Characteristics of the Geotectonics in South China and Their Constraints on Primary Diamond

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Abstract The Asian continent is one of the best places in the world to study continental dynamics. In this region the tectonic framework of the South China plate is related to the activity of the Pacific plate and Indian plate since the Mesozoic. In the South China plate, as the ophiolitic mélange of the middle Proterozoic in the Shaoxing-Yingtan-Tengxiàn-Beihai faulted zone was confirmed to be a subducting ocean, the evolution of the Yangtze block and Cathaysian block, which are located on both sides of the fault zone, becomes clearer and clearer. A primary diamond deposit, which was first found by Bao Chaomin and his colleagues in Longyou County of Zhejiang Province in 1998, originated from kimberlitoid pipes. The pipes are located in the Cretaceous basin beside this deep fault and the diamond-bearing pipe was formed deep within a favourable geological structure. Diamond there occurs as octahedral crystals without visual impurities. There are more than 100 similar pipes in the area, which have been poorly studied so far, so this area should have great prospects for diamond exploration.

Key words: Asia, South China, primary diamond, Yangtze block, Cathaysian block

1 Introduction

The Asian continent is the last continent formed on the earth, which is also commonly thought as one of the best places to study continental dynamics (Ren, 1996). It has an old metamorphic basement and intact stratigraphic sequences, especially, under joint activities of the Pacific plate and the Indian plate, significant geological events as the uplift of the Qingzang (Qinghai-Tibet) plateau and the formation of west Pacific marginal seas happened. In the South China tectonic unit, Bao Chaomin and his colleagues confirmed an ophiolitic mélange belt in the Shaoxing-Yingtan-Tengxian-Beihai fault zone in 1995 (Bao, 1995) and found primary diamond near this fault in 1998 (NLR, 1999; NEL, 1999), which could have great theoretical significance and potential economic values.

2 Geotectonics of the South China Plate and Its Neighbours and Their Internal Structures

South China neighbours the Qingzang plateau in the west and the Pacific Ocean in the east. Its present structure occurs in a perfect spectacle, which includes trenches, island arcs and basins from west to east and from continent to continental margin, forming an independent micro-plate in the great Eurasian plate (Zhang et al., 1991).

The South China plate has a clear boundary with its neighbouring geological structures: contiguous to Longmenshan-Honghe structural belt and Zang-Dian (Tibet-Yunnan) Indosinian block in the west, the latter of which is part of Gondwana; neighbouring with the Ryukyu trench ophiolitic mélange belt in the longitudinal valley of the east Taiwan-Philippine trench and the Pacific plate (including the microplate in the Philippine sea) in the east (Tang, 1998); in the south is the island-arc areas of southeast Asia; while the northern boundary matches the Kunlun-Qinling-Dabie-Zhoushan orogenic belt and is adjacent to the North China plate.

The South China plate could be divided into the Yangtze and Cathaysian blocks, with a deep active fault zone as the boundary which passes from Shaoxing, Chencai, Longyou, Jiangshan, Yingtan, Pingxiang, Tengxian to Beihai (Ren et al., 1984, 1996; Zhao et al.,

