

Tectonic features and evolution of the China seas and adjacent regions

QIU YAN AND LI TANGGEN

2nd Marine Geological Investigation Brigade
Ministry of Geology and Mineral Resources, Guangzhou, China

Abstract: Continental China was developed from many continental blocks which existed in Panthalassa and united as a whole in the late Paleozoic.

Since the Mesozoic, the tectonic evolution of the China seas has been closely related to the interactions between Eurasia, Pacific and Indian plates. After three times of collision at the southwestern margin and southeastern margin of the China mainland and a series of tectonic events in the China seas, the tectonic framework of the China seas and adjacent regions has been formed.

The tectonic systems of the region have the characteristics of E-W zonation and N-S blocks. EW orientation of tectonic systems was dominant in the pre-Indosinia period and NE-NNE since the Indosinian movements.

INTRODUCTION

The China seas, in the global plate tectonic framework, are situated between the East Asia continent and the Philippine sea subplate within the Pacific plate, and are an important part of the trench-arc-basin systems in the western Pacific. The scientists of the Ministry of Geology and Mineral Resources (MGMR) have been studying the data from geological and geophysical surveys for several decades, compiling the serial maps of geology and geophysics of the China seas and adjacent regions (1:5,000,000). The tectonic map compiled by authors is part of this project. This paper analyses the tectonic features and evolution of this domain.

TECTONIC FEATURES

Paleo-tectonic setting

The blocks in this domain, Huabei, Yangzi, Huanan, Indo-China exist among the tectonic belts which have been constructed since the Paleozoic (Cui and Li, 1990). These blocks once were separated by paleo-oceans and paleo-continental margins. During the periods of the Caledonian, Variscan and Indosinian orogenies, the Qinling and Yuebei troughs gradually evolved into folded belts which sutured the blocks together (Zhu and Chen, 1982). The paleotectonic and paleogeographic frameworks in the late Variscan period had the characteristics of EW extension and NS differentiation. The Indosinian period was an important stage of deformation, magmatism,

metamorphism and mineralization in this region. From the Indosinian movement to the Yanshan movement, active margins occurred on the east of the paleo East Asian continent, forming tectonic belts and magmatic belts. During the Indosinian period, some large-scale NE-NNE oriented tectonic systems were formed and were superimposed on previous EW oriented tectonic systems (Zhu and Chen, 1982). Then the tectonic pattern of EW zonation and NS blocks was basically constructed (Fig. 1).

Tectonic zonation and related characteristics

Since the late Yanshanian period, especially in the Himalayan period, affected by regional stress field paralleling alternating compression and extension, this region now displays the tectonic zonations which are of different origin, evolution and geological-geophysical features (Fig. 2).

- a. *Trench-Arc zone:* It is basically composed of a series of arcs with large curve protruding eastwards, such as Ryukyu islands, Taiwan island, Philippine islands and Borneo islands. Trenches are developed along the east of the arcs in most area. This trench-arc system is still the area of the strongest earthquakes and volcanism.
- b. *Marginal sea basin zone:* Associated with arc zones, it develops on the near-land side (e.g., Okinawa trough, the South China sea basin and troughs). Now the geomorphologic landscape is dominated by deep water basins and troughs. Continental crust thinning led to

transitional crust in the region with the exception of the central basin and southwest basin of the South China sea which is of oceanic crust due to sea-floor spreading.

- c. *East China sea-north South China sea shelf downfaulted system*: It is distributed in the east of a gravity gradient belt along the coasts of Fujian and Zhejiang. This system extends from the East China sea shelf, through the Taiwan strait, to the shelves of both the northern South China sea and the Indo-China peninsula. The boundary between the East China sea and the Okinawa trough is the fracture to the east of the Diaoyudao upwarping folded belt (Fig. 3). The shelf of the northern South China sea borders the marginal sea basin system on the stepped faults from Donsha islands to Xisha islands. The crustal thickness of the area is generally between 24 and 28 km (Ren, 1990).

- d. *Continental margin rift system*: The continental margin rift system consists of, from north to south, Bohai sea, Huabei, northern Jiangsu, southern Yellow sea, Jiangnan basin, Leizhou peninsula, Beibu gulf, probably extending to the southeastern Indo-China peninsula. There are a series of rift basins in this system. Its western boundary is limited to the Daxinganling-Taihang-Wuling mountains gravity gradient belt and the eastern boundary is terminated by the Tan-Lu deep fracture in the north whereas, in the south, by a series of NE and NNE fractures (Cui and Li, 1990). The development of rift basin underwent depression and differential subsidence and was accompanied by synsedimentary faulting. Mantle source multi-phase basalt erupted in many places. Below the major rift basin, the Moho upwarped, and the heat flow increased and the crust thinned (Xiu, 1988).

