DOI: 10.1007/s11430-006-0471-9

Mesozoic subduction-accretion zone in northeastern South China Sea inferred from geophysical interpretations

ZHOU Di[1], WANG Wanyin[2], WANG Jialin[3], PANG Xiong[4], CAI Dongsheng[5] & SUN Zhen[1]

1. Key Laboratory of Marginal Sea Geology, South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 510301, China;
2. College of Geological and Topographical Engineering, Chang'an University, Xi'an 710054, China;
3. Key Laboratory of Marine Geology, Tongji University, Shanghai 200092, China;
4. China National Offshore Oil Co. Limited – Shenzhen Branch, Shenzhen 518067, China;
5. China National Offshore Oil Co. Limited – Research Center, Beijing 100027, China

Correspondence should be addressed to Zhou Di (email: zhoudiscs@scsio.ac.cn)

Received May 18, 2005; accepted October 25, 2005

Abstract A segment of Mesozoic subduction-accretion zone was inferred across the northeastern South China Sea at approximately NE45° orientation. Basic evidence includes the following: A belt of peek gross horizontal Bouguer gravity gradient (PGHGBA) is comparable in size and intensity to that of the Manila subduction-accretion zone. A belt of high positive magnetic anomalies appears to the north and sub-parallel to the PGHGBA, representing the volcanic arc associated to the subduction zone. The PGHGBA crosses obliquely both Cenozoic structures and present seafloor topography, indicating a pre-Cenozoic age. The segment is offset left-laterally by NW-running strike-slip faults, in concord with the Mesozoic stress field of South China. In addition, the existence of the subduction zone is supported by wide-angle seismic data obtained in different years by different institutions. At approximate localities, a north-dipping ramp of Moho surface is indicated by records of ocean-bottom seismometers, and a strong reflector about 8 km beneath the Moho reflector is indicated by both OBS and long-cable seismic records. The identification of a segment of Mesozoic subduction zone in NE South China Sea fills nicely the gap of the Great Late Mesozoic Circum SE Asia Subduction-acrretion Zone, which extended from Sumatra, Java, SE Kalimantan to N Palawan, and from Taiwan, Ryukyu to SW Japan.

Keywords: Mesozoic, subduction zone, SE Asia, NE South China Sea, geophysics.

The northern South China Sea (SCS) is an important offshore exploration area of China, producing over 10 million tons of oil from Cenozoic reservoirs annually since 1996. The increasing energy consumption in China demands a rapid expansion of hydrocarbon exploration to new types, including pre-Cenozoic sources and reservoirs. This has stimulated a new phase of pre-Cenozoic researches in the area.

So far more than 100 exploration wells have reached the pre-Cenozoic basement in northern SCS. Together with geophysical modeling, some basic characteristics of the basement have been revealed[1−6]. The deep crustal structure of the northern SCS has been imaged by wide-angle seismic profiling along 9 sections during the last two decades[7−11]. Lately, gravity and magnetic data of the area were re-processed by

Wang1) and Wang and Zhang2). Based on interpretations of these newly processed results together with wide-angle seismic and drilling data, this paper proposes that a segment of Mesozoic subduction zone existed at approximately NE45º orientation across the northeastern SCS, accompanied by a volcanic arc to the northwest. This segment filled the gap of the Great Late Mesozic Circum SE Asia Subduction Zone.

1 Tectonic setting and regional geology

The study area (15°—24°N, 110°—122°E) is a portion of the South China Block and consists of several Cenozoic sedimentary basins (from west to east: the Qiongdongnan Basin, the Zhujiangkou Basin, and the SW Taiwan Basin), as well as the northern portion of the deep-sea basin of the SCS (Fig. 1). The deep-sea basin of the SCS opened in Late Oligocene to Early Miocene[13−15] and did not exist in the Mesozoic era. Thus the pre-Cenozoic basement discussed in this paper exists only under the present continental shelf and slope.

Regionally the study area is located near the SE margin of the Eurasian continent, which is encircled by the Paleo-Pacific ocean to the east and the Tethys ocean to the south. The Paleo-Pacific Ocean is a general term used here to represent the vast ocean beyond the eastern margin of the Eurasian and Gondwana continents as well as the Tethys ocean between them. According to the correlation of magnetic anomalies by Nakanishi *et al*.[16], the Paleo-Pacific ocean was composed of several oceanic plates, among which three oceanic plates, Izanagi, Pacific, and Farallon, were generated at the Shatsky hot spot in Middle Jurassic time. Then the NE-running spreading axis between the Izanagi Plate to the north and the Pacific Plate to the south moved northwards and rotated clockwisely, while the Izanagi Plate subducted towards the SE margin of the Eurasian Plate. This subduction was continued by the Pacific Plate after the Izanagi Plate consumed completely.

A striking feature of the SE margin of the Eurasian Plate is the development of a giant volcanic belt that extends more than 4000 km from Japan through SE China to southern Vietnam and SW Kalimantan. This volcanic belt is regarded as the volcanic arc accompanied the NW-ward subduction of the Izanagi and Pacific plates[13,14]. But several important characteristics of the belt, especially its dominantly granitic and rhyolitic (nearly 50% each[17]) with a small amount of basaltic composition, and its exceptionally large width (more than 600 km) make this belt quite different from typical Andean type dominantly andesitic volcanic arc. Origin of mantle heating[18] or intra-plate shearing plus subduction[19] was proposed to explain these distinct features. Recently, Zhou and Li[20,21] advocated a new model in which an early flat and later steepening subduction was used to explain the great width and oceanward shifting of the volcanism, and a basaltic underplating and its heating to produce felsic magma to explain the distinct composition of the volcanism.