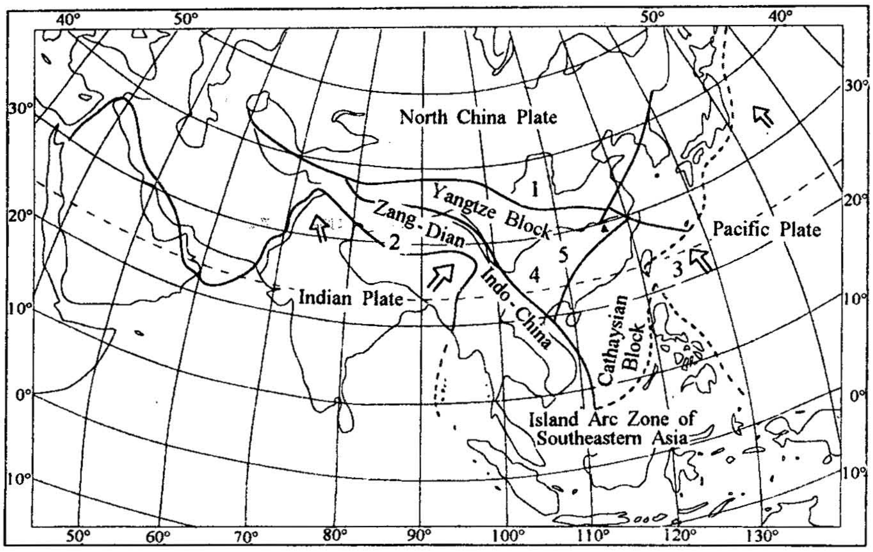

Fig. 1. Internal compositions of the South China plate and its boundaries.

1. Kunlun-Qinling-Dabie-Zhoushan orogenic belt; 2. suture zone of the Indian River and the Yalu Tsangpo River; 3. Ophiolitic mélange belt in the longitudinal valley of east Taiwan; 4. Longmenshan-Honghe structural belt; 5. Shaoxing-Yingtan-Tengxian-Beihai structural belt; ▲–site of primary diamond.

1983). The compositions of the two sides of the fault are greatly different (MGMRPRC, 1982). The diamond-bearing kimberlitoid (similar to kimberlite) pipes are located nearby Longyou County on the margin of the Yangtze block, 10 km away from the fault (Fig. 1).

3 Basic Geological Features of the South China Plate

The South China plate is located on the southeast margin of the Eurasian continent, where the structure of the crust is complex and the growth mode of the crust is very peculiar. It is the most active continental terrain for crust growth and the transition zone of continental-oceanic crust, as well as one of the areas on the earth that has the most obviously lateral discontinuity.

The growth modes of the crust in the South China continent are very complex and varied. The vertical growth of the mantle plume and the sialic underplating resulting from epicontinental splitting may be the two main modes, while lamellar suture and the accretion rhombic plume of the passive marginal foreland basin are the two main modes for horizontal growth.

Studies of deep seismology, convection field of the mantle, the Moho and the geothermal tomography showed that the migration and convection of the mantle, the variation and movement of the high-speed layer in the Moho and lower crust and the low-speed layer in the middle crust may be the main drive of the South China continental structure. With the present results, it possible now to establish a dynamic model of continent.

The South China plate has complexity of multi-stage evolution. It could be obviously seen from the compositions and structural modes of different masses, and from the ages of geodynamic mechanism and orogenic events.

The South China plate is composed of the Yangtze block and Cathaysian block, both of which have Archaeozoic rocks with 30–25 Ga in age, indicating that there exists an old basement and some features of craton. According to the seismic data available so far, the Yangtze block is composed of a series of old, high-velocity and low-resistance hard masses, which are bound together by the low-velocity flowage layer; while the Cathaysian block has such characteristics as high-temperature, low-pressure, shallow continental root and low-velocity soft masses of mantle (Bao et al., 1999; Xie et al., 1996).

4 Ophiolitic Mélange in the Shaoxing-Yingtan-Tengxian-Beihai Tectonic Zone and Its Tectonic Model

In recent years, the authors have found out some ophiolitic mélanges in the northeast section of this tectonic zone. Geological evidence indicates that this tectonic zone has a history of more than 10 Ga and has experienced many events (Kong et al., 1995).

Table 1 Chemical compositions (wt%)of ophiolitic mélange in Longyou and Chencai

No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	H_2O^+	Loss	Total
1	39.94	-	0.54	6.72	0.76	0.09	37.73	0.51	0.05	0.13	-	13.98	14.12	99.59
2	49.93	1.53	7.30	1.17	9.46	0.22	12.49	12.09	0.64	0.46	0.18	1.38	4.40	99.87
3	29.33	0.17	20.93	2.95	4.90	0.10	27.52	0.00	0.08	0.16	0.196	10.60	2.11	99.05
4	44.97	0.68	6.10	3.81	8.28	0.18	28.91	4.75	0.12	0.02	0.06	1.30	0.71	99.89
5	45.10	0.63	6.14	5.73	7.85	0.15	26.26	4.40	0.16	0.10	0.06	-	3.27	99.85

Nos. 1–3: Pyroxene peridotite in Longyou; Nos. 4–5: Olivine pyroxenite in Chencai.