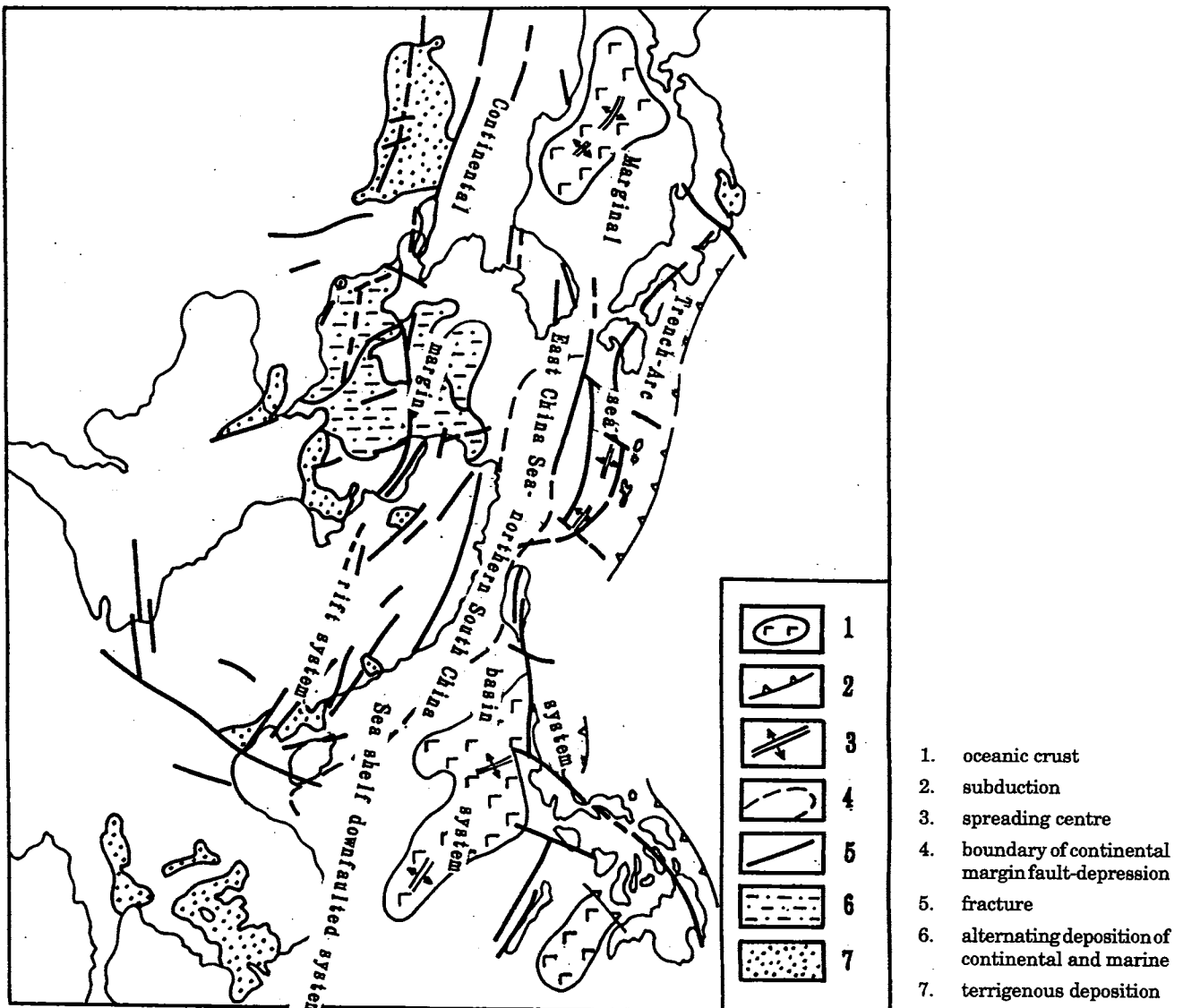


Figure 1. Tectonic zonation in the region.

TECTONIC EVOLUTION

Continental blocks formation and cratonization

Continental blocks, the embryo of the China continent, began formation in Archaean and Proterozoic. The Jilu core firstly appeared in the ocean in the Archaean. The Qianxi Formation in northern Hebei has an isotopic age of 3,500 Ma while the Dantazi and Shuangshanzi Formations in Hebei, the Anshan Formation in Liaoning and the Langling Formation in the northern Korea share the same isotopic age of over 2,500 Ma. These continental cores gradually developed and became stable platforms through the Liulian orogenic episode (Yang, Chen and Wang, 1988). In the late Archaean-early Proterozoic, such continental cores

as the Dabei Formation (2,900-1,800 Ma) in the middle of Anhui and the Ailaoshan Formation (2,500-1,800 Ma) in western Yunnan, which are located in the Yangzi area, were constructed and then, underwent cratonization through the Shibou orogenic episode. Pre-Sinian strata overlaid the cores mentioned above and were folded in Jingning orogenic episode (Yang, Chen and Wang, 1988). Both these cores and pre-Sinian strata were folded and became the double basements of the Yangzi block. In Huanan, the Jianou Formation (1,800 Ma), Chencai Formation (1,500 Ma) and Xiaobei Formation (1,400-1,800 Ma) emerged successively in Panthalassa in the early-middle Proterozoic, which stabilized into continental crust through the Caledonian orogeny (Chen, 1984). The Kunsong core in the Indo-China peninsula formed in the Proterozoic. There occurred several continental

