandstone



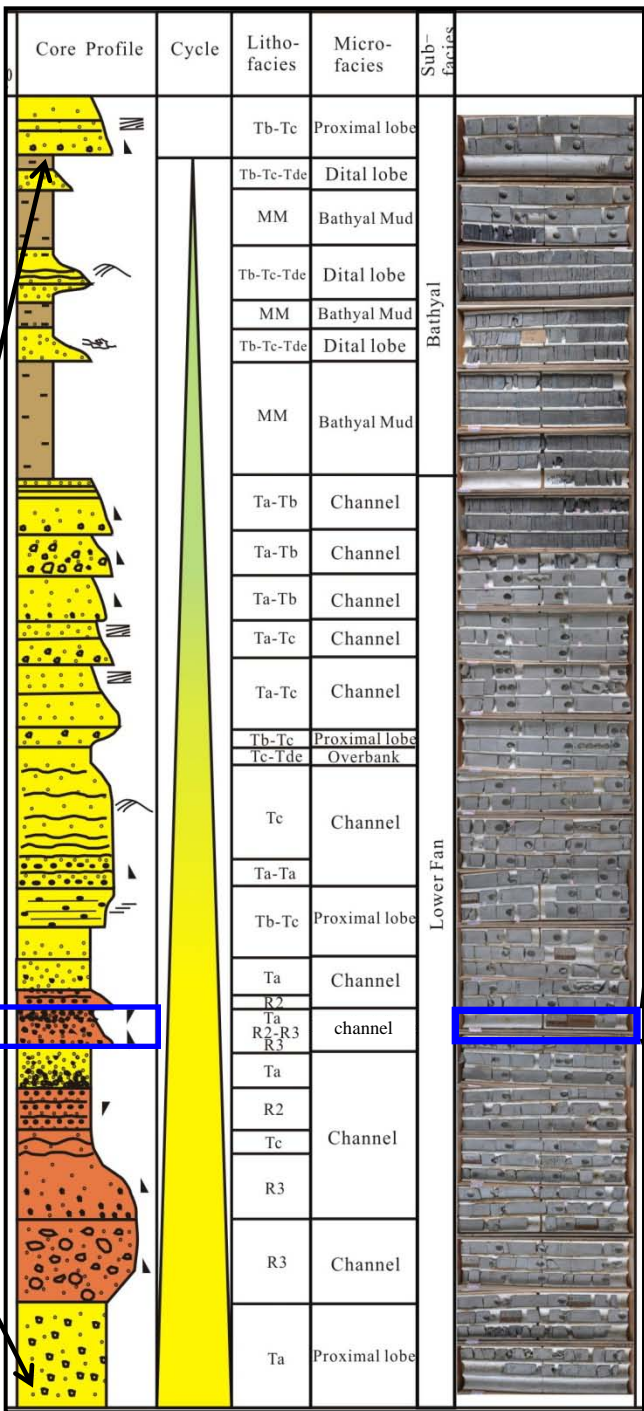
Ta

R3

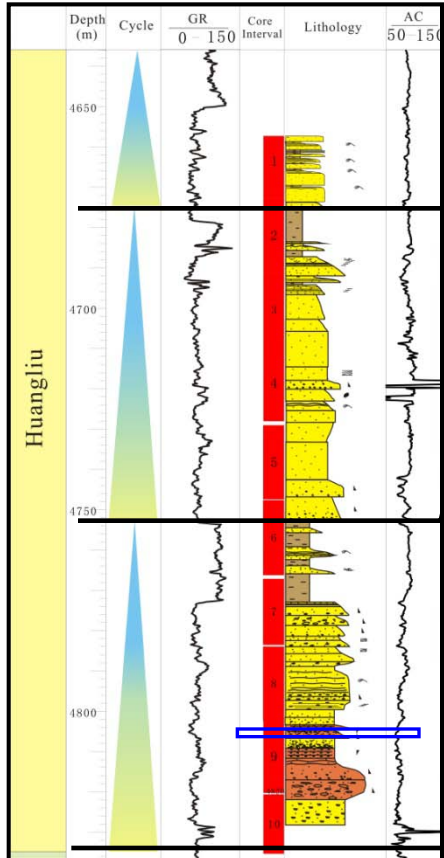
R2

R3

R3

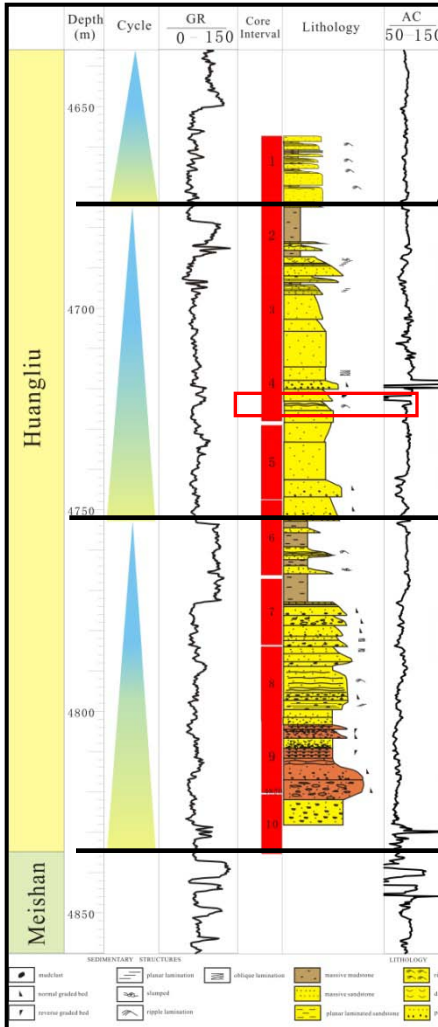


Three fining-upward cycles in the cored interval



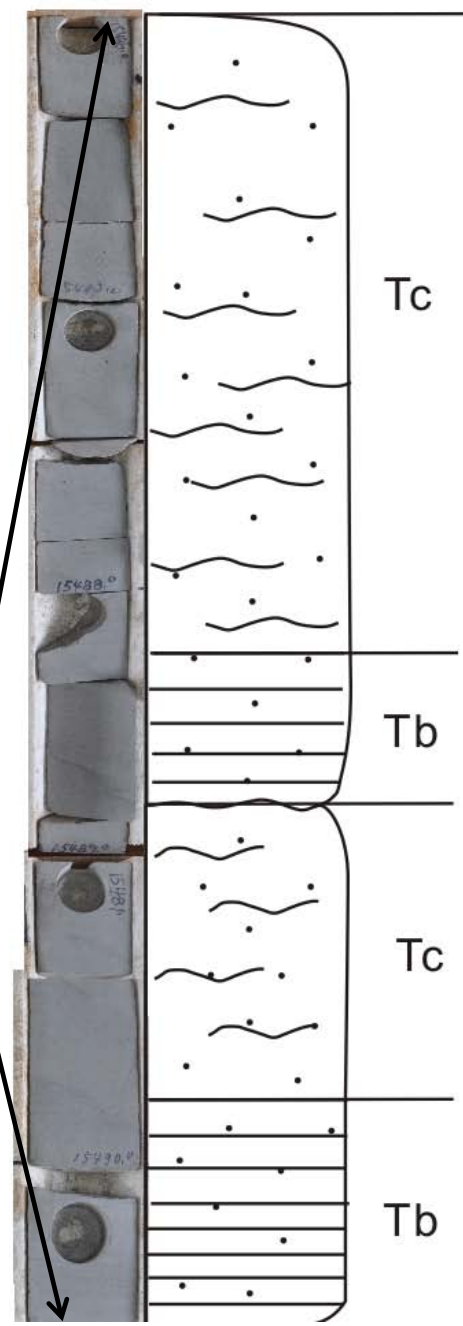
The lower most cycle consists mainly of coarse channel deposits, with pebbly sandstones in the lower part and normal-graded sandstones in the upper part.

The second cycle is finer grained. it consists of planar/wavy bedded sandstones in the lower part, interpreted as proximal lobe deposits . The upper part are mainly wavy/planar bedded very fine-grained sandstones and sandy mudstones, interpreted as distal lobe deposits.



| Core Profile | Cycle | Lithofacies | Microfacies | Sub-facies | Core Ph. |
