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Constraining lithospheric removal and asthenospheric input to melts in Central Asia: A geochemical study of Triassic to Cretaceous magmatic rocks in the Gobi Altai (Mongolia)

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ABSTRACT

Throughout northeast China, eastern and southern Mongolia, and eastern Russia there is widespread Mesozoic intracontinental magmatism. Extensive studies on the Chinese magmatic rocks have suggested lithospheric mantle removal was a driver of the magmatism. The timing, distribution and potential diachroneity of such lithospheric mantle removal remains poorly constrained. Here, we examine successions of Mesozoic lavas and shallow intrusive volcanic plugs from the Gobi Altai in southern Mongolia that appear to be unrelated to regional, relatively small-scale deformation; at the time of magmatism, the area was ~200 km from any active margin, or, after its Late Jurassic-Early Cretaceous closure, from the suture of the Mongol-Okhotsk Ocean. $^{40}Ar/^{39}Ar$ radiometric age data place magmatic events in the Gobi Altai between ~220 to 99.2 Ma. This succession overlaps Chinese successions and therefore provides an opportunity to constrain whether Mesozoic lithosphere removal may provide an explanation for the magmatism here too, and if so, when.

We show that Triassic to Lower Cretaceous lavas in the Gobi Altai (from Dulaan Bogd, Noyon Uul, Bulgantiin Uul, Jaran Bogd and Tsagaan Tsav) are all light rare-earth element (LREE) and large-ion lithophile element (LILE)-enriched, with negative Nb and Ta anomalies ($\frac{Nb}{La}$ and $\frac{Ta}{La} \leq 1$). Geochemical data suggest that these lavas formed by low degrees of partial melting of a metasomatised lithospheric mantle that may have been modified by melts derived from recycled rutile-bearing eclogite. A gradual reduction in the involvement of garnet in the source of these lavas points towards a shallowing of the depth of melting after ~125 Ma.

By contrast, geochemical and isotope data from the youngest magmatic rocks in the area — 107-99 Ma old volcanic plugs from Tsost Magmatic Field — have OIB-like trace element patterns and are interpreted to have formed by low degrees of partial melting of a garnet-bearing lherzolite mantle source. These rocks did not undergo significant crustal contamination, and were derived from asthenospheric mantle. The evidence of a gradual shallowing of melting in the Gobi lava provinces, culminating in an asthenospheric source signature in the youngest magmatic rocks is similar to examples from neighboring China, emphasising the wide-scale effect of a regional Mesozoic magmatic event during similar time periods. We suggest that Mongolia underwent lithospheric thinning/delamination during the Mesozoic (between ~125 and ~107 Ma) with patchy areas thinning sufficiently to enable the generation of relatively small-scale asthenospheric-derived magmatism to predominate in the late Cretaceous.

1. Introduction

Mesozoic mafic-intermediate magmatic rocks crop out over an estimated 9800 km^2 across southern and eastern Mongolia (Fig. 1A). The Mesozoic magmatism stretches from the Greater Xing'an Mountains in northeast China to far-east Russia (e.g., Badarch et al., 2002; Dash et al., 2015; Fan et al., 2003; Meng, 2003; Van Hinsbergen et al., 2008, 2015; Wang et al., 2006; Yarmolyuk and Kovalenko, 2001), largely within a Neoproterozoic to Mesozoic orogen known as the Central Asian Orogenic Belt (CAOB) (e.g., Windley et al., 2007; Xiao et al., 2015 and references therein). This widespread, low-volume magmatism is located within the east Asian continental interior, far away from continental margins, and its cause remains enigmatic.

Magmatism is often linked to plate boundary processes, either subduction or rifting and spreading, but such an explanation for the

