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Review Article

Investigation of the Moho discontinuity beneath the Chinese mainland using deep seismic sounding profiles

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ABSTRACT

We herein describe the depth distribution of the Moho beneath the Chinese mainland, determined via compilation and resampling of the interpreted results of crustal P-wave velocity structures obtained from deep seismic soundings (DSSs) performed since the pioneering DSS work carried out in the Qaidam basin in 1958. For the present study, 114 wide-angle seismic profiles acquired over the last 50 years were collated; we included results for crustal structures from several profiles in Japan and South Korea, to improve the reliability of the interpolation of the Moho depth distribution. Our final Moho map shows that the depth of the Moho ranges from 10 to 85 km. The deepest Moho discontinuity—at approximately 70–85 km beneath the Tibetan Plateau—was formed by ongoing continent–continent collision. The Moho beneath the eastern North China craton, at a relatively constant 30–35 km, has endured mantle lithosphere destruction. The Moho depths determined from active seismology are consistent (within 3–5 km) with results obtained from gravity inversion and surface wave tomography. The spatial variation of the Moho depth, crustal formation, and composition of different tectonic blocks contribute to controls on the spatial distribution of the seismicity and rheology in the crust beneath mainland China.

Contents

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1. Introduction

It is more than a century since the discovery of the Moho discontinuity by Mohorovicic in 1909. Successive experiments in different geophysical disciplines have confirmed the global existence of the discontinuity, but the depth of the Moho varies beneath different tectonic blocks, depending on their age and on the different tectonic environments (e.g., cratons and rifts, Christensen and Mooney, 1995). Different seismological methods are used to probe this discontinuity between the crust and mantle, including wide-angle seismic reflection/refraction surveys (Klemperer and Mooney, 1998a,b), nearly vertical seismic reflection profiling (Klemperer and Mooney, 1998a,b), and P/S wave receiver function imaging (Chen, 2010; Chen et al., 2006; Yuan, 1996). In China, pioneering experiments using deep seismic profiling were performed in the Qaidam basin, to the north of Tibet, by Rongsheng Zeng and Jiwen Teng (Teng, 1979; Zeng and Gan, 1961). These experiments were carried out in 1958, and were jointly sponsored by the Chinese Academy of Sciences and the Chinese Ministry of Petroleum. Later, and particularly from 1980 onwards, numerous wide-angle seismic profiles were obtained in China, especially following the disastrous 1966 Xingtai (Teng et al., 1974a,b, 1975) and 1976 Tangshan earthquakes (La et al., 2006). These surveys were conducted under the auspices of various international programs, including the 'International Geophysics Year' of the 1950s, the 'Crust and Upper Mantle Project' of the 1960s, the 'Geodynamics Project' of the 1970s, the 'International Geological Correlation Program', also of the 1970s, the 'International Lithosphere Program' of the 1980s, and the 'Continental and Ocean Drilling Program' of the 1980s and 1990s (Zhang et al., 2011a). To date, more than 60,000 km of wide-angle seismic profiles and approximately 10,000 km of reflection seismic profiles have been obtained (Alsdorf et al., 1988; Gao et al., 1999; Jiang et al., 2006; Kan et al., 1988; Kao et al., 2001; Kong et al., 1999; Li and Mooney, 1998; Program-8301 Cooperation Group, 1988; Su et al., 1984; Sun et al., 1988; Teng et al., 1997a,b; Wang and Qian, 2000; Wang et al., 2000, 2003a,b,c,d, 2005b, 2007a,b; Wu et al., 1991; Yan et al., 2001; Yang and Liu, 2002; Zhang and Klemperer, 2005, 2010; Zhang and Wang, 2007; Zhang et al., 1997b, 2000a,b, 2002a, 2003a,b; Zhang et al., 2005a,b,c, 2008a, 2009a,b,c, 2010, Zhao et al., 2001; Zhang and Zhang, 2002). Standard interpretative analyses have been applied to all these profiles, and most of the results have been published in Chinese journals, Chinese books, or project reports, with a few publications in English in international journals. The database has grown with the acquisition of additional datasets obtained via the application of gravity data inversion and Rayleigh wave seismic tomography to the continental and adjacent marine areas of China (Beckers et al., 1994; Carroll et al., 1995; Dewey et al., 1988; Ekström et al., 1997; Hirn et al., 1984a,b; Makovsky et al., 1996a,b; McNamara et al., 1994, 1995, 1996; Nelson et al., 1996; Yuan, 1996, 1997; Yuan and Egorov, 2000; Zhang et al., 1984, 2011a,b,c,d; Zhao and Morgan, 1987; Zhao and Windley, 1990; Zhu et al., 1995a).