|--------------|---------------|---------------|-----------------------|---------------|----------|
| | | MM | Bathyal Mud | Bathyal | |
| | | Tb-Tc-Tde | Distal turbidite lobe | Lower Fan | |
| | | MM | Bathyal Mud | | |
| | | Tb-Tc-Tde | Distal turbidite lobe | | |
| | | Tb-Tc-Tde | Distal turbidite lobe | Proximal lobe | |
| | | Tb-Tc | Proximal lobe | | |
| | | Tb-Tc | Proximal lobe | Proximal lobe | |
| | | Tb-Tc | Proximal lobe | | |
| | | Tb-Tc | Proximal lobe | Proximal lobe | |
| | | Tb-Tc | Proximal lobe | | |
| | | Tb-Tc | Proximal lobe | Proximal lobe | |
| | | Tb-Tc | Proximal lobe | | |
| Tb-Tc | Proximal lobe | Proximal lobe | | | |
| Tb-Tc | Proximal lobe | | | | |

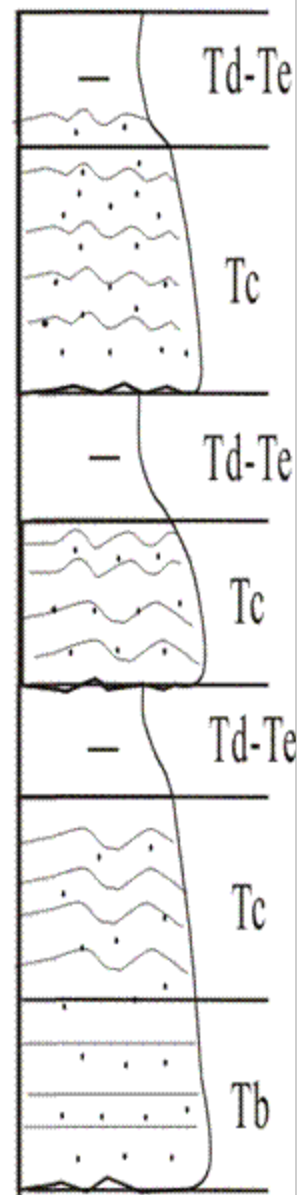
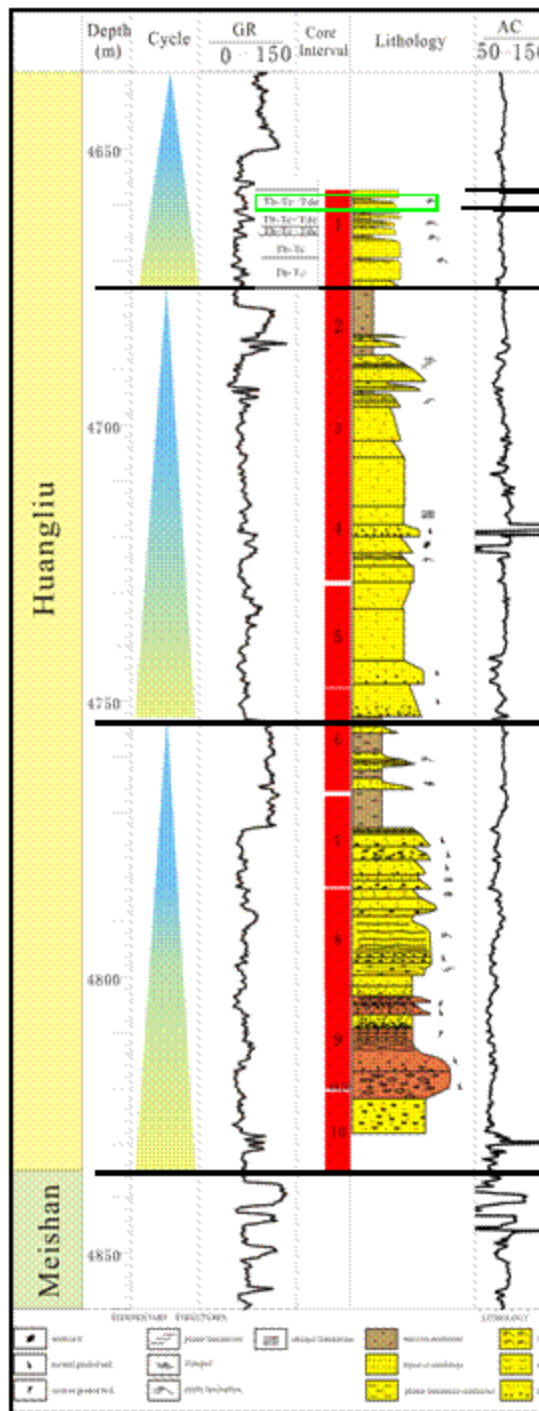
Proximal lobe

