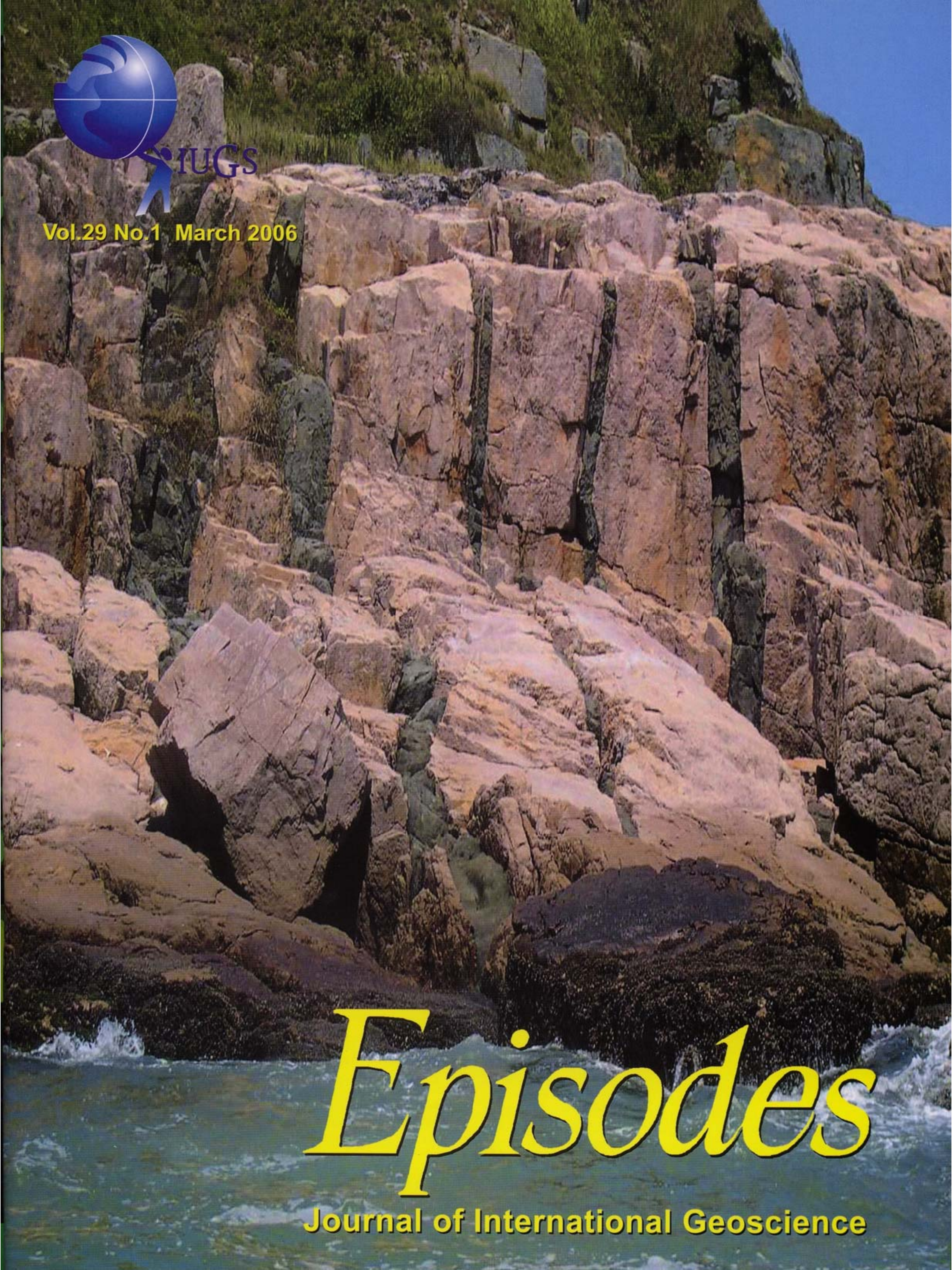

IUGS

Vol.29 No.1 March 2006

Episodes

Journal of International Geoscience

by Xinmin Zhou[1], Tao Sun[1], Weizhou Shen[1], Liangshu Shu[1], and Yaoling Niu[2]

Petrogenesis of Mesozoic granitoids and volcanic rocks in South China: A response to tectonic evolution

1 Department of Earth Sciences, Nanjing University, Nanjing 210093, China.
2 Department of Earth Sciences, Durham University, Durham DHI 3LE, UK.

This paper summarizes the new results on the petrogenesis of Mesozoic granitoids and volcanic rocks in South China. The authors propose that these rocks were formed in time and space as a response to regional tectonic regime change from the continent-continent collision of the Indosinian orogeny within the broad Tethyan orogenic domain in the Early Mesozoic (T_1–T_3) (Period I) to the largely extensional setting as a result of the Yanshanian orogeny genetically associated with the NW–WNW-ward subduction of the paleo-Pacific oceanic lithosphere in the Late Mesozoic (J_2–K_2) (Period II). Of the Period I Indosinian granitoids, the early (T_1–T_2^1) ones are syn-collisional, and formed in a compressional setting; the late (T_2^2–T_3) ones are late-collisional, and formed in a locally extensional environment. During the Period II Yanshanian magmatism, the Early Yanshanian (J_2–J_3) granitoid-volcanic rocks, which are distributed mainly in the Nanling Range and in the interior of the South China tectonic block (SCB), are characteristic of rift-type intraplate magmatism, whereas the Late Yanshanian K_1 granitoid-volcanic rocks are interpreted as genetically representing active continental margin magmatism. The K_2 tholeiitic basalts interlayered with red beds are interpreted as genetically associated with the development of back-arc extensional basins in the interior of the SCB. The Yanshanian granitoid-volcanic rocks are distributed widely in South China, reflecting extensional tectonics within much of the SCB. The extension-induced deep crustal melting and underplating of mantle-derived basaltic melts are suggested as the two principal driving mechanisms for the Yanshanian granitic magmatism in South China.

Introduction

The South China tectonic block (SCB) is bounded to the north by the Qinling-Dabie orogenic belt, and to the west and southwest by the Tibetan and Indochina blocks. The Mesozoic granitoids and volcanic rocks in the SCB are largely concentrated in the southeast region of the block; thus the authors use the acronym SE-SCB to emphysize their geographic and geological distributions. It has been known for many years (e.g., Department of Geology, Nanjing University, 1981; The Granitoid Research Group of the Nanling Project, Ministry of Geology and Mineral Resource, 1989; Xie et al., 1996; Wang and Zhou, 2002) that Mesozoic granitoid-volcanic rocks are widespread in the SE-SCB (Figure 1), and economically significant W, Sn, U, Nb-Ta, REE, Sb and Hg mineralizations are genetically associated with these rocks, particularly the strongly peraluminous granites with A/CNK (molar Al_2O_3/[CaO + Na_2O + K_2O]) > 1.1. Two periods of tectono-magmatism are recognized, i.e., the Indosinian Period and the Yanshanian Period. The former includes the Early (251–234 Ma) and Late (234–205 Ma) Indosinian sub-periods, and the latter includes the Early (180–142 Ma) and Late (142–67 Ma) sub-periods. Noticeably, there are two stages of tectono-magmatism in South China during the Late Yanshanian sub-period: (1) K_1 active continental margin magmatism, corresponding to low-angle fast subduction of the paleo-Pacific Plate, producing calc-alkaline granitoid-volcanic rocks (Zhou and Li, 2000), and (2) K_2 intra-plate magmatism, when a new subduction zone started further to the east (geologically equivalent to the Japan-Taiwan zone), corresponding to high-angle subduction of the paleo-Pacific Plate (Uyeda, 1983), forming fault-bounded basins with red beds and intra-continental tholeiitic basalts. A compressional tectonic event may have taken place ~ 100 Ma inferred from the interpreted Late Cretaceous angular unconformity (Charvet et al., 1994). The nature of this unconformity is debatable, but it is interpreted to be represented by the undeformed upper volcanic series overlying the highly sheared volcanics and deformed older granites in the coastal areas of the SE-SCB. This unconformity has been further interpreted as indicating the collision between the K_1 active margin of the SCB and the West Philippine block (Charvet et al., 1994; Lapierre et al., 1997; Maruyama et al., 1997). It is also known that the SE-SCB experienced a tectonic shift from being influenced by the eastern Tethyan tectonic regime in the early Mesozoic to being influenced by the paleo-Pacific tectonic regime in the late Mesozoic. The timing of such a tectonic shift remains debatable. Thus, the petrogenesis of granitoid-volcanic rocks and the tectonic evolution in the SE-SCB have attracted great attention (Tao et al., 1998; Chen et al., 2002). Current views on the Mesozoic petrogenesis in the SE-SCB include lithosphere extension and asthenosphere upwelling (Li, 2000; Li et al., 2001), rifting and large-scale lithosphere delamination/thinning in eastern Asia (Zhu et al., 1997; Cai et al., 2002), Mesozoic rifts in coastal areas of eastern China (Gilder et al., 1991), paleo-Pacific Plate subduction beneath East Asia (Jahn et al., 1976, 1990; Guo et al., 1980; Charvet et al., 1994; Lapierre et al., 1997; Zhou and Li, 2000; Niu, 2005), and Mesozoic mantle plume activities in South China (Xie et al., 1996; Xie et al., 2001).

