Chemical Geology 255 (2008) 329–345

Contents lists available at ScienceDirect

Chemical Geology

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

Zircon U–Pb geochronology and major, trace elemental and Sr–Nd–Pb isotopic geochemistry of mafic dykes in western Shandong Province, east China: Constrains on their petrogenesis and geodynamic significance

Shen Liu [a,b,*], RuiZhong Hu [a], Shan Gao [b], CaiXia Feng [a], Liang Qi [a], Hong Zhong [a], Tangfu Xiao [a], YouQiang Qi [a], Tao Wang [a], Ian M. Coulson [c]

[a] *State Key Laboratory of Ore Deposit Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550002, PR China*
[b] *State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan 430074, PR China*
[c] *Solid Earth Studies Laboratory, Department of Geology, University of Regina, Regina. Saskatchewan, Canada S4S 0A2*

ARTICLE INFO

Article history:
Received 29 November 2007
Received in revised form 10 July 2008
Accepted 11 July 2008

Editor: R.L. Rudnick

Keywords:
Mesozoic
Mafic dykes
Sr–Nd–Pb isotopes
Geochemistry
Lithsopheric mantle
North China Craton

ABSTRACT

Mesozoic mafic dykes in western Shandong Province (Luxi), SE, the North China Craton (NCC) provide an opportunity to examine the nature of their mantle source and the secular evolution of the Mesozoic lithospheric mantle beneath SE NCC. Chronological, geochemical and Sr–Nd–Pb isotopic analyses were carried out on two selected Mesozoic mafic dykes from Mengyin and Zichuan in western Shandong, respectively. Detailed SHRIMP zircon U–Pb dating yields emplacement ages of 144±2 Ma for the Mengyin mafic dykes and of 143±2 Ma for the Zichuan mafic dykes. Both are enriched in LILE (Rb, Ba, Sr, Pb) and LREE without Eu anomalies, but are depleted in HFSE (Nb, Ta and Ti). The dykes have relatively radiogenic Sr ($^{87}Sr/^{86}Sr)_i$ (0.706~0.707) and negative $\varepsilon_{Nd}(t)$ (−6.5 to −4.4), but remarkably unradiogenic Pb ($^{206}Pb/^{204}Pb$=16.99–18.36). Both dykes may have experienced crystal fractionation of olivine and clinopyroxene. The Mengyin mafic dykes are characterised by high MgO (9.66–17.97 wt.%), Mg# (66–74), Cr (809–1208 ppm) and Ni (171–390 ppm), indicative of derivation from mantle-derived melts with minor fractionation. In contrast, the Zichuan mafic dykes have relatively low MgO (3.38–4.14 wt.%), Cr (24–56 ppm) and Ni (14–24 ppm), suggesting that they may have originated from an extremely evolved magma. There is evidence in support of multiple enrichment events induced by hybridism of foundering lower crust at mantle depths. For example, phlogopite, amphibole and rutile metasomatism may have affected the lithospheric mantle beneath Mengyin, whereas phlogopite and carbonatite metasomatism modified the lithospheric mantle below Zichuan. This study sheds light also on the geodynamic significance of the 144–143 Ma mafic dykes, for example, we propose that lithospheric thinning underneath southeastern NCC of eastern China was caused by the removal of the lower lithosphere (mantle and lower crust).

1. Introduction

It is generally accepted that more than 100 km of ancient refractory lithospheric mantle beneath eastern North China Craton (NCC) has been removed and replaced by young and fertile mantle material in the late Mesozoic between the late Jurassic and early Cretaceous (Menzies et al., 1993; Griffin et al., 1998; Zheng and Lu, 1999; Fan et al., 2000; Xu, 2001; Gao et al., 2002; Zhou et al., 2002; Guo et al., 2003; Wu et al., 2003a; Yang et al., 2003; Wilde et al., 2003; Zhang et al., 2004). Such change is evidenced by the loss of physical integrity of the NCC as a result of the Triassic collision between the NCC and the Yangtze Block (Xu, 2001; Zhang et al., 2002). However, the exact timing of the lithospheric destruction beneath the NCC is poorly constrained. A number of controversial mechanisms are given in several hypotheses proposed for the lithosphere thinning beneath NCC; these include extension, delamination or foundering and thermal/chemical erosion (Zheng and Lu, 1999; Lu et al., 2000; Xu, 2001; Wu et al., 2003b; Gao et al., 2004).

Available isotopic data from late Mesozoic magmatic rocks in southern NCC indicate that their mantle domains are heterogeneous, including refractory lithosphere, EM1-like mantle to EM2-like mantle (Zhang et al., 2004). The transformation of the lithospheric architecture may be related to deep subduction of the Yangtze Craton and its subsequent collision with NCC during the Triassic (240~220 Ma), as suggested by seismic tomographic data and on mineralogical evidence (Xu et al., 1992; Ye et al., 2000; Liu et al., 2001; Xu et al., 2001; Zhang et al., 2002; Zhang et al., 2005a). Melts from the subducted crustal materials fertilized the overlying lithospheric mantle beneath the southern NCC, as reflected in the Mesozoic mantle-derived basaltic