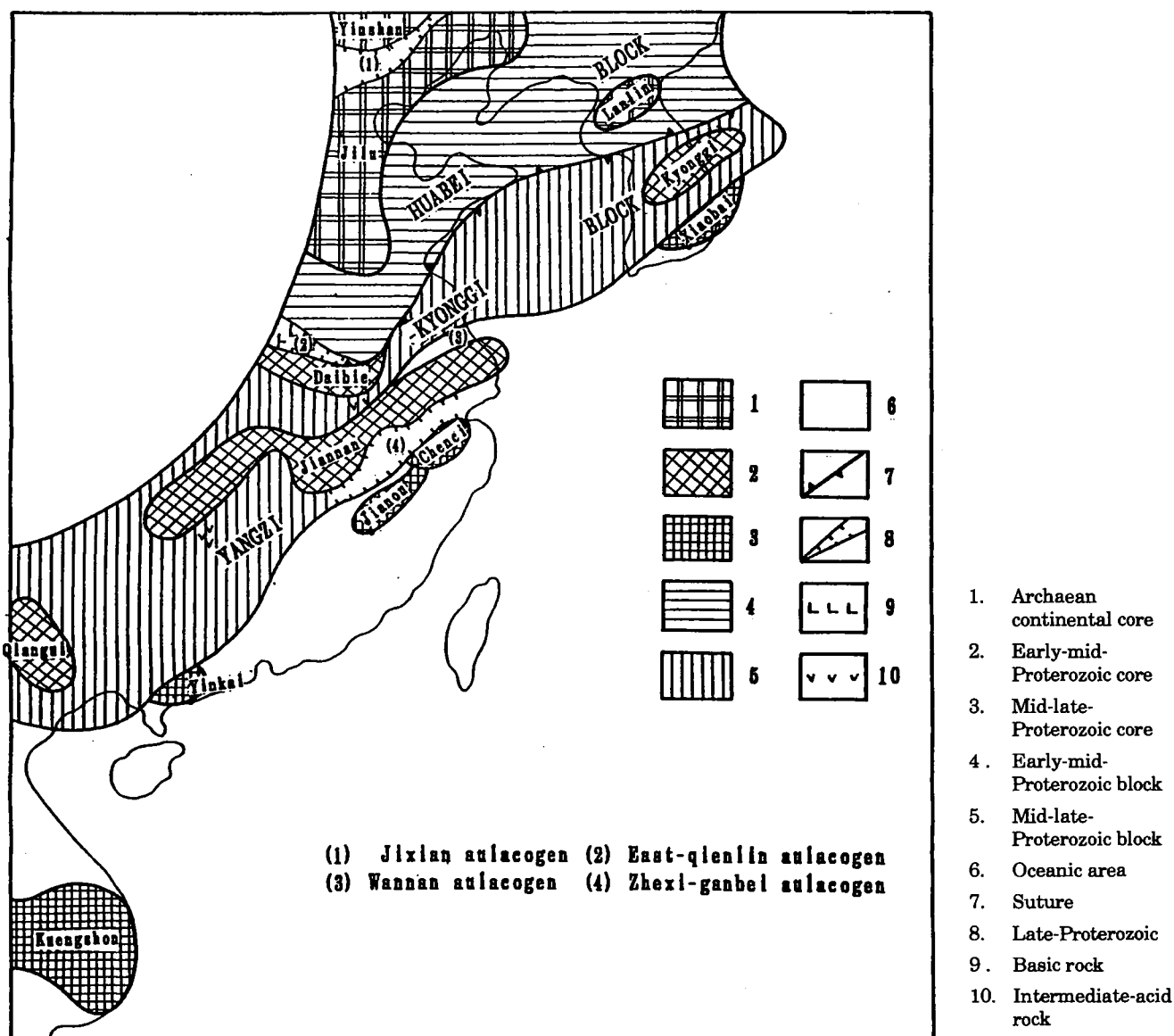


Figure 2. Tectonic sketch in pre-Phanerozoic.

cores (e.g., Xisha etc.) in the paleo-South China sea (He, 1987). Therefore, Huabei, Yangzi, Huanan, Indo-China and the South China sea blocks were formed in the Paleozoic, among which Huabei and Yangzi blocks had their first collision in late-Proterozoic and constructed the earliest China continent belonging to Pangea E (Wu, 1988) (Fig. 4).

Block Connection in the Paleozoic

From late-Proterozoic to Paleozoic, the above-mentioned blocks converged and diverged several times and were finally sutured together.