Therefore, it is timely and necessary to reassess these interpretations for the development of a unified model capable of explaining most geological observations on the petrogenesis of Mesozoic granitoid-volcanic rocks in the SE-SCB. This paper attempts to present such a model, which is largely based on our field observations and laboratory studies over the past 10 years. Emphases are placed on petrological and geochemical characteristics, and spatial and temporal distribution/variation of these rocks in the context of regional tectonic evolution, with particular reference to the tectonic regime shift from the influence of the Tethyan tectonics from the southwest to that of the Pacific tectonics.

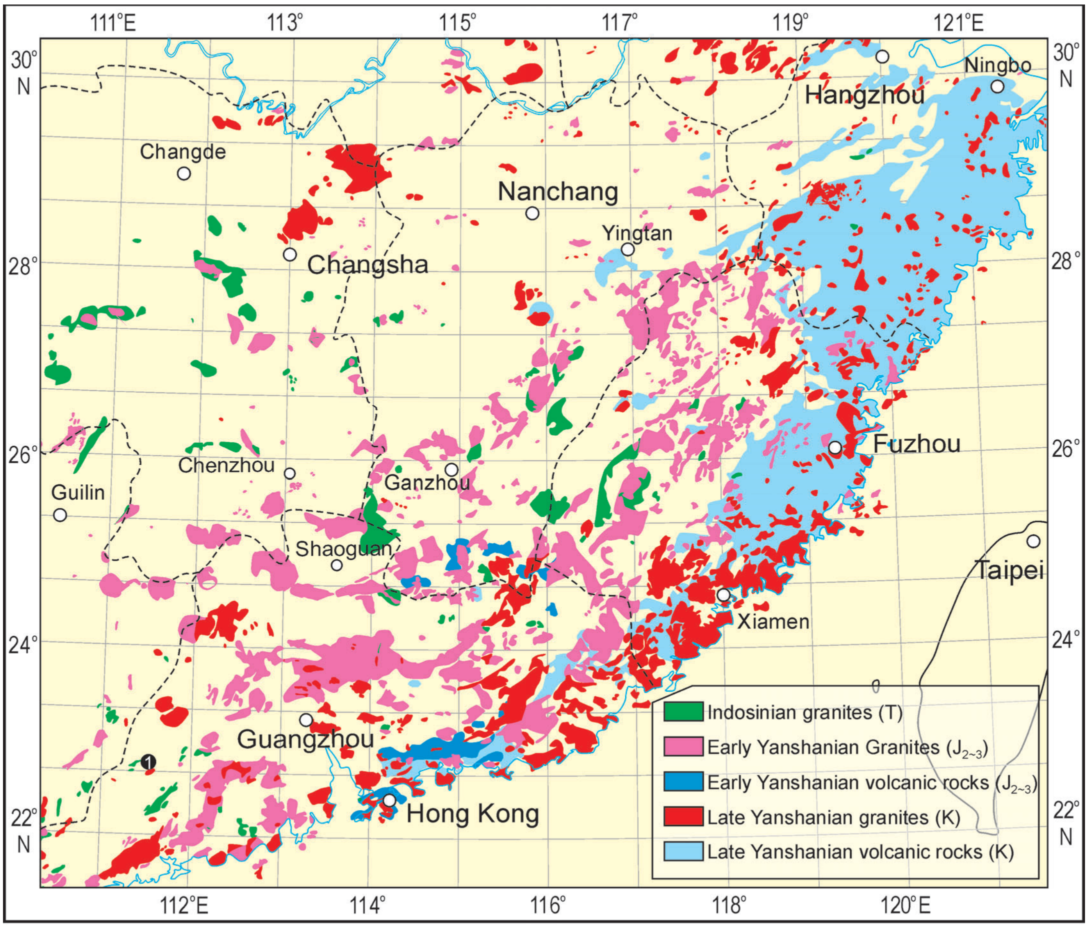

Figure 1 Distribution of Mesozoic granite-volcanic rocks in South China. ❶ *Location of Luoding, Fenjienan and Xishanling plutons.*

Distribution and general characteristics of the Mesozoic magmatic rocks

The Mesozoic magmatic rocks in the SE-SCB are distributed mostly in Zhejiang, Fujian, Jiangxi, Guangdong and Hunan Provinces with a total outcrop area of nearly 218,090 km^2 (Table 1), which is 28.3% of the entire land surface area of those provinces. The percentages of outcrop in coastal Zhejiang and Fujian Provinces are 62% (~ 62,000 km^2) and 55% (~ 66,000 km^2), respectively. Figure 1 shows explicitly that the Mesozoic magmatic rocks are concentrated in the coastal region, with the density increasing towards the ocean.

Lithologically, over 90% of the Mesozoic magmatic rocks in the SE-SCB are granitoids and equivalent volcanic rocks with minor basalts. These were formed in two periods: the Early Mesozoic Indosinian Period (T_1–T_3, 251–205 Ma) and the Late Mesozoic Yanshanian Period (J_2–K_2, 180–67 Ma). The principal characteristics of these rocks are discussed below.

Indosinian granitoids (251–205 Ma)

Except for the southwestern part of the SE-SCB, the Indosinian magmatic rocks in the SE-SCB occur only as plutons. Their total outcrop area is nearly 14,300 km^2 (Table 1). About 60% of the Indosinian granitoids are strongly peraluminous with A/CNK > 1.1. They may be defined as S-type granites, and contain high aluminous minerals such as muscovite, garnet and tourmaline (Sun et al., 2005). These strongly peraluminous granites plus weakly peraluminous granites with A/CNK ≈ 1.0–1.1 make up about 91% of the total outcrop area of Indosinian granitoids. The rest are calc-alkaline I-type granites, with or without amphiboles, but always coexist spatially with the Yanshanian granitoids, forming a series of multi-age granitic complexes.

The Late Indosinian granitoids (T_2^2–T_3, 234–205 Ma) make up about 90% of all the Indosinian granitoids. They occur as dispersed small plutons characterized by medium grain size and massive appearance, features that are consistent with being emplaced at a relatively shallow depth range of 6.5–13 km (Buddington, 1959) and solidified in the circumstances of relatively "free" space made available by localized extensions, while the overall tectonic regime may be under compression (e.g., during late-collisional phase). The authors interpret these granitoids to be late collisional granites. No

Table 1 Outcrop area of Mesozoic granitoid-volcanic rocks in South China.

Age	Actual (km^2) and relative (%) outcrop area	Outcrop area (km^2) and A/CNK ratios of various granitoids: Total area of granitoids (km^2)	A/CNK ratio <1.0	A/CNK ratio 1.0–1.1	A/CNK ratio >1.1	Outcrop area of volcanic rocks (km^2)
Indosinian EM, T_1–T_3 251–205 Ma	14300 6.6%	14300	1300 9.1%	4400 30.8%	8600 60.1%	0
Early Yanshanian LM_1, J_2–J_3 180–142 Ma	63870 29.3%	62700	12500 20.0%	29300 46.7%	20900 33.3%	1170
Late Yanshanian LM_2, K_1–K_2 (K_1 dominates) 140–66Ma	139920 61.7%	50300	19300 38.4%	21600 42.9%	9400 18.7%	89620
	218090	135000				90790

coeval volcanic rocks are found to be associated with the intrusives.

