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# A Possible Mechanism to Thin Lithosphere of the North China Craton: Insights from Cretaceous Mafic Dikes in the Jiaodong Pensinsula

MA Liang[1], JIANG Shaoyong[2], Albrecht W. Hofmann[3,4] and XU Yigang[1]

*1 State Key Laboratory of Isotope Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, 510640, China*
*2 State Key Laboratory of Geological Processes and Mineral Resources and Collaborative Innovation Center for Exploration of Strategic Mineral Resources, Faculty of Earth Resource, China University of Geosciences, Wuhan, 430074, China*
*3 Max-Planck-Institut für Chemie, Postfach 3060, D-55020 Mainz, Germany*
*4 Lamont-Doherty Earth Observatory of Columbia University, P.O. Box 1000, Palisades, NY 10964, USA*

The North China Craton (NCC) is a classic case of the destruction of an ancient craton, in that it records the loss of more than 100 km of ancient refractory lithospheric mantle during the Mesozoic (e.g., Menzies et al., 1993). This fundamental change in lithospheric architecture has attracted considerable attention over the last three decades, but the specific deep-level processes associated with the thinning of the lithosphere are still being actively debated. Thermo-mechanical-chemical erosion and rapid lithospheric delamination are two major hypotheses that have been suggested for the mode of lithospheric thinning. The former represents a slow thinning process lasting at least 100 Ma, whereas the latter marks a short event lasting about 10 Ma (Menzies et al., 2007). Asthenospheric mantle -derived mafic rocks are important indicators related to cratonic destruction, and they help us to resolve the above questions of timing and mechanism of lithospheric thinning. The thinning process is generally accompanied by upwelling of the convective asthenosphere and modification of the thermal structure of the lithosphere. During lithospheric extension, the source of magmas can shift from the lithosphere to the asthenosphere (Xu et al., 2009). Normally, the asthenosphere beneath an old craton cannot melt until the thickness of the lithosphere is markedly thinned (e.g., McKenzie and Bickle, 1988). Two key questions in constraining the mechanism of lithospheric thinning beneath the NCC are: (1) When did the magma source shift from lithospheric to asthenospheric mantle. (2) Was this transition a relatively "slow", or a "rapid" process (Ma et al., 2014a).

* Corresponding author. E-mail: njumaliang@163.com

The Mesozoic asthenospheric mantle-derived mafic rocks are key to understanding the thinning processes. However, the occurrences of asthenosphere-derived magmas during the Mesozoic in the NCC are extremely limited. Three places have been found recording the transition in magma source from a lithospheric to an asthenospheric mantle, including the Fuxin basalts (107–97 Ma) in the western Liaoning province (Zhang et al., 2003), the Daxizhuang alkali basalts (73 Ma) and Pishikou mafic dikes (86–78 Ma) in the Jiaodong Peninsula (Yan et al., 2003; Zhang et al., 2008). Recently, we reported on earlier (~120 Ma) asthenospheric mantle-derived high-Ti lamprophyres in the Jiaodong Peninsula, clearly demonstrating the asthenosphere mantle melting during the early Cretaceous (Ma et al., 2014a). Here, we report new zircon U–Pb geochronology, elemental geochemistry, and Sr–Nd–Hf isotopic data for lamprophyres and diabase-porphyries of the Jiaodong Peninsula in order to further place constraints on models for lithospheric thinning. Our results show that the lamprophyres and diabase-porphyries are derived from the convective asthenospheric mantle via different degrees of partial melting, and that this mantle source was previously modified by carbonatitic liquids. Zircon LA-ICP-MS U–Pb dating suggests an emplacement age for these rocks of 123–121 Ma, the earliest evidence for asthenospherically-derived melts in the Jiaodong Peninsula so far. This emplacement age indicates that the thickness of the lithosphere in the Jiaodong Peninsula was relatively thin at that time. Co-occurrence of the asthenospheric and lithospheric mantle-derived mafic rocks as well as high-Mg adakites record a rapid transition from lithospheric to

asthenospheric mantle sources, indicating that the lithosphere beneath the Jiaodong Peninsula was rapidly detached just prior to ca. 120 Ma (Ma et al., 2016).