The location of the subduction belt is another focus of attention. The Mino-Tamba, Sanbagawa, and northern Chichibu terranes in southwestern Japan[22,23] are similar to the Yuwan, Tomuru, and other formations in Ryukyu Islands[24] in lithology, chronology and structure. They both contain strongly deformed subduction complex of exotic blocks of Carboniferous-Permian, Triassic, and Jurassic pelagic bedded cherts and reef limestones embedded in metamorphosed Late Jurassic-Early Cretaceous muddy matrix. These are indicative of the Late Mesozoic subduction of the Paleo-Pacific ocean towards the Eurasian continent. To the south in Taiwan island, the Taroko high-T and low-P and the Yuli low-T and high-P metamorphic belts are regarded as a paired metamorphic belts related to subduction[25,26]. Detailed work in the North Palawan block has found subduction-accretion complex similar to those in Ryukyu and SW Japan[27]. These may be correlated even south to the Jurassic-Early Cretaceous subduction-accretion complex in the Meratus belt of SE Kalimantan[28], and even south-

1) Xi'an University of Engineering and CNOOC, Report of Re-processing of Gravimetric and Magnetic Data of Chinese Sea and Coastal Areas (in Chinese), 2000, 1—29.

2) Wang, J., Zhang, Y., Basement Composition and Structural Framework of NE South China Sea, Intermediate Report of G2000046702 Project (in Chinese), 2002.

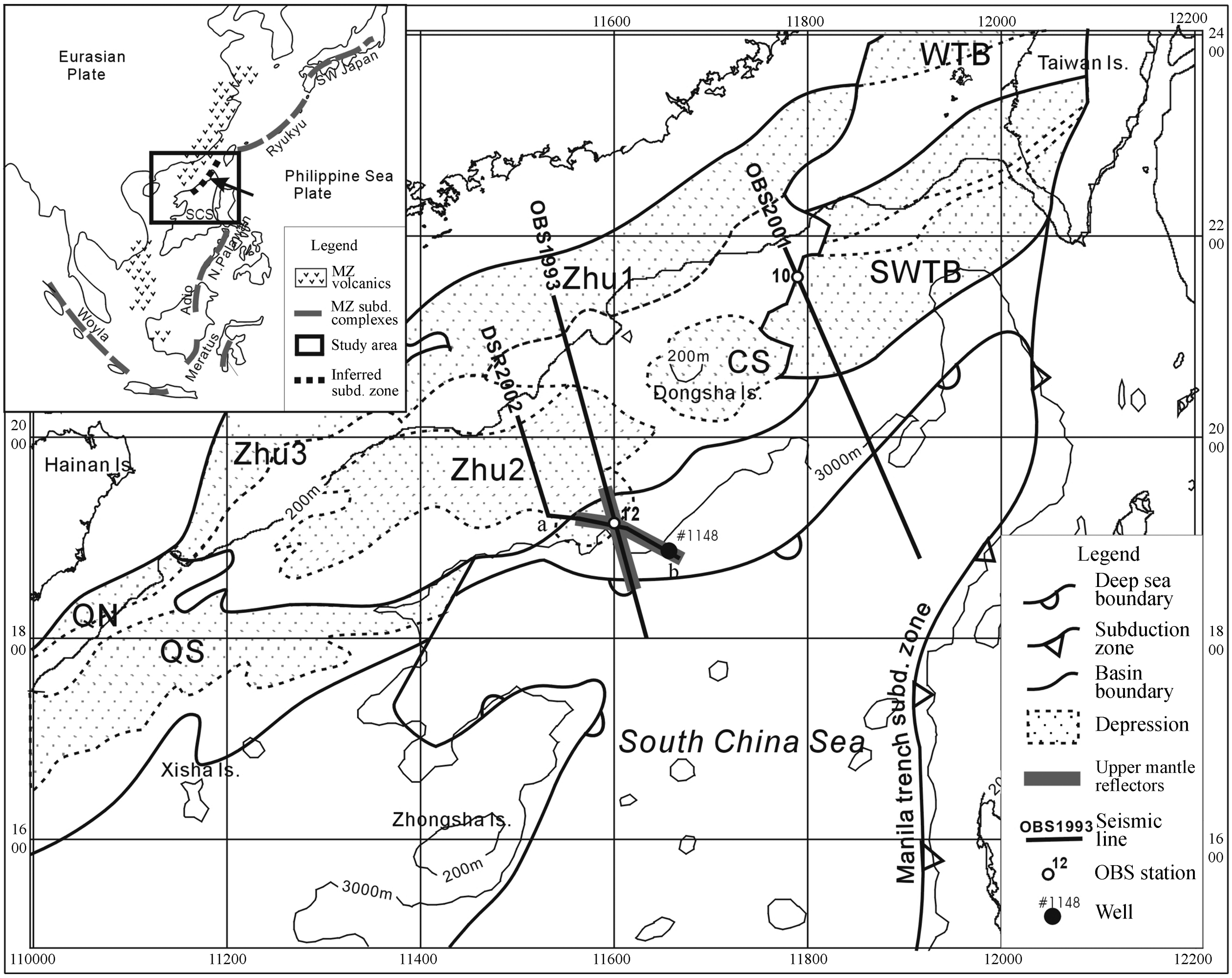

Fig. 1. Simplified geological map of the northern South China Sea, showing major Cenozoic structures, wide-angle seismic profiles and the stations mentioned in the text. Thick grey lines are segments where deep reflectors are observed below Moho reflector. ab is the location of the profile in Fig.4. Inset shows the regional tectonic setting, where the arrow indicates the segment of Mesozoic subduction-accretion zone inferred in this paper. Names of basins and depressions: ZHU 1, Zhu I depression; Zhu 2, Zhu II depression; Zhu3, Zhu III depression; QN, Qiong Bei sag; QS, Qiong Nan sag; CS, Chaoshan depression; WTB, West Taiwan basin; SWTB, SW Taiwan basin.