In contrast, the Early Indosinian granitoids (T_1–T_2^1, 251–234 Ma) show gneissic or mylonitized structures, which are interpreted as syn-collisional granites under compression. These rocks are well exposed along and in the vicinity of the Songma suture, where the Indochina Block collided with the SCB. The peak age of the collision is dated at 258 to 243 Ma (Carter et al., 2001). Luoding, Fenjienan and Xishanling plutons in the southwest SCB are good examples, with ^{40}Ar-^{39}Ar muscovite ages of 249.7±2.6 Ma (n = 8), 255.3±3.0 Ma (n = 3) and 229.4±2.5 Ma (n = 5), respectively (Shao et al., 1995).

Early Yanshanian granitoid-volcanic rocks (180–142 Ma)

The Early Yanshanian granitoid-volcanic rocks were emplaced in the mid- and late- Jurassic ($J_{2\text{-}3}$, 180–142 Ma), and are distributed in the interior of the SE-SCB, 250–800 km away from the southeast coastline. The total outcrop area is about 63,870 km^2. Most of the granitoids are distributed in zones parallel to the coastline, and extend discretely northeastward for about 1,000 km (Figures 1, 2). In the Nanling Range (110.0–116.5°E, 23.5–26.5°N), the granitoids strike E-W, and are distributed in three distinguishable belts with the between-belt intervals being about 1° in latitude (Table 2). These are the northern (Qitianling–Jiufeng), middle (Dadongshan-Guidong) and southern (Fugang-Xinfengjiang) granitoid belts. They represent three fault systems, in which some Indosinian granitoids are also emplaced. The compositions of the Early Yanshanian granites in various stages are similar, i.e. dominated by calc-alkaline I-type granites with A/CNK <1.1, and spatially coexisting with minor gabbro-diorites.

The Early Yanshanian volcanic rocks (180–170 Ma) are preserved mainly in the southern Jiangxi, southern Hunan and southwestern Fujian region, with a few in northern Guangdong. These rocks have unique compositions, with the following features (Chen et al., 2002):

Table 2 Three parallel E-W granitoid belts in the Nanling Range.

	Length (km)	Width (km)	Latitude	Representative granitoid plutons (do not include volcanic basins) (numbers in parentheses are plutonic map areas in km^2)
Northern granite belt (Qitianling-Jiufeng granite belt)	~300	~35	~ 25.7°N	Dupangling (196), Jiuyishan (including Jinjiling (350), Shaziling (90) and Xishan (705)), Xianghualing (2.2), Qitianling (531), Qianlishan (9.2), Jiufeng (1500), Piaotang (10), Xihuashan (19), Dabu (600)
Middle granite belt (Dadongshan-Guidong granite belt)	~400	~35	~ 24.8°N	Huashan (567), Guposhan (678), Hedong (270), Dadongshan (2245), Guidong (including Nanhuasi (300), Aizi (50), Siqian (9.5), Xiazhuang (157)), Hongling (250), Wuliting (20), Dajishan (150), Pitou (400), Zhaibei (300), Yanbei (7)
Southern granite belt (Fugang-Xinfengjiang granite belt)	~260	~50	~ 23.7°N	Deqing (398), Shidong (2200), Guangning (2000), Sihui (360), Fugang (3214), Xinfengjiang (1340), Baishigang (720), Longwo (316), Zhongba (208)

(1) A narrow age range of 180 to 170 Ma.
(2) Multiple small-scale volcanoes occurring as E-W linear arrays extending >400 km.
(3) A bimodal magmatic assemblage of basalts and rhyolites with similar thickness/abundance.
(4) Spatial association with intrusions of calc-alkaline granites, A-type granites, aegirine-bearing alkaline granites and syenites, which were apparently emplaced later than basalts and rhyolites along the pre-existing rift systems.

The Early Yanshanian volcanic rocks are interpreted to be of rift origin (Barberi et al., 1982), which probably represents the initial magmatism of continental rifts. The rocks are perhaps genetically associated with partial melting of the crust and the lithospheric mantle induced by subduction of the paleo-Pacific oceanic plate (Zhou, 2003). This might mark the ending of an old tectonic regime (Tethyan) and the beginning of a new tectono-magmatic cycle (paleo-Pacific).

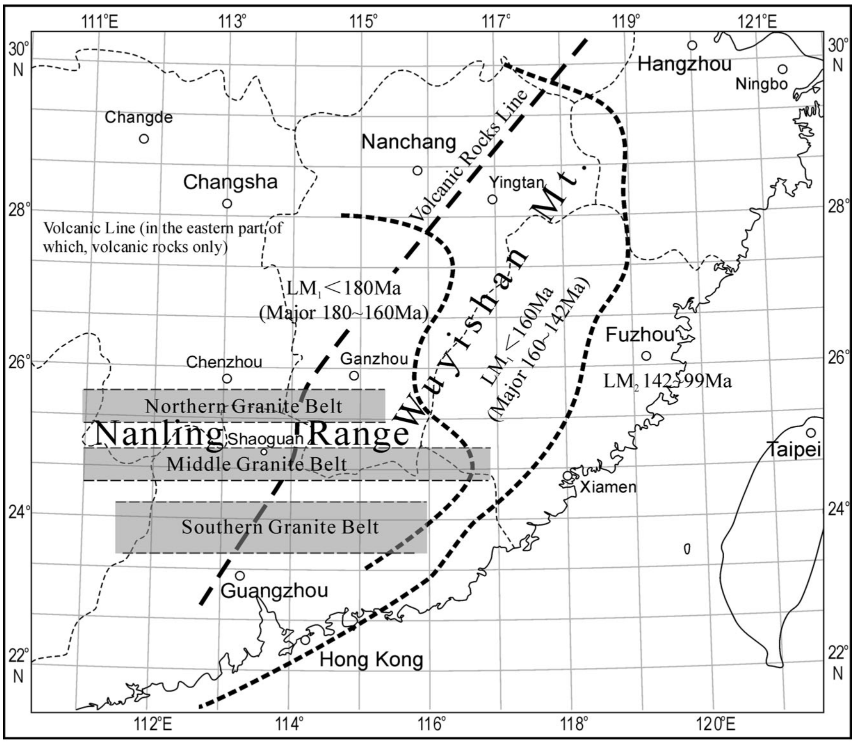

Figure 2 Oceanward younging Late Mesozoic granites-volcanic rocks of South China and three parallel E-W granite belts in Nanling Range. LM$_1$—Late Mesozoic Early Yanshanian; LM$_2$—Late Mesozoic Late Yanshanian.

Late Yanshanian granitoid-volcanic rocks (142–67 Ma)

The Late Yanshanian granitoids and volcanic rocks occupy about 139,920 km^2 in the SCB. They are divided into two stages: early Late Yanshanian (K_1) granitoid-volcanic rocks genetically associated with active continental margin magmatism and the late Late Yanshanian (K_2) tholeiitic basalt volcanism recorded in red beds of back-arc basins. They differ from the Early Yanshanian and Indosinian rocks in spatial and temporal distribution, rock assemblage and geochemistry. Their characteristics are described as follows:

(1) Granites and rhyolites commonly coexist, forming volcano-subvolcano-intrusion assemblages. In places, these assemblages are also associated with gabbros and basalts. However, the mafic rocks are volumetrically minor (<10%) to absent. The mafic/felsic rock ratios are much smaller than those of the Early Yanshanian bimodal magmatic assemblages in the southern Jiangxi-southwestern Fujian region.
(2) On the MORB-normalized incompatible trace element plot, the early Late Yanshanian basalts (Figure 3, LM_2-CAB, n = 21, K_1) show large ion lithophile element (LILE) enrichments with obvious Nb-Ta depletion, which is consistent with their origin being associated with subduction-related wet mantle wedge melting (McCulloch & Gamble, 1991). On the other hand, basalts (Figure 3, LM_1-

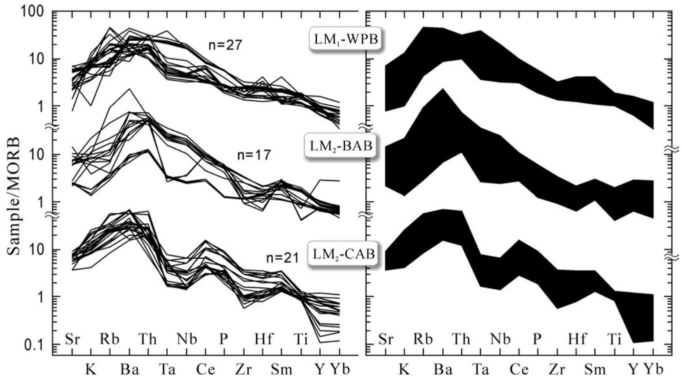

Figure 3 Trace element spider diagrams of Early Yanshanian intraplate basalts (LM_1–WPB) (Wang et al., 2004; Zhao et al., 1998; Chen, 1998; Yu, 2004; and Deng, 2003), Late Yanshanian back-arc basalts (LM_2–BAB) (Zhu et al., 1996 and Li et al., 2002), and continental margin arc basalts (LM_2–CAB) (Wang et al., 1994; Xie et al., 2003; and Zhou et al., 1994).