4.1 Ophiolitic mélange in Longyou County

It was found in the marginal structural belt of the northeast section of the Cathaysian block, dominated by peridotite, olivine pyroxenite and pyroxene peridotite, and associated with meta-gabbro, amphibolite, graywacke, thin-bedded silicalite and plagiogranite. It occurs as rootless cakes and lenses of different sizes, scattering in sillimanite mica mylonite and amphibolitic mylonite of the middle Proterozoic. The largest outcrop area is 0.2 km^2. It has obvious structural contact with the wall rocks, and marginal mylo-surface bedding of the orebody is developed. Olivine pyroxenite occurs in greyish-green to greyish black colour and blastogranular texture. The serpentine, which keeps the shape of olivine, formed network structure with magnetite; while the pyroxene was mostly metamorphosed into chlorite. The chemical compositions can be seen in Table 1.

Sample No.1 from Longyou is poor in aluminum and alkali, indicating the characteristics of depletion and fusible compositions of the liquated bodies from the mantle, which is the relict partly melted from the upper mantle; samples No.2 and No.3 from Longyou have high contents of Al_2O_3 and CaO, which could be the evidence for the high-temperature diapir of the materials from the lower mantle. The partition curves of rare earth elements occurs to be right-inclined. According to the Al_2O_3–CaO-MgO and FeO-Na_2O +K_2O-MgO illustrations by R.G. Caleman (1977), the samples mainly fall in the range of metamorphic peridotite and komatiite; however, according to the FeO+Fe_2O_3 +TiO_2–Al_2O_3–MgO illustration by L.S. Jenson (1976), they fall in the ranges of komatiite and basaltic komatiite respectively. The Sm-Nd isotopic isochron is shown in Fig. 2. T_1 has a relatively high $\varepsilon_{Nd}(t)$, showing that the rocks were derived from the upper mantle of moderate depletion and were not contaminated by the old crust during the process of crystallization. This indicates that there was an oceanic crust-transitional crust formed in this area in the late period of the middle Proterozoic, which is identical to the overall petrology features of the Cathaysian block in the period. T_2 indicates that divergent expansion occurred and oceanic crust was formed in this period.

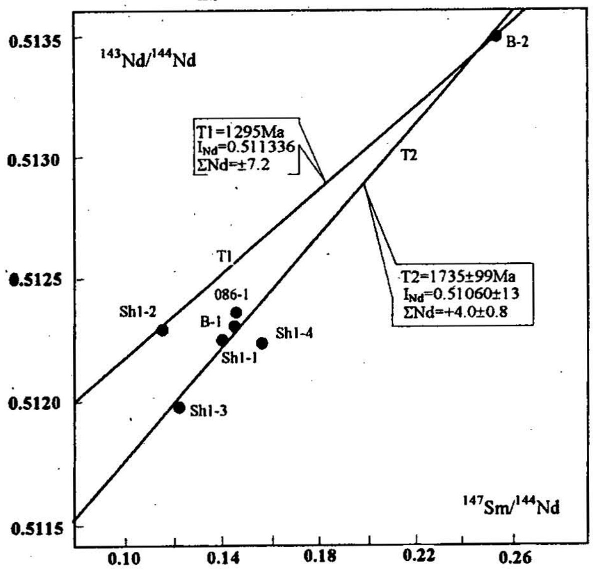

Fig. 2. Sm-Nd isochrons of pyroxene peridotite in Longyou.

4.2 Ophiolitic mélange in Chencai

The mélange was found in the marginal structural belt of the northeast section of the Cathaysian block. Its main body is composed of olivine pyroxenite with an area of 0.07 km^2. It is distributed in a northeast-extended ellipse, structurally contacted with amphibolite of the middle Proterozoic, and associated with meta-hornblendite, amphibolite, greywacke, bedded cherts and trondjemite.