In the early-Paleozoic, the Huabei and Yangzi blocks partially separated in the west and an aulacogen occurred in the Qinling-Daba region. Around Dabei and Jiaoliao regions, the extension declined as compared with the west and no oceanic crust was formed. The regions showed only the characteristics of severe intra-continental fault-

depression. Wulian-Qingdo-Linjinjian regions also developed aulacogen of small separation distance. By the end of early-Paleozoic, the "paleo-Qinling ocean" subducted northwards, the Qinglin-Baba aulacogen closed and formed the Caledonian orogenic belt which again connected the Huabei and Yangzi blocks (Liu, 1990). In the late-Paleozoic, an aulacogen occurred again in the south of the orogenic belt where flysch deposited due to severe extension and subsidence in Triassic time. From Permian to Triassic, the western aulacogen might have been connected to the Tethys ocean. During Sinian and middle-Ordovician, platform carbonate and shelf slope clastic sediments were deposited in the southeastern Yangzi block and Huanan region except for the Chencai and Jainou uplands, which were covered with water (Fig. 5). The Yangzi block and Huanan block were separated by the Qingfang, Zhexi and Wannan aulacogens in the Paleozoic (Wang, Yang and Liu, 1986). In late-Permian,

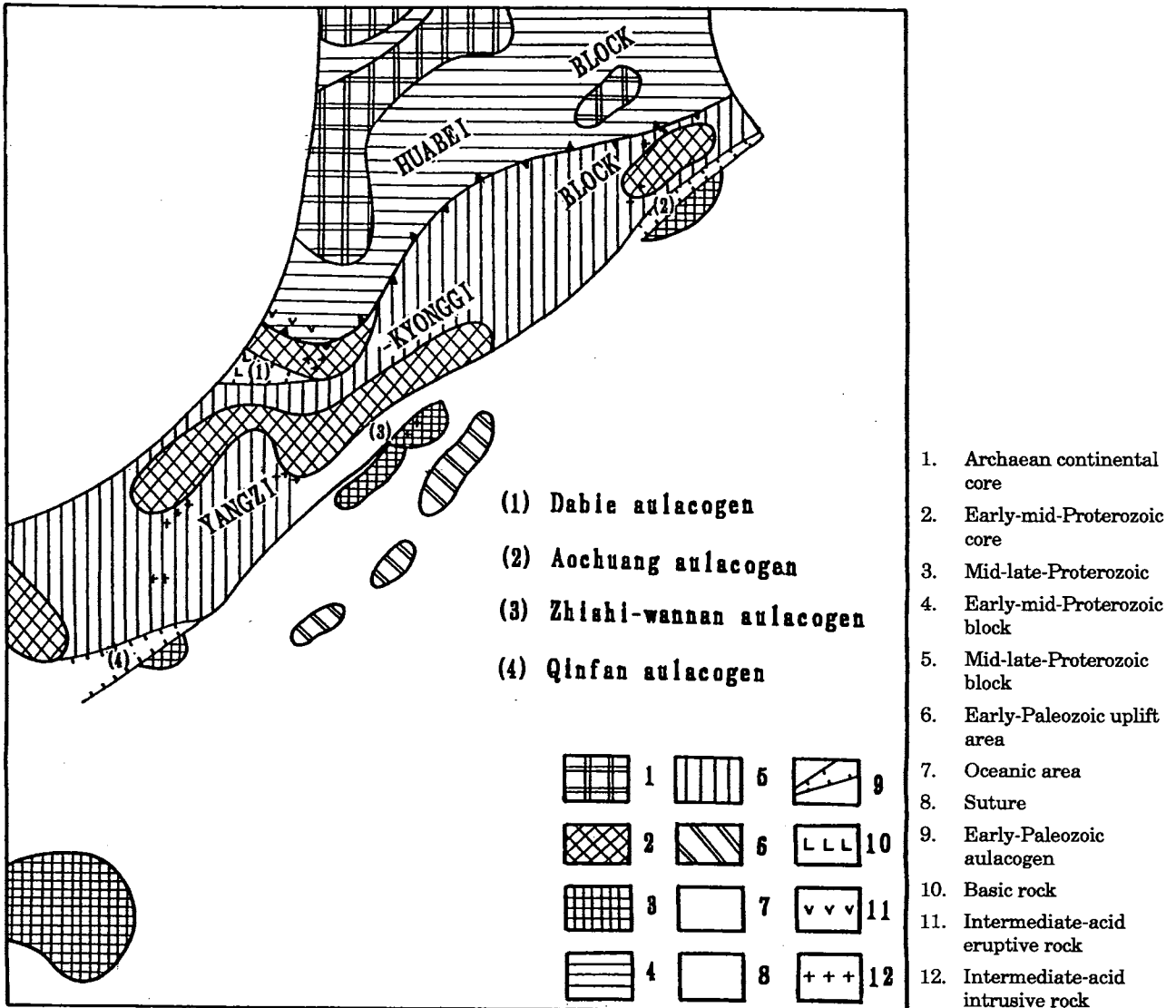


Figure 3. Tectonic sketch in early-Paleozoic.