WPB, n = 27; LM_2-BAB, n = 17) of the Early Yanshanian bimodal rift-type (J_2) as well the basalts in the late Late Yanshanian red-bed basins in the further interior of the SE-SCB (K_2) do not show such Nb-Ta depletion, suggesting that the latter may be of intraplate and back-arc basin origin, respectively.

(3) The Late Yanshanian granitoids are scattered throughout the SE-SCB, but the coeval volcanic rocks are distributed only in the coastal region. In contrast to the Early Yanshanian rocks, the Late Yanshanian magmatism exhibits an obvious ocean-ward migration toward the southeast. (Chen & Jahn, 1998; Zhou & Li, 2000).

In addition, the age data (n = 20, Li et al., 1999) of the granites from the drilling core samples of the maritime space 200 km south of Hong Kong show that the ages of the granites for the offshore sea floor are concentrated in the interval of 130–75 Ma, also displaying a younging trend towards the ocean (Li et al., 1999).

Therefore, the NE-trending Late Yanshanian magmatism is volumetrically the most important part of the late Mesozoic magmatic zone in the SE-SCB. Importantly, the Yanshanian granitoid-volcanic rocks in the SE-SCB, the synchronous granitoid-volcanic rocks on both sides of the Songliao Basin in Northeast China, in the Yanshan-Taihang Mountains of North China and in the Dabie Mountain in Central China, taken altogether, are compelling evidence that the Yanshanian period represents the most important tectono-magmatic period in eastern China. The Yanshanian magmatism produced rocks that form a giant ~ 3500 km long and ~ 800 km wide late Mesozoic NE-trending magmatic zone in East China. We strongly believe that such a giant magmatic belt is genetically associated with the NW–WNW-ward subduction of the paleo-Pacific plate.

(4) In terms of granite rock types, the I-type (A/CNK<1.0) is volumetrically more important than the S-type (A/CNK>1.1) among the Late Yanshanian granitoids. The authors suggest that the source rocks of these I-type granitic magmas may have derived from mafic igneous protoliths at mid-lower crustal depths (Zhou & Li, 2000), and the heat causing the crustal melting resulted from the underplating of basaltic magmas along the interpreted active continental margin. These interpretations are underpinned by the following observations that reflect crust-mantle interactions: 1) mixing of felsic and mafic melts within granites, 2) composite lava flows of rhyolites and basalts, 3) regional scale low initial $^{87}Sr/^{86}Sr$ ratios (I_{Sr}) and young Nd isotope model ages (T_{DM}), 4) both the felsic and the mafic rocks have similar initial Sr and Nd isotopic constitution, 5) the crust-mantle transition zone shows reverse Vp values, 6) the younger mafic granulite xenoliths of Late Mesozoic age in Cenozoic breccias pipes, and 7) high regional geothermal values in the Late Mesozoic (Zhou & Li, 2000).

In areas such as the northwestern Wuyishan slope, Xiangshan in central Jiangxi and Meizhou in northern Guangdong, compositionally complex conglomerates of 10–20 m thick occur between the Lower Cretaceous Series and the Middle-Upper Jurassic Series, suggesting a tectonic uplift event in South China.

Mesozoic granitoids and synchronous basins

The distribution of Mesozoic sedimentary basins and granites are closely related in the SE-SCB. Thus, understanding the development of sedimentary basins should help reveal the geological evolution and granite petrogenesis in the SE-SCB.

Mesozoic sedimentary basins in the SE-SCB can be divided into three types (Shu et al., 2004), i.e., para-foreland basins (T_3), rift basins (J_2), and faulted depression basins (K–E). The total area of these basins is nearly 143,100 km^2, which is about 18.6% of the total land area of the five provinces in South China. The ages, scale, rock assemblages and distribution of these basins, and the principal characteristics of the associated granitoid-volcanic rocks are summarized in Table 3.

Rift basins and faulted depression basins were formed under tectonic extension. Associated with such extension are synchronous granitoid-volcanic rocks. The development and evolution of these two types of basins took two-thirds of the Mesozoic Era. They share 89.4% of the total area of all the Mesozoic basins.

The large-scale red-bed basins mainly formed in K_2. Some of them contain tholeiitic basalts, as in the Quzhou-Guangfeng basin, the Ji'an-Taihe basin, the Nanxiong basin, etc. (Shu et al., 2004), but no granitoids. We interpret these basins to have been formed in extensional settings in response to the opening of backarc basins, perhaps in a scenario similar to the opening of the Japan Sea in the Cenozoic.

Para-foreland basins are not typical foreland basins (Dewey et al.,1987), because they are small in scale and have limited sediment accumulation. Such basins are characterized by sediments of low maturity and coarse fragments, and by the E-W trending stratigraphy perpendicular to the napping direction. Their associated granitoids are of strongly peraluminous S-type formed during the Late Indosin-

Table 3 Characteristics of Mesozoic basins and synchronous granitoid-volcanic rocks in the SE-SCB.

Type of basin		Age	Area (km^2)	Area % of basin type	Lithology	Main distribution areas	Synchronous granitoids
Para-foreland basin		T_3 (minor J_1)	15120	10.6	Lower: variegated coarse fragment molasses. Upper: light-colored clastic rocks with coal-bearing formation	South of the SCB	Late Indosinian granitoids (T_3)
Rift basin		J_2 (minor J_3)	4640	3.2	Bimodal volcanic rocks with basalts and rhyolites roughly equal thickness and volume. Interbedded light-colored clastic rocks	Southern Jiangxi and southwestern Fujian Provinces, Inland of the SCB	Early Yanshanian granitoids (J_2–J_3)
Faulted basin	Volcanic sedimentary basin	K_1	85490	59.7	K_1 is the peak period. Mostly rhyolites with minor basalts. Sediments are < 10% of the total sequence.	Coast region of the SE-SCB	Late Yanshanian granitoids (K_1)
	Back-arc sedimentary basin	K_2–E	37850	26.5	Mostly red bedding sedimentary rocks with evaporite such as gypsum and rock salt, reflecting dry-hot environment	Much of the vast area west of Wuyishan (including Guangdong Province)	
			143100	100.0			

ian Period. Of course, the origin of this type of basin is related to folding-napping and thickening of crust during the Indosinian collision (Liu, 2002), followed by local extension.

Tectonic evolution of the SE-SCB in the Mesozoic

Tectonic change from the Tethyan regime to the Pacific regime

Magmatism is a tectonic response. This is true on a global scale, and also true on regional scales. The type and scale of the magmatism thus reflect the nature and scale of the orogenesis. The isotopic ages of Mesozoic granitoid-volcanic rocks from 344 samples of the SE-SCB (Figure 4) show that there was a ~ 25 Myr magmatically inactive period during the Early Jurassic (J_1, 205–180 Ma). This tectonic quiescence in fact corresponds to the tectonic regime change from the influence of the Indosinian orogeny as part of the large-scale Tethyan tectonics to the influence of the Yanshanian orogeny genetically associated with the western Pacific tectonics. The outcrop area of the granitoids produced during the Indosinian orogeny (T_1–T_3) is significantly less than that produced during the Yanshanian (J_2–K_2), with a ratio of ~ 1:14.3. The outcrop area proportion of Early Yanshanian (J_2–J_3) to Late Yanshanian granitoid-volcanic (K_1–K_2) rocks is 1:2.2, the latter distributed mostly in the coastal region of the SE-SCB. We stress that the Late Mesozoic granitoid-volcanic rocks were the products of the NW–WNW-ward subduction of the paleo-Pacific plate beneath the eastern Asian continent (Figure 5). The Late Mesozoic magmatic belt in eastern China extends for ~ 3,500 km from Northeast China down to Hainan Island. In other words, the SE-SCB was tectonically influenced by the Tethyan tectonic domain before J_1, but has been controlled by the Pacific tectonics since J_2. Thus, the SE-SCB changed from being influenced by the Tethyan tectonics to being influenced by the Pacific tectonics during J_1.