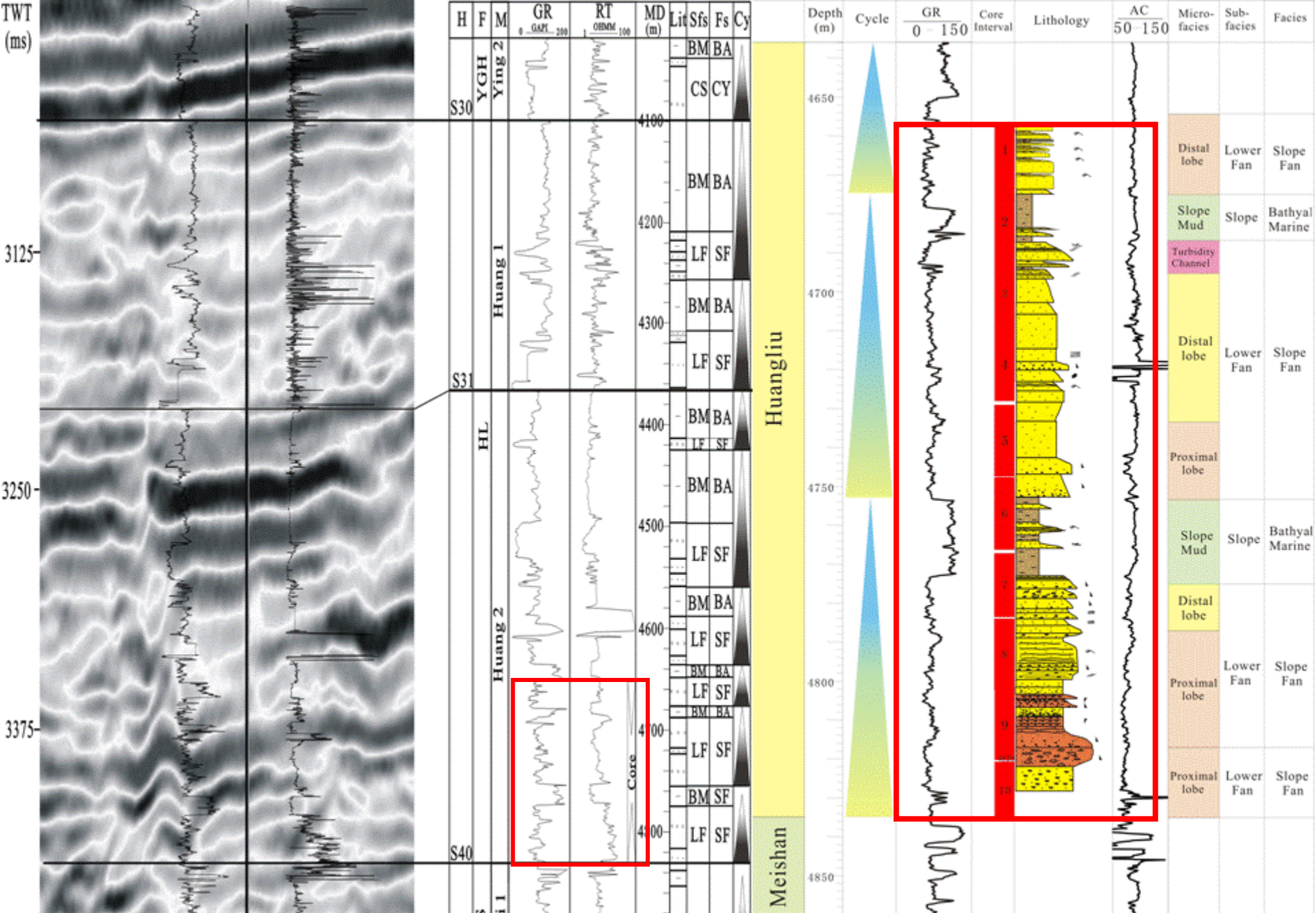


The third cycle

- Similar to the second cycle;
- Consists of even finer grained deposits than the older two cycles;
- Consists of interbedded very fine-grained planar stratified/wavy-bedded sandstones, sandy mudstones, and mudstones;
- Interpreted as distal lobe deposits.

The vertical facies assemblage from the oldest to the third cycle indicates an overall deepening-upward process.