The olivine pyroxenite occurs in dark green colour, prismatic texture and schistosity. The proportion of pyroxene and olivine varies greatly, and small inclusions of olivine crystals could be often seen in pyroxene crystals. The chemical compositions are shown in Table 1 (Nos. 4 and 5). According to the Al_2O_3–CaO–MgO illustration by R.G. Caleman (1977), both of the two samples fall in the province of ultramafic rocks, while according to $FeO+Fe_2O_3+TiO_2$–Al_2O_3–MgO illustration by L.S. Jenson (1976) they should fall in the province of komatiite. The rare earth shows a high ΣREE and has fractional distillation between light and heavy rare earth elements. The partition curves of rare earth elements occur right-inclined, same as that of the Proterozoic ophiolite in the South China plate.

4.3 Tectonic pattern

Generally, it is thought that the ophiolitic mélange belt from Yiyang (northeast Jiangxi) to Shexian (south Anhui) is the only one ophiolite belt existing in the South China continent (Chen et al., 1994). The discovery of several ophiolitic mélanges in Longyou and Chencai, the recovery of subduction ocean in the late middle Proterozoic as well as similar ages of the ophiolitic mélange belt in Yiyang-Shexian and the confirmation of the volcanic rocks of island arc type in the middle Proterozoic of the Shuangxiwu Group and Shuangqiaoshan Group made it possible to establish an orogenic model for continent-arc-continent collision in the late middle Proterozoic. It is reasonable to hypothesize that the ophiolitic mélange belt along Shaoxing-Yingtan is a subduction zone, while the old island arc of the middle Proterozoic between the Shaoxing-Yingtan ophiolitic mélange belt and the Yiyang-Shexian ophiolitic mélange belt is a marginal arc of the Yangtze micro-plate. Those kimberlitoid pipes are related to the long-duration activities of above two structural belts and other two Mesozoic northeast-striking fault zones (Fig. 3).

5 General Features of the Diamond-bearing Kimberlitoid

5.1 Pipes controlled by deep faults

The diamond-bearing kimberlitoid found so far is mainly located in the northeast section of the Shaoxing-Yingtan-Tengxian-Beihai fault zone. More than 80 pipes or veins have been found, which form several pipe groups in Longyou and Quzhou. The rocks in this area are dominated by breccia limburgite. The second belt is located in the northeast section of the Yiyang-Shexian-Huzhou fault zone, composed mainly of ultrabasic volcanic breccia and olivine pyroxene porphyrite. The third belt is located in the northeast section of the Yuyao-Lishui-Zhenghe-Lianhuashan fault zone, which is a very important Mesozoic structure in South China. More than 20 pipes have been found along this belt. The fourth belt is the Zhenghai-Wenzhou fault zone, where more than 30 pipes have been found.

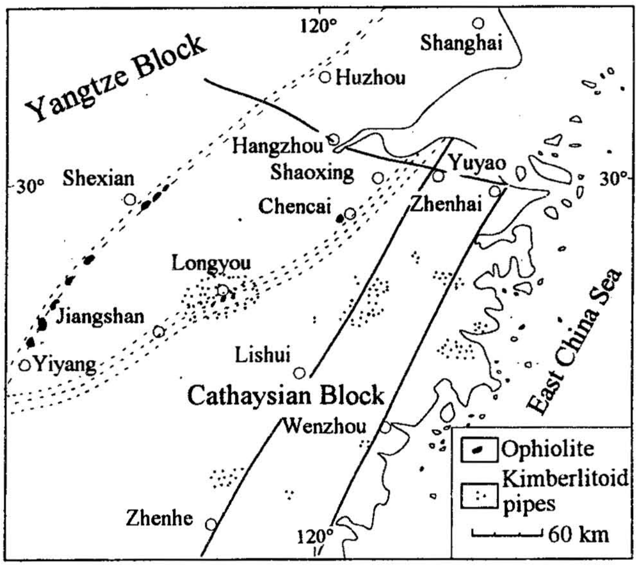

Fig. 3. Structural background of kimberlitoid in Longyou and its adjacent areas.