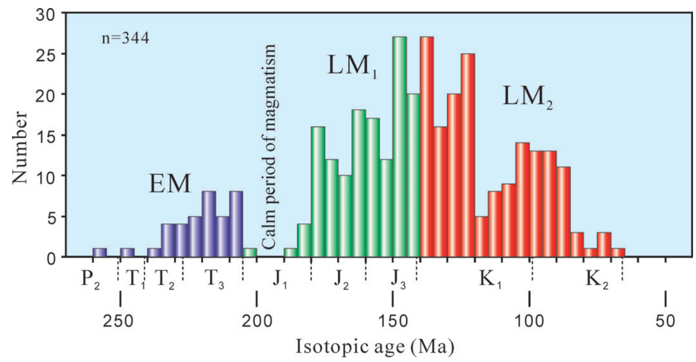

***Figure 4** Isotopic age histogram of Mesozoic granites-volcanic rocks in South China. EM—Early Mesozoic Indosinian; LM_1—Late Mesozoic Early Yanshanian; LM_2—Late Mesozoic Late Yanshanian.*

All these observations suggest that the SE-SCB was largely under extension in the Late Mesozoic. This may explain why the Late Mesozoic granitoids mostly appear as massive structures.

As part of the Eurasia Plate, the SE-SCB may have suffered the subduction of the Izanagi ocean plate since J_2 (Maruyama & Seno, 1986; Maruyama, 1997). The lithosphere stress distribution beneath the SE-SCB may be compressional at great depths, but extensional at shallow levels, just like cauliflower type divergence (Figure 5). Indeed, the integrated geophysical section of the SE-SCB (Zhou and Li, 2002) reveals that the base of the lithospheric mantle in the coastal region of the SE-SCB was 30–40 km shallower than that of the adjacent area due to the extension-induced asthenosphere uplift. Under this extensional condition, two-period granitoid-volcanic rocks were formed in the SE-SCB. In the Early Yanshanian, there was no magmatism in this active continental margin in the SE-SCB, probably because the Pacific lithosphere had not subducted to ~110 km in depth (Tatsumi et al., 1995). However, the stress may have been quickly propagated to the inland areas via the rigid SCB, where decompression melting might be triggered by localized extension and faulting. As a consequence, the intraplate granites and rift-type

Tectonic background and stress disposition of granitoid-volcanic rocks during J_2–K_2

A schematic diagram for extensional tectonism in the Late Mesozoic of South China is shown in Figure 6. As mentioned above, there are J_2 bimodal volcanic rocks in the interior of the SE-SCB, with similar amounts of basalts and rhyolites scattered in the eastern Nanling Range along E-W fault zones. In the coastal region of the SE-SCB, limited bimodal volcanic rocks were emplaced during K_1, with basalts being less than 10% of the total volcanic output. Geochemically, the K_1 basalts are of the continent margin arc type. In addition, spatially in coexistence with the K_1 bimodal volcanic rocks are synchronous mafic and felsic dike swarms, extrusive-hypabyssal porphyroclastic lava flows, 17 large volcano-tectonic depressions containing sedimentary layers, A-type alkaline and miarolitic granites, shoshonite zones, and a metamorphic core complex. All these rocks constitute an igneous rock assemblage characteristic of continental margin magmatic arc systems, indicating an extensional setting during J_2–K_1. After that, Late Cretaceous back-arc basins containing minor basalts developed inland throughout the SE-SCB without large-scale magmatism. The sediments of these K_2–E basins include red sandstones and mudstones with inter-layered gypsum, indicating a dry and semi-desert paleogeographical environment.

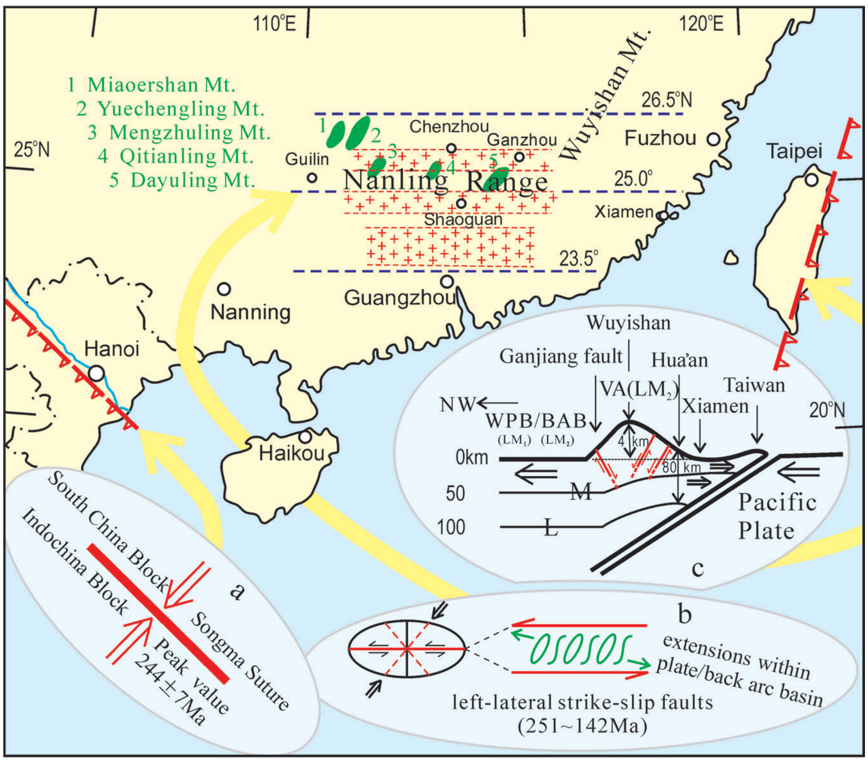

***Figure 5** Formation mechanism for Indosinian continent-continent collision, Yanshanian paleo-Pacific Plate subduction, origin of Nanling Range, and three E-W granite belts.*

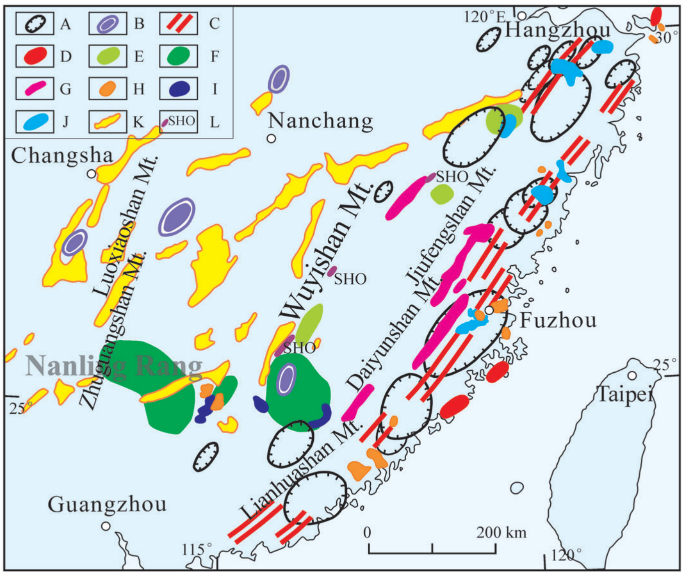

Figure 6 Schematic diagram for extensional tectonism in the Late Mesozoic of South China. A—Huge ringed volcano-tectonic depressions containing sedimentary layers (formed mainly in K_1, after satellite photos); B—Metamorphic core complex; C—Felsic dike swarms relating to rhyolitic rocks in coastal areas (K_1); D—Mafic dike swarms (K_1); E—Felsic dike-concentrated area (J_3~K_1); F—Mafic dike-concentrated area (J_3~K_1); G—Extrusive-hypabyssal porphyroclastic lava belts (K_1); H—A-type alkaline and miarolitic granites (K_1 in coastal areas and J_2 in Nanling Range); I—Bimodal volcanic rocks (basalt nearly equal to rhyolite in thickness, J_2); J—Bimodal volcanic rocks (rhyolite obviously thicker than basalt, K_1); K—Back-arc red sedimentary basins (K_2~E, formed mainly in K_2, basalt-bearing in some basins); L— Shoshonites (K_1).

