The age and duration of flood basalt magmatism: geochemical and palaeomagnetic constraints from the Siberian Province

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Introduction

Many recent models for continental flood basalt (CFB) magmatism imply that such provinces were produced rapidly. The possibility of erupting huge volumes of magma within a million years, or less, has led to the speculation that flood basalt volcanism may provide a causal mechanism for mass extinction events. For example, the Deccan Traps of India and the Siberian Traps appear respectively to be temporally associated with the Cretaceous-Tertiary (K-T) and Permo-Triassic (P-Tr) extinctions.

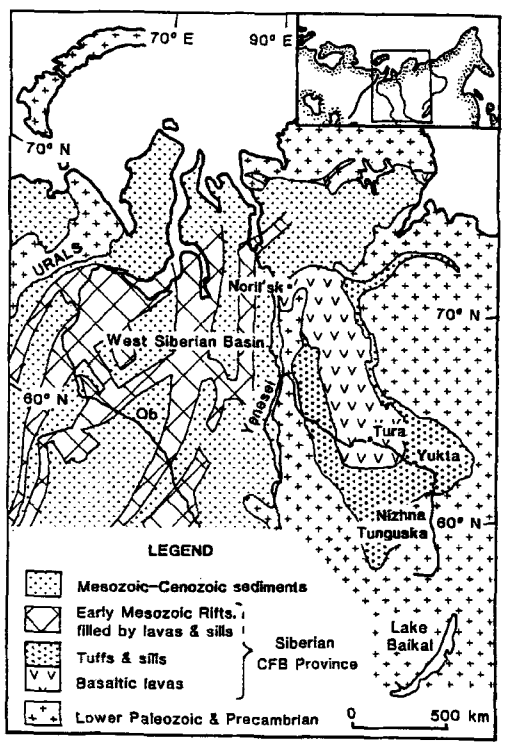

FIG. 1. Simplified geological map of the Siberian CFB Province.

The Siberian Traps is one of the largest CFB provinces of the Phanerozoic, occupying an area of 1.2–2.5 × 10^6 km^2, with a volume of 1.2–3 × 10^6 km^3; the larger dimensions include the basaltic rocks subcropping in the West Siberian Basin in addition to those cropping out on the Siberian Platform (Fig. 1). Published dates for the Siberian CFB Province cluster around 248 Ma, within error of the Permo-Triassic boundary. The radiometric dates, together with palaeomagnetic data are used to argue that the eruption of the Siberian CFB occurred within 600,000 years, spanning a R-N interval during the Illawara Reversals, a time of rapid reversals from the latest Permian to the middle Triassic (Campbell *et al.*, *Science* **258**, 1760–3, 1992). However, the samples analysed thus far come from a geographically limited area (mainly Noril'sk), and it has been assumed that the stratigraphy of the Noril'sk area can be simply extrapolated to the whole province.

A knowledge of the stratigraphy and structure of the lava pile is fundamental to establishing the age and duration of magmatism contributing to any CFB province, and is best achieved through geochemical and palaeomagnetic studies. Here, we present new geochemical and palaeomagnetic data to show that the simple correlations, assumed by many authors in arguing that the Siberian CFB province was produced rapidly, may not be applicable.

Geochemical stratigraphy

Petrographic and field characteristics have been employed to establish local stratigraphies in many CFB provinces, but such features may be highly variable even within individual flows, and more robust criteria are required to clarify the stratigraphy of the province as a whole. This has led to the use of magma types, which are defined on the basis of the chemical compositions of the basalts. Packets of lavas made up predominantly of a particular magma type can be mapped as

discrete 'formations'. In some CFB provinces these formations appear to have chronostratigraphic significance (e.g. the Deccan Traps), whereas others they may not (e.g. the Paraná). If magma types do not have chronostratigraphic significance across the whole province, then the age of the province can only be established by extensive sampling and dating of the localised stratigraphic sections that make up the province.

The qualitative stratigraphy for the Noril'sk area has been substantiated by noting changes in the chemical compositions of the lavas, and 5 Magma Types have been defined spanning 11 suites. We have collected 76 samples from the Niznha Tunguska River between Yukta and Tura (Fig. 1). All of the samples belong to magma type 5, and thus appear to correlate with the upper suites of the Noril'sk area, confirming earlier correlations based on field and petrographic characteristics. Magma type 5 thus appears to blanket the province, and constitutes from 66% of the lava pile, in Noril'sk, to 100% elsewhere. Assuming that magma types do have chronostratigraphic significance across the province, the simplest interpretation is that the province was produced by eruptions predominantly from Noril'sk, filling the Tunguska Basin to the SE, producing a simple layer-cake structure. If so, then the samples from the Niznha Tunguska River should have normal polarity, consistent with their counterparts in Noril'sk.

Palaeomagnetic stratigraphy

Three samples from the three lowermost flows along the Nizhna Tunguska River analysed in the present study all have reversed polarity. The present results can be interpreted in at least four ways:

1. Magma types in the Siberian CFB province do not have chronological significance.

2. The lowermost flows along the Nizhna Tunguska river in fact correlate with the lowermost flows of the Noril'sk area, on the basis of their palaeomagnetic characteristics.

3. The flows cropping out along the Nizhna Tunguska river are actually younger than those of the Noril'sk area.

4. The Noril'sk area may in fact be a R-N-R sequence. Detailed flow-by-flow sampling would be required to observe all the reversals during a period such as the Illawara Reversals.

More detailed combined palaeomagnetic and geochemical studies of the lava pile are required to differentiate between these possibilities. If the basaltic rocks subcropping in the West Siberian Basin are considered part of the Siberian CFB province, then the observation that the upper flows in the West Siberian Basin are interbedded with middle-Triassic sediments seriously undermines arguments that the entire province was erupted rapidly.

Conclusions

The results of the present study indicate that the Siberian CFB province was formed by magmatism continuing for as much as 20 Ma. and was not the short-lived event suggested by previous workers.