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# A gravity study along a profile across the Sichuan Basin, the Qinling Mountains and the Ordos Basin (central China): Density, isostasy and dynamics

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ABSTRACT

In order to investigate the structure of the crust beneath the Middle Qinling Mountains (MQL) and neighboring areas in the North China Block and South China Block, a north-south gravity profile from Yuquan in the Sichuan Basin to Yulin in the Ordos Basin was conducted in 2011. The Bouguer gravity anomaly is determined from a high-quality gravity dataset collected between 31°N and 36°N of latitude, and varies between −200 and −110 mGal in the study region. Using accredited velocity density relationships, an initial crust-mantle density model is constructed for MQL and adjacent areas, which is later refined interactively to simulate the observed gravity anomaly. The present study reveals the features of the density and Bouguer gravity with respect to the tectonic units sampled by the profile. The lithosphere density model shows typical density values that depict a layered structure and allow differentiate the blocks that extend along the reference profile. The gravity field calculated by forward modeling from the final density distribution model correlates well with the measured gravity field within a standard deviation of 1.26 mGal. The density in the crystalline crust increases with depth from 2.65 g/cm$^3$ up to the highest value of 2.95 g/cm$^3$ near the bottom of the crust. The Conrad interface is identified as a density jump of about 0.05 g/cm$^3$. The average density of the crust in MQL is clearly lower than the density in the formations on both sides. Starting from a combined Airy-Pratt isostatic compensation model, a partly compensated crust is found below MQL, suggesting future growth of the crust, unlike the Ordos and Sichuan basins that will remain stable. On the basis of the density and isostatic state of the crust and additional seismological research, such as the P-wave velocity model and Poisson's ratio, it is concluded that the lower crust delamination is a reasonable interpretation for the geophysical characteristics below the Qinling Orogen.

## 1. Introduction

The Qinling-Dabie Orogen crosses central China and extends about 1500 km from west to east so that it separates the North China Block to the north from the South China Block to the south (Li et al., 2007; Ratschbacher et al., 2003, 2006). This orogen contains the most abundant ultrahigh pressure metamorphic rocks in the world. On the basis of the structural features, a “three plates with two suture zones” model has been proposed and documented for this orogen (Dong et al., 2004, 2011a, 2011b, 2013; Li et al., 1996; Meng and Zhang, 1999, 2000; Zhang et al., 1995, 2001). According to this model, the Qinling Orogen was developed tectonically in the course of long multiphase processes of compression and extension, ending in a complex tectonic scenario that may well be considered as the result of the interaction between continental blocks (Fig. 1): the North China Block that includes the North Qinling Block, the South Qinling Block and the South China Block, separated from each other by the Shangdan and Mianlue sutures (Dong et al., 2004, 2011a, 2011b, 2015; Dong and Santosh, 2016; Li et al., 2007; Meng and Zhang, 1999, 2000). The Shangdan suture zone was formed by the collision between the North China Block and the South Qinling Block during the Middle Paleozoic, while the Mianlue suture zone was formed from the collision of the latter and the South

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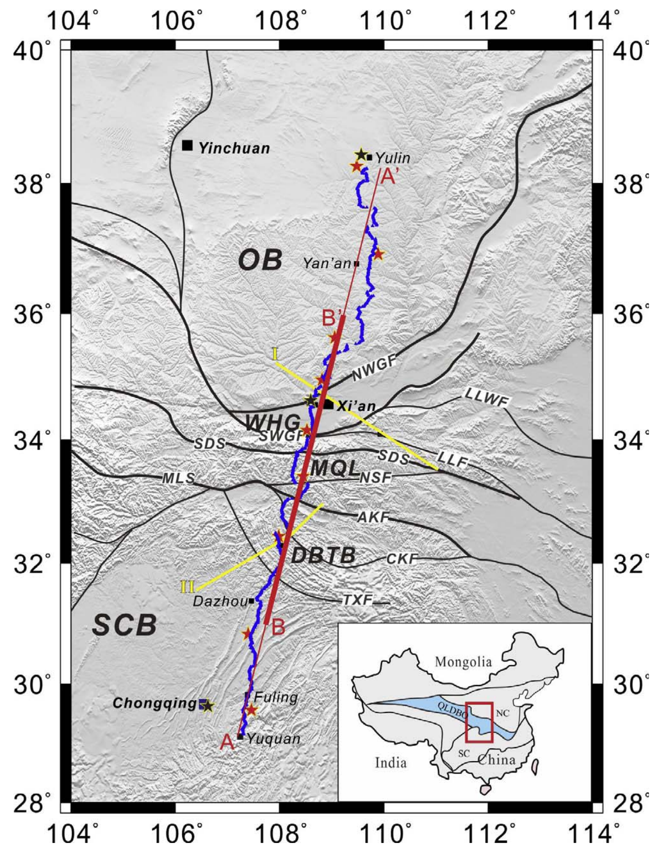


**Fig. 1.** Location map of the north-south integrated geophysical profile between Yuquan and Yulin (line A-A′). The inset in the bottom right corner shows the geographical position of the study area in central China. The blue triangles indicate the geographical positions of the gravity measurement points and the black stars the absolute gravity measurement points. The red stars mark the locations of the shot points fired in the course of a wide-angle seismic sounding (Teng et al., 2014a). The transect B-B′ indicates the gravity profile studied in this work. The yellow lines show two seismic profiles conducted by other authors: I, wide-angle seismic reflection/refraction profile (Ren et al., 2012); II, deep seismic reflection profile (Dong et al., 2013). Major tectonic boundaries: SDS, Shangdan suture; MLS, Mianlue suture; NWGF, North Weihe Graben fault; SWGF, South Weihe Graben fault; LLWF, Lingbao-Lushan-Wuyang fault; LLF, Luonan-Luanchuan fault; NSF, Ningshan fault; AKF, Ankang fault; CKF, Chengkou fault; TXF, Tiexi fault. Abbreviations for tectonic units are as follows: OB, Ordos Basin; WHG, Weihe Graben; MQL, Middle Qinling Mountains; DBTB, Dabashan Thrust Belt; SCB, Sichuan Basin. Abbreviations in the inset map: NC, North China Block; SC, South China Block; QLDBO, Qinling-Dabie Orogen. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

China Block during the Late Triassic.

