http://www.geojournals.cn/dzxbcn/ch/index.aspx

Intracontinental Collisional Orogeny During Late Permian–Middle Triassic in South China: Sedimentary Records of the Shiwandashan Basin

LIANG Xinquan[1], LI Xianhua[1] and QIU Yuanxi[2]
1 *Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, Guangdong 510640; E-mail: liangxq@gig.ac.cn*
2 *Geoscience Department, Zhongshan University, Guangzhou, Guangdong 510275*

Abstract Sedimentary response to an orogenic process is important for determining whether South China had compressional or extensional orogeny during the period from the Late Permian to the Middle Triassic besides the tectonic and magmatologic evidence. An intracontinental collision event took place between the Yangtze and Cathaysia blocks in the Late Permian. Beginning at the Late Triassic, the tectonic movement was completely changed in nature and entered a post-collisional extensional orogenic and basin-making process. This paper presents sedimentological evidence from the Late Permian to the Middle Triassic in the Shiwandashan basin at the southwestern end of the junction zone between the Yangtze and Cathaysia blocks.

Key words: Shiwandashan basin, intracontinental collisional orogeny, sedimentary record, Late Permian to Middle Triassic, South China.

1 Introduction

The complex Indosinian tectonic-magmatic-metallogenic processes in South China and their geodynamic settings have made geologists bewildered, and a series of viewpoints or models have been proposed (Chen, 1956; Ren, 1980; Holloway, 1982; Huang, 1986; Hsü et al., 1987,1988, 1990; Gilder et al., 1996; Chen, 1999; Yan et al., 2003). Of them the understandings relating the Indosinian orogeny in South China by Hsü et al. (1987, 1988, 1990) and Gilder et al. (1996) are completely different from each other. Hsü et al., on the basis of tectonic facies, pointed out that there existed a Triassic collision orogen in South China, which was created by the closing of the Nanpanjiang ocean between the Yangtze and Cathaysia blocks with the Shiwandashan area as a tectonic window. Based on the study of geochemistry of granite, Gilder et al. recognized a high $\varepsilon_{Nd}(t)$ and low T_{DM} granite zone (named Shi-Hang zone) in South China and this zone extends from Hangzhou through central Jiangxi Province to the Shiwandashan Mountains. It trends NE and coincides with the arrangement of the Mesozoic pull-apart basins. They believed that the zone, produced probably by Mesozoic crustal extension rather than continental collision, was an approximate boundary between an active region with well-developed Mesozoic magmatic rocks and basins in eastern and a relatively stable region in western South China. Sedimentary response to an orogenic process is important for determining whether South China had compressional or extensional orogeny during the period from Late Permian to Middle Triassic besides the tectonic and magmatologic evidence. This paper provides sedimentological evidence for the understanding of compressional orogeny from Late Permian to Middle Triassic and extensional basinogeny after the Late Triassic in South China.

2 Regional Geology and Pre-Mesozoic Tectonic Evolution

The Shiwandashan basin lies in the eastern part of Guangxi Zhuang Autonomous Region at the southwestern end of the junction zone between the stable Yangtze region and the relatively active Cathaysian region in South China (Figs. 1 and 3). It is separated from the Liuwandashan and Yunkaidashan Mountains by the Qinzhou-Lingshan fault in the southeast and from the Yangtze block by the Pingxiang-Nanning fault in the northwest (Fig. 1).

Data of remote sensing, gravity and magnetic anomalies, and seismological and magnetotelluric sounding profiles (Bureau of Geology and Mineral Resources of Guangxi Zhuang Autonomous Region, 1985) demonstrate that the study area is divided into four tectonic units by three NE-trending faults (Cenxi-Bobai, Qinzhou-Lingshan and Pingxiang-Nanning faults). From east to west they are (1) the Yunkai orogenic belt, (2) the Liuwandashan fold-thrust zone, (3) the Shiwandashan foreland basin and (4) the Wuming forebulge depozone. Judging from their tectonic patterns, temporal-spatial distribution of rocks and sedimentary sequences, the four tectonic units look like unconnected narrow and long slices (Xu et al., 2001).

