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Systematic variations in seismic velocity and reflection in the crust of Cathaysia: New constraints on intraplate orogeny in the South China continent

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ABSTRACT

The South China continent has a Mesozoic intraplate orogeny in its interior and an oceanward younging in postorogenic magmatic activity. In order to determine the constraints afforded by deep structure on the formation of these characteristics, we reevaluate the distribution of crustal velocities and wide-angle seismic reflections in a 400 km-long wide-angle seismic profile between Lianxian, near Hunan Province, and Gangkou Island, near Guangzhou City, South China. The results demonstrate that to the east of the Chenzhou-Linwu Fault (CLF) (the southern segment of the Jiangshan–Shaoxing Fault), the thickness and average P-wave velocity both of the sedimentary layer and the crystalline basement display abrupt lateral variations, in contrast to layering to the west of the fault. This suggests that the deformation is well developed in the whole of the crust beneath the Cathaysia block, in agreement with seismic evidence on the eastwards migration of the orogeny and the development of a vast magmatic province. Further evidence of this phenomenon is provided in the systematic increases in seismic reflection strength from the Moho eastwards away from the boundary of the CLF, as revealed by multi-filtered (with band-pass frequency range of 1–4, 1–8, 1–12 and 1–16 Hz) wide-angle seismic images through pre-stack migration in the depth domain, and in the P-wave velocity model obtained by travel time fitting. The CLF itself penetrates with a dip angle of about 22° to the bottom of the middle part of the crust, and then penetrates with a dip angle of less than 17° in the lower crust. The systematic variation in seismic velocity, reflection strength and discrepancy of extensional factors between the crust and the lithosphere, are interpreted to be the seismic signature of the magmatic activity in the interest area, most likely caused by the intrusion of magma into the deep crust by lithospheric extension or mantle extrusion.

1. Introduction

The South China continent is located alongside the western margin of the Pacific plate, and has endured the subduction of this plate beneath mainland China (Grabau, 1924; Huang, 1980; Guo et al., 1983; Yang et al., 1986; Yin and Nie, 1993; Zhang et al., 1994). This region includes the Huanan fold belt, where a significant occurrence of Jurassic–Cretaceous postorogenic magmatism makes up a broad extension to the northeast (Li and Li, 2007). Late Mesozoic magmatic rocks, composed mostly of granite and rhyolite, outcrop at the surface, and are spread over a large area, making up 95% of a belt 600 km wide that lies along the southeastern coastline of China (Wang et al., 2003) (Fig. 1). Throughout the continent, volcanic rocks exist mainly to the east of the Chenzhou-Linwu Fault (CLF) or the southern segment of the Jiangshan–Shaoxing Fault. The CLF lies at a distance of about 450 km from the belt. The igneous rocks found in South China fall into three main age groups, namely early (180–160 Ma), mid (160–140 Ma) and late (140–97 Ma) Yanshanian (Wang et al., 2003). In some areas, the late Yanshanian group includes rocks as young as ca. 79 Ma (Martin et al., 1994). The early Yanshanian volcanism belongs to a K-rich calc-alkaline series inter-layered with other rocks or shallow-water detrital materials. In contrast, the late Yanshanian volcanism has a bimodal character associated with the continental red beds that lie along grabens that trend NE–SW, and indicate intraplate rifting. Granitoids are found in a great variety of petrographic types from biotite–granite to tonalite. Peraluminous granitoids formed by crustal melting are also common (Jahn et al., 1990). Outcrops of volcanic rock become more common nearer the ocean (Zeng et al., 1997; Zhou and Li, 2000; Wang et al., 2003). Li and Li (2007) divided the synorogenic magmatism into three age groups, 230–210, 240–230 and 280–240 Ma, and the postorogenic magmatism into four age groups, namely 120–80, 145–120, 170–145, and 195–170 Ma. The exact character of the intraplate orogeny and the extensive postorogenic magmatism are still the subject of considerable debate.

