Earth-Science Reviews 130 (2014) 1–48

Contents lists available at ScienceDirect

Earth-Science Reviews

journal homepage: www.elsevier.com/locate/earscirev

Geophysical constraints on the link between cratonization and orogeny: Evidence from the Tibetan Plateau and the North China Craton

Zhongjie Zhang [a,†], Jiwen Teng [a], Fabio Romanelli [b], Carla Braitenberg [b], Zhifeng Ding [c], Xuemei Zhang [a], Lihua Fang [c], Sufang Zhang [a], Jianping Wu [c], Yangfan Deng [a,d,*], Ting Ma [a], Ruomei Sun [a], Giuliano F. Panza [b,c,e]

[a] State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
[b] Department of Mathematics and Geosciences, University of Trieste, Via Weiss, I-34127 Trieste, Italy
[c] Institute of Geophysics, China Earthquake Administration, Beijing 100080, China
[d] Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China
[e] International Centre for Theoretical Physics, SAND Group, I-34151 Trieste, Italy

ARTICLE INFO

Article history:
Received 21 August 2013
Accepted 16 December 2013
Available online 30 December 2013

Keywords:
Cratonization
Orogeny
Tibetan Plateau
North China Craton
3D seismic and gravity tomography
Mantle flow

ABSTRACT

Understanding the geodynamic process of orogeny and cratonization, and their transition is among the key topics of research in evaluating the link between plate tectonics and continental dynamics. The Tibetan Plateau and the North China Craton (NCC), two key areas in mainland China, offer excellent laboratories to understand continental tectonics over a broad span of Earth history. Particularly, the deep structure of the lithosphere as imaged from geophysical data on the Tibetan Plateau and the NCC provide important clues in understanding orogeny and cratonization. The Tibetan Plateau is the largest and highest plateau on Earth in terms of mean altitude, and is an important region for understanding the mechanisms of continent–continent collision and Cenozoic plateau uplift. The NCC is an Archean craton that underwent lithospheric disruption during the Mesozoic. Here we reconstruct the main features of the structure of the crust and upper mantle from surface wave tomography and gravity modeling in Tibet and its neighboring regions, in order to understand the modality of the convergence and collision process between the Indian and Eurasian plates, and the influence of this process on the uplift of the plateau. In the NCC, geological, geochemical, geophysical and tectonic investigations demonstrate that lithospheric destruction mainly occurred in the Eastern Block. The crustal structure of the NCC is reconstructed from ambient noise surface wave tomography and the different possible disruption mechanisms are evaluated. The Vs (shear-wave velocity) tomography results, and the density (ρ) structure of the crust and upper mantle (to about 350 km depth) demonstrate the lateral variation of the thickness of the metasomatic lid between the south and north of the Bangong–Nujiang suture (BNS) and the west and east of Tibet, which suggest that the leading edge of the subducting Indian slab reaches the BNS. The subduction angle of Indian Plate indicates a transition from steep to shallow from the west to east Tibet. Sections depicting the gravitational potential energy suggest that mantle flow contributes to the subduction of the Indian Plate as far as the BNS and the transition from the asthenospheric layer to the metasomatic lid overlaps with the transition from north–south shortening in south Tibet to eastward tectonic escape in north Tibet (Qiangtang and Songpan–Ganzi blocks). Both Vs and ρ models suggest the following. (1) North–southward lower-crust flow beneath the eastern NCC and interaction between the westward mantle flow and eastward escape flow beneath the central NCC (in addition to the earlier proposed mechanisms of delamination and thermal erosion) played important roles in the lithospheric disruption of the Archean craton. (2) Mantle flow plays an important role in the continental tectonic transition between neighboring tectonic blocks and within the cycle between orogeny and cratonization.

Contents

* Corresponding author at: State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China.
E-mail addresses: dengyangfan@mail.iggcas.ac.cn (Y. Deng), panza@units.it (G.F. Panza).
† Deceased: [1964–2013].

0012-8252/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.earscirev.2013.12.005

1. Introduction

Since late 60s, plate tectonics has been accepted as the general framework that governs global tectonics with supportive evidence from multi-disciplinary investigations and considerably advanced our understanding of orogeny and the evolution of cratons. China mainland, composed of three tectonic domains: the Tethys, circum Pacific and Paleo-Asia (Fig. 1a), and subdivided into 18 tectonic units, is one of the excellent regions to evaluate continental dynamics (Yuan, 1996a, b; Li and Mooney, 1998; Zhang et al., 2011e; Teng et al., 2013). The Tibetan Plateau (Fig. 1b) and the North China Craton (NCC) (Fig. 1c) have been in global focus for two main reasons: (1) the Tibetan Plateau is a key area for the understanding of the Cenozoic (and ongoing) continent–continent collision (Yin and Harrison, 2000; Aitchison et al., 2011; Zhang et al., 2012), and (2) the NCC is one of the best natural laboratories to evaluate decratonization through Mesozoic lithospheric thinning (Zhai et al., 2007; Zhu and Zheng, 2009; G. Zhu et al., 2012; Zhang et al., 2012; Guo et al., 2013; Li et al., 2013a,b; Yang et al., 2013; Zhang et al., 2013b,c).

The Tibetan Plateau is characterized by a high mean altitude (>4000 m) and ongoing continent–continent collisional orogeny. This orogenic system has been largely created by the India–Asian collision over the past 70–50 million years, and is part of the greater Himalayan–Alpine system that extends from the Mediterranean Sea in the west, to the Sumatra arc of Indonesia in the east, over a distance of more than 7000 km (Yin, 2006). This extraordinarily long and complex amalgamated belt developed in response to the closure of the Tethys Ocean between two great landmasses, namely between Laurasia in the north and Gondwana in the south, a process that has been taking place since the Paleozoic (Hsü et al., 1995; Sengör and Natal'in, 1996).

The Himalayan–Tibetan orogen and its neighboring regions in East Asia are ideal regions for studying continent–continent collision (Yin, 2006). The mountain building process is active, so many geological relationships can be demonstrated directly using the methods of neotectonic studies (Armijo et al., 1989; Holt et al., 1995; Bilham et al., 1997; Lacassin et al., 1998; Van der Woerd et al., 1998; Larson et al., 1999; Shen and Jin, 1999; Shen et al., 2001). Secondly, the history of the plate boundary is well known, so the cause of intracontinental deformation can be quantitatively defined as a time-dependent, boundary-value problem (Peltzer and Tapponnier, 1988; Houseman and England, 1996; Kong and Bird, 1996; Peltzer and Saucier, 1996; Royden, 1996; Kong et al., 1997; Royden et al., 1997; Kumar et al., 2006). Thirdly, the collision process has produced a variety of geological characteristics, such as large-scale thrust, strike-slip and normal fault systems (Burg and Chen, 1984; Tapponnier et al., 1986; Burchfiel et al., 1992; Yin et al., 1994), leucogranite magmatism (Harrison et al., 1998), widespread volcanism (Deng, 1989; Arnaud et al., 1992; Turner et al., 1993; Chung et al., 1998; Deng, 1998), regional metamorphism (Le Fort, 1996; Searle, 1996) and the formation of intracontinental and continental-margin oceanic basins (Brias et al., 1993; Song and Wang, 1993). All these geological characteristics and processes may be useful