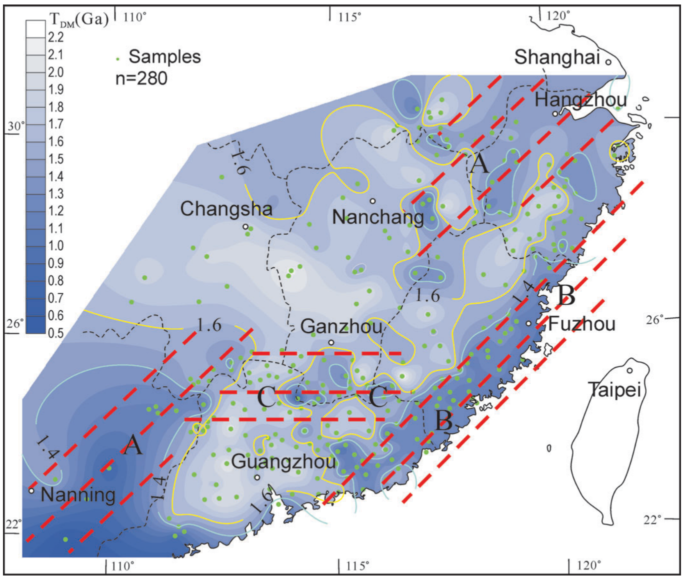

Figure 7 Isoline map of Nd isotopic model ages (T_{DM}) of Mesozoic granite-volcanic rocks, South China. Belts with low Nd isotopic model ages: A–A—Shiwandashan Mt.–Hangzhou belt; B–B—Coastal area belt; C–C—Nanling belt. They represent the potential ultra-crustal deep faults and the channels of underplating basaltic magmas from mantle wedge.

magmatic assemblage were produced in the interior of the SE-SCB during this time period. In the Late Yanshanian subducting slab had reached the depth of 110 km beneath the SE-SCB of the east side of the Ganjiang fault (115°E), and slab-dehydration melting started (Hatherton & Dickinson, 1969; Tatsumi et al., 1995). The mantle wedge wet melting produced a large amount of basaltic magmas. The basaltic magmas ascended, and underplated at the base of the lower crust. The basaltic magmas acted as a heat source that induced large- scale crustal melting and granitic magma formation. Such processes of granitic magma genesis readily explain the familiar geochemical characteristics of continental margin granitoids. Compositionally, such granitoids have high-K calc-alkaline rock assemblages (Zhou and Yu, 2001; Zhou and Li, 2002; Mao et al., 2002; Gu, 2003). In the same stress regime, a series of sedimentary basins seemed to have developed in the SE-SCB (Shu et al., 2004). Corresponding to this geological process in the SE-SCB, contemporaneous basalt magma underplating and crust-mantle interaction were also taking place (i.e., 180–80 Ma) in North China (Wilde et al., 2003).

The Late Mesozoic magmatism is distributed mainly in zones predominantly trending NE, which parallel the coastal line of the SE-SCB, and in zones subordinately trending E-W in the Nanling Range. We reason that such granitoid distribution may be caused by deep-seated faulting, which was ultimately caused by oceanic lithosphere subduction. The zones of low Nd isotopic model ages (T_{DM}) provide at least some circumstantial support for the suggested subduction-related deep-seated faults in the SE-SCB. Figure 7 shows that two of them are in an NE direction (Groups A and B), and the other (Group C) is in E-W direction (Gilder et al., 1996; Darbyshire & Sewell, 1997; Chen et al., 1999; Zhou & Li, 2000). Three low T_{DM} zones may indeed represent three buried extensional lithospheric (i.e., cutting through the Moho) fault systems. These faults could be potential channels for the underplating of mantle-wedge- derived basaltic magmas. As a consequence, the petrological and geochemical features of the Late Mesozoic granitoids in these three belts and their adjacent areas are broadly similar, all showing magma mixing between granitoids and gabbros, complex volcanic successions and crust-mantle interactions, as revealed by isotopic and trace element data (Dong et al., 1998; Li et al., 1999; Zhou et al.,1994; Zhou, 2003).

A new petrogenesis model

Chinese geologists have been studying the petrogenesis and tectonic background of the Mesozoic granitoid-volcanic rocks for nearly 60 years (Hsu and Ting, 1942; Huang, 1945; Jahn et al., 1976; Chen and Jahn, 1998; Zhou and Li, 2000; Zhou, 2003). On the basis of our field observations, up-to-date geochemical analyses, age data, and regional-scale stress analysis of the Mesozoic granitoids of the SE-SCB, the first-order characteristics, spatial and temporal distribution and evolution trend of Mesozoic granitoid-volcanic rocks have become clear. Some data and isotopic ages for individual rock suites used in this paper may be refined in the future, but these will unlikely alter the first-order interpretations discussed above. Therefore, it is timely and necessary to present an updated model capable of explaining major observations concerning the Mesozoic granitoid-volcanic rocks in the SE-SCB.

The new model considers two independent periods of magmatism spatially and temporally associated with different tectonic regimes. The continent-continent collisional orogeny produced the Early Mesozoic Indosinian granitoids and para-foreland molasse basins, and was followed by the ocean-continent subduction that caused the Late Mesozoic Yanshanian granitoid-volcanic magmatism. In the Early Mesozoic, the continent-continent collision, which took place on the Indochina peninsula, formed syn-collisional granitoids under regional compression at the earlier Indosinian stage (T_1–T_2^1), and late-collisional granitoids which are rich in muscovite (Eskola, 1932; Marmo, 1971) under a local extensional setting at the Late Indosinian stage (T_2^2–T_3, about 20 Ma later than the time of the syn-collisional granitoid formation; Sun et al., 2005). Since J_2, the paleo-Pacific oceanic plate subducted NW–WNW-ward beneath the eastern Asian continent. The Late Mesozoic magmatism in the SE-

SCB underwent three stages: (1) intraplate magmatism including initial rift-type magmatism at the Early Yanshanian stage (J_2–J_3), (2) continental margin arc magmatism at the early Late Yanshanian stage (K_1), and (3) tholeiitic basalt volcanism recorded in red beds of back-arc basins at the Late Yanshanian stage (K_2).

The extension-induced deep crustal melting and the underplating of basaltic magmas were the two main driving forces for the Yanshanian granitic magmatism. Progressively broader and stronger underplating of basaltic magmas in the lower crust in the SE-SCB were the most important factors in vertical crust growth. The above-mentioned Early Mesozoic Indosinian event was controlled by Tethyan tectonics, whereas the Late Mesozoic Yanshanian tectonic-magma event was caused by the paleo-Pacific plate subduction beneath the eastern Asian margin. The timing of the tectonic regime change seems to be associated with a magmatically inactive period of 205–180 Ma (J_1) (Figure 4). The Nanling Range marks the zone of transition between the two tectonic regimes.

The authors recognize that the spatial coexistence of plutons and volcanic rocks of the same origin is tectonically incompatible. The exposure of plutons would suggest some significant tectonic uplift and erosion, probably >10 km, yet the preservation of volcanic rocks indicates no significant uplift or erosion since their emplacement. These straightforward observations point to some highly localized uplift and erosion events since the Mesozoic. It is considered that these phenomena resulted from some more recent tectonic reactivation of the existing rift/fault systems. A detailed account will be given separately.

Acknowledgements

We are grateful to Prof. Z-Y Yang, who read an early draft of the manuscript and provided invaluable suggestions. We thank Prof. J. Charvet for his careful review and constructive suggestions. This study is supported by the National Natural Sciences Foundation of China (No 40132010) and the Foundation of the Education Ministry of China (No. 20030284026).

References

Barberi, F., Santacroce, R., Varet, J., 1982, Chemical aspects of rift magmatism, *in*: G Palmason, ed, Continental and oceanic rifts: Washington D C., American Geophysical Union, Geodynamics Series, 8, 223-235.

Buddington, A.F., 1959, Granite emplacement with special reference to North American: Geological Society of America Bulletin, v. 70, pp. 671-747.

Cai, X.L., Zhu, J.S., Cao, J.M., Yan, Z.Q., Yang, Z.X., and Hong, X.H., 2002, Structure and dynamics of lithosphere and asthenosphere in the gigantic East Asian-West Pacific rift system: Geology in China, v. 29, no. 3, pp. 234-245 (in Chinese with English abstract).

Carter, A., Rogues, D., Bristar, C., and King, P., 2001, Understanding Mesozoic accretion in Southeast Asia: Significance of Triassic thermotectonism (Indosinian orogeny) in Vietnam: Geology, v. 29, pp. 211-214.