More than 120 sites of pipes are located along the line of 29 degree north latitude, taking up about 88% of the total found so far (Xu et al., 1974).

5.2 Shape and size

Most of the ultrabasic volcanic breccia occurs in pipes, only a few in veins. Various shapes could be seen on the profiles of the pipes, such as funnels and other irregular shapes. On horizontal plane, they are in round, oval, rectangular and irregular shapes. So far, it has been determined estimated that the biggest pipe is 650 m long and 550 m wide, the smallest pipe is 22 m long and 6 m wide, and the average size is 50–150 m long and 30–100 m wide.

6 Geological Features of the Diamond-bearing Kimberlitoid in Longyou

The outcrop of the diamond-bearing kimberlitoid in Longyou is 140 m long and 80 m wide, and it occurs as a vertical pipe, intruding into late Cretaceous red sandy gravels. There are few slithers inside the pipe, while primary prismatic joints are developed locally. However, there are a lot of debris and some primary platy joints outside the pipe. The diamond-bearing rock shows breccia structure with greyish black in color, which turns into bluish grey once weathered. It often contains pyrope, chrom-diopside, picotite, perovskite, garnet, magnetite, and many enclaves of olivine, pyroxene aggregate, eclogite and pyrolite. The rock occurs in heterogranular texture, of which the phenocryst is composed mainly of olivine, pyroxene and picotite with uneven grain sizes and obvious corrosion, while the matrix is composed mainly of olivine, pyroxene, picotite and perovskite. Alterations such as serpentinization, carbonation and chloritization, and tuffite enclaves of Sinian basement could be seen in the rock. The compositions of the rock are similar to those of the kimberlite in South Africa (Table 2), except that the contents of Al_2O_3, CaO and K_2O are a bit higher and the content of MgO a bit lower. That is why the authors named it "kimberlitoid". The contents of trace elements Co, Ba, Cr and Ni in the rock are higher than those in ultramafic rocks, but similar to those of the kimberlite in South Africa (Daosen, 1986).

7 Prospecting Potential for Diamond in Longyou

The primary diamond first found in south China occurs as colorless and transparent grains in brilliant luster with good quality, high purity and perfect octahedral crystal form.

7.1 Favourable geotectonic locations

The diamond-bearing pipe is located on the margin of the Yangtze block and controlled by a deep fault, which was subducting oceanic crust at the end of the middle Proterozoic, turning into thick Sinian-Palaeozoic sediments after collision and orogeny, then into folded thrust at the end of Triassic and finally forming a fault basin in the Cretaceous. Drilling and geophysical data indicate that the Cretaceous sediments at this place are 3 km thick, with a Palaeozoic basement of sedimentary rocks underlain, while the crust at this place is about 32 km thick, which is quite stable.

7.2 Great depth of the diamond-bearing pipe

Based on the mineral assemblage of the kimberlitoid in Longyou and its cognate enclaves of eclogite, inclusions of pyrolite, pyrope and olivine, it is inferred that the diamond-bearing pipe was formed at a depth of 150–180 km.

7.3 Stable tectonic setting during the rock formation stage

The diamond-bearing pipe was formed at the end of Cretaceous, which is similar to the main diamond deposits found so far in the world. This site was mature continental crust at the end of Cretaceous and had the properties of a craton. Because no earthquake has been recorded in recent ages, it is analyzed that the fault zone had gradually died out. Therefore, the activities of the pipe was controlled by deep faults on the margins of the craton.

Table 2 Comparison of chemical compositions (wt%) of the kimberlitoid in Longyou and the kimberlite in South Africa

No.	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	CO_2	P_2O_5	H_2O	loss	Total
1	44.34	1.44	11.55	0.14	9.19	2.64	0.21	11.96	9.85	3.23	2.15	-	0.02	0.76	2.73	100.21
2	45.01	2.30	13.14	0.10	4.48	7.60	0.20	10.60	9.11	4.15	1.00	-	1.20	2.44	-	101.33
3	48.50	1.77	4.12	-	8.53	-	0.15	23.00	4.46	0.57	0.74	0.83	0.18	2.21	4.52	99.56
4	40.70	0.90	5.56	-	7.60	-	0.13	23.70	3.69	0.29	0.69	0.90	0.34	6.81	7.92	99.23

No. 1: from Longyou; No. 2: from Longyou (Xu et al., 1974); No. 3: average percentage of 4 samples from the Premier Mine in South Africa; . 4: average percentage of 10 samples from the Koffiefontein Mine in South Africa.