collision and compression between the Yangzi and Huanan blocks caused basement decoupling, forming large-scale nappe structures. The compressive deformation lasted until Cretaceous. In this process, sea water regressed from the northeast to the southwest in Huanan and northern Jiangshu-south Yellow sea region was uplifted, while the Yuebei-Guangxi regions experienced only neritic environment only. Eventually, the Huabei, Yangzi and Huanan blocks were sutured together onto the China continent (Wu, 1988).

Action of Collision during Mesozoic and early-Cenozoic

During the Mesozoic, there were three episodes of rifting of continental blocks from Gondwanaland. These blocks drifted across the Tethys ocean and collided with southwestern China on three separate occasions, constructing the Lancangjiang suture (T_a-J_1), Bongonghu-Nujing suture (J_a-K_1) and

Yarlung-Zangbojiang suture (K_2-E) in sequence (Liu, Zhong and Yao, 1989). Consequently, the resulting northward and southward compression stresses from the collision resulted in the gigantic Tethys-Himalayan tectonic belts in the southwestern China mainland (Fig. 6).

At almost the same period, three times of collisions also occurred in the southeastern China continent under the effects of the Kula plate and later Pacific plate action. The Hide-Sangun paired metamorphic belts were formed in T_2-T_a . There were many effusive and intrusive events in these belts so that they are of the geophysical characteristics of striped high magnetic anomaly and high gravity anomaly. In mid-late Jurassic, another collision resulted in the central structure line of Japan, constructing the Ryoke-Sambogawa paired metamorphic belt ($J_{2,3}$). In the late-Cretaceous, the Shimanto mega-complex aggraded at southwest Japan (SEATAR, 1978). However, no