west to the Woyla belt in Sumatra[29−31]. All these complexes together formed a "Great Late Mesozoic Circum SE Asia Subduction-accretion Zone", where the late Paleozoic to Mesozoic oceanic crust subducted and accreted to the Eurasian plate in Late Jurassic to Cretaceous. According to this correlation, there must exist a segment of the subduction zone between Taiwan and North Palawan under the Cenozoic cover in the northeastern SCS.

The existence of a Mesozoic subduction zone in northern SCS and adjacent areas have been discussed for a long time. Li *et al*.[32] proposed that a relict Indosinian-Yanshanean subduction zone extended from the northern Hainan Island eastwards, through the inner shelf of the northern SCS, along the 50 m isobath off the coast of Fujian and Zhejiang provinces of China, and finally to northern Japan. Other authors[7,33] suggested that a Mesozoic subduction zone extended along the lower slope of the northern SCS and westwards to the Xisha Trough, based on the the deep-penetrating Lower Slope Fault Zone coupled with the high magnetic anomaly and thickened crust along the Dongsha Uplift. Xia and Huang[34] propose that from Late Paleozoic to Late Triassic there was a "Dongsha sea", which is connected to the "Jingsha-jiang-Tengtiaohe-Heshuihe sea" to the west in Indochina and the "Tianxiang sea" to the east in Taiwan, forming a branch of the Paleo-Tethys. They also suggest that along the lower slope there is a NE-NEE running "South Dongsha suture zone" of paleo-Tethys. Zhou[35] proposed that the Putian belt of mafic-ultramafic rocks were emplaced into Late Jurassic volcanic rocks during an Early Cretaceous subduction.

In the Zhujiangkou Basin (Pearl River Mouth Basin, PRMB)[1,2], most wells encountered Mesozoic granites with ages ranging from 118—66 Ma; two wells encountered granites of 130 Ma and 153 Ma respectively; and 8 wells in the western PRMB encountered metamorphic rocks (mainly quartzite of perhaps Paleozoic age). In the SW Taiwan Basin over 20 wells encountered Lower Cretaceous and Jurassic (?) sandstones and shales of marine or transitional facies[3−5]. Together with regional tectonic and geophysical studies, it is inferred that the pre-Cenozoic basement of the northern SCS is composed of metamorphosed sedimentary rocks of Caledonian foldbelt to the west, and of Mesozoic (mainly Cretaceous, especially Late Cretaceous) granites of Yanshanean orogen in the central and east. In the east most, the SW Taiwan basin contains un-metamorphosed Early Cretaceous marine and transitional clastic rocks and Jurassic (?) pelagic dark shale. According to the interpretation of seismic profiles, there may exist even older un-metamorphosed marine strata, and these may extend westwards to Dongsha Uplift and Chaoshan Depression[1−7].

2 Re-processing of gravimetric and magnetic data and their interpretations

2.1 The map of PGHGBA (peak gross horizontal gradient of Bouguer gravity anomaly) and its correlation with known structural features

The Bouguer anomaly of the sea area was calculated from the satellite gravimetric data[1)] with seawater density of 1030 kg/m^3 and crust density of 2670 kg/m^3. Then this is united with the inland Bouguer anomaly, forming the Bouguer anomaly map of the land and sea of East China. Compared with the free-air gravity anomaly map, the Bouguer anomaly map is less affected by topography and thus of better correlation to the crustal structures.

Let $\Delta g(x, y)$ denotes the Bouguer gravity anomaly, the gross horizontal gradient of Bouguer gravity anomaly (GHGBA) $Dg(x, y)$ is the modulus of the horizontal gradient components calculated by

$$Dg(x,y)=\sqrt{\left(\frac{\partial \Delta g(x,y)}{\partial x}\right)^2+\left(\frac{\partial \Delta g(x,y)}{\partial y}\right)^2}. \quad (1)$$

To reduce the effect of errors, two sets of gradient components are used in the calculation, and the formula becomes

$$Dg(x,y)=\sqrt{\frac{dg_0(x,y)^2+dg_{45}(x,y)^2+dg_{90}(x,y)^2+dg_{135}(x,y)^2}{2}}, \quad (2)$$

where $dg_0(x, y)$, $dg_{45}(x, y)$, $dg_{90}(x, y)$, and $dg_{135}(x, y)$ are the horizontal gradients at 0º, 45º, 90º, and 135º azimuths, respectively.

The maximum GHGBA is indicative of linear structures such as faults and litho-boundaries. But its variation is often gentle and obscured by lower gradient values. In order to improve its resolution, the peak value $Sg(x, y)$ is defined as the positive portion of the vertical gradient of $Dg(x, y)$, as in the following formula:

$$Sg(x,y)=Max\left(0.0,\frac{\partial Dg(x,y)}{\partial z}\right). \quad (3)$$

$Sg(x, y)$ is used to compile the Map of Peak Gross Horizontal Gradient of Bouguer Gravity Anomaly of the Land and Sea of East China (map of PGHGBA)[2)]. This map reveals clearly the location, strike, and strength of the maximum density gradient of the crustal rocks, and thus provides a good indication to geological structures.

