

The geophysical characteristics and extension model of South China Sea

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Abstract South China Sea is a marginal sea. Its epicontinental margins were extended and thinned in an asymmetrical way. The continental crust was even thinned in south margin and gradually thinned in north margin. The sedimentary structures appeared different over these margins. A simple shear extension model was proposed to fit the extension of South China Sea.

Structural division of South China Sea and its geologic background

In 1989-1990, South China Sea Institute(SCSI), Academia Sinica, has carried out a comprehensive geophysical survey from Pearl River Mouth to Liyue Bank to Nansha Trough. Along this line (Fig.1), South China Sea can be divided into three parts, north epicontinental block (NEB), central SCS basin and south epicontinental block (SEB). The NEB includes Pearl River Mouth Basin and a uplifted margin to its south. The SEB includes Liyue Bank (Reeds Bank), Nansha Trough

and Nansha Islands. In between is the central SCS basin where the seawater depth is 3-4 km.

South China Sea is a marginal sea. Over its north margin and south margin, the continental crust was extended and thinned with many basins developed. Magnetic anomaly lineations trending roughly E-W in central SCS basin were ascertained to be 5D-11, implying that the present South China Sea started S-N spreading in Late Oligocene (32 m.y.) and ceased spreading in Middle Miocene(17 m.y.) (Taylor and Hayes, 1983; Biais, 1993). Scarborough Seamount Chain was commonly regarded as the position of the died spreading ridge. The absence of magnetic anomaly lineation 7 in the southern half part of Central Basin and its smaller width support a southward jump of the spreading ridge. Further, the width of the north part of the central basin was wider than that of the south part.

Structures of the sedimentary basins and the forming of the Central Basin strongly proved the extension and rifting process of the continental crust. By comparison of the geo-