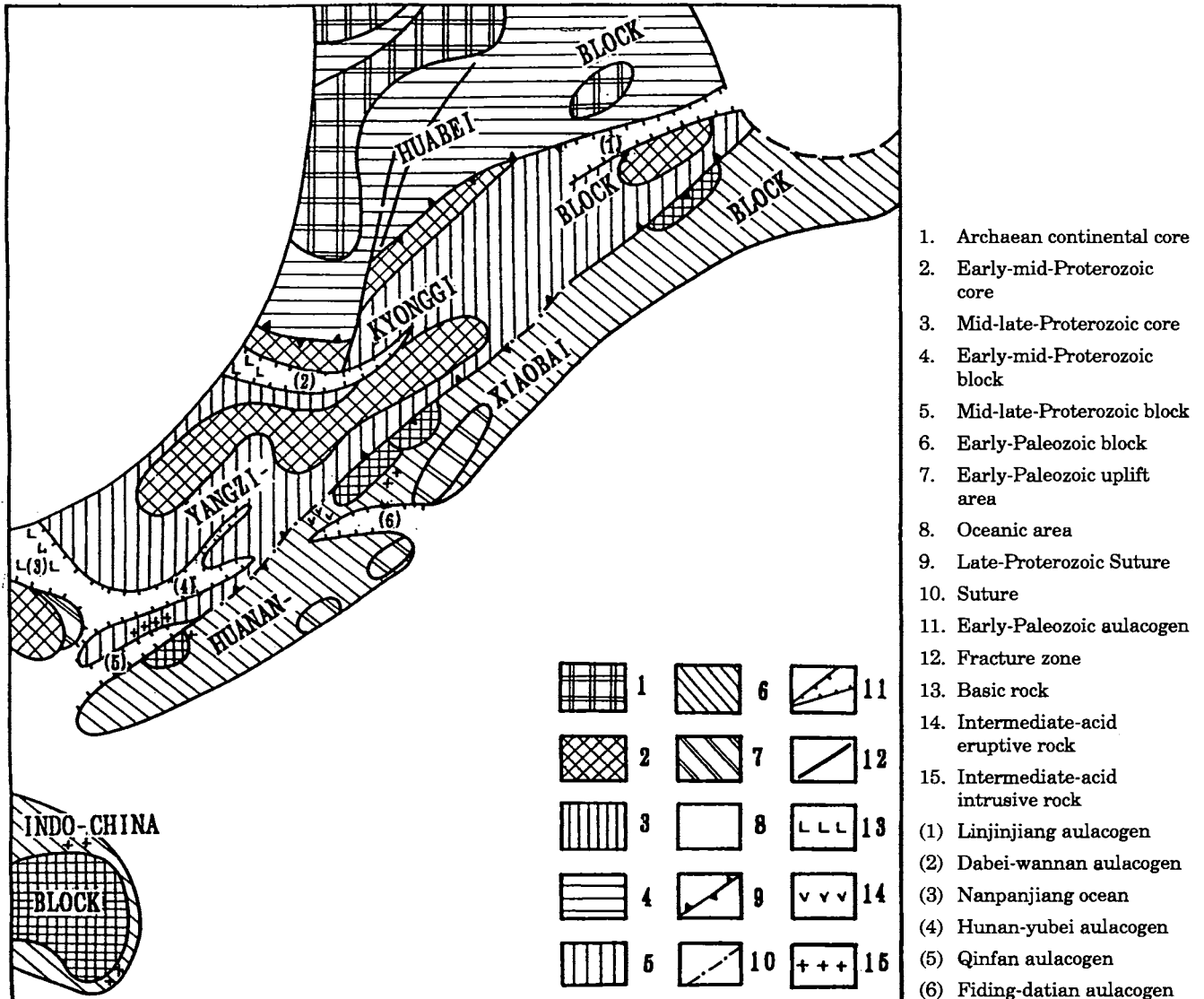


Figure 4. Tectonic sketch in late-Paleozoic.

paired metamorphic belts came into existence there. Evidence for collision and convergence are also found in the East China sea. There is a dynamic metamorphic belt which probably is a paleosubduction zone, along the offshore areas off southeastern Fujian. The features of this belt changed from subduction in the southeast to strike-slip in the northwest in its action period due to the existence there of a transform fault. The second collision belt extends from the east of the central range of Taiwan, which is associated with Yuli-Tacluge paired metamorphic belts, to the east of Diaoyudao upwarping folded zones in the East China sea. This collision belt possibly links with the central tectonic line of Japan and is characterized by a high magnetic anomaly and high gravity anomaly. Similar anomaly characteristics are also shown in the middle and north of Ryukyu, so it is inferred that spreading of the Okinawa

trough once separated this collision belt. In addition, evidences for one more collision belt is traceable in the center of the Ryukyu islands arc (Qiu, 1990).

In general, evidences for three times of collision mentioned above are not obvious in the southern margin of China mainland perhaps because of seafloor spreading. In northern Hainan island, however, there are indications that Hainan island had collided with the Huanan block. Paleontological analysis indicate that fusulinid fauna and Permian flora in Hainan island are different from these in the Huanan block (Qiu, 1990). On the contrary, early-Paleozoic trilobites and other fauna in Hainan island are similar to those in Australia (Qiu, 1990). Moreover, there is an obvious striped high magnetic anomaly in the region of Dongsha island. However, it is insufficient to be the indication of a collision belt.