The map of PGHGBA has good correlations with known structural features of East China in the following aspects: (1) The PGHGBA of highest amplitude and best continuity are correlated with the Manila-trench and Ryukyu-trench subduction-accretion

1) http://nssdc.gsfc.nasa.gov
2) See footnote 1) on page 472.

zones and the Luzon volcanic arc. (2) Sets of boudinage PGHGBAs are correlated with block boundaries and deep-penetrating faults, such as the Xiangfan-Guangji fault along the northern boundary of the Yangtze platform, the Pingxiang-Jiangshan-Shaoxing fault along the northern boundary of the South China foldbelt, and the NE faults of Tancheng-Lujiang, Changle-Nan'ao, Wuchuan-Sihui, Susong-Lingshan, as well as the EW Guidong-Quanzhou fault. (3) Large batholith is associated with circular PGHGBA at its edge, such as the Hercynian batholith of the Wuzhishan in Hainan Island. 4) NW-running strike-slip faults are indicated by the offset or termination of NE-running PGHGBAs, such as the faults of Zhanjiang-Xining-Bama, Huizhou-Qingyuan-Guilin, Yangjiang-Guiping-Laibin, etc.

2.2 The map of MARTOP (magnetic anomaly reduced to the pole) and its correlation with known structural features

The seas of China span more than 40º latitudes. The northern SCS is located at middle to low latitude of the Northern Hemisphere. Due to the inclined magnetization the peak of magnetic anomaly is offset southward with respect to the axis of the magnetic body. This brings difficulty to the correlation of magnetic anomaly with its magnetic source. A common practice for overcoming the difficulty is to reduce the magnetic anomaly to the pole. The Map of Magnetic Anomaly Reduced to the Pole for East China Land and Sea (map of MARTOP)[1,2] is produced using the technique of variable magnetization and self-adapting filtering on the basic data from the Magnetic Anomaly Map of East Asia[12]. Mainly because the direction and inclination of magnetization and the remnant magnetization cannot be estimated accurately for each locality, the magnetic field reduced to the pole could not be exactly the same as the magnetic field under vertical magnetization. By constructing the map of MARTOP, however, the offset between maximum magnetic anomaly and the magnetic body is significantly reduced, which makes the interpretation much more easy.

By comparing the map of MARTOP with the geological map of SE China, the following correspondences are seen clearly: (1) Boundaries of the first and second order tectonic units often coincide with the boundaries of magnetic divisions, such as the faults of Tancheng-Lujiang, Xiangfan-Guangji, Pingxiang-Jiangshan-Shaoxing, Susong-Lingshan, Ganjiang-Wuchuan-Sihui, Lishui-Haifeng, *etc*. (2) The common feature of magnetic field in areas of ancient metamorphic rocks is irregularly patched variation, although the general intensity varies with tectonic settings. For example, the area of Archean metamorphic rocks in the North China platform shows strong magnetic field, the area of Upper Proterozoic to Sinian metamorphic rocks in South China foldbelts shows intermediately strong field, but the Jiangnan anticline in the Yangtze platform has week magnetic field despite the existence of ophiolite suit in its Proterozoic basement. (3) The Mesozoic volcanic belt in the coastal areas of SE China is characterized by high magnetic anomaly belt. This high magnetic anomaly belt extends east of the Lishui-Haifeng fault from Yiwu of Zhejiang Province in the north to Dongshan of Fujian Province in the south, and continues even SE-ward to the northern SCS. Aeromagnetic mapping indicated that intensity of magnetic anomalies in this belt is in general higher than 100 nT, corresponding to the widely distributed Late Jurassic felsic-intermediate volcanic rocks that are of high remnant magnetization[17]. Very high spikes of magnetic anomaly appear along the coast at Linghai, Changle, Putian, Quanzhou, and Nan'ao, corresponding to the small beads of Yanshanean mafic-ultramafic rocks and Neogene-Quaternary basalts[38].

These correlations demonstrated that the newly compiled maps of PGHGBA and MARTOP reflect reasonably well important geological and tectonic features. This has given us confidence and provided a good basis for the interpretation of unknown structures offshore in northern SCS, as discussed in the following sections.

1) See footnote 1) on page 472.
2) See footnote 2) on page 472.

3 Identification of Mesozoic subduction-accretion zone in NE South China Sea

Figs. 2 and 3 are the maps of PGHGBA and MARTOP for the northern SCS (110°—122°E, 15°—24°N) constructed by the methods described in the previous section. Pre-Cenozoic structures identified during the present work are also superimposed on the maps.

In Fig. 2 three long and high-amplitude belts of PGHGBA are striking, namely, the PGHGBA belts of Manila trench (BB′B″ in Fig. 2), of the Luzon volcanic arc (CC′ in Fig. 2), and from SW Taiwan to North Zhongsha (AA′A″ in Fig. 2). The origins of the first two belts are respectively the subduction of the SCS along the Manila trench and the Luzon volcanic arc. The belt AA′A″ is the focus of this paper. This belt of PGHGBA strikes ca. NE45°—SW225° from off the western coast of Taiwan Island, through the SW Taiwan shoal and reaches the northern portion of the NW deep-sea basin, and is offset left-laterally by NW-running faults. The belt crosses continental shelf and slope and extends to the deep-sea basin, with the water depth <200 m at its northern end and >3000 m at its southern end. This gradient belt is not easily identifiable because it is oblique at high angle to the isobath and span across different Bouguer anomaly backgrounds, but now emerges after the processing with the definition of the PGHGBA. However, if we now go back to examine the previously published[37] and newly calculated maps of Bouguer gravity anomaly, this gradient belt can be seen vaguely still.