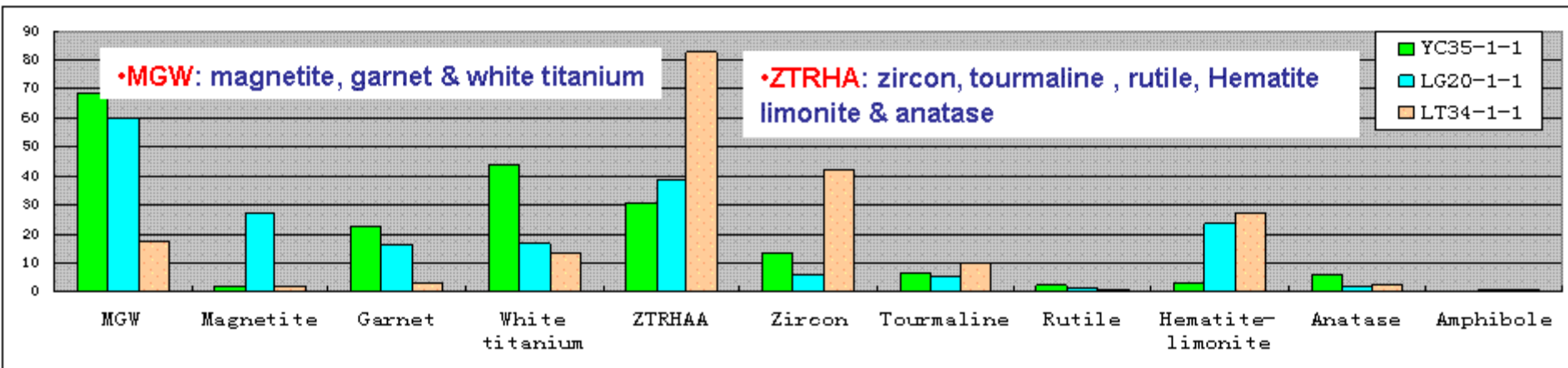




8 fining-upward cycles in the whole Huangliu Fm., 6 in the lower Huangliu Fm.



3. Where the sediments in the submarine fan come from?



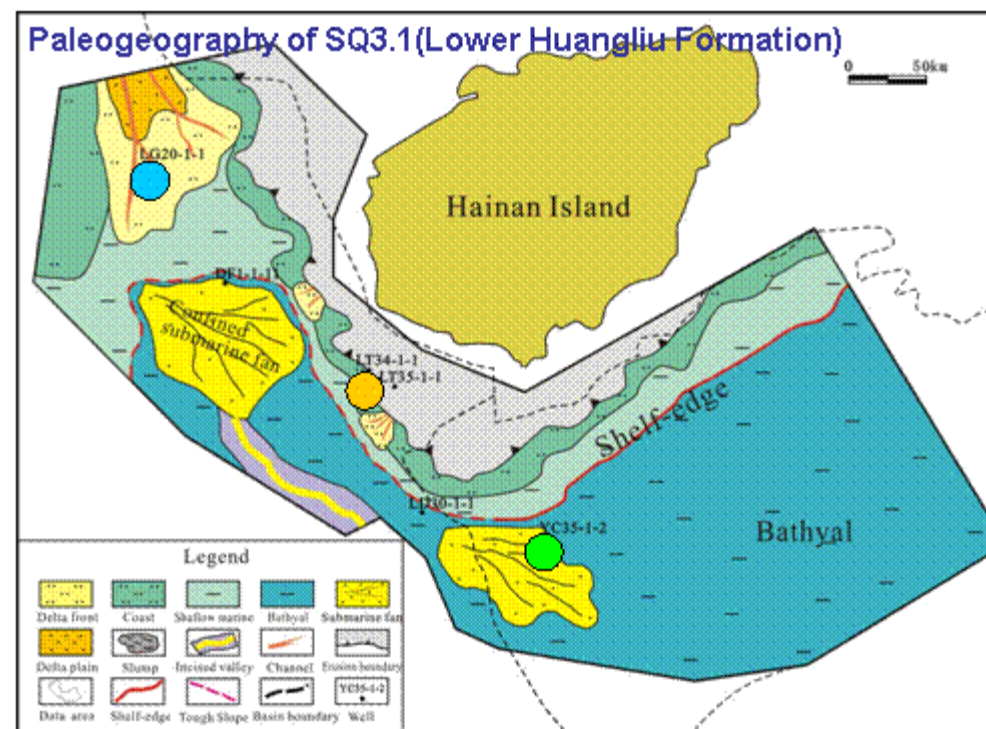
There are two major sources in the study area, the Red River and the Hainan Island.

The Red River source is represented by LG20-1-1, and sediments are from a metamorphic provenance.

The Hainan Island is represented by LT34-1-1, and it is an intrusive igneous provenance.

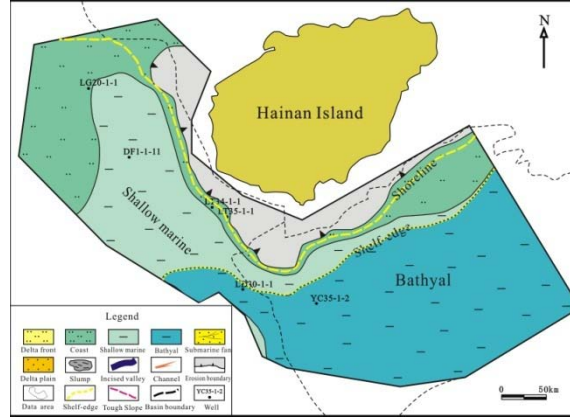
On the heavy mineral assemblage diagram, these two provenances are separated by MGW and ZTR. The metamorphic provenance shows high MGW and low ZTR, and the intrusive provenance shows low MGW and high ZTR.

Assemblage in YC35-1-1 is similar to LG20-1-1, indicating sediments in the submarine fan are from the Red River.