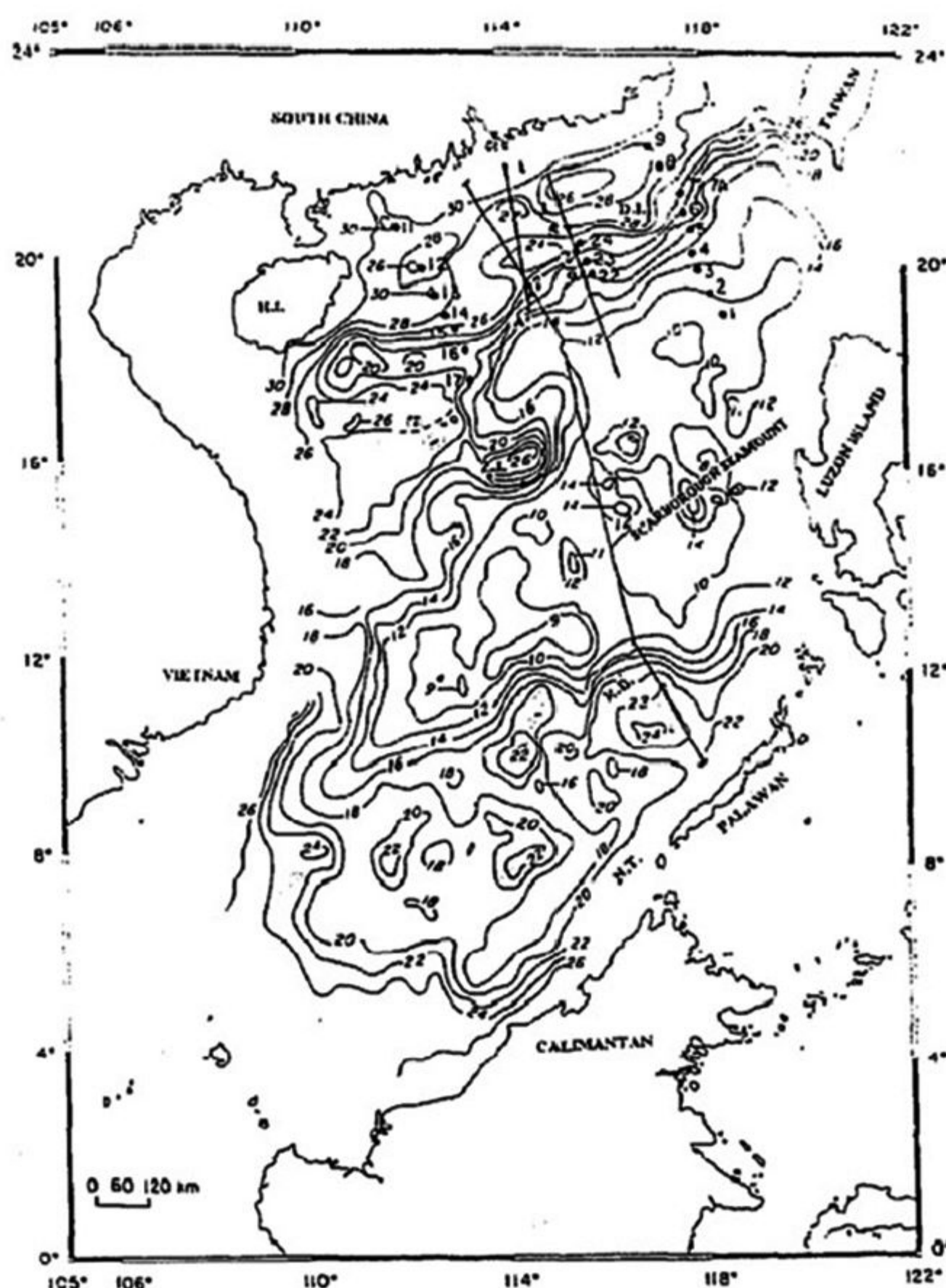


Figure 1. Countour map of depth to Moho in the South China Sea revised from Splanger, S.E., (1991). Locations of ESP, OBS and geophysical survey lines are shown. D.I.=Dongsha Islands, H.I.=Hainan Island, L.I.=Luzon Island, N.T.=Nansha Trough, R.B.=Reeds Bank, Z.I.=Zhongsha Islands. —=geophysical survey line, ●=ESP midpoint, —●=OBS.

physical features among different parts, an extension model of SCS was proposed.

Gravity anomaly and magnetic anomaly features

The Bouguer anomaly fluctuated in very low value ($\pm 100 \times 10^{-5} \text{m/s}^2$) over the NEB and SEB while very high (approximating $300 \times 10^{-5} \text{m/s}^2$) over the central basin. Magnetic anomaly changed in low amplitude (tens of nT) over the NEB and SEB. Over the Central Basin, the magnetic anomaly fluctuated in high amplitude (200 nT) and high frequency (wavelength of 50 km or so).

Three structural layers corresponding to three seismic sequences

Almost all deposits are of marine facies. Three seismic supersequences can be identified from the multi-channel seismic data, i.e., the Upper Structural Layer, the Middle Structural Layer and the Lower Structural Layer. The Upper Structural Layer distributed over the whole marine area. In this layer, seismic wave has strong amplitude, high frequency, good continuity, clear stratification and parallel and sheet-draped texture. Its age is dated to be Oligocene-Recent, locally Late Eocene. The deposit thickness is generally 2-4 km over the south and north margin, whereas less than 1 km in the central basin. Wave series from the middle layer is of weak to moderate amplitude, moderate frequency, good continuity, clear stratification, sub-parallel to divergent, fold and deformation texture. Its marine sediments developed during Paleocene-Eocene and distributed over the two epicontinental blocks. Under this upper layer, listric fault and fold developed. For the Lower Structural Layer, the events are of weak amplitude, low frequency, bad continuity, and fold and tilt texture. It appeared only in the South Epicontinental Block and

deposited mainly during Jurassic-Cretaceous.

Two major tectonic movements since Cretaceous

According to seismic data, three major regional unconformities T_s , T_h and T_m can be (Fig.2, Fig.3) continuously traced and compared over whole study area. Interfaces T_h and T_s separated the sedimentary rocks into three structural layers, i.e., Lower Structural Layer, Middle Structural Layer and Upper Structural Layer. According to the age of the stratum on and under these interfaces, two tectonic movements are inferred to be existed. The one corresponding to T_h started from Middle Cretaceous and ended in Early Paleocene and was named as Nansha Movement; the other one corresponding to T_s started from Late Eocene and ended in Middle Oligocene and was named as Nanhai Movement.