We interpret the SW Taiwan to North Zhongsha belt of PGHGBA as an indication of the buried Mesozoic subduction-accretion belt for the following reasons: (1) This belt is only secondary to the belts of Manila trench and Luzon arc in amplitude, linear shape, and scale. It differs from the belt of Luzon arc by lacking magnetic anomaly along the belt. Thus it is more like to have a similar origin with the Manila trench belt, but with weaker gravity gradient because it is buried by thick Cenozoic sediments. (2) This belt is oblique not only to seafloor topography, but also to Cenozoic structure fabric which is mainly NEE striking. Thus it must be generated by some pre-Cenozoic structure. (3) The general NE strike of the belt agrees with that of the Mesozoic structures inland SE China. The left-lateral offset by NW faults is concordant with the Mesozoic stress field of South China before the tectonic transform at Middle Cretaceous[38,39] and very different from the Cenozoic style of right-lateral offset along NW faults. Thus the belt is most likely an indication of Mesozoic structure. In addition, there is a belt of high magnetic anomaly about 100—200 km north of the belt, and the existence of subducted oceanic plate is suggested by several wide-angle seismic profiles. These may be also the evidence and will be discussed in later sections.

4 The belt of high magnetic anomalies in NE SCS is an indication of Mesozoic volcanic arc

The most striking feature of the magnetic field in northern SCS is the belt of high magnetic anomalies. The map of MARTOP reveals that there are actually 2 belts (2 circles A in Fig. 3), both striking ca. NE60º with length over 700 km, width of 30—80 km, and intensity of 60—200 nT. The northern belt extends from the Daya bay near the Pearl River Mouth NE-ward to the sea area east of the Jinmen Island in Fujian Province, and then connected with the belt of high magnetic anomalies in eastern Fujian and Zhejiang provinces[17]1), intensifies northward and landward. The southern belt starts north of the Baiyun sag of the Pearl River Mouth basin, extends NE-ward through the Dongsha, Penghu, and Beigang uplifts to the southern Xingzhu depression in the West Taiwan Basin. These two belts are separated by a narrow belt of low magnetic anomalies, which is coincident with the PGHGBA at the northern edge of the Pearl River Mouth basin and may be a fault. Negative anomalies appear north and south of these 2 belts of high magnetic anomalies.

The belt of high magnetic anomalies has been recognized for many years, but its origin remains controversial. Some authors[7,33] regard that the anomalies were generated by mafic-ultra mafic rocks, providing

1) See footnote 1) on page 472.

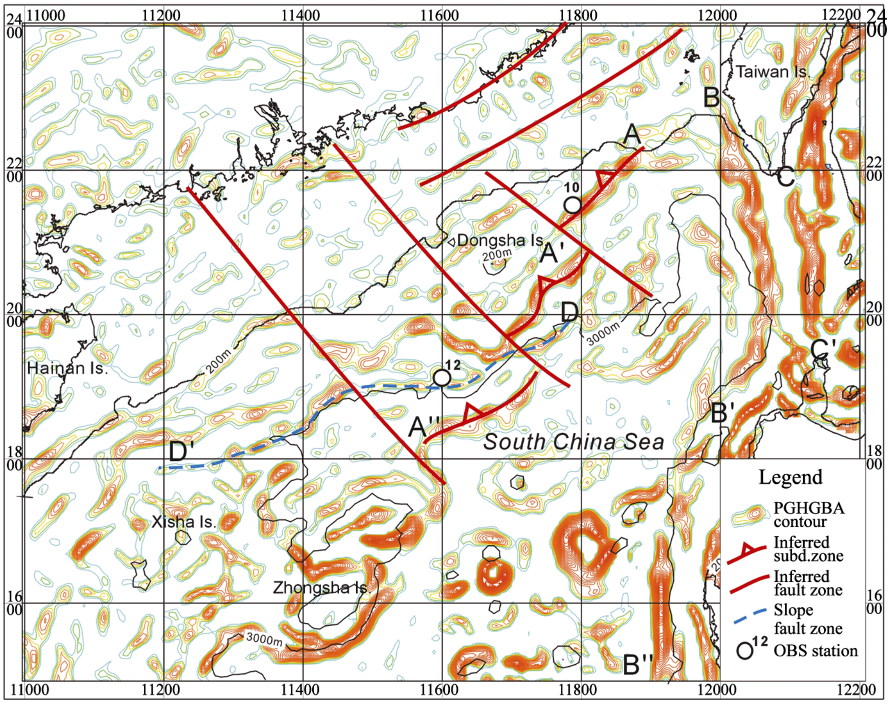

Fig. 2. Map of peak gross horizontal gradient of Bouguer gravity anomalies (map of PGHGBA) for the northern South China Sea. The segment of Mesozoic subduction-accretion zone and faults inferred in the paper are also shown. AA′A″, BB′B″, CC′ are belts of PGHGBA as explained in the text. DD′ is the slope fault zone inferred by Yao *et al*.[7].