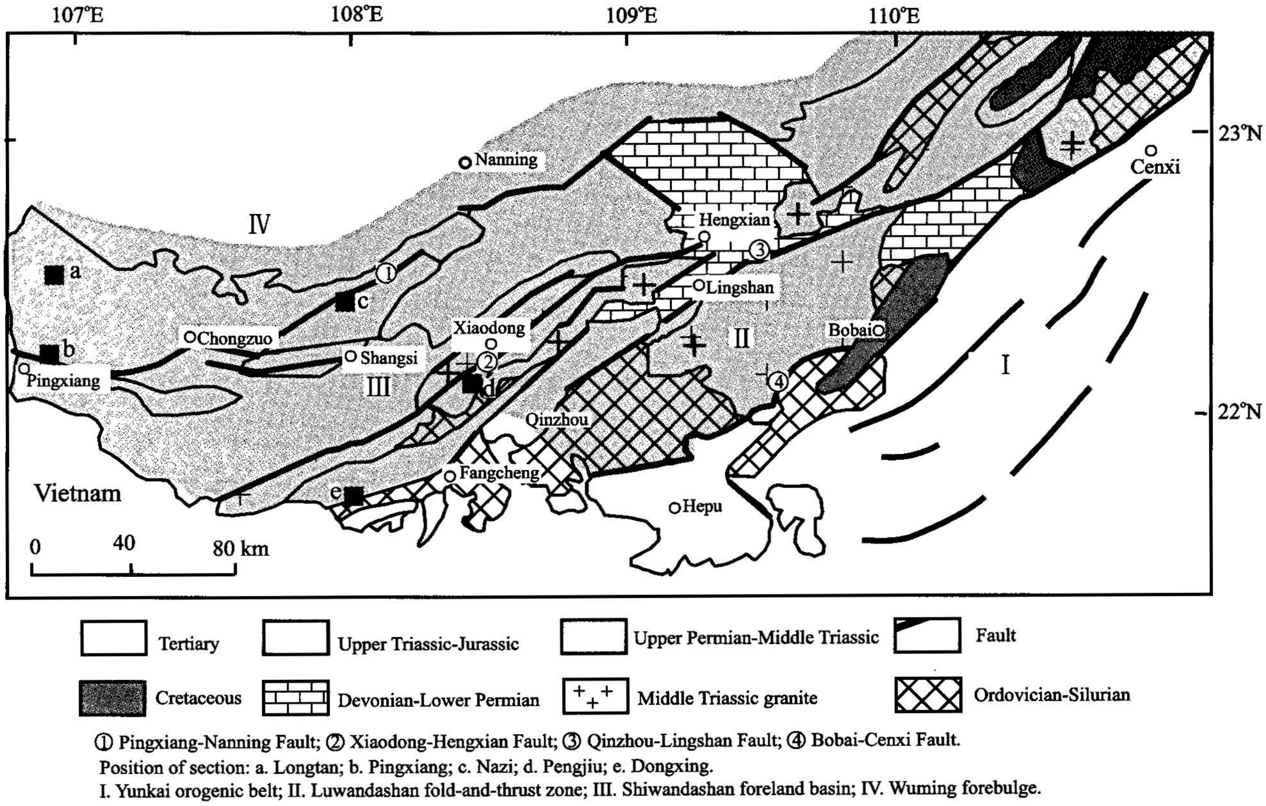

Fig. 1. A map showing tectonic units and regional geology in the Shiwandashan basin

The tectonic evolution of the Shiwandashan area from Late Permian to Middle Triassic was related to the convergence between the Yangtze and Cathaysia blocks. (1) During 850–800 Ma, the Yangtze and Cathaysia blocks collided like scissors along the Jiangshan-Shaoxing fractural zone extending from Hangzhou in Zhejiang Province to Qinzhou in Guangxi Zhuang Autonomous Region, resulting in the formation of the Jiangshan-Shaoxing suture zone, and the South China residual abyssal or bathyal sea basin (Shui, 1987; Xu, 1995). (2) In 800 Ma, the Jiangshan-Shaoxing suture zone transformed from oblique subduction to sinistral strike-slip, thus forming the Jiangshan-Shaoxing transform zone. Meanwhile, the South China residual marine basin was extended and replaced by an extension rift (Liu, 1993). (3) During 500–470 Ma, the South China rift contracted, the Cathaysia and Yangtze blocks collided, and the Nanning-Wuzhou area in Guangxi entered a collisional orogenic and basinogenic stage (Ting, 1929; Wu, 2000). (4) During 470–256 Ma, rifting took place again on the South China continental margin, forming the South China Paleo-tethys Ocean (Liu, 1993), and the Shiwandashan area became a NE-trending bathyal lithofacies zone named the Qinfang trough (Bureau of Geology and Mineral Resources of Guangxi Zhuang Autonomous Region, 1985; Liu et al., 1994; Liu, 1998) or aulacogen (Ma, 1996). (5) In 256 Ma, the sea along the Qinzhou-Fangcheng line suddenly became shallower and narrower, and migrated westwards, and the Qinfang trough reversed to a near-land margin or shore (Li, 1998). The geodynamic setting and the nature of the basin in the study area again had radical changes, and a clear-cut sedimentary-tectonic transform surface from unconformity through parallel unconformity to conformity was preserved from east to west between the Lower and Upper Permian. The event was named the "Dongwu revolution" in China.