Nansha Movement

Nansha Movement has produced a series of extensional structures which controlled the Middle Structural Layer. During Middle Cretaceous, there formed a series of syn-deposition half-graben and tilt and fault doming and further basin-and-ridge architecture, which suggested that Nansha Movement has resulted in crust extending, uplifting and block faulting.

Ophiolite of Cretaceous-Eocene found in northwest Calimantan-South Palawan showed that there might be a proto-South China Sea basin with oceanic crust to the south of Nansha micro-continental block. It started to drift away from South China continent after the rifting initiated in Middle Cretaceous and was consumed during the subsequent seafloor spreading of SCS. That is to say, Nansha Micro-continental Block was once located to the north of the proto-South China Sea and connected directly with South China.

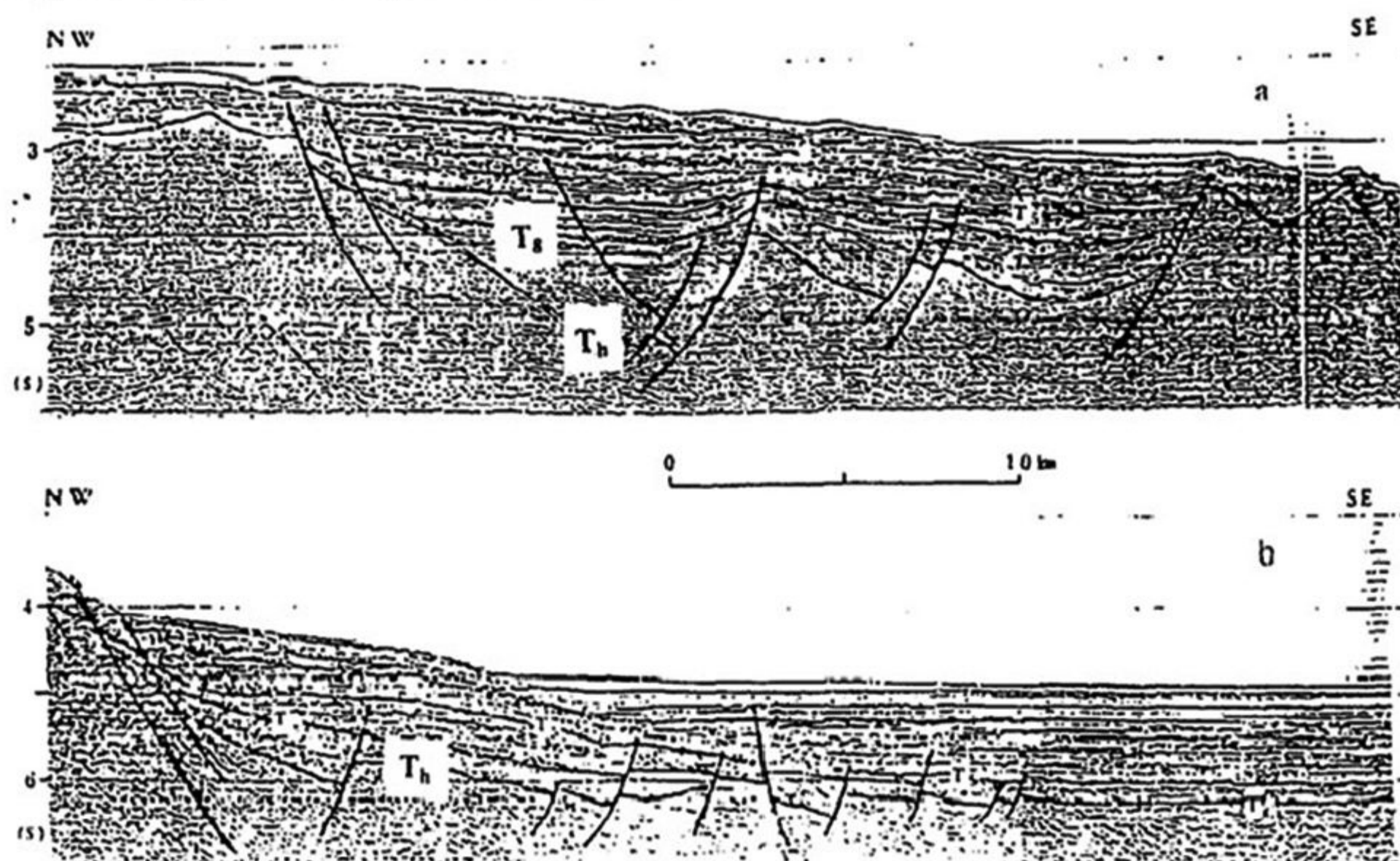


Figure 2. Multi-channel seismic profiles over the southern rise (a) in Pearl River Mouth Basin and its south wing nearby the South China Sea basin(b)

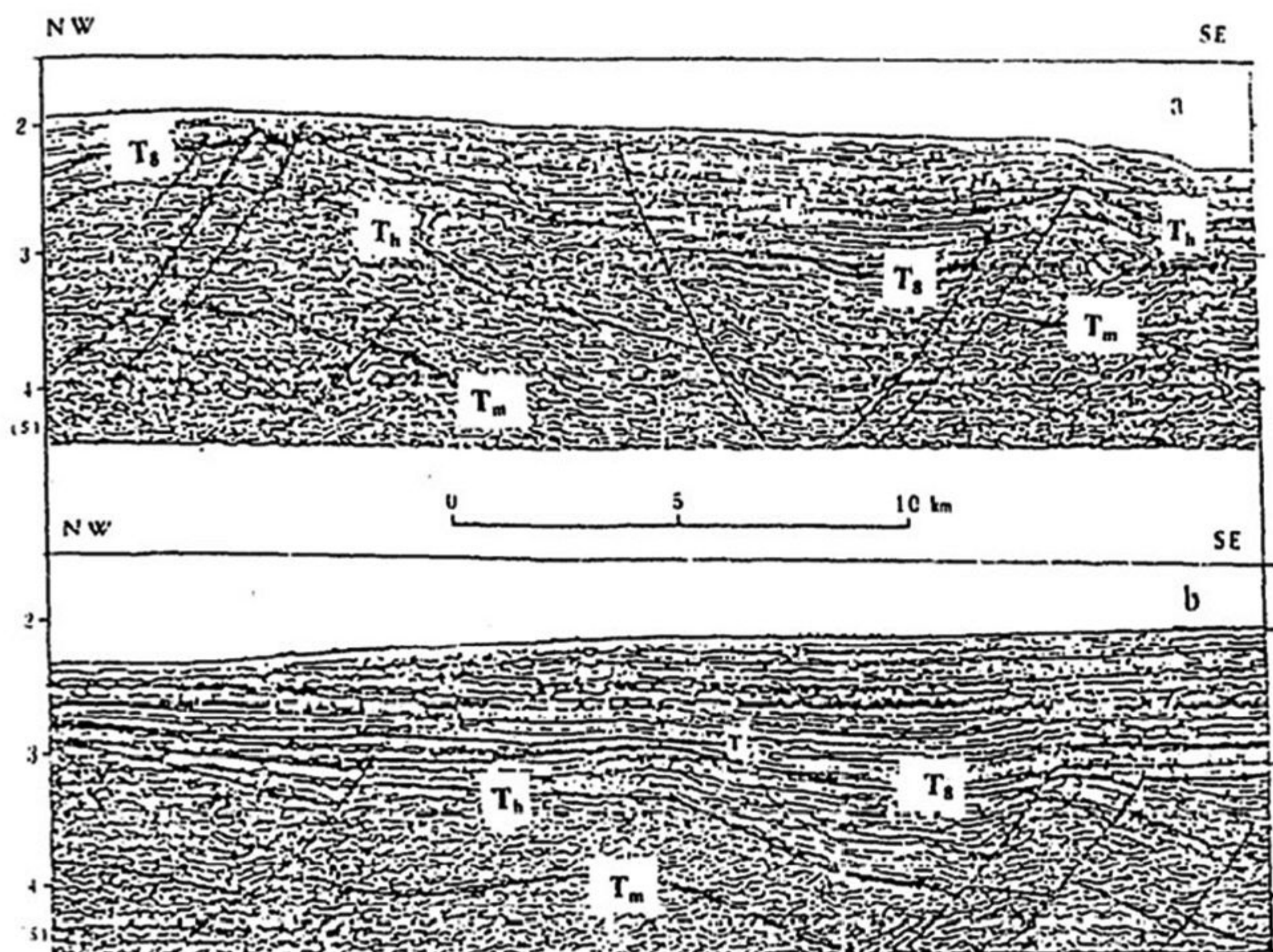


Figure 3. Multi-channel seismic profiles over the south part of Liyue Bank(a) and Nansha Trough(b)

