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Characterising the world's most catastrophic volcanism: constraints from trace elements and radiogenic isotopes of the Siberian Traps large igneous province

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Radiometric dating strongly indicates that the bulk of the Siberian large igneous province is contemporaneous with the end-Permian mass extinction, approximately 251 m.y. ago. The most visible manifestation of the Siberian Traps are outcrops on the Siberian craton (Noril'sk, Putorana Plateau, Maymecha-Kotuy and Tunguska Basin), which are also the most intensively sampled and analysed regions of the province. However, the greater province extends beneath the West Siberian Basin (WSB) to the central (Chelyabinsk) and polar (Vorkuta) Urals, north to the Taimyr Peninsula, and south to the Kuzbass. Many of these areas appear not to be contiguous, either because they were erupted as discrete subprovinces, or because tectonic activity and erosion has subsequently isolated them. The genetic link between these areas continues to be a subject of active debate; questions remain as to the contributing source materials and the process of their formation.

The thick sections of basalts at Noril'sk have provided the defining characteristics (elemental and isotopic) of the Siberian suites. In summary, these show a series of lower suites, typified by high Gd/Yb ratios which indicate higher pressure melting, and high La/Sm and ϵ Nd<0 except the Gudchikhinsky suite with low La/Sm and ϵ Nd>2. Suites of the upper series display generally low La/Sm and Gd/Yb indicating low pressure melting combined with ϵ Nd>0 expect for the strongly crustally contaminated Nadezhdinsky suite with high La/Sm and negative ϵ Nd. The latter are followed by Morongovsky suite basalts with transitional less contaminated composition between basalts of the last Nadezhdinsky and the first Morongovsky suite.

We present new major and trace element data, and radiogenic Sr, Nd, Hf, and Pb isotope data for over 50 samples taken from the Siberian large igneous province in order to understand the process of their formation. The basaltic rocks of the Province as a whole can broadly be divided into low- and high-Ti groups; all our analysed samples belong to the low-Ti group. From trace element data we infer that these low-Ti basalts were derived by large degrees of partial melting. Basalts from the WSB, and the Taimyr, Kuzbass, and central to polar Urals regions, exhibit major and trace element characteristics typical of evolved, crustally-contaminated continental flood basalts (e.g., low Mg#, negative Nb anomaly, high La/Sm) showing affinities with the Noril'sk Nadezhdinsky suite of the main Traps. The trace element data are consistent with a process of fractional crystallisation coupled with assimilation of incompatible-element-enriched lower crust. Despite the elemental similarities, however, the radiogenic isotope compositions of the igneous rocks west and south of the Siberian craton (WSB, Kuzbass, and central to polar Urals regions) are very different from those of the Nadezhdinsky suite. The WSB, Kuzbass and Urals regions basalts display remarkably small ranges in initial Hf and Sr ratios (0.2827−0.2829 and 0.7043−0.7056, respectively) and ϵ Nd (2.26−4.16), although their Pb isotope ratios are more varied (e.g. $^{206}Pb/^{204}Pb$ between 18.15 and 19.73). In terms of the isotope data, the basalts of the WSB, Kuzbass, and central

to polar Urals are similar to the Noril'sk Morongovsky and Mokulaevsky Upper Series basalts, but from the elemental data, these two Upper Series appear to be far less contaminated by upper crust.

The isotopic composition of these rocks indicates the involvement of several distinct mantle and lithospheric sources. Given the large areal extent of the Siberian large igneous province, this is not altogether surprising, but the data do indicate that the subprovinces were derived locally and not from a single point source or single rift system. This is a likely scenario considering the varied composition of the continental crust even on a small scale.