Charvet, J., Lapierre, H. and Yu, Y.W., 1994, Geodynamic significance of the Mesozoic volcanism of southeastern China: J. Southeast Asian Earth Sci., v. 9, no.4, pp. 387-396.

Chen, J.F. and Jahn, B.M., 1998, Crustal evolution of southeastern China: Nd and Sr isotopic evidence: Tectonophysics, v. 284, no. 1-2, pp. 101-133.

Chen, J.F., Guo, X.S., Tang, J.F., and Zhou, T.X., 1999, Nd Isotopic model ages: implications of the growth of the continental crust of southeastern China: Journal of Nanjing University, Natural Science, v. 35, no. 6, pp. 649-685 (in Chinese with English abstract).

Chen, P.R., 1998, Geodynamic settings, petrogenesis and evolution of early Yanshanian bimodal volcanic-intrusive complexes in southern Jiangxi province: Ph.D. thesis, Nanjing University, pp.1-126 (in Chinese with English abstract).

Chen, P.R., Hua, R.M., Zhang, B.T., Lu, J.J., and Fan, C.F., 2002, Early Yanshanian post-orogenic granitoids in the Nanling Range region—Petrological constraints and geodynamic settings: Science in China, Series D, v. 48, no. 8, pp. 755-768.

Darbyshire D.P.F. and Sewell R.J., 1997, Nd and Sr isotope geochemistry of plutonic rocks from Hong Kong: implications for granite petrogenesis, regional structure and crustal evolution: Chemical Geology., v. 143, pp.81-93.

Deng, P., 2003, Study of the geodynamics of the Mesozoic-Cenozoic Basin-Range evolution in the eastern Nanling Range Belt and their uranium metallization: Ph.D. thesis, Nanjing University, pp.1-199 (in Chinese with English abstract).

Department of Geology, Nanjing University, 1981, Different era granitoids in South China and their mineralization relation: Beijing, Science Press, pp.1-395 (in Chinese).

Dewey, J.F., Hemptom, M.R., Kidd, W.S.F., et al., 1986, Shortening of continent—a young collision zone, *in*: Coward, M.P., Ries, A.C., eds, Collision tectonics, Blackwell Scientific Publications, no. 1-4, pp.3-36.

Dong, C.W., Li, W.X., Chen, X.M., Xu, X.S., and Zhou, X.M., 1998, Late Mesozoic magma mixing in SE-Fujian: petrologic evidence from Pingtan igneous complex: Progress in Natural Science, v. 8, pp.196-201.

Eskola, P., 1932, Origin of granites: Mineral. Petrol. Mitteil., v. 42, pp.455-481.

Faure, M., Marchadier, Y., and Rangin, C., 1989, Pre-Eocene synmetamorphic structure in the Mondoro-Romblon-Palawan area, west Philippines, and implications for the history of Southeast Asia:Tectonics, v.8, no.5, pp. 963-979.

Feng, Z.Z., Qi, R.Z., Huang, S.X., and Li, J.T., 1991, Mesozoic volcanology and mineralization related to volcanics in Yongtai-Dehua, Fujian province: Bulletin of Nanjing Institute of Geology & Mineral Resources, Suppl. 9, pp. 1-100 (in Chinese with English abstract).

Gilder, S.A., Gill, J., Coe, R.S., Zhao, X.X., Liu, Z.W., Wang. G.X., Yuan, K.R., Liu, W.L., Kuang, G.D., and Wu, H.R., 1996, Isotopic and paleomagnetic constraints on the Mesozoic tectonic evolution of South China: Journal of Geophysical Research, v. 101, pp.16137-16155.

Gilder, S.A., Keller, G.R., Luo, M., and Goodell, P.C., 1991, Timing and spatial distribution of rifting in China: Tectonophysics, v. 197, pp.225-243.

Gu, M.G., 2003, Geochemical study of volcanic rocks of the Moshishan Group in Yantou region of southeast Zhejiang: Geology and Mineral Resources of South China, no. 4, pp.24-30 (in Chinese with English abstract).

Guo, L.Z., Shi, Y.S., and Ma, R.S., 1980, The geotectonic framework and crustal evolution of South China, *in* Guo, L.Z., ed, 2001, The plate tectonics of South China: Beijing, Geological Publishing House, pp.1-264 (in Chinese).

Hatherton, T. and Dickinson, W. R., 1969, The relationship between andesitic volcanism and seismicity in Indonesia, the Lesser Antilles and other island arcs: Journal of Geophysical Research, v. 74, pp.5301-5310.

Hsu, K.C. and Ting, I., 1942, Geology and tungsten deposits of southern Kiangsi: Geological Memoirs, Ser. A, v. 17, pp.1-75.

Huang, T.K., 1945, On major tectonic forms of China: Geological Memoirs, Ser. A, v. 20, pp.1-165.

Jahn, B.M., Chen, P.Y., and Yen, T.P., 1976, Rb-Sr ages of the granitic rocks in southeastern China and their tectonic significance: Geological Society of America Bulletin, v. 87, pp.763-776.

Jahn, B.M., Zhou, X.H., and Li, J.L., 1990, Formation and tectonic evolution of southeastern China and Taiwan: isotopic and geochemical constraints: Tectonophysics, v. 183, pp.145-160.

Lapierre, H., Jahn, B. M., Charvet, J. and Yu, Y.W., 1997, Mesozoic felsic arc magmatism and continental olivine tholeiites in Zhejiang Province and their relationship with tectonic activities in SE China: Tectonophysics,¨v. 274, pp.321-338.

Lan, C.Y., Chung, S.L., Shen, J.S., Lo, C.H., Wang, P.L., Wang, P.L., Tran, T.H., Hoang, H.T., and Mertzman, S.A., 2000, Geochemical and Sr-Nd isotopic characteristic of granitic rocks from northern Vietnam: Journal of Asian Earth Science, v. 18, pp.267-280.

Li, C.W., Wang, Y.J., Guo, F., Peng, T.P., and Yu, X.B., 2002, Geochemistry of late Mesozoic volcanic rocks in Rucheng area and its implication for the source nature: Geotectonica et Metallogenia, v. 26, no. 4, pp.354-362 (in Chinese with English abstract).

Li, L.P., Liang, H.X., Dai, Y.D., and Liu, H.M., 1999, Origin and tectonic setting of the Yanshanian igneous rocks in the Pearl River mouth basin: Guangdong Geology, v. 14, no. 1, pp.1-8 (in Chinese with English abstract).

Li, W.X., Dong, C.W., and Zhou, X.M., 1999. Plagioclase xenocryst and magma mingling in Pingtan and Zhuangzhou complexes: Acta Petrologica Sinica, v. 15, no. 2, pp.286-290 (in Chinese with English abstract).

Li, X.H., 2000, Cretaceous magmatism and lithosphere extension in Southeast China: Journal of Asian Earth Science, v. 18, pp.293-305.

Li, X.H., Zhou, H.W., Liu, Y., Lee, C.Y., Chen, C.H., Yu, J.S., and Gui, X.T., 2001, Mesozoic shoshonitic intrusives in the Yangchun Basin, western Guangdong, and the tectonic significance: II. Trace elements and Sr-Nd isotopes: Geochinica, v. 30, no. 1, pp. 57-65 (in Chinese with English abstract).

Li, X.H., Zhou, H.W., Liu, Y., Lee, C.Y., Chen, Z.H., Yu, J.S., and Gui, X.T., 2001, Mesozoic shoshonitic intrusives in the Yangchun Basin, western Guangdong, and the tectonic significance: I. Petrology and isotopes geochronology: Geochinica, v. 29, no. 6, pp.513-520 (in Chinese with English abstract).

Liu, M., 2002, Gravitational collapse in orogenic belt, *in* Zhang, Y.X. and Yin, A., eds, Struture, evolution, and dynamics of the Earth, Beijing, Higher Education Press, Chap. 6, pp.177-206 (in Chinese).

Mao, J.R., Tao K.Y., Lee, C.Y., Xie, F.C., and Xu, N.Z., 2002, Geochronology and geochemical characteristics in late Mesozoic Sifang pluton, southwestern Fujian and their significance: Acta Petrologica Sinica, v. 18, pp.449-458 (in Chinese with English abstract).

Marmo, V., 1971, Granite petrology and the granite problem: Amsterdam, Elsevier, pp. 1-244.

