Gondwana Research 25 (2014) 1501–1516

Contents lists available at ScienceDirect

Gondwana Research

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

The carbonated source region of Cenozoic mafic and ultra-mafic lavas from western Qinling: Implications for eastern mantle extrusion in the northeastern margin of the Tibetan Plateau

Shao-cong Lai [a,*], Jiang-feng Qin [a], Jahanzeb Khan [b,c]

[a] State Key Laboratory of Continental Dynamics, Department of Geology, Northwest University, Xi'an 710069, China
[b] Geologie, Technische Universität Bergakademie Freiberg, 09599 Freiberg, Germany
[c] Institute of Geology, University of Azad Jammu and Kashmir Muzaffarabad, AJK 13100, Pakistan

ARTICLE INFO

Article history:
Received 29 October 2012
Received in revised form 27 May 2013
Accepted 28 May 2013
Available online 22 June 2013

Handling Editor: W.J. Xiao

Keywords:
Cenozoic
Northeastern margin of the Tibetan Plateau
Mantle extrusion
Carbonated source region
Mafic and ultra-mafic rocks

ABSTRACT

Cenozoic Indo-Asian collision caused significant crustal shortening in central Tibet. The strike-slip faults around the Tibetan Plateau (TP) are generally attributed to extrusion tectonics, resulting from lower crust flow. Therefore, the mantle extrusion site corresponding to the Cenozoic elevation of the TP needs to be identified. This paper reports the petrology and geochemistry of Cenozoic mafic and ultra-mafic volcanic rocks in the Xiahe and Lixian areas, at the northeastern margin of the TP. Detailed analysis indicates a regular change in partial melting conditions and source regions of the volcanic rocks from west to east, revealing a Cenozoic eastward mantle extrusion in the eastern margin of the TP. The Xiahe volcanic rocks display ocean island basalt affinity with negative K anomalies and positive Nb and Ta anomalies. They are alkaline with extremely high Na_2O/K_2O ratios and relatively enriched Sr–Nd–Pb isotopic compositions, indicating that these basalts were derived from partial melting of carbonated pyroxenite. The Lixian picro-basalts are closely associated with igneous carbonatites. They have relatively high TiO_2 (3.47–4.66%) and MgO (11.24–18.88%) contents and low SiO_2 (41.14–44.82%) and Al_2O_3 (5.84–9.18%) contents. Based on the depleted Sr–Nd–Pb isotopic compositions, we propose that the Lixian picro-basalts may have originated from the partial melting of carbonated lithosphere mantle peridotites at relatively high pressure (>3 GPa). Minor hornblendite in their source region can account for the high TiO_2 and $Na_2O + K_2O$ contents. Thus, we argue that these volcanic rocks were formed by episodic decompression melting of the carbonated mantle lithosphere during the eastward extrusion of the Tibetan lithosphere, in contrast to the conventional view that they were formed in a continental rift setting. Their partial melting and eruption processes may be closely related to the Cenozoic strike-slip fault activities in the northeastern margin of the TP.

1. Introduction

The Cenozoic Indo-Asian collision caused significant N–S crustal shortening of about 2000 km (Yin and Harrison, 2000; Xia et al., 2011; Zhang and Santosh, 2011) and significant uplift of the Tibetan Plateau up to 5000 m. It is the most spectacular example of mountain building, plateau development, and continental-scale strike-slip faulting on Earth (Schoenbohm et al., 2006; Xu et al., 2012). Several lines of evidence from geological, geo-chronological, and seismic studies indicate that strike-slip faults (Tapponnier et al., 1982, 2001; Bowman et al., 2003; Cao et al., 2011; Zhang et al., 2011) and lateral extrusion of blocks of Asian continent around the Tibetan Plateau (TP) (Clark and Royden, 2000) are significant controlling factors in the growth of the TP. Wang and Burchfiel (2004) proposed that there are three regions of different late Cenozoic and currently active deformations in the eastern margin of the TP: (1) the northeastern region, where displacement along the sinistral east-northeast-striking Altyn Tagh fault is transferred to northeast–southwest shortening in the Qilian Shan; (2) the central region, where the Longmen Shan rises to more than 6 km above the Sichuan basin, forming one of the steepest mountain fronts along any margin of the TP; and (3) the southwest region, where there is no prominent topographic break that defines the eastern margin of the plateau (Cao et al., 2011).

Cenozoic volcanic rocks in the TP display obvious and regular migration corresponding to the different stages of the Indo-Asian collision (Chung et al., 2005; Mo et al., 2006). The 65–70 Ma Linzizong arc volcanic rocks represent the start of the collision between India and Asia; 45–40 Ma post-collisional igneous rocks are subsequently found in the Qiangtang and northern part of the Sanjiang area, and the Miocene to Quaternary volcanic rocks in the Hoh Xil, Tengchong, and western Qinling are believed to result from the Indo-Asian collision (Mo et al., 2006; Hu et al., 2012). These migrations clearly suggest the lateral extrusion of the Tibetan lithosphere. However, whether the

* Corresponding author. Tel.: +86 29 88307610.
E-mail address: shaocong@nwu.edu.cn (S. Lai).

1342-937X/$ – see front matter.
http://dx.doi.org/10.1016/j.gr.2013.05.019

lateral extrusion only involved the lower crust, or the lithospheric mantle and asthenosphere were also involved is yet to be determined.