3 Sedimentary Records from Late Permian to Middle Triassic

Figure 2 is a columnar section showing typical Late Permian strata and sedimentary facies of the Shiwandashan basin.

In the Late Permian, very thick molasse-type piedmont sediments accumulated in the Fangcheng-Qinzhou area adjacent to the Yunkai orogenic belt. They rest unconformably on the underlying intensely folded Silurian to Lower Permian. On the Pengjiu and Dongxing cross-sections, Qinzhou City (Fig. 2), sediments are composed of four lithologic members. From bottom to top, the first member (F-1a, 1b), about 500–2300 m thick, is made of two reverse-grading sedimentary units consisting of conglomerate, pebbly sandstone, fine sandstone, muddy siltstone and mudstone. The pebbles are commonly fragments of purplish red or yellow siliceous rocks, poorly

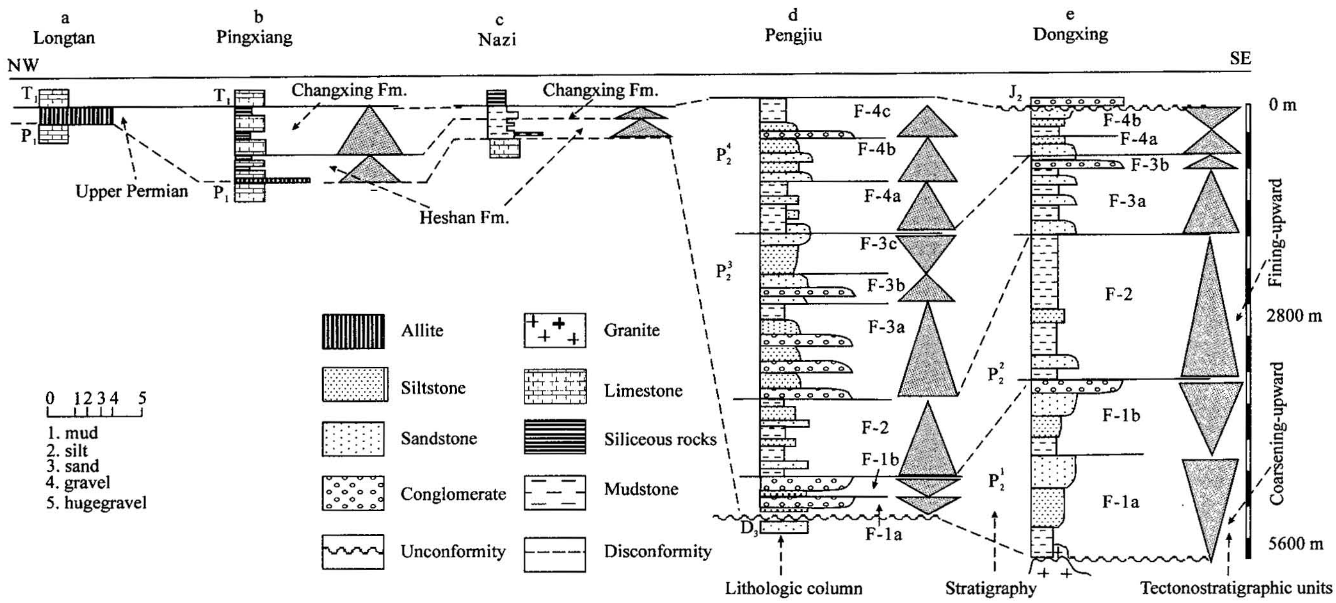

Fig. 2. Columnar sections showing typical Late Permian strata and sedimentary facies of the Shiwandashan basin (see Fig. 1 for the positions of sections).