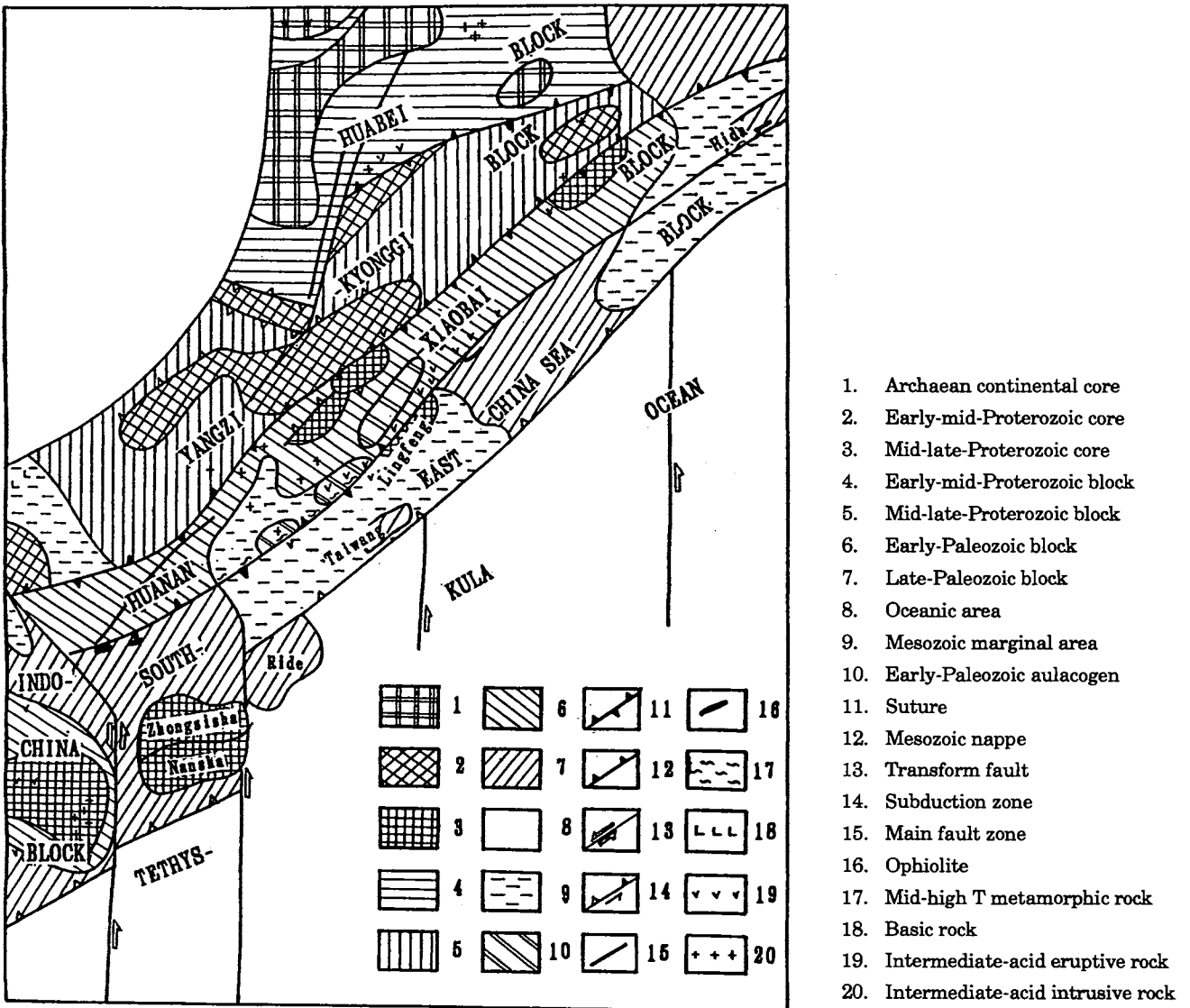


Figure 5. Tectonic sketch in Mesozoic.

Interaction of the collisions of blocks associated with Eurasian plate, Pacific plate and India plate movements reconstructed the paleotectonic framework of southeastern China continent which was originally formed before the Indosinian movement. The southern China mainland moved northwards. The part of the Yangzi paraplatform in the east of Tan-Lu deep fractures moved hundreds of kilometers and the western Qingling belt completely closed and was folded in Cretaceous time. Large-scale compression and overthrusting occurred within both the Yangzi paraplatform and

Huanan block, which caused basement decoupling and a series of nappes as well as overthrust faults (Liang, 1988). Crustal thinning resulted in severe faulting and magmatism. The vigorous intermediate and acid magmatism in southeastern China mainland caused extensive S-granite in Huanan and intermediate and acid magmatic zones along Fujian and Zhejiang (Wang, Yang and Liu, 1986). In late Cretaceous, the southeastern margin of the China continent was in a state of extensive stress, so a series of rift downfaulted basins (e.g. Huabei-Bohai basin, north Jiangsu-south Yellow