8 Conclusions

The primary diamond deposit found in Longyou is fine in crystal form with high purity. The ore-bearing pipe was formed at great depths. The tectonic setting and rock types are favourable for diamond formation. There are more than 140 similar pipes in the area. These pipes are poorly investigated and should has great significance for future diamond prospecting.

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References

Bao Chaomin, 1995. The dual basements of Presinian period in Xiaoshan-Fuyang and its structural Evolution. *Collection of Papers at the Geological Conference Across the Taiwan Straits*, Taipei: Taiwan University, 65–69 (in Chinese).

Bao Chaomin et al., 1998. Discussions on the Dabie-Zhoushan orogenic belt. *The Annual Publication of the Geophysical Society of China*, Xi'an: Xi'an Map Publishing House, 342p (in Chinese).

Bao Chaomin et al., 1999. Volcano-sedimentary strata and tectonic events in Mesozoic Era in Zhejiang. *Regional Geology of China*, Beijing: Geological Publishing House, 201–204 (in Chinese).

Cheng Yuqi et al., 1994. *Introduction to the regional geology in China*. Beijing: Geological Publishing House, 371p (in Chinese).

Daosen, J.B., 1986. *Kimberlite and its xenolith*. Beijing: Geological Publishing House, 61–68 (in Chinese).

Kong Xiangsheng and Bao Chaomin et al., 1995. *Division and correlation of the metamorphic rock series in southeast Zhejiang and the tectonic evolution*, 43–47, 140–158 (in Chinese).

News of Land and Resources (NLR), 1999. Discovery of primary diamond in south of China, *Land and Resources Newspaper, Page 1*, 15th March, Ministry of Land and Resources (in Chinese).

News of Economy and Life (NEL), 1999. Discovery of primary diamond in Longyou, *Economy and Life, Page 1*, 8th August, Office of Zhejiang Daily (in Chinese).

Ministry of Geology and Mineral Resources of the People's Republic of China (MGMRPRC), 1982. *Geological map of Asia and its appendices*. Beijing: Geological Publishing house (in Chinese).

Ren Jishun, 1990. On the tectonics of southern China. *Acta Geologica Sinica* (English Edition), 4(2): 111–130.

Ren Jishun, 1996. Thoughts on the study of tectonics of China. *Geological Review*, 42(4): 290–294 (in Chinese with English abstract).

Ren Jishun, Chen Tingyu and Liu Zhigang, 1984. Some problems on the division of tectonic units in eastern China. *Geological Review*, 30(4): 382–385 (in Chinese with English abstract).

Tang Wenquan, 1998. Discussions on the geological features of oil and gas in the shelf basins of East China Sea and the development plan, *Collection of Papers at the Geological Conference Across the Taiwan Straits*, Taipei: Taiwan University, 469–478 (in Chinese).

Xie Douke *et al.*, 1996. *The growth process of continental crust and the structure of mantle plume in South China*. Beijing: Geological Publishing House, 2–11 (in Chinese).

Xu Zhonglian and Ye Guishun *et al.*, 1974. Summary of the Prospecting on Primary Ores of Diamond in Zhejiang, 32–38 (in Chinese).

Zhang Hunan and Wu Qianhong, 1991. A comparative structural study of several active fault zones along the coast of South China. *Geological Review*, 37(1): 12–23 (in Chinese with English abstract).

Zhao Mingde and Zhang Peiyao, 1983. Plate tectonics of Zhejiang Province. *Acta Geologica Sinica*, 57(4): 369–378 (in Chinese with English abstract).

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