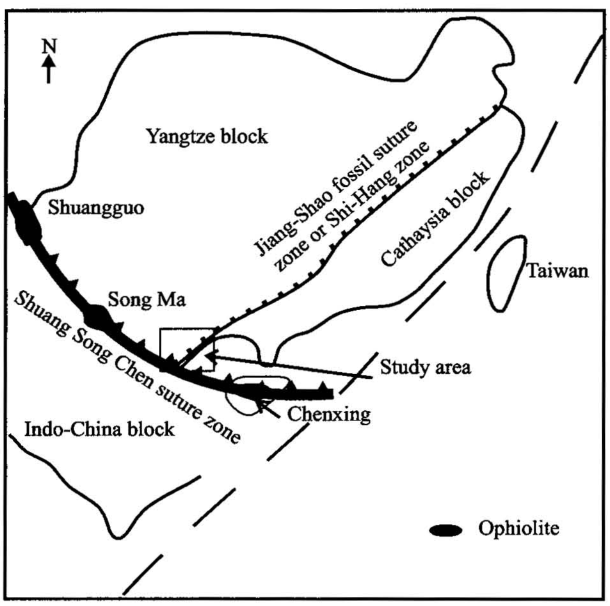

Fig. 3. A modified tectonic model showing tectonics in South China during the Late Permian-Middle Triassic period.

rounded and assorted, derived obviously from the Lower Permian Bancheng siliceous rocks laid down in an area adjacent to the Shiwandashan basin (Wang et al., 1998). The second member (F-2), 1000–1800 m thick, is a normal-grading sedimentary unit composed of siltstone, mudstone and dark thin-bedded siliceous rock. The third member (F-3a, 3b), 800–2000 m thick, is made of two normal-grading sedimentary units composed of pebbly, psephitic sandstone, sandstone and mudstone, with a reverse-grading sedimentary unit deposited locally. The pebbles were derived from Lower Permian purplish red and yellow siliceous rocks, Carboniferous black siliceous rocks and light gray or red Devonian sandstone (Wu et al., 1994). The fourth member (F-4a, 4b), 600–1600 m thick, is made of a normal-grading and reverse-grading sedimentary units composed of sandstone, mudstone and pebble sandstone. The pebbles were derived mainly from sandstone having cross bedding and being similar to the Devonian sandstone in Hepu or Fangcheng. Their good roundness suggests that they have migrated for a long distance. The characteristics of Late Permian molasse in Qinzhou imply that the provenance lay in the Yunkai orogenic belt adjacent to the basin, and that the Yunkai orogenic belt was in obduction during the continent-continent convergence. The Late Permian conglomerate shows a rapid facies change along the dip. For example, westwards to Shangsi and Nazi, it changes to siliceous rock of abyssal facies. Further westwards to Chongzuo and Pingxiang, it changes to shallow–water sediments such as limestone or chert limestone interbedded with siliceous rocks, which have only a thickness of about 100–150 m and rest unconformably on the underlying Lower Permian limestone (Fig. 2). Still further westwards to Longtan and Wuming, where a NE-trending uplift stands, the Upper Permian is completely missing or consists only of thin residual or marsh-facies ferralite. This suggests that the Wuming area is a forebulge depozone (Figs. 1 and 2). On the southern margin of the Wuming forebuge depozone, a

Lower Permian organic reef is overlain by Upper Permian radiolarian siliceous rocks, suggesting that the basin became deepened and lay at the position of intracontinental subduction (Wu et al., 2000).

The Upper Permian molasse becomes fine upwards, replaced by siltstone and mudstone in the upper part, which are overlain by Lower Triassic shore-or shelf-facies clastic rock, deep-water turbidite and shallow-sea limestone. In the Early Triassic, the basin migrated, sedimentary characteristics markedly changed, piedmont accumulation no longer existed, and a NE-trending deep-water turbidity basin was formed with Shangsi as the center. The eastern part of the basin has accumulated shore- and shelf –facies clastic rocks. The main part of the basin consists of rhythmic beds of thin-bedded inequigranular greywacke, siltstone, silty mudstone and mudstone. These rocks contain rare fossils and may be ascribed to distal low-density turbidity sediments, which are interbedded locally with high-density medium- to thick-bedded fine sandstone, siltstone and seldom radiolarian micrite. The former has typical intervals CDE and DE of the Bouma cycle with well-developed sand laminations, micro-grain sequences, horizontal laminations and convolute bedding, while the latter, massive bedding, bottom scour molds and flute casts (You et al., 1998). The total thickness is 300–800 m. The western part of the basin is covered by carbonate rocks, including two facies area, platform slope and carbonate platform. The former occurs in a narrow and long belt extending from Ningming to Chongzuo, while the latter, in a wide region including the Nanning and Chongzuo. The platform slope facies includes two types, deposits and talus, composed mainly of dark gray thin-bedded micrite interbedded with thick-bedded platy or massive calcirudite. Interbeds of calcirudite formed by slumping or collapse are located chiefly in the upper or lower part of cross-sections. The carbonate platform facieses is composed commonly of sparry calcarenite and oosparite. Their total thickness is 800–900 m.