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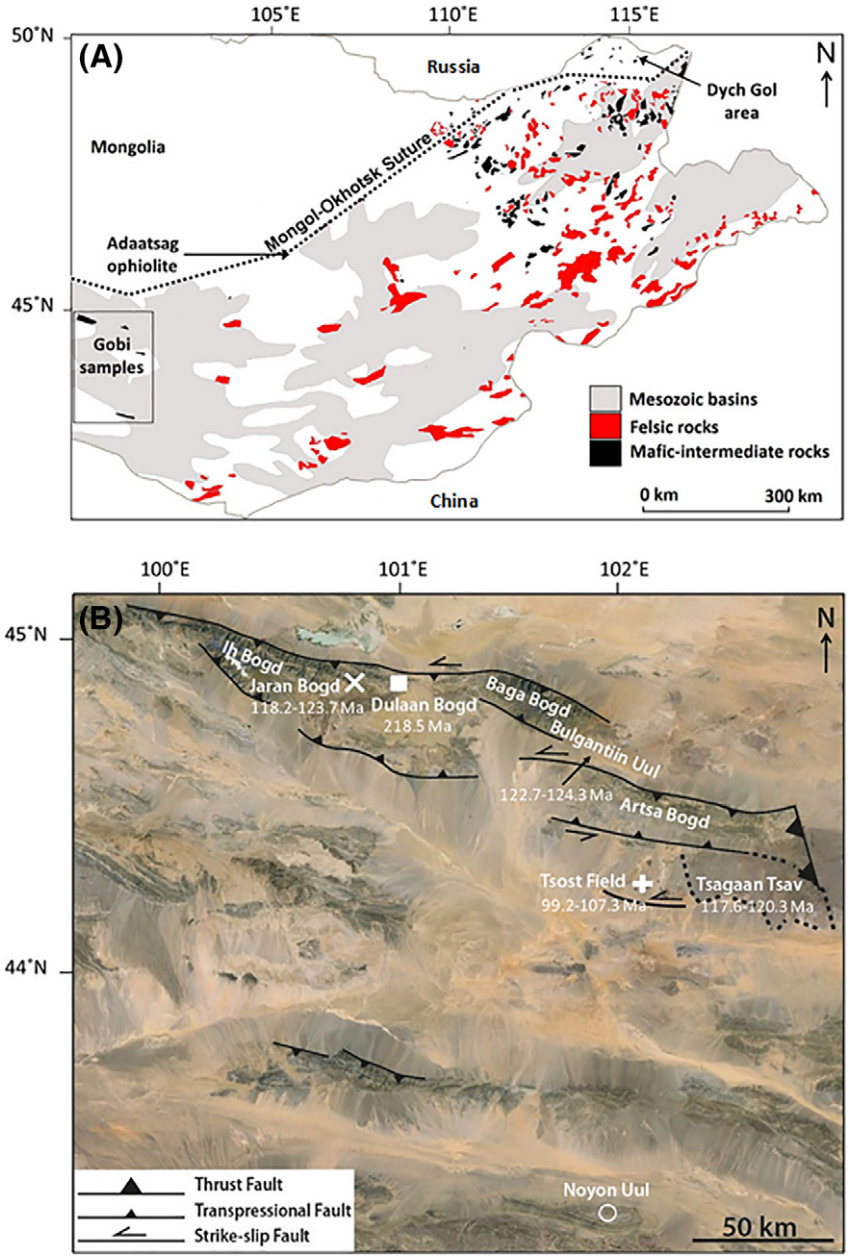

Fig. 1. (A) A sketch map of Mongolia showing the sample area (boxed area) and the distribution of Mesozoic mafic to intermediate lavas. Felsic magmatism is also shown, but age relationships are often not established. The distribution of volcanism is based on Mongolian government geological maps and field observations. The distribution of Mesozoic sedimentary basins is from Johnson et al. (2003). (B) A portion of the Gobi Altai showing our field localities (Google Earth). Information on the distribution of faults is taken from Van Hinsbergen et al. (2008).

magmatism of central Asia is problematic. Most of the formation of the CAOB occurred via subduction processes in the Palaeozoic, which came to a halt in the Triassic (e.g., Xiao et al., 2015). Subduction of Paleo-Pacific lithosphere in the east, or Neotethys lithosphere in the south, occurred >2000 km away from Mongolian Mesozoic lava fields (e.g., Torsvik and Cocks, 2017; Van Hinsbergen et al., 2015). The Mongolian Mesozoic magmatism often appears to be spatially and temporally related to the widespread formation of extensional sedimentary basins (e.g., Meng, 2003; Johnson et al., 2014; Van Hinsbergen et al., 2015). Interbedded sedimentary and basaltic successions in some of the Mongolian Mesozoic extensional basins reach up to 3 km in thickness (Graham et al., 2012), but these large cumulative thicknesses of Mesozoic magmatism are inconsistent with the existence of only relatively small-scale (half)-grabens that would have accommodated no more than a few kilometres of extension (e.g., Johnson et al., 2014; Van Hinsbergen et al., 2015). Therefore, while this regional extension may be related to the same geodynamic process that caused the volcanism, the small magnitude of the extension makes it unlikely to have been the cause of the magmatism. The only plate boundary that was active in the vicinity of the Mongolian magmatic fields during the earlier part of their formation was the subduction zone associated with the closure of the Mongol-Okhotsk Ocean, which was active until latest Jurassic - earliest Cretaceous time (Cogné et al., 2005; Van der Voo et al., 2015). Yet this boundary was distant from the penecontemporaneous magmatism in the North China Craton where volcanic rocks and xenolith data have led to suggestions for widespread lithosphere removal during the Mesozoic (e.g., Gao et al., 2002; Menzies et al., 1993; Windley et al., 2010). Within Mongolia, the presence of Mesozoic extensional basins, A-type granites and extensive mafic, and subordinate felsic volcanism have been suggested as evidence for similar