Previous studies revealed that the collision of the Yangtze Craton with the NCC took place in the Triassic (e.g., Li et al., 1993). The few Late Triassic syenite and mafic dikes in eastern Jiaodong are generally thought to represent a post-orogenic extensional regime resulting from such a collision (Yang et al., 2005; Zhao et al., 2012). The Palaeo-Pacific plate was subducted beneath the Eurasian continent before Jurassic time (e.g., Maruyama et al., 1997) This resulted in crustal thickening in eastern China and partial melting of pre-existing ancient crust (Wu et al., 2005), and the formation of low-Mg adakitic granites in the Jiaodong Peninsula such as the Linglong and Kunyushan granites (e.g., Zhang et al., 2010; Ma et al., 2013). During the Early Cretaceous, large-scale magmatism occurred within a short period, including both lithospheric and asthenospheric mantle-derived mafic rocks as well as high-Mg adakites (e.g., Yang et al., 2004; Ma et al., 2014a, 2014b). After this period, all magmas were sourced in the asthenosphere, and magmatism within the lithosphere became nearly extinct. Thus, the transition from lithospheric to asthenospheric mantle sources took place about 120 Ma ago, and this transition was a relatively rapid process, in ~10 Myrs. Thus, the NCC probably experienced a catastrophic lithospheric thinning event at ca.120 Ma. Geophysical data show that the lithosphere today is very thin (60–100 km) beneath the Jiaodong Peninsula and Bohai Sea, but that it is 100–150 km thick in the surrounding areas (e.g., Xu and Zhao, 2009). Coincidentally, Mesozoic asthenospheric mantle-derived mafic rocks are exclusively distributed in the Jiaodong Peninsula and on the northern margin of the Bohai Sea. It therefore appears that the Jiaodong and Bohai areas were the center of lithospheric thinning beneath the NCC. If true, the rapid lithospheric delamination of the Jiaodong Peninsula and Bohai Sea would have induced decompressional melting of upwelling asthenospheric mantle to generate asthenospheric mantle-derived magmas, while the subcontinental lithospheric mantle was heated by the underlying convective asthenosphere and underwent partial melting to generate lithospheric mantle-derived magmas. Underplating of these hot mafic magmas would result in remelting of the lower crust and magma mixing to generate the high-Mg adakites. The rapid lithospheric delamination of the Jiaodong Peninsula and Bohai Sea would thus induce thermo-mechanical erosion of surrounding area of the NCC. Thus, the large-scale lithospheric thinning of the NCC may have been initiated beneath the Jiaodong Peninsula and Bohai Sea and then propagated towards the interior of the continent.

**References**

Li, S.G., Xiao, Y.L., Liou, D.L., Chen, Y.Z., Ge, N.J., Zhang, Z.Q., Sun, S.S., Cong, B.L., Zhang, R.Y., Hart, S.R., Wang, S.S., 1993. Collision of the North China and Yangtse Blocks and formation of coesite-bearing eclogites: timing and processes. Chemical Geology 109, 89–111.

Ma, L., Jiang, S.Y., Dai, B.Z., Jiang, Y.H., Hou, M.L., Pu, W., Xu, B., 2013. Multiple sources for the origin of Late Jurassic Linglong adakitic granite in the Shandong Peninsula, eastern China: Zircon U–Pb geochronological, geochemical and Sr–Nd–Hf isotopic evidence. Lithos 162-163, 251–263.

Ma, L., Jiang, S.Y., Hofmann, A.W., Dai, B.Z., Hou, M.L., Zhao, K.D., Chen, L.H., Li, J.W., Jiang, Y.H., 2014a. Lithospheric and asthenospheric sources of lamprophyres in the Jiaodong Peninsula: a consequence of rapid lithospheric thinning beneath the North China Craton? Geochimica et Cosmochimica Acta 124, 250–271.