In the Middle Triassic, the coast continued to migrate westwards, and the Shangsi turbidity basin became shallower, filled with fine clastic rocks and mudstone. Sedimentary structures of shallow-water origin are well-developed in sandstone. Along the fracture zones bordering the basin on the northern and southern sides there occurred a suite of intermediate-acidic volcanic rocks interbedded with sandy mudstone and argillaceous limestone containing *Posidonia* sp (Yang, 1997a, b). The southern belt of volcanic rocks extends southwestwards to Xialongwan, Vietnam, accompanied by a 1–3 km wide and 20 km long peraluminous granite belt. The granite was intruded into the Late Permian molasse and overlain by Late Triassic sediments. Its zircon age is 233±3 Ma (Deng, 2003). Therefore, normal deposition in the eastern part ended, but turbidity deposition of sandstone and shale continued in the western part, and turbidity deposition of clastic rocks took place in the central part of the basin, with the ancient water current pointing to NW.

Late Triassic sediments are distributed at the main peak of the Shiwandashan Mountains and extending southwards to Vietnam. There are 600–8000 m thick red clastic rocks of continental and paralic facies, which have no direct contact with the Middle Triassic, and rest unconformably on Indosinian granite. Field investigation demonstrates that at the bottom of the Upper Triassic there occurs thick-bedded conglomerate. The gravels are well-rounded, derived from peraluminous granite and intermediate acidic volcanic rocks similar to the Middle Triassic granite and volcanic rocks.

4 Tectonic Significance of Sedimentary Records

4.1 Late Permian to Middle Triassic collisional orogenic and basinogenesis

Judging from the sedimentary records in the Shiwandashan basin to the west of the Yunkai orogenic belt, we can draw the following conclusions: (1) The Shiwandashan area is a Late Permian–Middle Triassic foreland basin resulted from convergence and collisional orogeny between the Yangtze and Cathaysia blocks . The formation and evolution of the basin and the sequence of sediment filling were controlled by thrusts-nappe of the Yunkai orogenic belt adjacent to the basin over the foreland. (2) The interface between the Upper and Lower Permian is a geological response to the Dongwu revolution and also the prelude to the Permian collisional orogeny in South China. It is both a sedimentary transform surface from deep-water to terrigenous shore or shall-water deposition and a tectonic transform surface from extension to compression. (3) The interface between the Middle and Upper Triassic marks the ending of the orogeny beginning in the Late Permian. It is both a sedimentary transform surface from pyroclastic rock deposition to continental or continental-marine deposition and a tectonic transform surface from compression to extension. (4) The sedimentary records indicate that from the Late Permian till the Middle Triassic, the South China land area underwent an orogenic process from the south. It resulted in wide marine regression in South China, and rapid change of ecological environment. This orogenic process manifests itself most clearly on the border between Guangdong and Guangxi, where molasse and mélange appeared as the product of collision. Spatially they occur only in the surroundings of the Yunkai orogenic belt, reflecting obviously the amalgamation and collision between the Yangtze and Cathaysia blocks at the southwestern end of the Shi-Hang zone. The orogenic and basinogenic process can be ascribed to intracontinental collisional orogenesis and basinogenesis.

4.2 Late Triassic post-collisional extension

The Upper Triassic rests unconformably on Middle Triassic granite. It has a large thickness and does not show depositional features of a foreland basin. Gravels in the basal conglomerate were derived from Middle Triassic granite and acidic lava. Middle Triassic granite experienced a series of geological processes, including outcropping, abrasion, grinding, transportation and accumulation as gravels of the basal conglomerate, during a short period of time (about 5–20 Ma) . This suggests that the study area underwent a short-term rapid uplifting, denudation, relatively tectonic quiescence, long-distance transportation-abrasion and rapid subsidence and deposition. There is no doubt that such a geological process cannot be accomplished solely by thrusting. Considering also the development of a series of extensional structures from Upper Permian to Middle Triassic, we think that it must be a response to extensional orogeny or collapse of the orogenic belt. This indicates that during the Late Triassic, tectonic the dynamics changed in nature and the study area entered a post-orogenic extension-taphrogeny or collapse stage.