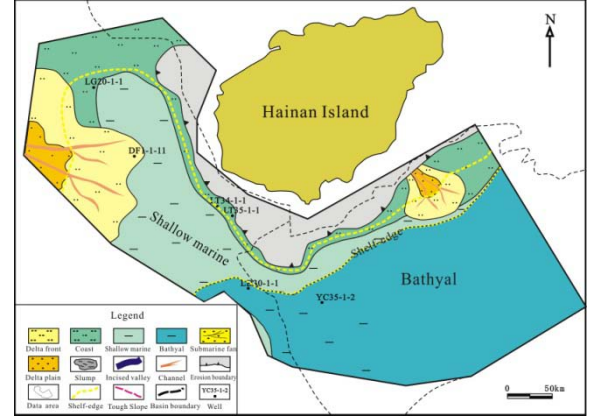


4. Why the fan is developed ~500 km basinward from the Red River mouth, and its grain size is coarser than the sediments on the shelf?

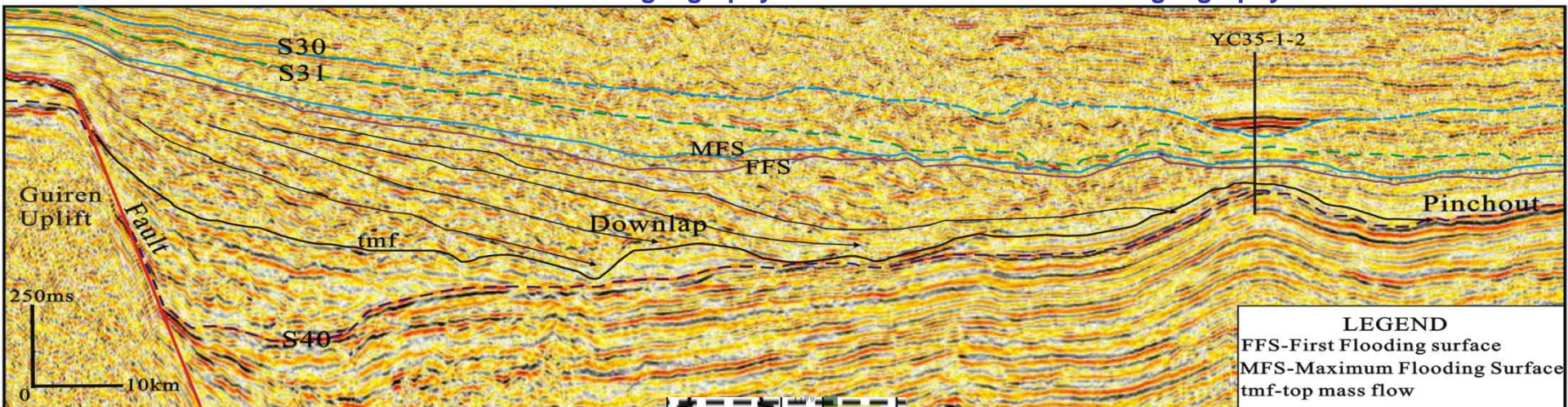
Depositional Model of SQ3.1



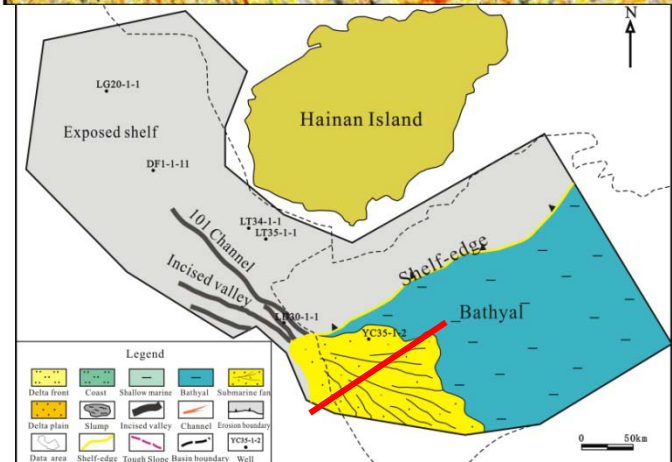
Paleogeography of TST in SQ3.1



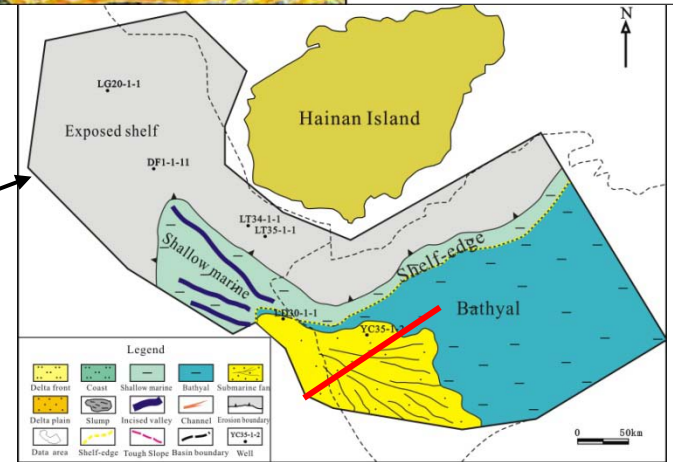
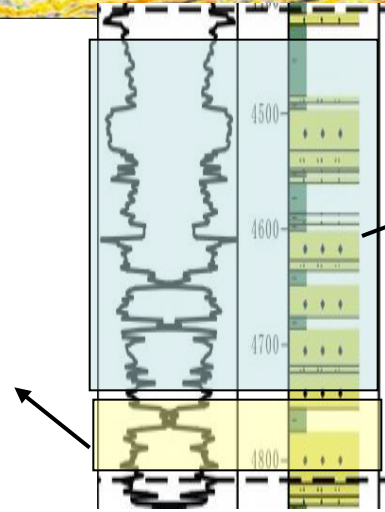
Paleogeography of HST in SQ3.1