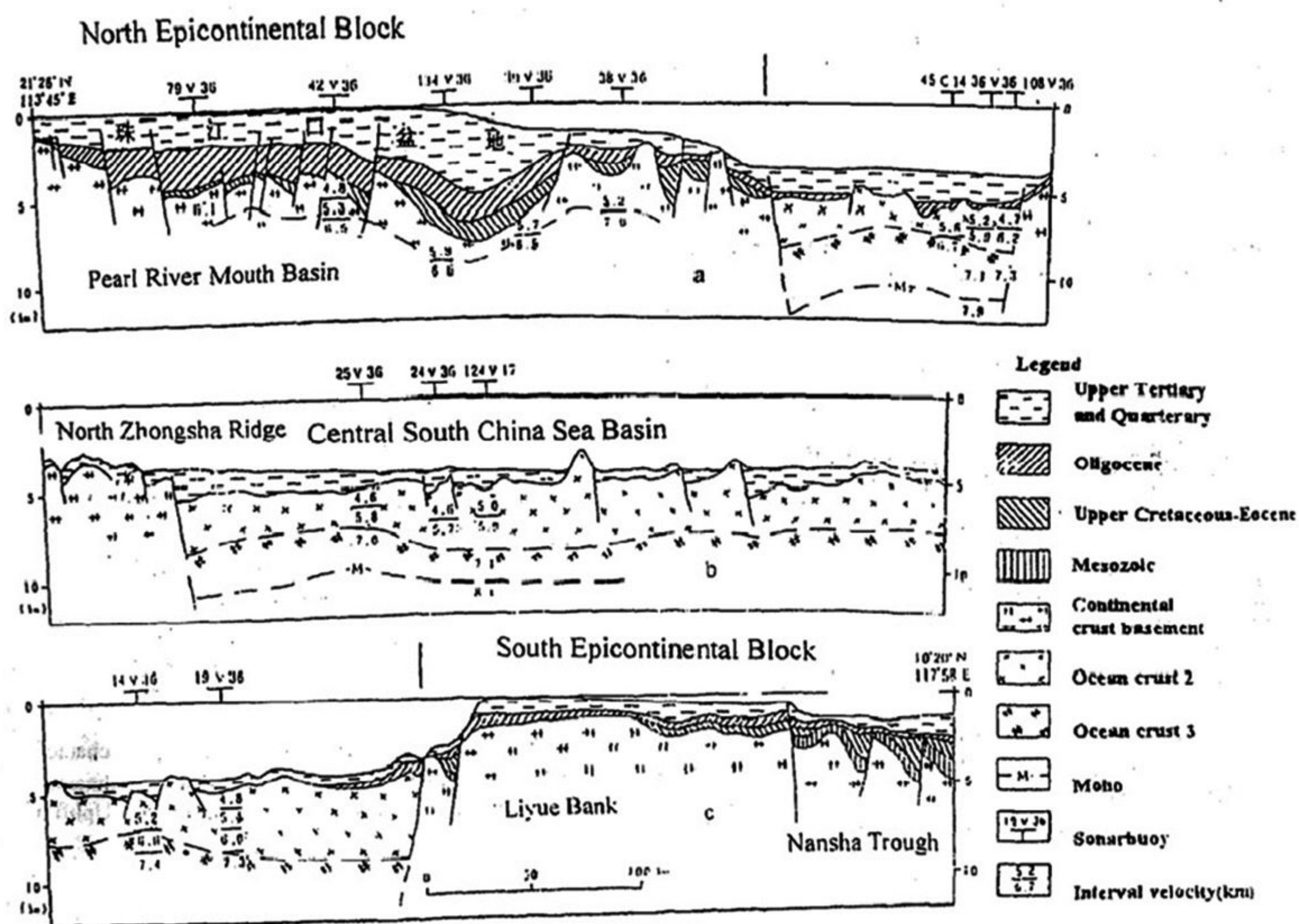


Figure 4. Geological profiles of Pearl River Mouth-Liyue Bank-Nansha Trough

Nanhai Movement

Started from Late Eocene, Nansha Movement has made the Middle Structural Layer pervasively folded and uplifted to form lands, then severely extended and block-faulted, and brought in a series of half-graben and tilt fault dome. Upto Middle Oligocene, basic lava erupted and seafloor spreading started to form the recent central South China Sea basin with oceanic crust. As the oceanic crust of the proto-South China Sea Basin subducted to the south during Late Eocene and consumed, Nansha Micro-continental Block collided with the original Calimantan Micro-continent. But in South Palawan, oceanic crust obducted to the northwest and the sedimentary cap folded imbricated on Nansha Micro-continental Block.

Crust structure

There existed a series of graben and fault steps controlled by southward dipping and northward dipping normal faults in the northern and southern NEB, respectively. In SEB, there developed a series of graben and fault block tilting southward. Most of the sedimentary basins and adjacent fault domes over SEB and NEB elongated in NE or NNE direction (Zhou Di, 1996). Deposits in the basins were mainly tilt to south (Fig.4).

Under T_m was the metamorphic-igneous basement. Over NEB, the continental crust thickness (Fig.5) decreased gradually from $30 \pm$ km in the continental shelf toward its southern continental-ocean boundary (COB), which was not clearly defined. Over the Central Basin, the oceanic crust is averaged 6 km in thickness. As a special