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The timing and extent of the eruption of the Siberian Traps large igneous province: Implications for the end-Permian environmental crisis

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ABSTRACT

We present new high-precision $^{40}Ar/^{39}Ar$ ages on feldspar and biotite separates to establish the age, duration and extent of the larger Siberian Traps volcanic province. Samples include basalts and gabbros from Noril'sk, the Lower Tunguska area on the Siberian craton, the Taimyr Peninsula, the Kuznetsk Basin, Vorkuta in the Polar Urals, and from Chelyabinsk in the southern Urals. Most of the ages, except for those from Chelyabinsk, are indistinguishable from those found at Noril'sk. Cessation of activity at Noril'sk is constrained by a $^{40}Ar/^{39}Ar$ age of 250.3±1.1 Ma for the uppermost Kumginsky Suite.

The new $^{40}Ar/^{39}Ar$ data confirm that the bulk of Siberian volcanism occurred at 250 Ma during a period of less than 2 Ma, extending over an area of up to 5 million km^2. The resolution of the data allows us to confidently conclude that the main stage of volcanism either immediately predates, or is synchronous with, the end-Permian mass extinction, further strengthening an association between volcanism and the end-Permian crisis. A sanidine age of 249.25±0.14 Ma from Bed 28 tuff at the global section and stratotype at Meishan, China, allows us to bracket the P–Tr boundary to 0.58±0.21 myr, and enables a direct comparison between the $^{40}Ar/^{39}Ar$ age of the Traps and the Permo–Triassic boundary section.

Younger ages (243 Ma) obtained for basalts from Chelyabinsk indicate that volcanism in at least the southern part of the province continued into the Triassic.

1. Introduction

The outpouring of enormous volumes of magma during short periods of time produces so-called large igneous provinces (LIPs) on the Earth's seafloor and continents. The origins of these LIPs and the influences they might have on the climate, in particular continental provinces, are matter of current and vigorous debate. The Siberian Traps represent the largest continental flood basalt province, and they have been linked to the end-Permian crisis, the largest known mass extinction (Erwin, 1994; Wignall, 2001). The degassing of magma accompanied by the volcanic eruptions has been implicated in changes to global climate and, ultimately, as the cause of mass extinctions (Rampino and Stothers, 1988; Wignall, 2001). Although the details of the links between the volcanism and the extinctions are unclear, a prerequisite to establishing a causal relationship between volcanism and extinction is the relative timing of the two events. Furthermore, despite representing the largest continental LIP, the extent and volume of the Siberian Traps province still remain hugely controversial, demonstrated by the range of published figures (e.g., Reichow et al., 2002; Dobretsov, 2005). For example, it is often suggested that outlying volcanic rocks exposed in Taimyr, the Urals and the Kuznetsk Basin, and buried beneath the West Siberian Basin (WSB) form part of the Siberian Traps volcanic activity (e.g., Dobretsov,

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2005), but precise age determinations with which to confirm or dismiss these correlations have yet to be confirmed.

Age and volume estimates are required not only for understanding any link between volcanism and the end-Permian crisis, but also to develop models for the formation of the Traps. Was activity for the entire province restricted to one short pulse of magmatic activity, or was volcanism more protracted? Is there any evidence for migration of volcanic centres both spatially and temporally?

In this contribution we present new, high-precision $^{40}Ar/^{39}Ar$ dates on basalt plagioclase feldspar and gabbro biotite separates from the Siberian large igneous province. Our aim is to refine the timing of the emplacement of the province, and to assess its geographical extent. To this end we have analysed a series of samples from Noril'sk and Tunguska on the main outcrop of the Traps exposed on the Siberian craton and from a series of geographically dispersed outliers of basalt (previously recognised as Permo–Triassic or Triassic in the literature; e.g. Milanovskiy, 1976) in Taimyr, Urals Mountains, and the Kuznetsk Basin (Fig. 1, modified after Reichow et al., 2002; Surkov, 2002; Kletz et al., 2007). We also analysed a set of sanidine feldspar separates from Bed 28 of the Permo–Triassic Global Stratotype and Section, Meishan (previously dated by Bowring et al., 1998), for calibration purposes. This will also aid in refining the timing of deposition between Meishan Beds 25 and 28 bracketing the P–Tr boundary.

2. Geological setting of sampling localities

2.1. Noril'sk and Putorana

The most visible manifestation of the Siberian Traps are outcrops on the Siberian craton covering ~2.5×10^6 km^2 (Lur'ye and Masaytis, 1964; Fedorenko et al., 1996). Noril'sk and Putorana are the most intensively sampled and analysed regions of the Siberian LIP (e.g., Fedorenko et al., 1996; Sharma, 1997). The Noril'sk volcanics reach a total thickness of ~3.5 km, and the uppermost 1.5 km comprises three formations or suites that correlate with lavas in Putorana (where the total thickness is nearly 2 km) and Lower Tunguska (up to 1 km). These uppermost formations represent about 90% of the erupted volume on the craton.