4.3 Dynamics of orogenesis and basinogenesis

The orogenic and basingenic dynamics in the period from Late Permian to Middle Triassic is probably related to the disappearance of paleo-Tethys existing at the southern margin of South China and the convergence and collision between the Yangtze and Cathaysia blocks caused by the paleo-Tethys subduction (Fig. 3). They all together controlled the tectono-magmatic-sedimentary response in South China, especially in the junction zone between the Yangtze and Cathaysia blocks.

Available information suggests that a WNW-EW-trending paleo-Tethys exists in a zone extending from the Ailaoshan Mountains and Shuangguo in Yunnan Province through Song-Ma in Vietnam eastwards to Chenxing in Hainan Province between the southern margin of the South China and Indo-China blocks (Fig. 3; Zhang et al., 1994; Jian et al., 1997; Chen et al., 1998; Shen et al., 1998; Zhong et al., 1998; Li et al., 2000 a, b). It has been widely accepted that there exists an aulacogen in an area extending from the Qinfang trough through Guangxi, Guangdong and Hunan to northeastern Jiangxi from Late Devonian to Early Permian though it is still disputable whether a paleo-Tethys existed or not (Ying et al., 1999; Qiu et al., 2000). In the Late Permian, paleo-Tethys was successively subducted northwards and northwestwards along the Bentong-Raub and Uttaradit zones, and the Indo-China block rotated clockwise to join with the South China block in the Permian (Sengör et al., 1984; Zhang et al., 1994; Lepvrier et al., 1997; Lacassin et al., 1998; Nam et al., 1998; Lan et al., 2000; Singharajwarapan et al., 2000; Carter, 2001).

Meanwhile, the amalgamated, relatively stable South China block, especially the amalgamated, structurally weak positions or interior fossil Jiangshan-Shaoxing suture zone (e.g. the Shi-Hang zone), were passively involved in intracontinental shortening and crustal thickening to form a intracontinental collisional orogenic belt and an accompanied foreland basin. Intracontinental shortening of this kind was completed under such pre-existing boundary conditions as fossil subduction zones and amalgamation zones of blocks.

5 Conclusions

It is true that there exists a Mesozoic collisional orogene in South China based on sedimentary records. Its age, however, is from Late Permian to Middle Triassic. In the Late Triassic and thereafter, the tectonic movement changed to crust extension. This process is related to the closing of the paleo-Tethys existing at the southern margin of South China and the rejuvenation of the interior fossil suture zone caused by subduction of the paleo-Tethys and subsequent intracontinental collision events between the Yangtze and Cathaysia blocks.

Acknowledgments

Our thanks are due to Prof. Z. Li from the University of Western Australia for review the manuscript and offering helpful and constructive suggestions, and Prof. Wang Yuejun and Dr. Wang Yang for their assistance in field work. Financial support of the National Natural Science Foundation of China (Grants 40272092 and 40334039), the Chinese Academy of Sciences (Grant KZCX2-102) and China Postdoctoral Science Foundation (200333418) is gratefully acknowledged.

Manuscript received Nov. 3, 2003
accepted March 2, 2004
edited by Liu Xinzhu

References

Bureau of Geology and Mineral Resources of Guangxi Zhuang Autonomous Region, 1985. *Regional Geology of Guangxi Zhuang Autonomous Region*. Beijing: Geological Publishing House, 853 (in Chinese with English abstract).

Carter, A., Roques, D., Bristow, C., and Kinny, P., 2001.

Understanding Mesozoic accretion in Southeast Asia: significance of Triassic thermotectonism (Indosinian orogen) in Vietnam. *Geology*, 29: 211–214.

Chen, A., 1999. Mirror-image thrusting in the South China Orogenic Belt: tectonic evidence from western Fujian, southeastern China. *Tectonophysics*, 305: 497–519.

Chen, Guoda, 1956. Examples of "activated region" in the Chinese platform with special reference to the "Cathaysia" problem. *Acta Geologica Sinica* (Chinese edition), 36: 239–376 (in Chinese with English abstract).

Chen, J.F., and Jahn, B.M., 1998. Crustal evolution of southeastern China: Nd and Sr isotopic evolution. *Tectonophysics*, 284: 101–133.