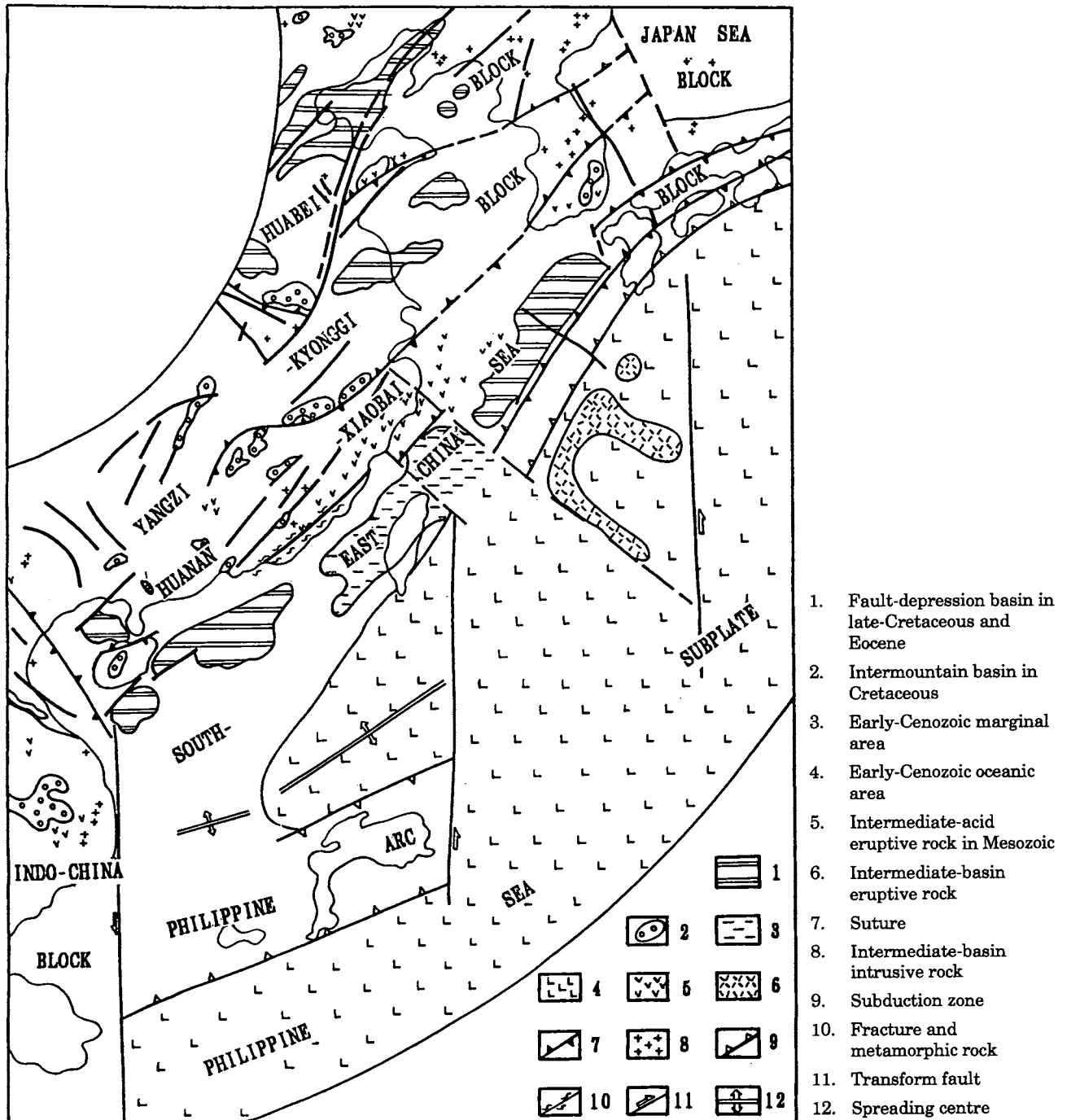


Figure 6. Tectonic sketch in early-Cenozoic.

sea basin and Beibu Gulf basin) and shelf downfaulted basins (e.g. East China sea basin and Pearl river mouth basin) came into existence, constructing the huge NE-NNE striking marginal rift system and shelf downfaulted system (Liu, 1990).

Tectonism in the Cenozoic

From late Eocene to early-Oligocene, the India plate collided with the Eurasian plate and the Qing-Zang plateau upwarped significantly. In Eocene the southwest basin of South China sea began to spread, on which a suit of deposits were accumulated and then were deformed due to later tectonism. About 42 Ma, the direction of the Pacific plate subducting beneath Eurasian plate changed from NW to WNW. As a result, the southeastern margin of the China continent suffered from both eastward and westward compressive stresses and, then, rose regionally which yield an important unconformity in the China sea and vicinity. During early and middle Oligocene, the second seafloor spreading in the South China sea formed the central basin and separated the Nansha block from the Xisha-Zhongsha blocks. Also, the Philippine islands arc moved northwards, rotated counter-clockwise and gradually surrounded the South China sea on the east. A succession of tectonic events changed the original stress states in the region so that those downfaulted deposits within the basin of the China seas and eastern China continent gradually changed to depressive and draping deposits. A great thickness of terrigenous clastic rocks in early-Tertiary was sedimented in the Huabei-Bohai gulf, north Jiangsu-south Yellow sea and East China sea shelf basin. Because of seafloor spreading of the South China sea in middle-late Oligocene, the Nansha block collided with the Palawan arc and then the Nansha-Palawan trough closed (He, 1987).

Since the end of the Miocene, under the effect of the Philippine sea subplate subduction, spreading between Ryukyu arc off Diaoyudao upwarping folded zone caused formation of the Okinawa trough, which has remained active. The trench-arc-basin system in the East China sea gradually evolved into a mature system. Spreading of the South China sea and Okinawa trough laid the foundation for the embryonic patterns of the marginal sea basin system in these regions. Since the late Miocene, severe tension of the northern South China sea caused the crust of Xisha, Zhongsha and Nansha blocks to be thinned. A series of ENE and WNW striking faults developed in the northern shelf of the South China sea. These fault systems controlled the south-faulted and north onlap or north-faulted and south-onlap depressions, on which over 10,000

meters of Tertiary littoral and neritic sediments accumulated (Qiu, 1990). Both the collision of the Luzon arc with Taiwan island and subduction of Philippine sea subplate resulted in partial early Tertiary strata of Taiwan island becoming folded and metamorphosed, and caused the central range to uplift (Liu, 1990). Since then, the modern tectonic framework of the China seas has been gradually taking shape.

DISCUSSION

The tectonic development stages can be divided into: a paleo-global tectonic stage and a neo-global tectonic stage. There mainly occurred the formation of continental cores, platform transition and cratonization or platform stabilization, and the action of opening and closing between blocks acted only as "accordion" in paleo-global tectonic stage. Through the Indosinia orogenic movements, and especially the Alpides movements, large-scale seafloor spreading and subduction of oceanic plates has led to the neo-global tectonic action. The tectonic evolution of the China seas and adjacent regions went through the two developing stages and gradually formed the modern framework.

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