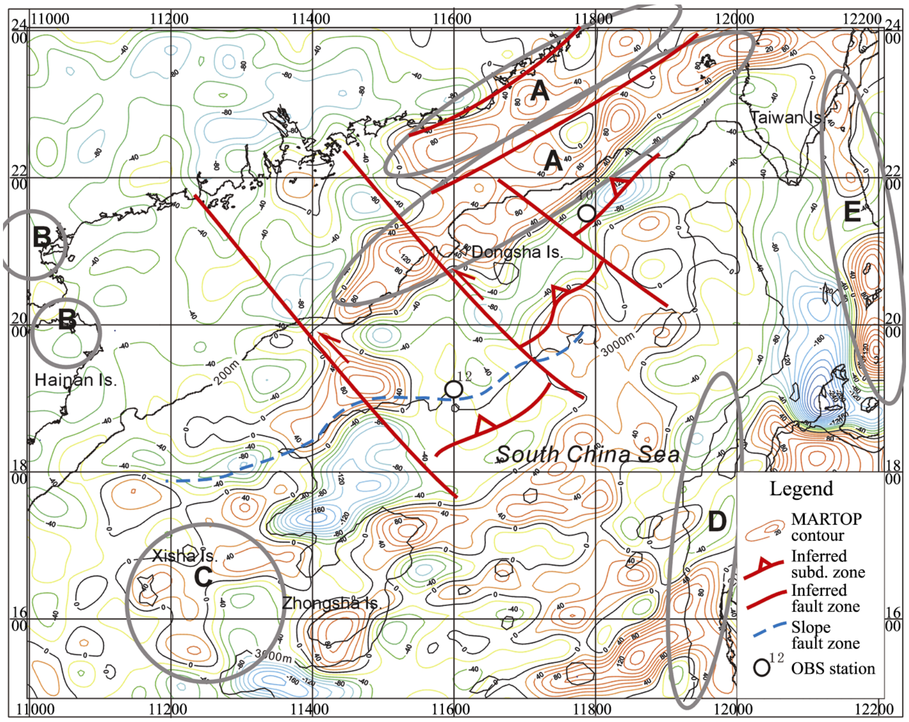

Fig. 3. Map of magnetic anomaly reduced to the pole (map of MARTOP) for the northern South China Sea. The segment of Mesozoic subduction-accretion and faults inferred in the paper are also shown. Grey circles A, B, C, D, E are explained in the text.

evidence of an Yanshanian subduction-accretion belt along the southern slope of the Dongsha uplift[3]. But we know that the Cenozoic subduction zone along the Manila trench is not associated with high magnetic anomalies (circle D in Fig.3). This is because the high magnetic anomalies may be generated only when the subduction is accompanied by the exhumation of oceanic crust (and upper mantle). For such a large-scaled magnetic anomaly belt the exhumation needs to be in large scale also. Although the possibility could not be routed out completely, so far we do not have other evidence. The known Mesozoic subduction-accretion complex in North Palawan[27] is not associated with high magnetic anomaly belt, as seen from the map of MARTOP for East China Land and Sea1). Other mafic rocks found in the northern SCS and adjacent coastal areas do not form a large belt of high magnetic anomalies. For example, the Quaternary basalts in Leizhou Peninsular and northern Hainan Island have very weak anomalies (circle B in Fig. 3), and the Early Cretaceous mafic-ultramafic rocks in coastal Fujian Province[35] generate only local high magnetic spikes[17]. Both are far from compatible to the belt of high magnetic anomalies in NE SCS.

Do the high magnetic anomalies reflect ancient (Proterozoic and/or Archean) complexes of metamorphic rocks? As discussed previously in this paper, the area of pre-Cambrian metamorphic rocks in the Xisha island (circle C in Fig. 3) and in the South China fold belt on land have irregularly patched magnetic anomalies of variable intensity, which are quite different from the belt of high magnetic anomalies in NE SCS.

In the study region and adjacent areas, magnetic anomalies compatible to the belt of high magnetic anomalies in NE SCS are seen only in the Luzon island arc (circle E in Fig.3) and in the coastal area of Fujian and Zhejiang provinces[17]1). The former is a subduction-related Cenozoic volcanic arc. The latter is a well-known Mesozoic volcanic arc associated with subduction of Paleo-Pacific plate toward the Eurasia continent. The widely developed Late Jurassic felsic to intermediate volcanic rocks in coastal SE China have high remnant magnetization and are the source of the magnetic anomalies. It is most likely that the belt of high magnetic anomalies in NE SCS is the offshore extension of the coastal anomaly belt and thus should be also the Mesozoic volcanic arc by analogue. This volcanic arc extends SW-ward to the north of the NW deep-sea subbasin of the SCS, and is offset left-laterally by NW faults (Fig. 3).

5 Evidence from wide-angle seismic profiles

The proposed subduction-accretion zone is also evidenced by 3 wide-angle seismic profiles (for their locations see Fig. 1). The line OBS1993 was obtained in a joint expedition of the South China Sea Institute of Oceanology and the Tokyo University in 1993, using dynamite and airgun as source and ocean-bottom seismometer as receivers. Under the stations 11 to 13 there is a deep reflector about 8—10 km below the Moho surface (see Fig. 9 of Yan *et al.*[9]). The line DSR2002 was the first deep seismic reflection profile obtained by the China Offshore Oil Company in 2002 using a cable up to 7400 m in length and 37.5 m in geophone spacing. Under the lower slope there is also a deep reflector about 4 km below Moho reflectors[41,42] (Fig. 4). The locations of deep reflectors identified from OBS1993 and DSR2002 are similar, although the depths differ by 4—6 km perhaps due to the uncertainty in seismic recording and time-depth inversion. In conjunction with other evidence, this deep reflector may be interpreted as the Moho surface of the subducted oceanic crust. OBS2001 is a line obtained by the South China Sea Institute of Oceanology and the Taiwan Ocean University in 2001 using airgun as source and ocean-bottom seismometer as receiver. Under the station 10 the Moho surface ramps down northward steeply for several kilometers2) (Fig. 5). This Moho ramp is located at the intersection of the OBS2001 line with the SW Taiwan to North Zhongsha belt of PGHGBA (Fig. 2), which should not be coincident but an indication that the ramp may be the bending portion of the subducted oceanic crust.