rise, Zhongsha Massif with continental crust was surrounded by oceanic crust. It was inferred as a rifted relict continental block. While in SEB, the continental crust thickness fluctuated little around 20 km and the COB nearby Liyue Bank is very clearly indicated by a steep slope.

Extension model of South China Sea

According to the features of the sedimentary basins and the thickness variation of the crust, the SEB and NEB seem to be a pair of conjugate margins. Further, it can be inferred that SCS

be rifted dominantly in a simple shear extension model, roughly similar to Lister, et al's (1986) model (Fig.6). The major pre-rift fracture tilted southward and there were at least two rift phases corresponding to Nansha Movement and Nanhai Movement. During extending, the upper plate, i.e., the SEB initially slipped down southward along the major detachment fault and received deposits, and the Lower Structural Layer developed. However, in Liyue Bank where the rift center is nearby, there developed only Upper Structural Layer, perhaps because of uplifting resulted from mantle upwelling and erosion. The crust was thinned evenly and the faults were small. While the lower plate (NEB) was extended along subordinate detachment fault, gradually thinned, faulted and subsided with Middle Structural Layer and Upper Structural Layer developed. As the extension and rifting lasted, the seafloor spreading started from Late Oligocene. Only a thin upper part of Upper Structural Layer of abyssal facies formed in the Central Basin. This model is well consistent with the southward jump of the spreading center.