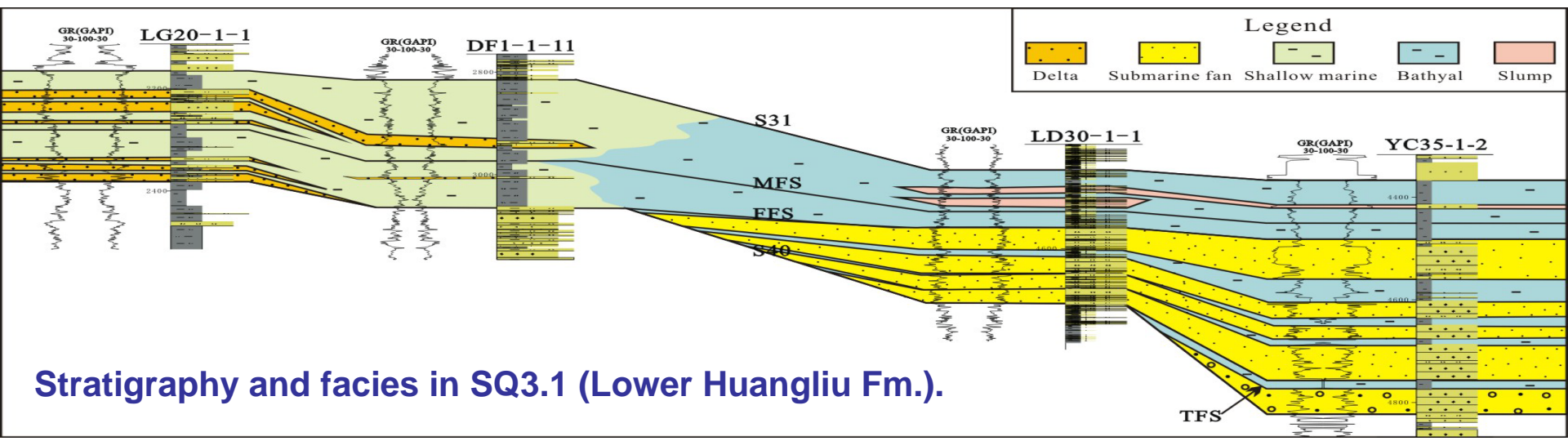
LEGEND
 FFS-First Flooding surface
 MFS-Maximum Flooding Surface
 tmf-top mass flow



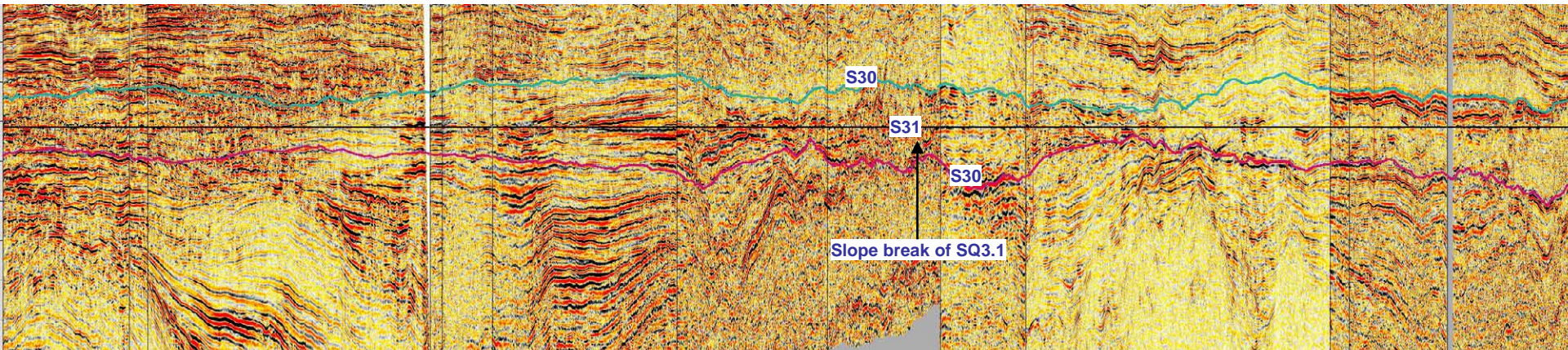
Paleogeography of Early LST in SQ3.1



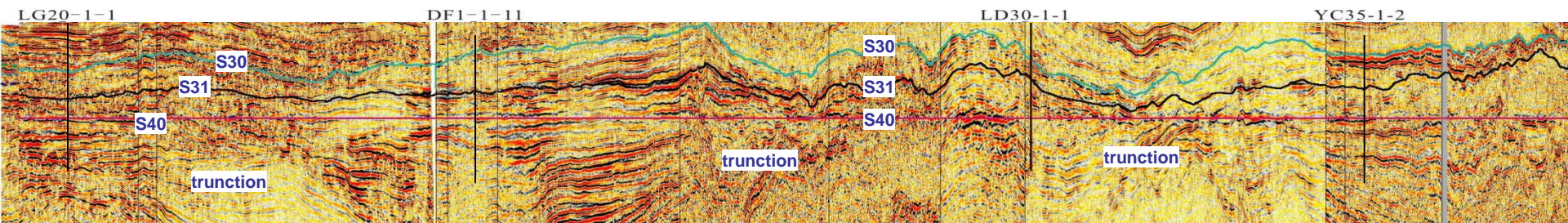
paleogeography of late LST in SQ3.1



Stratigraphy and facies in SQ3.1 (Lower Huangliu Fm.).

