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# Petrogenesis and timing of mafic magmatism, South Taimyr, Arctic Siberia: A northerly continuation of the Siberian Traps?

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The Siberian large igneous province (LIP) forms the world's most extensive continental exposure of basalt and has several sub-provinces surrounding it, which may be genetically related. The Taimyr peninsula of north Siberia is one of these sub-provinces and is frequently assumed to be the northerly continuation of the basalts exposed at Noril'sk, the best-studied area of the Siberian LIP. However, the correlation is uncertain.
We present new major and trace element data from 35 samples of extrusive and intrusive rocks from Taimyr, with Sr and Nd isotope data from a subset of ten. The Taimyr rocks fall into two groups with low (~7 wt.%) and elevated (~9 wt.%) MgO concentrations. The high-MgO rocks display a restricted range of initial $^{87}Sr/^{86}Sr$ (0.705 to 0.706) and $^{143}Nd/^{144}Nd$ (0.5122 to 0.5124) ratios, and share bulk silicate earth normalised rare earth element patterns strikingly similar to data observed in the ore-related Noril'sk intrusions. The remaining low-MgO group samples have a broader range with higher Sr and lower Nd isotope values and higher incompatible trace element ratios (e.g., Th/Ta > 5.3 and $La/Sm_n$ > 1.7) similar to the crustally-contaminated Nadezhdinsky and Morongovsky suite basalts of the Noril'sk region. The major and trace element data for both groups are consistent with a process of fractional crystallisation coupled with small degrees of assimilation of incompatible-element-enriched lower crust involving different contaminants. Trace element model calculations indicate a process of magma formation at large degrees of partial melting and at pressures of less than 3 GPa, probably within the garnet–spinel transition zone or the spinel stability field of the asthenospheric mantle. We obtained an argon plateau age of ~252 (252.7 ± 1.5) Ma and a ~239 Ma total fusion age from a Taimyr lava and intrusive sample, respectively, confirming that volcanism is only partly contemporaneous with the activity of the Siberian LIP. Although this is in agreement with previous interpretations, we argue that the age difference between both events is only ~13 Ma and probably less (~5 Ma) although further investigation of the relationship is required. Our data allow correlation with distinct Noril'sk members and most importantly to the ore-bearing (Ni–Cu) intrusions implying that whole rock chemistry could have value as a prospecting tool in Taimyr.


## 1. Introduction

The Siberian large igneous province (LIP) can be traced from the Siberian Platform (or craton) to the Ural Mountains, and from the Kuznetsk Basin in the south, to the Arctic Circle, including the Taimyr peninsula in the north (Fedorenko et al., 1996; Maysatis, 1983; Reichow et al., 2002, 2009; Sharma, 1997; Scott et al., 2010). The evidence for this vast areal coverage comes primarily from the occurrence of large volumes of basaltic lavas, intrusions (mainly dykes and sills), and pyroclastic rocks (e.g., Fedorenko et al., 1996). Radiometric age data, primarily $^{40}Ar/^{39}Ar$, have been used to show that most of the activity was broadly contemporaneous at about 252 Ma, and thus represented a surge in volcanism that may have triggered the end–Permian mass extinction (e.g., Burgess et al., 2014; Reichow et al., 2002, 2009; Renne and Basu, 1991; Renne et al., 1995).

There are, however, few published compositional data for the magmatic products found in most sub-provinces of the Siberian LIP, including the Taimyr peninsula, Urals, and the Kuznetsk Basin. Such data are important to understand the petrogenesis of the Siberian LIP as a whole and for the identification of magmatic processes that control compositional diversity in each of the sub-provinces. A key question is whether the igneous bodies found in each of these sub-provinces can be correlated with the intensively studied igneous stratigraphy in the main part of the province at Noril'sk (e.g., Fedorenko et al.,

