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Syntectonic emplacement of Late Cretaceous mafic dyke swarms in coastal southeastern China: Insights from magnetic fabrics, rock magnetism and field evidence

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ABSTRACT

Magma flow directions for 6 Late Cretaceous mafic dyke swarms exposed in coastal southeastern China (SE China) were analyzed using anisotropy of magnetic susceptibility (AMS) and field evidence. Normal AMS fabrics are predominant. The AMS of the dyke swarms originates mainly from the distribution anisotropy of intersertal magnetite that crystallized during late stage magma flow or after the magma cooled. The AMS fabrics record tectonic stress combined with magma flow. Sub-vertical to vertical magma flow is inferred from symmetrical imbricated magnetic foliations of dyke walls and field evidence for 5 dyke swarms. The inferred (sub-) vertical flow directions also indicate that the magma chambers were probably just beneath the sampled locations. Low anisotropy degree, different orientations of principal AMS axes, and asymmetrical magnetic foliations of normal fabrics oblique to dyke walls indicate syntectonic emplacement of the Late Cretaceous dyke swarms under an extensional tectonic regime caused by Paleo-Pacific plate subduction.

1. Introduction

In recent years, dyke emplacement processes have become an increasing subject of investigation (Airoldi et al., 2011; Aubourg et al., 2002; Callot et al., 2001; Creixell et al., 2006, 2009; Eriksson et al., 2011; Hastie et al., 2011; Herrero-Bervera et al., 2001; Kissel et al., 2010; Pan et al., 2012; Raposo and D'Agrella-Filho, 2000; Raposo and Ernesto, 1995; Raposo et al., 2007; Schultz et al., 2008). Dykes, probably as the primary conduits for magma transportation from deep sources to the upper crust, provide a wealth of information concerning the tectonic setting, deep mantle properties, and crust–mantle evolution. The location of potential magma reservoirs, either as source areas or as staging chambers during magma ascent, can also be constrained from dyke emplacement information. While magma propagates upward for magmas injected directly from the source reservoir or shallower reservoirs, lateral magma propagation over large distances from the source area is being increasingly documented, such as in the Proterozoic Mackenzie dyke swarm (Ernst and Baragar, 1992), the Early Cretaceous Rio Ceará Mirim dyke swarm (Archanjo et al., 2000), the coast-parallel dyke swarm of the East Greenland volcanic margin (Callot and Geoffroy, 2004), and Mesozoic dyke swarms of Western Dronning Maud Land, Antarctica (Curtis et al., 2008). In these cases, magma flowed vertically above the source area, and then moved in an increasing lateral direction away from the source. Such flow patterns could be related to mantle plumes (Ernst and Baragar, 1992) or to smaller more localized magma centers (Archanjo et al., 2000). Composite (i.e. both lateral and vertical) flow paths have also been reported from Ferrar Dolerite sheets, Allan Hills, South Victoria Land, Antarctica (Airoldi et al., 2012). The multiple flow directions represent a distinctly magmatic style of crustal deformation, with 'passive' injection of magma via hydrofracturing that produced the local shallow large igneous province plumbing as a sill-dominated intrusive complex close to, or intersecting, the paleosurface (Airoldi et al., 2012).

Magma flow directions have been inferred from field (dyke segmentation, gas bubbles, elongated vesicles, mineral lineation, finger grooves or striae) and petrographic (textural) observations. Dyke segmentation is also related to crack propagation. However, meaningful field indicators are relatively rare and can be ambiguous. Thin section analysis is a traditional way to determine flow direction, but is time-consuming (Varga, 1998). In contrast, as a sensitive, efficient and time-saving petrofabric indicator, the anisotropy of magnetic susceptibility (AMS) has become one of the most effective methods to better understand magma propagation processes.

Cretaceous mafic dyke swarms are well developed in coastal SE China, intruding widespread Mesozoic granitoids and volcanic rocks (Zhou et al., 2006). Previous studies of the dyke swarms have mainly focused on petrological, geochronological and geochemical analyses of