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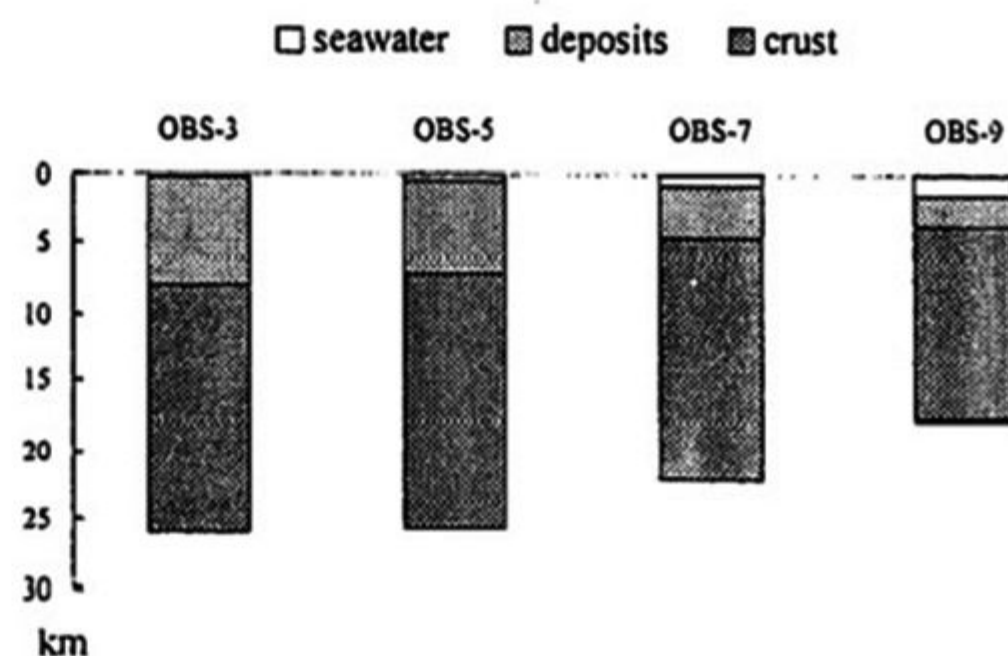


Figure 5. Illustration of the crust thickness interpreted from OBS record

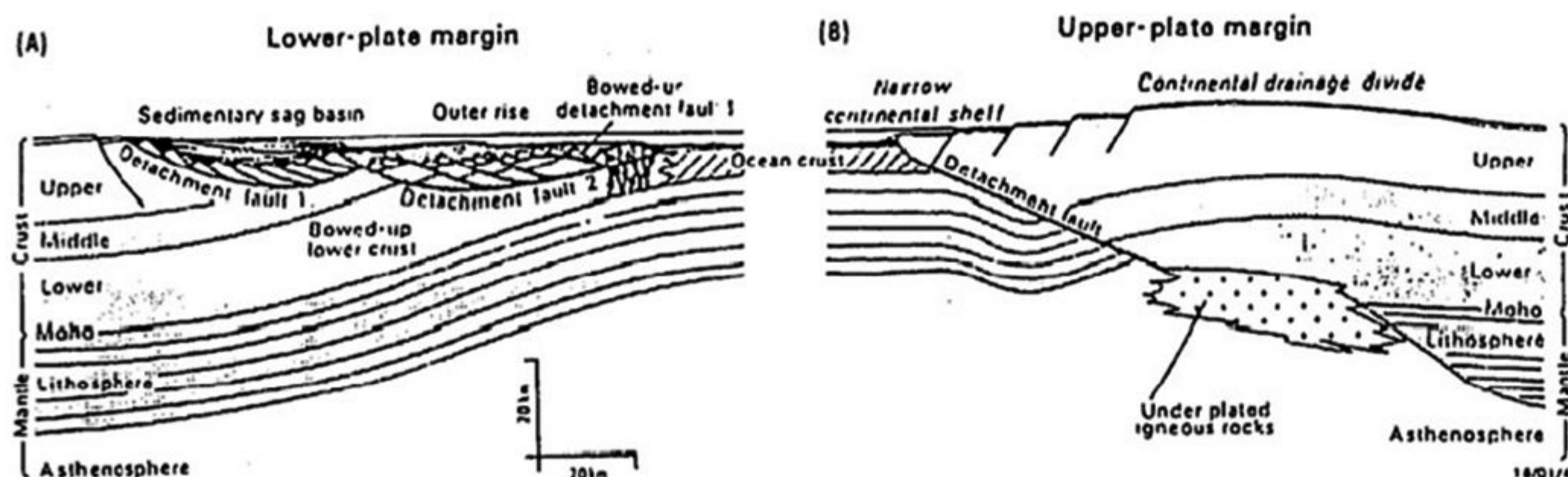


Figure 6. Lister et al's (1986) detachment-fault model of passive continental margins with lower-plate and upper-plate characteristics. Lower-plate margin (A) has complex structure: tilt blocks are remnant from upper plate, above bowed-up detachment-fault. Multiple detachments have led to two generations of tilt blocks. Upper-plate margin (B) is relatively unstructured. Uplift of adjacent continent is caused by underplating of igneous rocks.

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