The IGCP 474 project (Snyder et al., 2006) offers a catalyst for bringing together the results obtained from the different regional programs into a common scientific framework, and for the generation of seismic images across representative orogenic belts, rifts, continental margins, etc.; this allows a number of different problems to be tackled at a regional scale. These results could be available in a database, educators and researchers in developing nations would have the opportunity to develop their own research programs. To realize the goals of IGCP 474, it is first necessary to compile all the available results at a continental and marine scale. The first version of a Moho depth map of the Chinese mainland was achieved via the collection of the interpreted results of wide-angle seismic profiling performed from 1958 to 1996 (Li and Mooney, 1998; Yuan, 1996). A further version was then produced in 2001 (Li et al., 2006). Several updated versions have been created with the inclusion of deep seismic profiles obtained since 2001 beneath East Asia (Teng, 2001), and China (Zhang et al., 2011c). Some maps of the crustal structure of particular tectonic blocks, such as Tibet (Zhang et al., 2011a), the North China craton (Jia and Liu, 1995, Ruan, 2011), and South China (Deng et al., 2011) have also been compiled. In the present study, we compiled the interpreted results of wide-angle seismic profiles obtained from China and the surrounding seas from 1958 to 2010 (Bai and Wang, 2004, 2006a,b; Bai et al., 2007; Beckers et al., 1994; Carroll et al., 1995; Dewey et al., 1988; Ekström et al., 1997; Galvé et al., 2002; Gao et al., 1999; Hirn et al., 1984a,b; Hsu et al., 1990; Hu et al., 1988a,b; Kan et al., 1986, 1988; Kao et al., 2001; Kong et al., 1999; LERG, 1988; Li and Mooney, 1998; Q.H. Li et al., 1999; Q.S. Li et al., 2001a,b; S.L. Li et al., 2002, 2006; Liao et al., 1988a,b; Lin et al., 1988, 1992, 1993; C.Q. Liu et al., 1991; M.J. Liu et al., 2006; Lu and Xia, 1992; Ma et al., 1991; Makovsky et al., 1996a,b; McNamara et al., 1994, 1995, 1996; Nelson et al., 1996; Sapin et al., 1985; Shi et al., 1989; Teng, 1979, 1985; Teng et al., 1983a,b,c, 1985a,b, 1997a,b, 2003a,b, 2006, 2008a,b, 2010; Wang and Qian, 2000; Wu et al., 1991,1993; Xiong et al., 1986, 2002; Yang and Liu, 2002; Zhang and Klemperer, 2005, 2010; Zhang and Li, 2003; Zhang et al., 1984; X.K. Zhang et al., 2002b, 2003a, 2007a, 2008a; Zhang et al., 2002c, 2003b, 2005b, 2010, Zhao and Morgan, 1987; Zhao and Windley, 1990; Zhu et al., 1995b).

The remainder of the paper is arranged as follows: First, we summarize the tectonic setting of China, and then briefly describe the wide-angle seismic profiles collected in this study. We then show the interpolation results for the depth of the Moho beneath the Chinese mainland, and the crustal velocity distributions for the Tibet, South China, and North China blocks, where wide-angle seismic coverage is relatively dense. In the last section, we make some comparisons between the depth of the Moho as determined using wide-angle seismic profiling gravity inversion and surface wave tomography, and also describe some simple relationships between the crustal structure, composition, and seismogenic layer beneath different tectonic blocks in the Chinese mainland.

2. Tectonic setting

In China there are three platforms: the Tarim platform (west), Yangtze platform (south), and North-China platform (east) (Huang et al., 1981; Li and Zhou, 1990; Luo and Tong, 1988; Ma, 1989; Zhang et al., 1984, 1996). Additionally, there are three major fold tectonic units in the continental domain and adjacent oceanic areas; these are the Tethyan-Himalayan zone (south and west), Paleo-Asian zone (northwest and northeast), and Circum-Pacific zone (east), which in turn are divided into 15 fold systems (Hsu et al., 1990; Huang et al., 1981; Ma, 1989; Yuan, 1996, Zhang et al., 1984). Fig. 1 shows an overall view of the platforms and fold systems from the geological and geophysical mapping of China (Ma, 1989; Yuan, 1996). A remarkable geophysical characteristic in the Chinese mainland is the north–south trending belt of gravity gradients extending from the north of the Huonan Mountains, through the Longmen Mountains, to the south of the Daxue Mountains (Ma, 1989; Yuan, 1996). This gravity gradient belt is accepted to be an important north–south trending tectonic belt associated with strong earthquakes, including the disastrous Wenchuan earthquake of May 12, 2008. Additionally, the basins are usually divided into two groups, separated by the north–south active earthquake occurrence belt (also called the N–S tectonic belt, or N–S gravity gradient belt); these are known as the eastern basins and the western basins (Li and Zhou, 1990; Luo and Tong, 1988; Zhang et al., 1996), and have their own characteristics. It is largely accepted that the eastern basins formed during the Mesozoic/Cenozoic in the back-arc from the West Pacific subduction under continental China, while the western basins formed more recently in the course of the crustal growth underneath the Tibetan Plateau, after the collision of the Indian and Eurasian plates (Li and Zhou, 1990; Luo and Tong, 1988; Zhang et al., 1996, 2011b).

3. Wide-angle seismic profiles

We compiled a Moho depth map of continental China, constrained by wide-angle seismic profiles obtained between 1958 and 2010. For