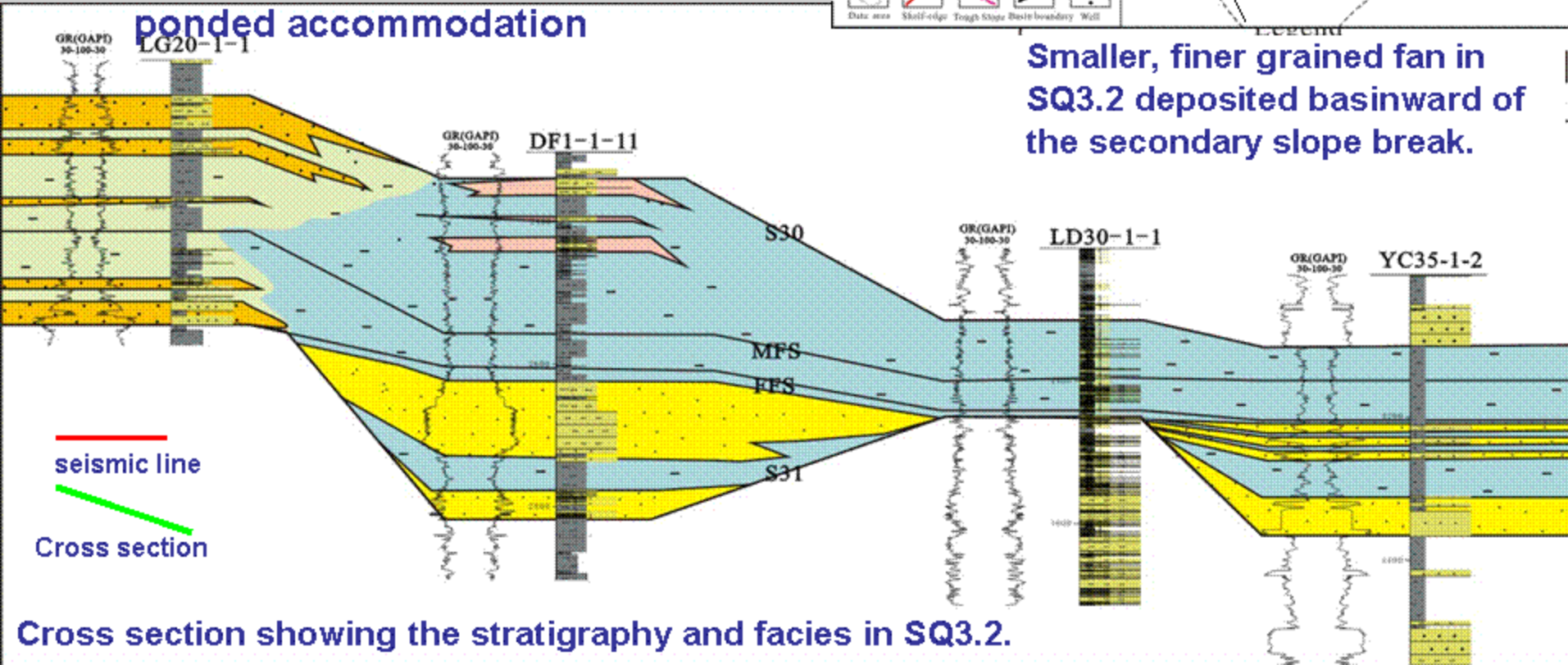
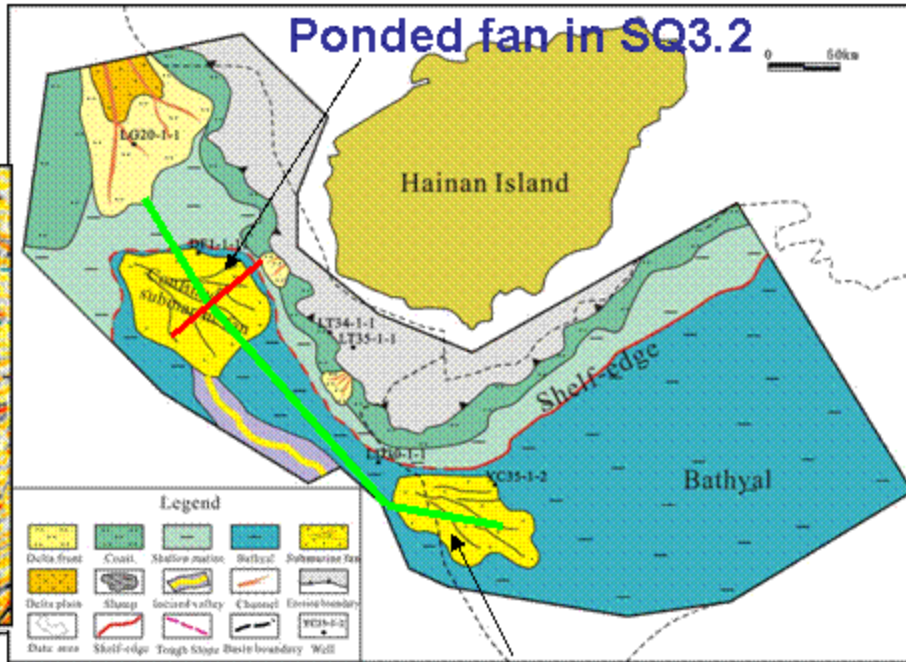
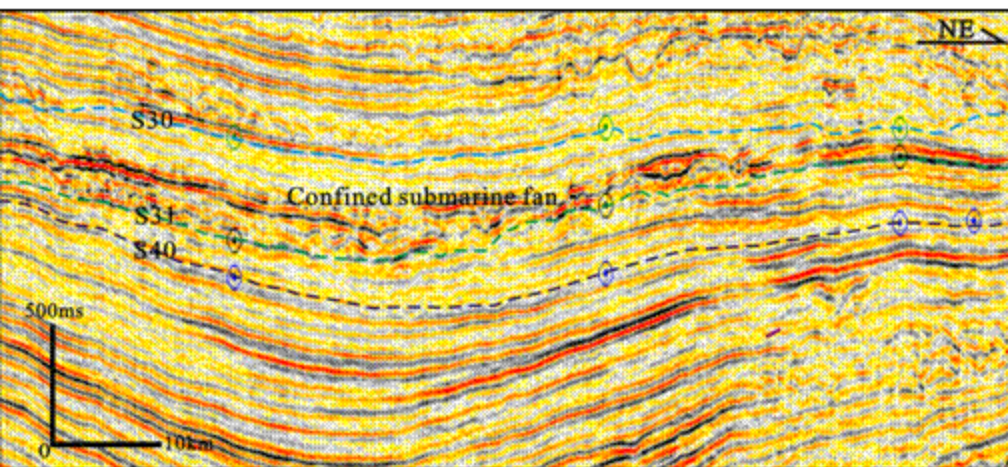


Seismic line flattened on S31 showing slope break in the Yinggehai Basin.