6 Conclusion and discussion

This paper reported a segment of the Masozoic

1) See footnote 1) on page 472.
2) Wang, T. K., Chen, M. K., Lee, C. S. *et al.*, Seismic imaging of the transitional crust across the northeastern margin of the South China Sea, submitted to *Tectonophysics*.

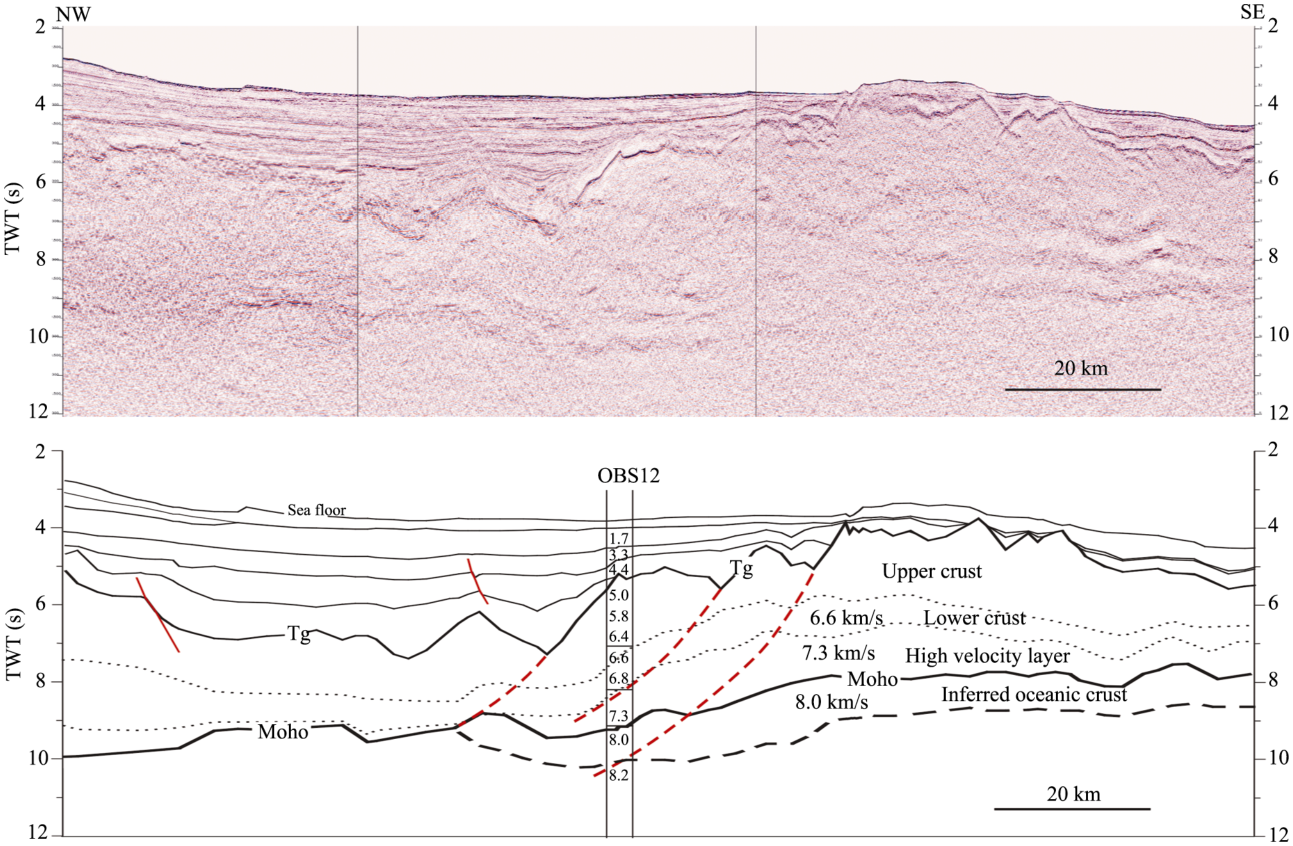

Fig. 4. The segment of the deep reflection seismic profile DSR2002 across the slope of northern South China Sea (upper) and its geological interpretation (lower)[42]. The location is shown as the ab segment of DSR2002 in Fig.1. OBS12 and the associated column and numbers show the velocity section at the OBS12 station along OBS1993 line. Tg is Cenozoic basement.