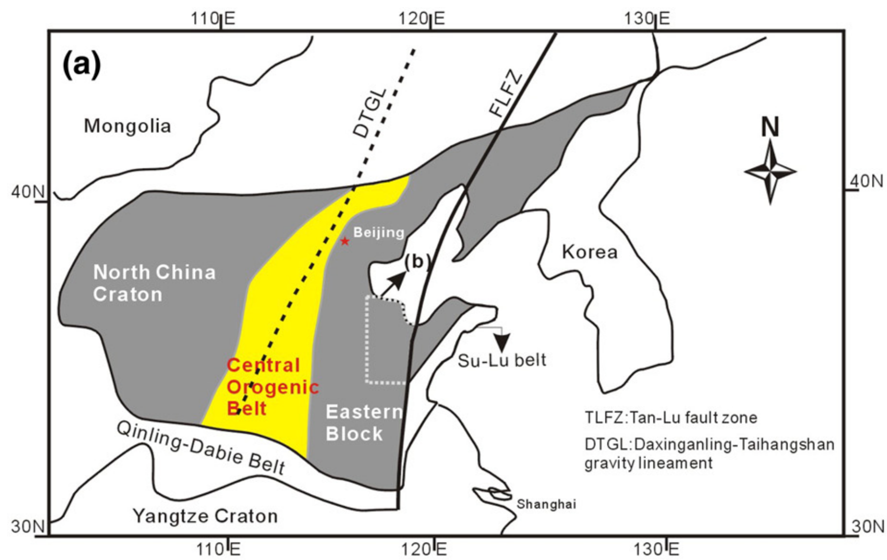
* Corresponding author. State Key Laboratory of Ore Deposit Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550002, PR China. Tel.: +86 851 5891962; fax: +86 851 5891664.
E-mail address: liushen@vip.gyig.ac.cn (S. Liu).

0009-2541/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.chemgeo.2008.07.006

rocks and alkaline complexes (Zhang et al., 2002, 2004, 2005a,b; Liu et al., 2006). Nevertheless, different opinions on the genesis and spatial distribution of enriched mantle still exist within southern NCC (e.g., Xu et al., 2004a; Zhai et al., 2004). Furthermore, there is wide debate relating to how the subduction of paleo-Pacific plate affected magmatic activities and the lithospheric architecture within southern NCC (e.g., Chen et al., 2004; Zhang et al., 2005b).

Consequently, systematic geochronological, geochemical and isotopic investigations of all the late Mesozoic lithospheric mantle samples in NCC are needed. Age constraints and the geochemistry of mantle xenoliths, gabbroic complexes and basalts in many localities of NCC have been well documented (Xu et al., 1993, 2003; Chen et al., 1997; Zheng et al., 1999; Fan et al., 2001; Guo et al., 2001; Qiu et al., 2002; Zhang et al., 2002, 2003, 2004; Zhang and Sun, 2002; Xu et al., 2001, 2003, 2004a; Yan et al., 2003a; Chen and Zhou, 2004, 2005). However, because of a paucity of the Mesozoic mantle-derived samples in NCC, detailed age constraints and geochemistry are still scarce (Yan et al., 2003a).

Mafic dykes of Mesozoic age are widespread in the NCC, occurring as NE–NW-trending swarms. These mafic dykes formed as a result of considerable extension of the continental lithosphere (Hall, 1982; Hall and Fahrig, 1987; Tarney and Weaver, 1987; Zhao and McCulloch, 1993). Studies of these rift-related mafic dyke swarms are essential for understanding generation of such extensive mafic magmatism, which can provide valuable information about the Mesozoic lithospheric evolution beneath the NCC (Liu et al., 2004, 2006). Some investigations on these mafic dykes have been carried out, and the available K–Ar and Ar–Ar dates range from 230 Ma to 88 Ma (Shao and Zhang, 2002, and references therein; Liu et al., 2004, and references therein). Mesozoic mafic dykes are widely distributed in Luxi and Jiaodong, respectively (Liu et al., 2004, 2006). The published K–Ar ages for these dykes vary from 143 Ma to 88 Ma in Luxi (Mengyin and Zichuan), and



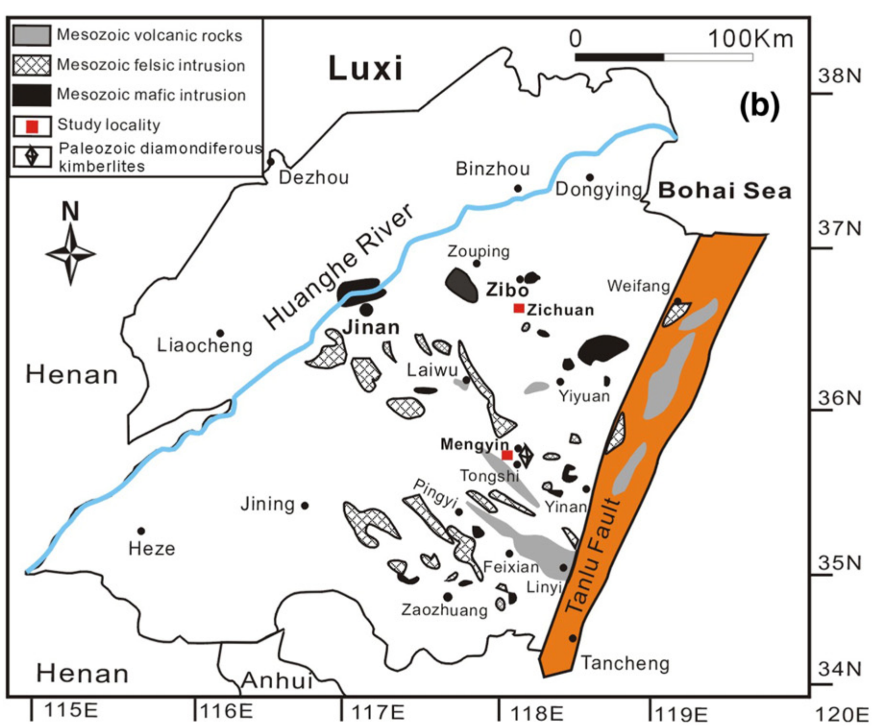


Fig. 1. a. Simplified tectonic map of eastern China (modified after Xu, 2002). b. The geological map of Luxi and the sampling localities of the Mengyin and Zichuan mafic dykes.