Maruyama, S. and Seno, T., 1986, Orogeny and relative plate motions; example of the Japanese islands: Tectonophysics, v. 127, no. 3-4, pp. 305-329.
Maruyama, S., Isozaki, Y., Kimura, G. and Terabayashi, M., 1997, Paleogeographic maps of the Japanese Islands: plate tectonic synthesis from 750 Ma to the present: The island arc, v. 6, no. 1, pp. 121-142.
McCulloch, M.T. and Gamble, A.J., 1991, Geochemical and geodynamical constraints on subduction zone magmatism: Earth and Planetary Science Letters, v. 102, no. 2-3, pp.358-374.
Niu, Y.L., 2005, Generation and evolution of basaltic magmas: Some basic concepts and new views on the origin of Mesozoic-Cenozoic basaltic volcanism in eastern China: Geological Journal of China Universities, v. 11, pp. 9-46.
Qiu, J.S., Wang, D.Z., and McInnes, B.I.A., 1999, Geochemistry and petrogenesis of the I- and A-type composite granite in the coastal area of Zhejiang and Fujian provinces: Acta Petrologica Sinica, v. 15, no. 2, pp.237-246 (in Chinese with English abstract).
Shao, J.G., Peng, S.M., and Peng, S.B., 1995, $^{40}Ar/^{36}Ar$-$^{39}Ar/^{36}Ar$ isochrone dating for peripheral faults of Yunkai Massif: Guangdong Geology, v, 10, no. 2, pp.34-40 (in Chinese with English abstract).
Shu, L.S., Zhou, X.M., Deng, P., Yu, X.Q., Wang, B., and Zu, F.P., 2004, Geological features and tectonic evolution of Meso-Cenozoic basins in southeastern China: Geological Bulletin of China, v. 23, no. 9-10, pp.876-884 (in Chinese with English abstract).
Sun, T., Zhou, X.M., Chen, P.R., Li, H.M., Zhou, H.Y., Wang, Z.C., and Shen, W.Z., 2005, Mesozoic strongly peraluminous granites from eastern Nanling Range, southern China: Petrogenesis and implications for tectonics: Science in China, Series D, v. 48, no. 2, pp.164-174.
Sylvester, P.J., 1988, Post-collisional strongly peraluminous granites: Lithos, v. 45, pp. 29-44.
Tao, K.Y., Mao, J.R., Yang, Z.L., Zhao, Y., Xing, G.F., and Xue, H.M., 1998, Mesozoic petro-tectonic associations and records of the geodynamic processes in Southeast China: Earth Science Frontiers, v. 5, no. 4, pp.183-191 (in Chinese with English abstract).
Tatsumi, Y., and Eggins, S., 1995, Subduction zone magmatism: Blackwell Science Inc.
The Granitoid Research Group of the Nanling Project, Ministry of Geology and Mineral Resource, 1989, Geology of granitoids of Nanling Region and their petrogenesis and mineralization: Beijing, Geological Publish House, pp.1-471 (in Chinese with English abstract).
Uyeda, S., 1983, Comparative subductology: Episodes, v.2, pp. 19-24.
Wang, D.Z. and Zhou, X.M., 2002, Crustal evolution and petrogenesis of Late Mesozoic granitic volcanic-intrusive complexes in southeastern China: Beijing, Science Press, pp. 1-295 (in Chinese).
Wang, D.Z., Zhou, J.C., Qiu, J.S., and Zhang, H.J., 1994, The magma mixing in early Cretaceous volcanic activities and evidence for crust-mantle interaction in southeastern coast of China: Journal of Nanjing University, Earth Sciences, v. 6, no. 4, pp.317-325 (in Chinese with English abstract).
Wang, Y.J., Liao, C.L., Fan, W.M., and Peng, T.P., 2004, Early Mesozoic OIB-type alkaline basalt in central Jiangxi Province and its tectonic implications: Geochimica, v,. 33, no. 2, pp.109-117 (in Chinese with English abstract).
Wilde, S.A., Zhou, X.H., Nemchim, A.A., and Sun, M., 2003, Mesozoic crust-mantle interaction beneath the North China craton: A consequence of the dispersal of Gondwanaland and accretion of Asia: Geology, v. 31, no. 9, pp.817-820.
Xie, D.K., Ma, R.S., Zhang Y.S., Zhao, X.X., and Coe, R.S., 1996, The crust growth and mantle plume tectonics of South China Continent: Beijing, Geological Publishing House, pp.1-257 (in Chinese with English abstract).
Xie, G.Q., Hu, R.Z., Zhao, J.H., Jiang, G.H., 2001, Mantle plume and the relationship between it and Mesozoic large-scale metallogenesis in southeastern China: A preliminary discussion: Geotectonica et Metallogenia, v. 25, no. 2, pp.179-186 (in Chinese with English abstract).
Xie, J.Y., Tao, K.Y., Feng, Z.Z, and Yu, Y.W., 1996, Mesozoic volcanic geology and volcano-intrusive complexes of Southeast China Continent: Beijing, Geological Publish House, pp.1-277 (in Chinese with English abstract).
Xie, X., Xu, X.S., Xing, G.F., and Zou, H.B., 2003, Geochemistry and genesis of early Cretaceous volcanic rock assemblages in eastern Zhejiang: Acta Petrologica Sinica, v. 19, no. 3, pp. 385-398 (in Chinese with English abstract).
Yu, X.Q., 2004, Tectonic evolutionary features of the Mesozoic basins in Zhejiang, Fujian, Jiangxi and Guangdong Provinces: Ph.D. thesis, Nanjing University, pp. 1-127 (in Chinese with English abstract).
Yu, Y.W., Zhou, T.X., and Chen, J.F., 1993, The characteristics and origin of the Xuantandi bimodel volcanic rocks of the late stage of early Cretaceous, Zhejiang: Journal of Nanjing University, Earth Science, v. 5, pp.420-429 (in Chinese with English abstract).
Zhao, Z.H., Bao, Z.W., and Zhang, B.Y., 2002, Geochemistry of the Mesozoic basaltic rocks in southern Hunan Province: Science in China, Series D, supp. 41, pp.102-112.
Zhou, J.C., Zhang, H.J., and Yu, Y.W., 1994, Magma mixing in early Cretaceous composite lava in Xinchang, Zhejiang, E-China: Acta Petrologica Sinica, v. 10, pp. 236-247 (in Chinese ,with English abstract).
Zhou, X. and Yu, J.H., 2001, Geochemistry of the granitoids in Mesozoic metamorphic belt of coastal Fujian Province: Geochimica, v. 30, no. 3, pp.282-292 (in Chinese with English abstract).
Zhou, X.M., 2003, My thinking abount granite geneses of South China: Geological Journal of China Universities, v. 9, no. 4, pp. 556-565 (in Chinese with English abstract).
Zhou, X.M., and Li, W.X., 2000, Origin of Late Mesozoic igneous rocks of southeastern China: implications for lithosphere subduction and underplating of mafic magma: Tectonophysics, v. 326, pp.269-287.
Zhu, J.S., Cao, J.M., Li, X.G., and Zhou, B., 1997, A preliminary three-dimensional Earth's model of China and adjacent regions and its implications: Chinese Journal of Geophysics, v. 40, no. 4, pp.499-518.
Zhu, Q.W., Wang, F.Z., Lu, F.X., and Zhong, Z.Q., 1996, Petrological properties of Mesozoic- Cenozoic basalts from southern Hunan Province: Geoscience, v. 10, no. 4, pp.461-469 (in Chinese with English abstract).

Xinmin Zhou *is a professor of petrology of the Nanjing University. His scientific work has being mainly concentrated on the research of granites, ophiolites, and basalts in South China. He has been in charge of nine projects supported by National Natural Science Foundation of China and Education Ministry of China. Besides, he was chairman of the Petrological Committee of the Mineralogical, Petrological, and Geochemical Society of China, and head of Instructive Committee of Geological Education under the Education Ministry of China.*

Tao Sun *is Instructor of the Department of Earth Sciences of the Nanjing University. He obtained his bachelor degree in geology from Lanzhou University in 1998 and his PhD in petrology from Nanjing University in 2003. As a post doctor, he was engaged in the study on the petrogenesis of Mesozoic granites of South China at Nanjing University from 2003 to 2005. His major interest is related to the petrology and geochemistry of igneous and crustal evolution.*

Weizhou Shen *is presently a professor of the Department of Earth Sciences, Nanjing University, China. He obtained his MSC degree from the Department of Geology of the Nanjing University in 1965. Most of his work deals with the isotope geochemistry and geneses of granites and the related deposits in South China.*