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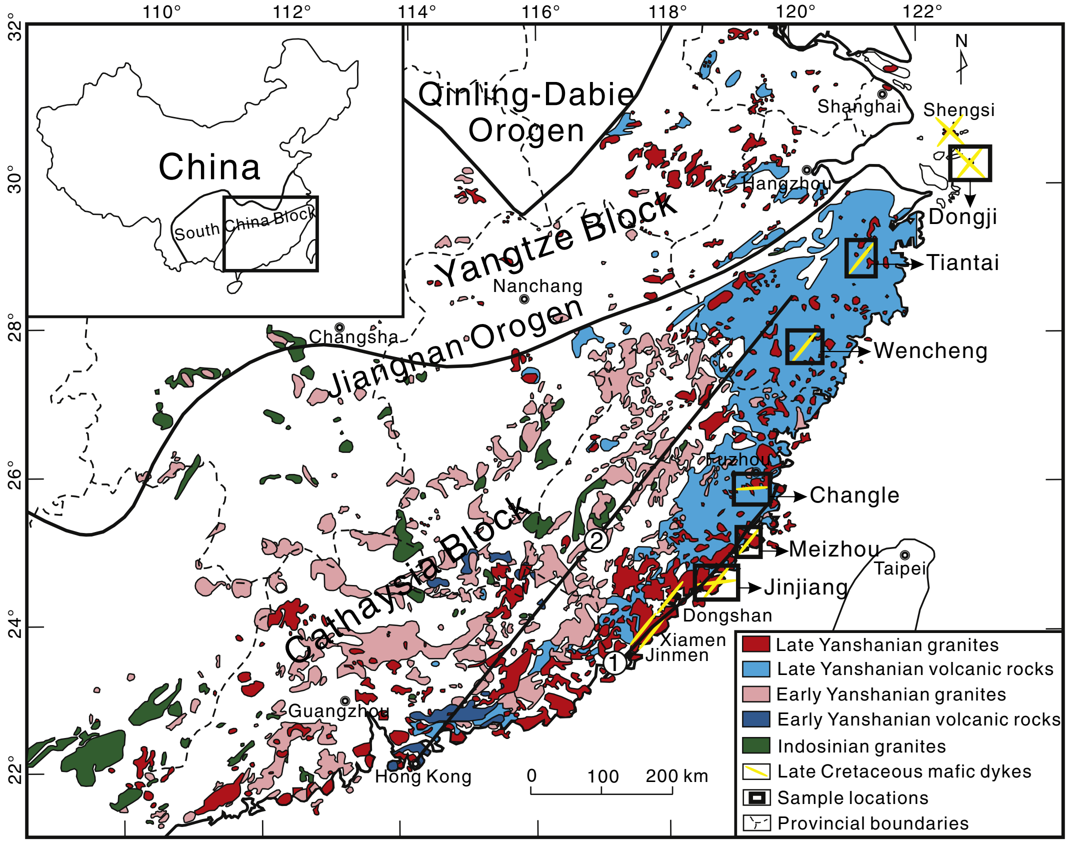

Fig. 1. Distribution of Mesozoic granites and volcanic rocks and Late Cretaceous mafic dykes in the South China Block (SCB) and sample locations (modified from Zhou et al., 2006). ① Changle–Nanao Fault; ② Zhenghe–Dapu Fault.

the origin of the dykes, the nature of the magma source and the tectonic setting (Dong et al., 2006, 2010, 2011; Qin et al., 2010; Zhang, 2006; Zhao, 2004). Overall elemental and Sr–Nd isotopic characteristics of the Cretaceous mafic dykes are similar, with features typical of island-arc basalts (Dong et al., 2011; Zhao, 2004). They formed in a back-arc extensional setting with magma generated from partial melting of mantle wedge peridotite (Dong et al., 2011). The origin of the dykes has commonly been interpreted as the result of lithospheric mantle melting induced by Paleo-Pacific plate subduction and mantle–crust interaction (Dong et al., 2006, 2010, 2011; Yang et al., 2010). However, little attention has been given to emplacement processes and the potential magma source locations of these dyke swarms (Pan et al., 2012). In this paper, we present a detailed study of rock magnetic properties and AMS of Late Cretaceous mafic dyke swarms in coastal SE China to reconstruct magma emplacement processes, to locate possible feeder magma chambers and to better understand the tectonic setting that controlled dyke swarm emplacement.

2. Geological setting and sampling

The South China Block (SCB) is bounded to the north by the Qilian–Qinling–Dabie–Sula suture and the Tan Lu Fault, to the south by the Song Ma suture, and to the west by the Songpan Ganzi accretionary complex. The SCB comprises the Yangtze Block in the northeast and the Cathaysia Block in the southeast, which amalgamated along the Jiangnan suture during early Neoproterozoic time (Charvet et al., 1996; Wang et al., 2012) (Fig. 1).

Mesozoic magmatism in the SCB gave rise to widespread Mesozoic magmatic rocks, with a total outcrop area of nearly 218,090 km^2, which are largely concentrated in the southeast in Zhejiang, Fujian,

Table 1
Geochronology of Late Cretaceous dyke swarms in coastal SE China.

Location	Lithology	Trending	Age/Ma	Dating method
Dongji	Hornblende diabase	NNE/NW	93.4 (Dong et al., 2010)	^{40}Ar–^{39}Ar
Shengsi	Hornblende diabase	NNE/NW	About 90 (personal communication with Dong)	Zircon SHRIMP U–Pb
Tiantai	Diabase	NE	–	–
Wencheng	Diabase	NE	94 (Qin et al., 2010)	^{40}Ar–^{39}Ar
Changle	Diabase	E–W	–	–
Meizhou	Hornblende diabase	NE	95 ± 2 (Dong et al., 2011)	Zircon SHRIMP U–Pb
Jinjiang	Hornblende diabase	E–W	90 ± 2 (Dong et al., 2006)	Zircon SHRIMP U–Pb
	Quartz diorite	NE	87 ± 2 (Dong et al., 2006)	Zircon SHRIMP U–Pb
Dongshan	Gabbro porphyrite	NW	83.9 ± 1.6 (Zhang, 2006)	K–Ar
Chinmen	Mafic	NE	90.7 (Lee, 1994)	K–Ar
			97.8 (Yang et al., 1994)	K–Ar
			98/76 (Lan et al., 1995)	K–Ar
Xiamen	Gabbro	NE	77.06 ± 1.63/88.44 ± 2.44 (Zhao, 2004)	K–Ar