Deng, X.G., 2003. *Shrimp U-Pb zircon geochronological, geochemical and Sr-Nd isotopic study on the S-type granites, southeastern Guangxi, China*. Post-doctor thesis, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, 88.

Gilder, S.A., Gill, J., and Coe, R.S., 1996. Isotopic and paleomagnetic constraints on the Mesozoic tectonic evolution of South China. *J. Geophys. Res.*, 101: 16137–16154.

Holloway, N.H., 1982. North Palawan block, Philippins--its relation to Asian mainland and role in evolution of South China Sea. *Am. Assoc. Petrol. Geol. Bull.*, 66: 1355–1383.

Hsü, K.J., Li, J.L., Chen, H., and Wang, Q.C., 1990. Tectonics of South China: key to understanding West Pacific geology. *Tectonophysics*, 183: 9–39.

Hsü, K.J., Sun, S., and Li, J., 1987. Mesozoic suture in the Huanan Alps and the tectonic assembly of South China. *Scientia Sinica* (Ser.B), 1107–1115.

Hsü, K.J., Sun, S., Li, J., Chen, H.,Pen, H., and Sengor, A.M.C., 1988. Mesozoic overthrust tectonics in South China. *Geology*, 16: 418–421.

Huang, H.Z., 1986. Geotectonic development of China. In: Yang, T.I. (ed.), *The Geology of China*. Oxford, England: Clarendon Press, 235–276.

Jian, P., Wang, X.F., He, L.Q., and Zhong, D., 1998. U-Pb zircon dating of the Shuanggou ophiolite from Xingping County, YunnanProvince. *Acta Petrologica Sinica*, 14: 207–211 (in Chinese with English abstract).

Lacassin, R., Leioup, P.H., Trinh, P.T., and Tapponnier, P., 1998. Unconformity of red sandstones in northern Vietnam: Field evidence for Indosinian orogeny in northern Vietnam. *Terra Nova*, 10: 106–111.

Lan, C.Y., Chung, S., and Shen, J., 2000. Geochemical and Sr-Nd isotopic characteristics of granitic rocks from northern Vietnam. *J. Asian Earth Sci.*, 18: 267–280.

Lepvrier, C., Maluski, H., and Vuong, N., 1997. Indosinian NW-trending shear zone within the Truong Son belt (Vietnam): ^{40}Ar-^{39}Ar Triassic and Cretaceous to Cenozoic overprints. *Tectonophysics*, 283: 105–128.

Li Xianhua, Zhou Hanwen, Ding Shijiang, Li Jiyu, Zhang Renjie, Zhang Yeming and Ge Wenchun, 2000a. Metamorphosed mafic rocks with N-type MORB geochemical features in Hainan Island: Remnants of the Palaeo-Tethys oceanic crust? *Chinese Sci. Bull.*, 45: 84–89 (in Chinese).

Li Xianhua, Zhou Hanwen, Ding Shijiang, Li Ji'yu, Zhang Renjie, Zhang Yeming and Ge Wenchun, 2000b. Sm-Nd isotopic constraints on the age of the Bangxi-Chenxing ophiolite in Hainan Island: implications for the tectonic evolution of eastern Paleo-Tethys. *Acta Petrologica Sinica*, 16: 425–432 (in Chinese with English abstract).

Li, Z.X., 1998. Tectonic evolution of the major East Asian lithospheric blocks since mid-Proterozoic—a synthesis. In: Martin, F.J., Chung, S.-L., Lo, C.-H. and Lee, T.-Y. (eds.), *Mantle Dynamics and Plate Interactions in East Asia*. American Geophysical Union, Washington, D.C., 221–243.

Liu Baojun and Xu Xiaosong (Chief editors), 1994. *Atlas of Lithofacies and Paleogeography of South China*. Beijing: Geological Publishing House, 188 (in Chinese with English abstract).

Liu Baojun, Xu Xiaosong, Pan Xinan, Huang Huiqiong, and Xu Qiang, 1993. *Paleocontinental sediments, crust evolution and ore deposits of South China*. Beijing: Science Press, 236 (in Chinese).

Liu Wenjun, 1998. Evolution of sedimentation of South China plate in the Hercynian-Indosinian stage. *J. Chengdu Univ. Technol.*, 25: 328–336 (in Chinese with English abstract).

Ma Wenpu, 1996. Paleotethys in South China,Permian orogeny and the eastwards extension of interchange domain. *Scientia Geologica Sinica*, 31: 105–113 (in Chinese with English abstract).