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1996; Lightfoot et al., 1990, 1993). Was the activity in each of these sub-provinces genetically linked, or is each sub-province characterised by distinctive processes (melting, contamination, and fractionation)? We present new $^{40}Ar/^{39}Ar$ data, whole-rock and mineralogical compositional data for suites of basaltic rocks and dolerite sills and dykes from the South Taimyr peninsula (Fig. 1). Using age constraints to determine if the lavas are contemporaneous with the Siberian Traps volcanism, we can address whether these rocks also share any geochemical similarities with basalts of the Noril'sk region, and if correlations can be made between the intrusive rocks at Taimyr and at Noril'sk. The latter correlation is of particular interest, because the world's greatest concentrations of platinum group elements and massive Ni–Cu sulphide ores are located at Noril'sk, and similar deposits occur in Taimyr (e.g., Yakubchuk and Nikishin, 2004).

## 2. Geological setting

The Taimyr peninsula is located between the Kara and Laptev Seas in Arctic Russia (Fig. 1a). The peninsula is bounded to the south by the NE–SW trending ~300 km wide Yenesei–Khatanga trough, which separates it from the Siberian Platform. The Yenesei–Khatanga trough is filled with Triassic to Early Cretaceous sediments and, based on the interpretation of seismic data, the deeper part of the basin contains volcanic rocks (Vernikovsky, 1996). The Taimyr peninsula is traditionally divided into three ENE–WSW trending structural–stratigraphical domains (Vernikovsky, 1996; Zonenshain et al., 1990): North, Central and South Taimyr (Fig. 1a). North Taimyr is characterised by Precambrian basement with strongly deformed Precambrian to Early Palaeozoic flysch deposits that are intruded by Late Palaeozoic Uralian collisional granites. North Taimyr has been interpreted to be an independent crustal block (i.e., the North Kara Terrain or North Kara Massif; Metelkin et al., 2005), and detrital zircon ages indicate that it was probably part of Baltica in Early Palaeozoic time (Pease and Scott, 2009). The Central Taimyr zone, separated from North Taimyr by the Main Taimyr Thrust, contains a weakly to unmetamorphosed Late Neoproterozoic (Vendian) to Early Palaeozoic continental margin succession which unconformably overlies various Precambrian crystalline units. The Neoproterozoic to Early Palaeozoic succession is interpreted to be the continental slope of Siberia (Inger et al., 1999; Pease and Scott, 2009) and indicates that central/South Taimyr has been a coherent part of Siberia since at least late Neoproterozoic time.

The South Taimyr domain comprises mainly folded Ordovician to Carboniferous carbonate-dominated sediments that were deposited on the passive margin of Siberia, overlain by Late Carboniferous to Triassic shallow-marine and deltaic sedimentary rocks (Fig. 1b; Inger et al., 1999). Mafic lavas, sills and dykes are present in South Taimyr and are deformed together with their sedimentary host rocks (Inger et al., 1999). Fedorenko et al. (1996) estimated that the cumulative thickness of mafic lavas and sills in South Taimyr reaches at least 2 km. The igneous rocks are usually attributed to the late Permian to early Triassic magmatic activity of the Siberian large igneous province (e.g., Gurevitch et al., 1995; Vernikovsky et al., 2003). Initial $^{40}Ar/^{39}Ar$ age determinations of these lavas and sills indicated Triassic and Early Jurassic ages (Walderhaug et al., 2005), respectively. Dating of the