Seismic line flattened on S40 showing significant erosion of the underlying strata in the Yinggehai Basin.

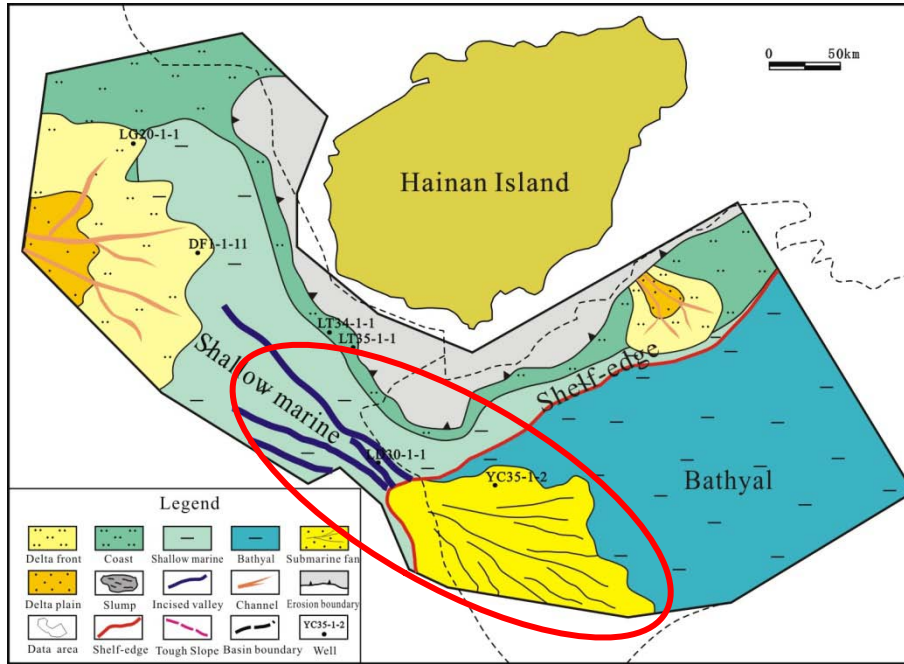
Depositional Model of SQ3.2



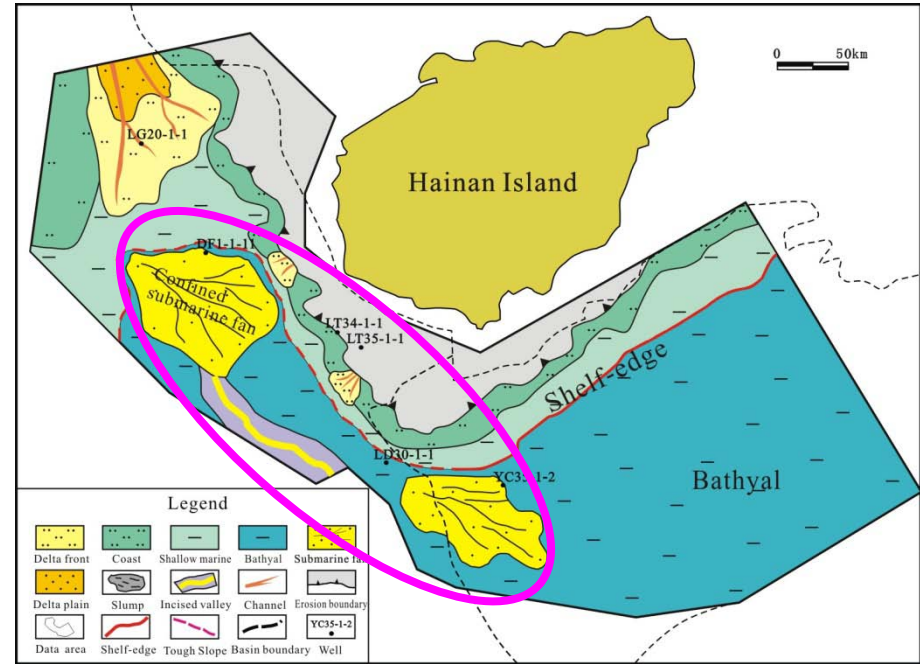
Smaller, finer grained fan in SQ3.2 deposited basinward of the secondary slope break.

Cross section showing the stratigraphy and facies in SQ3.2.

5. Exploration Significance



Paleogeography of SQ3.1



Paleogeography of SQ3.2

Potential New Plays include:

- (1) the coarser submarine fan located at the junction between the Yinggehai and Qiongdongnan basins and incised-valley fills updip in the LST of SQ3.1.
- (2) the finer submarine fans and submarine channels connecting them located in the continental shelf of the Yinggehai Basin and the junction between the Yinggehai and Qiongdongnan basins in the LST of SQ3.2.

Conclusions

- 1. A large submarine fan is discovered in front of the Red River delta.**
- 2. The fan was developed during the Huangliu Stage of Late Miocene. Mainly in LST.**
- 3. The fan is mud/sand rich. Sediments in the fan is mainly from the Red River.**
- 4. Main controls for the development of the submarine fan 500 km basinward of the Red River mouth include: (1) sediment bypass on the shelf during large relative sea-level fall, (2) increased sediment supply induced by rapid uplift of the Tibet Plateau, and (3) confined and restricted physiography.**
- 5. There are new potential plays in the LST in both SQ3.1 and SQ3.2 that can form prospect exploration targets.**