In the last 20 years, a number of tectonic models have been postulated to account for the Mesozoic tectonic evolution of the South China block (Jahn et al., 1986; Hsü et al., 1988; Rodgers, 1989; Rowley et al., 1989; Jahn et al., 1990; Charvet et al., 1996; Li et al., 2000; Zhou and

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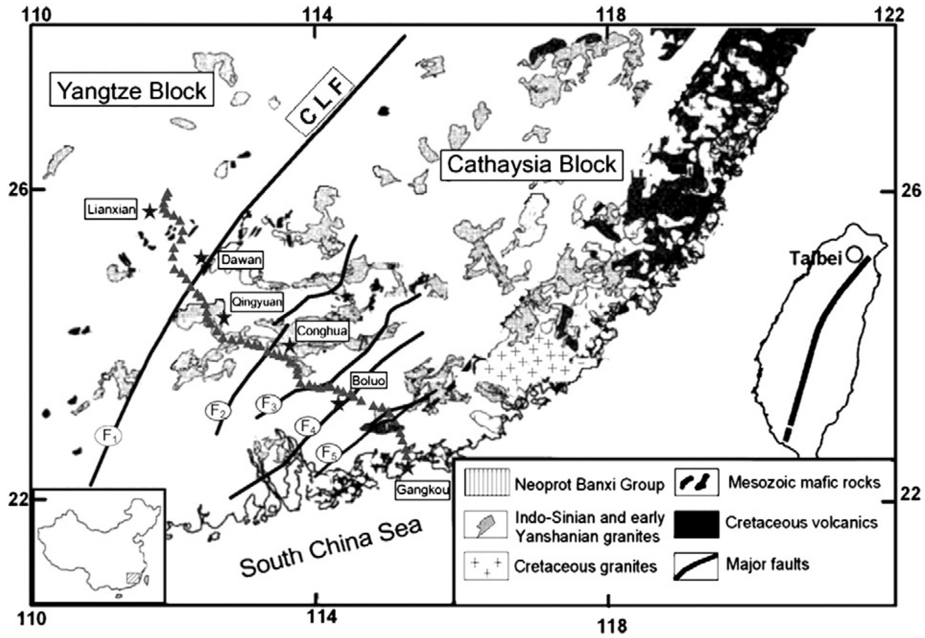

Fig. 1. Location map showing the wide-angle seismic profile from northwest to southeast between Lianxian and Gangkou Island. The triangles and stars respectively mark the geographical positions of the stations and shot points (Lianxian, Dawan, Qingyuan, Conghua, Boluo and Gangkou). The major active faults that cross the seismic profile almost perpendicularly are: F1, Chenzhou-Linwu fault; F2, Enping-Xinfeng fault; F3, Heyuan-Zengcheng fault; F4, Zijjin-Boluo fault; F5, Lianhuashan fault. The inset at the bottom left shows the study region and the extent of the South China fold belt. The classification of the regional magmatism is also shown by geological age (bottom of figure).

Li, 2000; Wang et al., 2003). These models include an Andean-type active continental margin (Guo et al., 1983), an Alpine-type collision belt (Hsü et al., 1988, 1990), and lithospheric subduction (Holloway, 1982; Faure, 1996; Zhou and Li, 2000) with an underplating of mafic magma (Li and Li, 2007); all these models suppose that the tectonic regime was dominantly compressive as a result of either a westward subduction of a Mesozoic Pacific plate, or the closure of an oceanic basin in the interior of the South China block (Holloway, 1982; Hsü et al., 1990; Faure, 1996; Zhou and Li, 2000). Other alternative models include wrench faulting (Xu et al., 1993), continental rifting and extension (Gilder et al., 1996; Li et al., 2000; Wang et al., 2003) and a flat-slab subduction model (Li and Li, 2007); these models differ from the previous because they suggest that intraplate lithospheric extension and thinning have been dominant since the overthrusting tectonics that took place during the Early Mesozoic in south China (Li et al., 1989; Faure, 1996; Gilder et al., 1996; Li et al., 2000; Wang et al., 2003; Li and Li, 2007). All these tectonic models have been proposed in reference to the tectonics and the data on surface geology and geochemistry, but they must all be tightly constrained by the seismic structure of the crust and uppermost mantle.