Nam, T.N., Toriumi, M., and Itaya, T., 1998. P-T-t paths and postmetamorphic exhumation of the Day Nui Con Voi shear zone in Vietnam. *Tectonophysics*, 290: 299–318.

Qiu Yuanxi and Zhang Baiyou, 2000. On eastern extension of the Palaeo-Tethys in South China. *Regional Geology of China*, 19: 176–180 (in Chinese with English abstract).

Ren Jishun, Jiang Chunfa, Zhang Zhenkun and Qin Deyu, 1980. *Geotectonic Evolution of China*. Beijing: Science Press, 124 (in Chinese).

Sengör, A.M., and Hsü, J., 1984. The Cimmerides of eastern Asia: history of the eastern end of Paleo-Tethys. *Mem. Soc.Geo. Fr.*, 147: 139–147.

Shen, Shangyue, Wei, Qirong, Chen, Huilian and Mo xuanxue, 1998. Characteristics of ophiolites in Ailaoshan belt, Sanjiang region. *Acta Petrologica et Mineralogica*, 17: 1–8 (in Chinese with English abstract).

Shui, T., 1987. Tectonic framework of southeastern continental basement. *Science in China* (B), 4: 414–422.

Singharajwarapan, S., and Berry, R., 2000. Tectonic implications of the Nan suture zone and its relationship to the Sukhothai fold belt, northern Thailand. *J. Asian Earth Sci.*, 18: 663–673.

Ting, V.K, 1929. The orogenic movements in China. *Bull. Geol. Soc. China*, 8: 151–170.

Wang, Y.J., Luo, H., Kuang, G.D., and Li, J.X., 1998. Late Devonian-Late Permian strata of cherty facies at Xiaodong and Bancheng Counties of the Qinzhou area,SE Guangxi. *Acta Micropaleontologica Sinica*, 15: 351–366.

Wu Haoruo, 2000. A Discussion on the tectonic palaeogeography related to the Caledonian movement in Guangxi. *J. Palaeogeogr.*, 2: 70–76 (in Chinese with English abstract).

Wu Haoruo, Kuang Guodun, Xian Xiangyang, Li Yuejun and Wang Zhongcheng, 1994. Study on late Palaeozoic radiolarian silicalite of Southern Guangxi and Guangxi Palaeo-Tethys. *Chinese Sci. Bull.*, 39: 809–812 (in Chinese).

Xu Xiaosong, Yin Fuguang, Wang Fang, Liang Zonghua, Wei Baodong and Zhang Jinrui, 2001. The migration of Qinzhou-Fangcheng trough in Guangxi and associated sedimentary-tectonic transform surfaces. *Sedimentary Geol. Tethyan Geol.*, 21: 1–10 (in Chinese with English abstract).

Xu Zhigang, 1995. Late Precammbrian scissors-type opening-closing tectonics and its dynamics in South China. *Acta*

Geologica Sinica (English edition), 9: 109–122.

Yan, D.P., Zhou, M.F., Song, H.L., Wang, X.W., and John, M., 2003. Origin and tectonic significance of a Mesozoic multi-layer over-thrust system within the Yangtze Block (South China). *Tectonophysics*, 361: 239–254.

Yang Lizhen, 1997a. *The Mesozoic Volcanic Rocks in South Guangxi Province, China*. Beijing: China University of Geosciences Press, 47 (in Chinese with English abstract).

Yang Lizhen, 1997b. Division of Mesozoic volcanic cycle in southeast and southwest Guangxi. *Guangxi Geology*, 10(2): 9–12.

Ying Hongfu, Wu Shunbao, Du Yuansheng and Peiyuanqiao, 1999. South China defined as part of Tethyan archipelagic ocean system. *Earth Science*, 24: 1–12 (in Chinese with English abstract).

You Qimei, Yu, Guang, He Zhongguan, Lin Niantian and Xia Jiufeng, 1998. Tectonic evolution and hydrocarbon prospecting in Shiwandashan district. *Marine Origin Petroleum Geology*, 3: 11–21 (in Chinese).

Zhang, Q., Zhou, D.J., Zhao, D.S., 1994. Ophiolites of the Hengduan Mountains, China: Characteristics and tectonic settings. *J. SE Asian Earth Sci.*, 9: 335–344.

Zhong Dalai, Wu Gengyao and Ji Jianqing, 1998. Discovery of ophiolite in southeast Yunnan, China. *Chinese Sci. Bull.*, 43: 1365–1370 (in Chinese).