The Noril'sk succession and parts of Putorana have been extensively radiometrically dated (Renne and Basu, 1991; Campbell et al.,

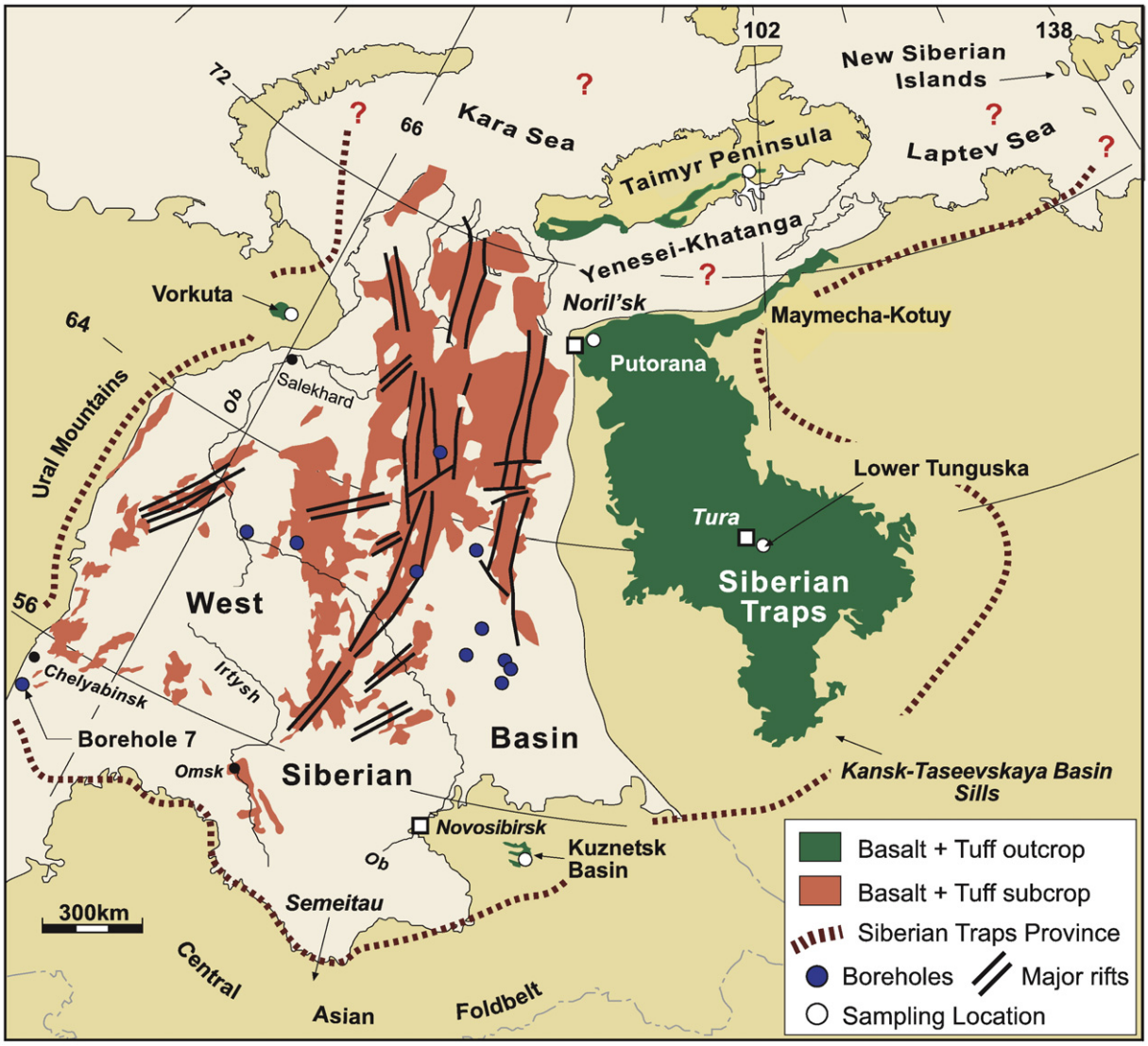

Fig. 1. Simplified geological map of the Siberian Traps large igneous province and surrounding areas. The dashed line indicates the suggested extent of Permo–Triassic volcanism in the province. Unconfirmed evidence suggests that the Siberian Traps extend much farther to the north beneath the Kara (e.g. Vyssotski et al., 2006) and Laptev Seas to the New Siberian Islands (Kuzmichev and Pease, 2007), as indicated by question marks. Outline of basalt subcrops buried within the West Siberian Basin are derived from borehole, seismic, magnetic and gravimetrical data (redrawn after Reichow et al., 2002, Surkov, 2002, and Kletz et al., 2007).