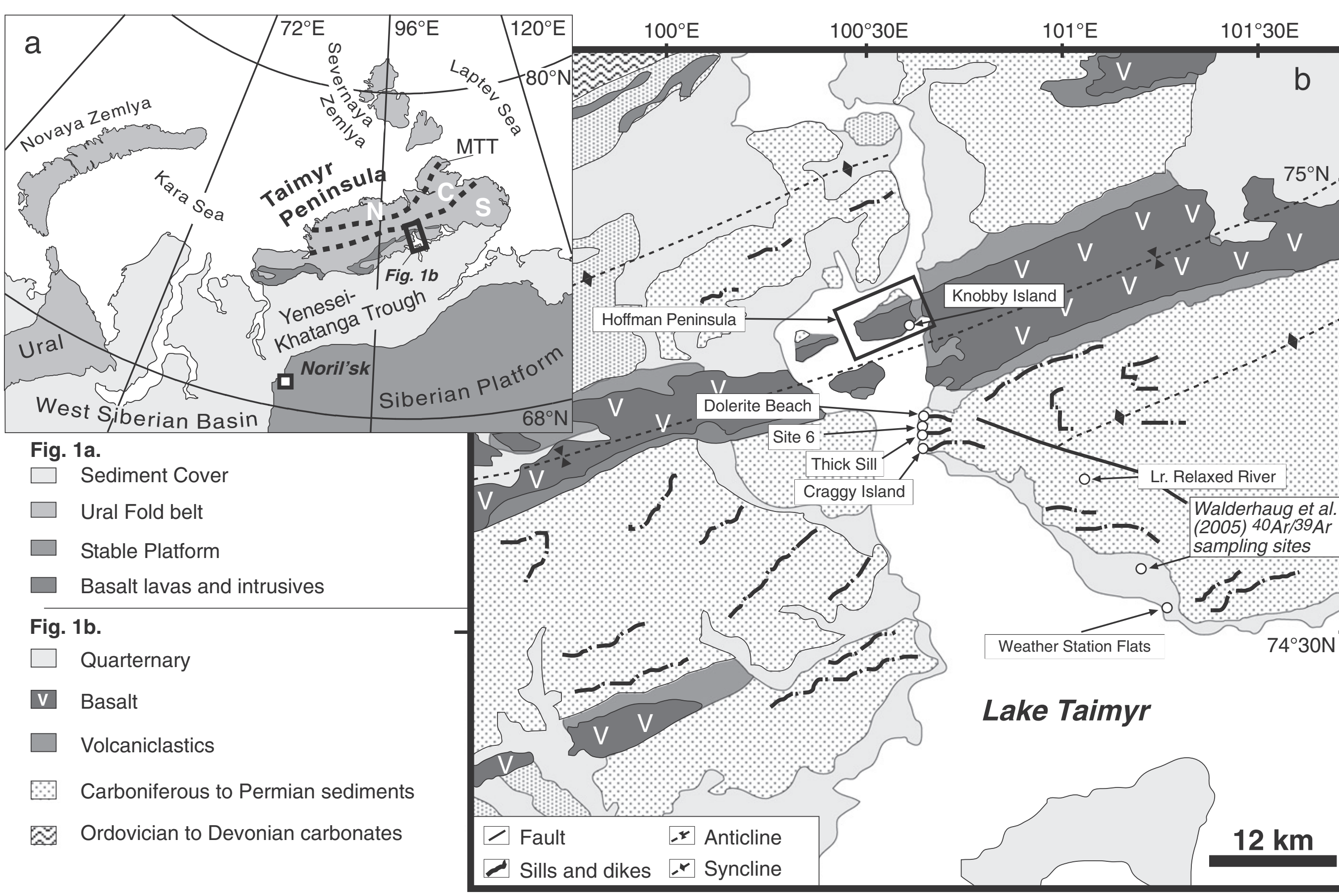


**Fig. 1.** a) Generalized geological map of the Taimyr peninsula and surrounding areas modified after Zonenshain et al. (1990) and Vernikovsky (1996). Abbreviations are as follows: N, C, S are North, Central, and South Taimyr domains, respectively, and MTT = Main Taimyr Thrust. Sampling area and geological map in b) is shown as rectangle. b) Simplified geological map of central Taimyr partially redrawn after Bezzubtsev et al. (1983), Inger et al. (1999) and CASP field observations. Basalt sample from 'Knobby Island', and dolerite sill and dyke sampling locations are indicated as open circles. Remaining basalt sampling locations are indicated as rectangle (see Table S1 for details).