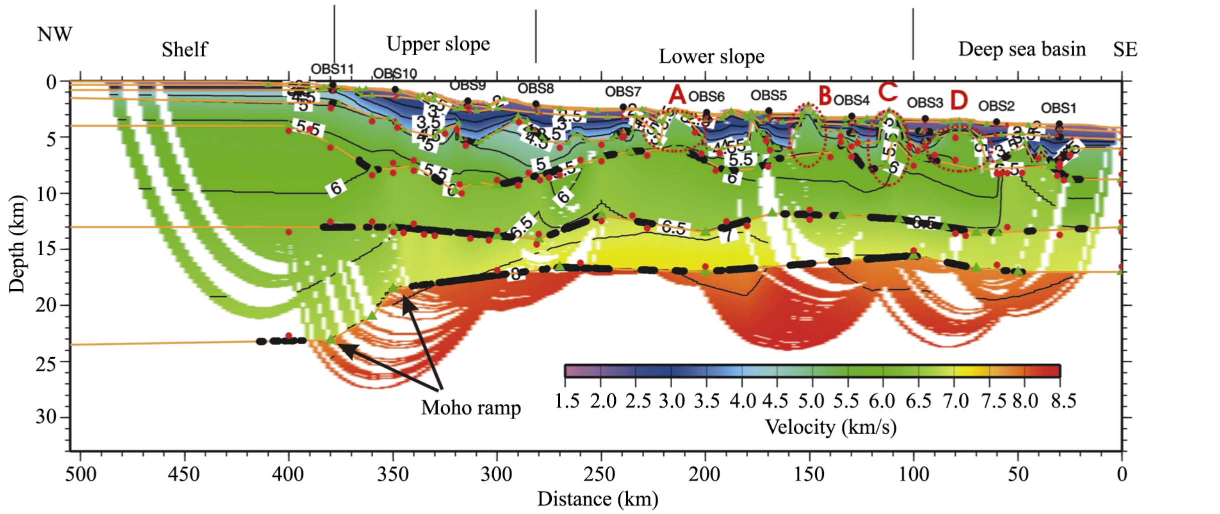

Fig. 5. P-wave velocity model of OBS2001 profile (from Wang *et al*., footnote 1 on page 10 with permission). Location of the profile is shown in Fig. 1. Note the north-dipping ramp of the Moho surface as indicated by black arrows, which lies under the station OBS10. Small black dots on seafloor are the localities of OBS; red dots and green triangles are respectively control points for velocity and interfaces; black dots superimposed on interfaces are reflection points; A, B, C, D and associated dasheds ellipsoids indicate inferred sub-marine volcanoes.

subduction-accretion belt of SE Asian margin newly recognized in the NE South China Sea based on gravimetric, magnetic, and wide-angle seismic data. This segment extends approximately from19°E, 22°20′N to115°30′E, 18°10′N, striking NE45°—55°, and being offset left-laterally by NW-running faults. Its expressions include a belt of strong PGHGBA (peak gross horizontal gradient of Bouguer anomalies), a steeply north-dipping ramp of the Moho surface indicating the bending of the subducted plate, and a deep reflector several km below the Moho surface representing the Moho surface of the subducted oceanic plate. About 50—200 km north of the segment there is a wide belt of high magnetic anomalies, indicating the volcanic arc associated with the subduction. The age of the subduction is inferred as Mesozoic based on the facts that the segment is oblique to both present seafloor topography and Cenozoic structural fabric, and that its NE strike and being offset left-laterally by NW faults demonstrate the characteristics of Mesozoic stress field in SE China.

This interpretation is in concordance with regional tectonic setting. As depicted in the inset of Fig. 1 and described in the section 1 of this paper and references[31,43], a more than 1500-km-long belt of Late Jurassic to Early Cretaceous subduction-accretion complexes is identified from SW Japan, through Ryukyu islands to NE Taiwan. Similar complexes are found also in North Palawan, the Adio belt of Sabah, the Meratus belt of SW Kalimantan, and the Woyla belt of Sumatra. The newly identified segment in the NE South China Sea fills nicely the gap between Taiwan and North Palawan. Thus it may be inferred further that this segment subducted and accreted also in Late Jurassic to Early Cretaceous and ended in middle Cretaceous. Altogether they formed the Great Late Mesozoic Circum SE Asia Subduction Zone.

Our interpretation needs to be checked further by more evidences. If the interpretation is valid, then some new questions on the tectonic evolution of the SCS are raised, such as: (1) The nature of the pre-Cenozoic basement of SW Taiwan, Chaoshan, and Baiyun depressions. They are located in the fore-arc area in between subduction belt and volcanic arc and expressed as a belt of strong negative magnetic anomalies (Fig. 3). Were there Mesozoic for-arc basins? (2) The nature of the NW subbasin of the SCS. If the NW subbasin is indeed a part of the SCS and opened in Late Oligocene[13,15], it should cut and make a gap to the Mesozoic subduction-accretion zone. But now we see the NW subbasin is separated from the East subbasin by the inferred Mesozoic subduction-accretion zone. It should be pointed out that the nature and age of the NW subbasin are not uncontroversial. Wissmann *et al.*[44] noticed that the correlation of seismic profile suggested the overlay of Paleocene to Late Eocene strata above the oceanic crust of the NW subbasin. He proposed the possibility of a Mesozoic age of the NW subbasin. From the map of MARTOP (Fig.3) we may see that the NW subbasin is characterized by wide and strong negative magnetic anomalies, quite different from the banded magnetic anomalies in the East subbasin. (3) Strong belts of PGHGBA appear also at the SE edge of the Zhongsha islands. This curved belt is apparently related to topography. But it is not clear by now if there is the superposition of deep-seated structures and if the segment of Mesozoic subduction-accretion belt might extend even further SW.

Acknowledgements Thanks to CNOOC China Ltd. for providing DSR2002 seismic profile and the “Report of gravimetric and magnetic data processing for offshore China and adjacent areas”, and to Qiu Xuelin and Wang Tiankai for providing the unpublished profile on OBS2001. The senior author was enlightened by discussions with Shigeki Hada and the papers provided by him. This research was supported by the National Natural Science Foundation of China (Grant No. 40238060), the National Basic Research Program of China (Grant No. G20000467-02), the Key Project of the Chinese Academy of Sciences (Grant No. KZCX2-SW-117), and the National Special Project (Grant No.2001DIA50041).

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