With the intention of providing a broader view on this issue, and of contributing to our understanding of the intraplate tectonics of Asia through seismology, based on the seismic response of the crust in the frame of the Mesozoic tectonic evolution, we have constructed a set of wide-angle seismic reflection sections by taking advantage of the high quality data provided by an active source experiment consisting of a 400-km-long seismic profile (Fig. 1). Even though the contact relationship between the Cathaysia and the Yangtze blocks with reference to crustal P-wave velocity model has previously been described (Zhang and Wang, 2007), the geometry of the fault is still unclear, and this is important if we are to understand the intraplate deformation. To that end we herein reevaluate the crustal P-wave velocity distribution (Zhang and Wang, 2007) and pre-stack migrated wide-angle seismic reflections (Milkereit, 1987; Milkereit et al., 1990; Lafond and Levander, 1995; Zhang et al., 2000).

The remainder of the paper is organized as follows: (1) we provide a brief picture of the tectonic setting of the study region probed by wide-angle seismic profiling; (2) we give a short description of the seismic dataset and its multi-filtered processing; (3) we describe the crustal P-velocity model used when implementing the working method, beginning with the application of a pre-stack migration scheme; (4) we discuss the reconstruction of seismic reflection sections in a multi-frequency band; (5) finally, we provide a discussion focused on the crustal response prior to the Mesozoic tectonic evolution.

2. Tectonic setting

Li and McCulloch (1996) declared that both the Yangtze and Cathaysia blocks were consolidated at ca. 970 Ma based on geological mapping of the tectonics of South China. In fact, a number of authors have shown that the Yangtze and Cathaysia blocks were consolidated during the Neoproterozoic rather than at ca. 970 Ma (e.g., Li et al., 1995, 2000, 2002a, 2002b; Zhou et al., 2002; Li et al., 2003, 2005; Greentree et al., 2006; Li et al., 2008; Wang et al., 2012). In recent years, the Neoproterozoic amalgamation of the Yangtze and Cathaysia Blocks is a hotly debated issue, with three viewpoints having been proposed. The first view involves amalgamation ages of (1) ca. 880 Ma (e.g., Li et al., 1995, 2002a, 2002b; Greentree et al., 2006; Li et al., 2008), (2) ca. 830 Ma (e.g., Li et al., 2002a, 2002b, 2003, 2005), and (3) ca. 800 Ma (e.g., Zhou et al., 2002). In the second view, the Cathaysia basement was traditionally considered to be characterized by the Paleoproterozoic Badou, Mayuan, Yunkai and Zhoutan Groups exposed mainly along Wuyi–Nanling–Yunkai domains (e.g., Li et al., 1989). However, the latest geochronological data show that these metamorphic rocks, which had previously been mapped as the Paleoproterozoic basement, and in particular the migmatite and gneissoid granites, have a wide range of ages from 410 to 1890 Ma (e.g., Wang et al., 2004, 2005, 2007, 2010, 2011).

The crystalline basement of the Yangtze block has an average age of 2.7–2.8 Ga (Qiu et al., 2000), with the oldest materials having an age of more than 3.2 Ga. In contrast, the crystalline basement of the Cathaysia block is made up of Paleo-to-Mesoproterozoic and possibly Late Archean rocks of about 2.5 Ga (Chen and Jahn, 1998; Wang et al., 2003).

Late Mesozoic magmatic rocks composed predominantly of granite and rhyolite are spread across a 600 km-long belt along the southeastern coastline of China, and form outcrops over 95% of the total exposed area