Knowledge of the structure and history of the Qinling Orogen is important to place tight constraints on the way in which the eastern part of the Asian continent was assembled and evolved during the Phanerozoic (Mattauer et al., 1985). During the past decades, a great number of geological, geochemical and geochronological studies on the Qinling Orogen have been carried out (Ames et al., 1996; Dong et al., 2004, 2011a, 2011b, 2015; Dong and Santosh, 2016; Gao et al., 1995; Hacker et al., 1998; Li et al., 1996, 2007; Mattauer et al., 1985; Meng and Zhang, 1999, 2000; Ratschbacher et al., 2003, 2006; Wu et al., 2014; Zhang et al., 1995, 1996, 1997, 2001). Some geophysical investigations have also been performed, including teleseismic studies (He et al., 1998; Huang et al., 2014), wide-angle seismic reflection/refraction soundings (Ren et al., 2012; Teng et al., 2014a, 2014b; Zhang et al., 2008a), deep seismic reflection profiles (Dong et al., 2013; Gao et al., 2014; Li et al., 2015; Wang et al., 2007; Yuan et al., 1994) and a magneto-telluric study (Cheng et al., 2003); all of them have allowed to better understand the deep structure and characteristics of the crust and upper mantle throughout the Qinling Orogen. However, the existing geophysical research on Qinling focuses mainly on the eastern segment (He et al., 1998; Yuan et al., 1994; Zhang et al., 1996) or the western segment (Gao et al., 2014; Wang et al., 2007; Zhang et al., 2007, 2008a); only a few studies focus on the deep structure and geodynamics under the Middle Qinling Mountains (MQL) and the Dabashan Thrust Belt (DBTB) on its southern flank (Dong et al., 2013; Ren et al., 2012; Teng et al., 2014a, 2014b; Wang et al., 2014). The present work addresses a comprehensive gravity study that is added to other previous geophysical studies based on wide-angle seismic reflection/refraction soundings (Teng et al., 2014a, 2014b), teleseismic receiver functions (Si, 2015; Si et al., 2016) or a geomagnetic survey (Hu et al., 2014).

With the purpose of characterizing the complex crustal structure under MQL and DBTB (to the south) and the Ordos Basin (to the north), as well as the interaction between the North China Block and the South China Block, a 1000-km-long south-to-north gravity profile was performed in 2011 along the line Yuquan-Xi'an-Yan'an-Yulin (line A-A′ in Fig. 1), which goes from the Sichuan Basin to the Ordos Basin across Dabashan, Qinling and the Weihe Graben. In this paper, available seismic data are combined with new gravity data, and the density structure and isostatic equilibrium state of the crust along the reference profile is studied. Finally the geodynamic implications are discussed.

## 2. Tectonic setting

The profile A-A′ (Fig. 1) runs across the five major tectonic units that make up the study area, namely (from south to north): Sichuan Basin (SCB), Dabashan Thrust Belt (DBTB), Qinling Orogen (QLO), Weihe Graben (WHG) and Ordos Basin (OB). SCB is roughly circular and contains mainly Paleozoic and Mesozoic sedimentary rocks that are bordered by Cenozoic formations on the southern margin, which are merged westward and northward in Longmen Shan (Burchfiel et al., 2008). There are folded belts of the Late Triassic-Cretaceous to the north and the Late Cretaceous to the east. The basement of the basin has remained relatively undeformed or stable during the Mesozoic and Cenozoic deformation episodes that affected the surrounding regions (Burchfiel et al., 2008).

DBTB is a curved tectonic belt located in the transition zone between SCB and QLO, which was formed as a result of the collision between the Qinling Orogen and the South China Block during the Late Triassic (Hu et al., 2012; Li et al., 2013, 2015). Generally, this belt is characterized by southwestward thrusting kinematics, representing the propagation of an orogenic belt toward the foreland (Li et al., 2012). DBTB limits with QLO to the north through the Ankang fault and with SCB to the south through the Tiexi fault (Shi et al., 2012, 2013); the formation is crossed by the Chengkou fault that separates two petrotectonic units called southern and northern DBTB (Zhang et al., 2010b; Shi et al., 2012, 2013). These two belts have complex structures along the transverse and longitudinal directions (Dong et al., 2011a, 2011b; Li et al., 2012; Shi et al., 2012, 2013).

The geological framework of QLO was built by the interaction of three blocks, namely: North Qinling, South Qinling and the South China Block, separated by the Shangdan and Mianlue sutures (Meng and Zhang, 2000). QLO has experienced a prolonged divergence and convergence between blocks (Zhang et al., 1996). During the period between the Late Neoproterozoic and the Early Paleozoic, South Qinling was the northern margin of the South China Block, while North Qinling was the southern margin of the North China Block, both formations separated by the Proto-Tethyan Qinling Ocean. North Qinling evolved into an active margin on the occasion of the northward subduction of the Proto-Tethyan Qinling Ocean during the Ordovician period. The collision between South and North Qinling took place in the Middle Paleozoic along the Shangdan suture. Synchronously with this collision, it occurred rifting on the southern border of South Qinling, which was followed by the opening of the Paleo-Tethys Ocean during the Late-Paleozoic and the splitting of the South China Block from South Qinling. The collision between South Qinling and the South China Block