The TP is surrounded by the Pamirs block to the west, the Tarim block to the north, the Ordos block to the northeast, and the Yangtze block to the east. These blocks have thick lithosphere (Mo, 2011 and references therein; Li et al., 2012), which makes lateral extrusion against these blocks difficult. However, the weak channel along the Qinling and Sanjiang orogenic belt may have facilitated the lateral extrusion that resulted from Indo-Asian collision (Mo, 2011). Cenozoic potassic rocks (Huang et al., 2010) and igneous carbonatites (Hou et al., 2006) provide direct petrological evidence that mantle extrusion took place along the Sanjiang orogenic belt. Paleogene potassic and ultra-potassic rocks (Huang et al., 2010) in the Tengchong area, at the southeastern margin of the TP, were inferred to be derived from very low-degree decompression melting of metasomatized mantle lithosphere. Hou et al. (2006) reported Cenozoic igneous carbonatites at the eastern margin of the TP. They proposed that the carbonatites were formed by partial melting of the metasomatized mantle and that they represent the transition from transpression to transtension at the Eocene/Oligocene boundary at the eastern margin of the TP.

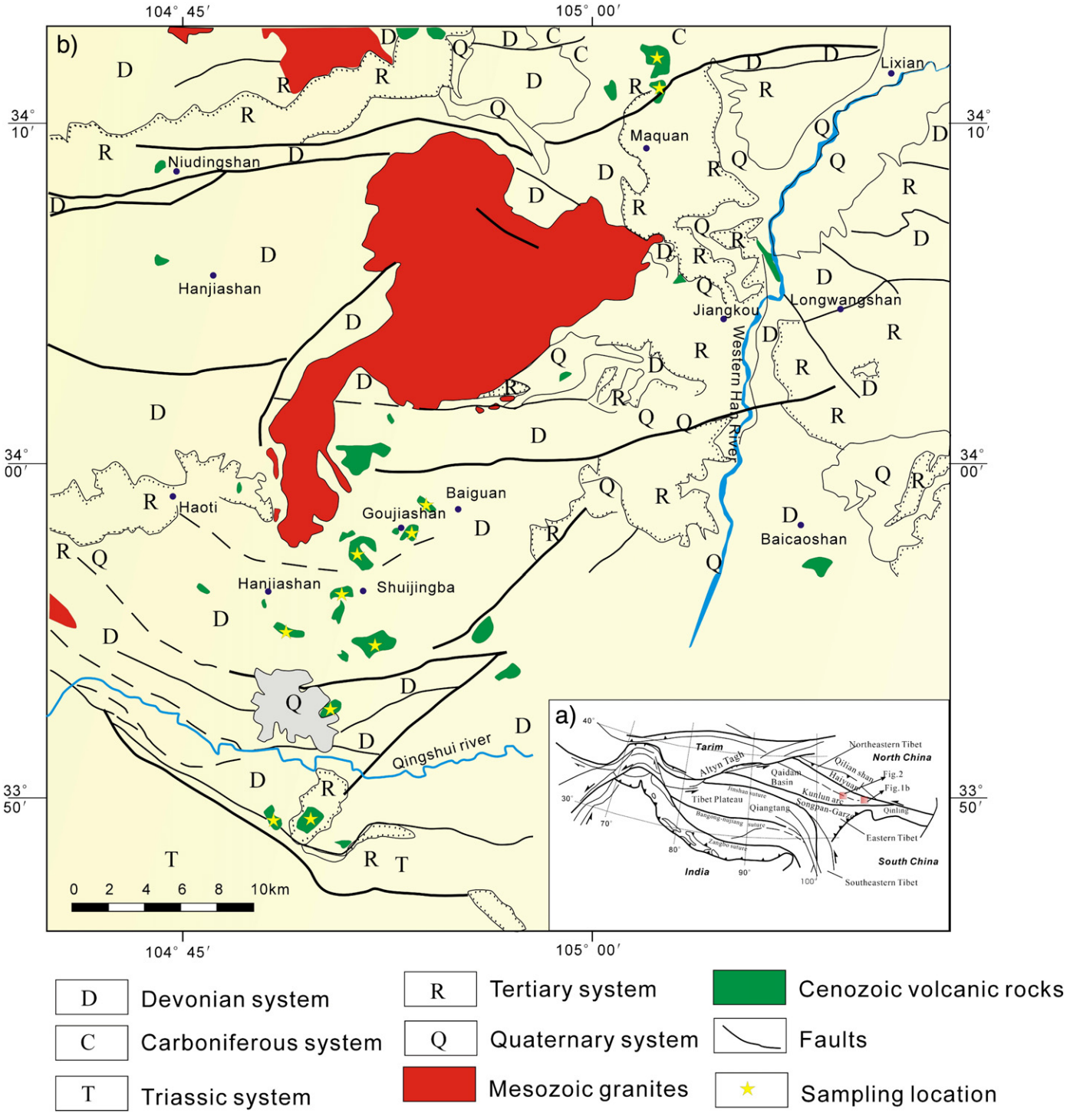

Fig. 1. (a) Simplified geological map of the Tibetan plateau and surrounding areas; (b). Sketch geological map of the Lixian area. Panel (a) is modified from Enkelmann et al. (2006).