Ma, L., Jiang, S.Y., Hou, M.L., Dai, B.Z., Jiang, Y.H., Yang, T., Zhao, K.D., Pu, W., Zhu, Z.Y., Xu, B., 2014b. Geochemistry of Early Cretaceous calc-alkaline lamprophyres in the Jiaodong Peninsula: implication for lithospheric evolution of the eastern North China Craton. Gondwana Research 25, 859–872.

Ma, L., Jiang, S.Y., Hofmann, A.W., Xu, Y.G., Dai, B.Z., Hou, M.L., Rapid lithospheric thinning of the North China Craton: New evidence from Cretaceous mafic dikes in the Jiaodong Peninsula. Chemical Geology, 432: 1–15.

Maruyama, S., Isozaki, Y., Kimura, G., Terabayashi, M., 1997. Paleogeographic maps of the Japanese Islands: Plate tectonic synthesis from 750 Ma to the present. Island Arc 6, 121–142.

Mckenzie, D.P., Bickle, M.J., 1988. The volume and composition of melt generated by extension of the lithosphere. Journal of Petrology 29, 625–679.

Menzies, M.A., Fan, W.M., Zhang, M., 1993. Palaeozoic and Cenozoic lithoprobes and the loss of >120 km of Archaean lithosphere, Sino-Korean craton, China, In: Prichard, H.M., Alabaster, T., Harris, N.B.W., Neary, C.R. (Eds.), Magmatic processes and plate tectonics. Geological Society Special Publications, pp. 71–78.

Menzies, M.A., Xu, Y.G., Zhang, H.F., Fan, W.M., 2007. Integration of geology, geophysics and geochemistry: A key to understanding the North China Craton. Lithos 96, 1–21.

Wu, F.Y., Yang, J.H., Wilde, S.A., Zhang, X.O., 2005. Geochronology, petrogenesis and tectonic implications of Jurassic granites in the Liaodong Peninsula, NE China. Chemical geology 221, 127–156.

Xu, Y.G., Li, H.Y., Pang, C.J., He, B., 2009. On the timing and duration of the destruction of the North China Craton. Chinese Science Bulletin 54, 3379–3396.

Yan, J., Chen, J.F., Xie, Z., 2003. Mantle xenoliths from Late Cretaceous basalt in eastern Shandong Province: New constraint on the timing of lithospheric thinning in eastern China. Chinese Science Bulletin 48, 2139–2144.

Yang, J.H., Chung, S.L., Zhai, M.G., Zhou, X.H., 2004. Geochemical and Sr–Nd–Pb isotopic compositions of mafic dikes from the Jiaodong Peninsula, China: evidence for vein-plus-peridotite melting in the lithospheric mantle. Lithos 73, 145–160.

Yang, J.H., Chung, S.L., Wilde, S.A., Wu, F.Y., Chu, M.F., Lo, C.H., Fan, H.R., 2005. Petrogenesis of post-orogenic syenites

in the Sulu Orogenic Belt, East China: geochronological, geochemical and Nd-Sr isotopic evidence. Chemical Geology 214, 99–125.

Zhang, H.F., Sun, M., Zhou, X.H., Zhou, M.F., Fan, W.M., Zheng, J.P., 2003. Secular evolution of the lithosphere beneath the eastern North China Craton: evidence from Mesozoic basalts and high-Mg andesites. Geochimica et Cosmochimica Acta 67, 4373–4387.

Zhang, J., Zhang, H.F., Ying, J.F., Tang, Y.J., Niu, L.F., 2008. Contribution of subducted Pacific slab to Late Cretaceous mafic magmatism in Qingdao region, China: A petrological record. Island Arc 17, 231–241.

Zhao, Z.F., Zheng, Y.F., Zhang, J., Dai, L.Q., Li, Q.L., Liu, X.M., 2012. Syn-exhumation magmatism during continental collision: evidence from alkaline intrusives of Triassic age in the Sulu orogen. Chemical Geology 328, 70–88.

Zhang, J., Zhao, Z.F., Zheng, Y.F. Dai, M.N., 2010. Postcollisional magmatism: Geochemical constraints on the petrogenesis of Mesozoic granitoids in the Sulu orogen, China. Lithos 119: 512–536.