

## U-Pb Zircon and Baddeleyite and U-Th-Pb Perovskite Ages for Siberian Flood Volcanism, Maymecha-Kotuy Area, Siberia

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The objective of this study was to constrain the duration of the voluminous Siberian flood volcanic (SFV) event and to establish the timing of this volcanism with respect to the age of the Noril'sk ore-bearing intrusions and the Permian-Triassic, mass extinction event, using the U-Pb IDTIMS dating method. This volcanism was the most extensive in Earth's history, with an estimated  $\sim 4 \times 10^6$  km<sup>3</sup> of lava in a 6500 m-thick sequence (Fedorenko and Czamanske, 1997), originally extending over  $\sim 7$  million km<sup>2</sup>. This volcanic event has been widely speculated to have had a causal link with the P-Tr mass extinction, the greatest in the geologic record.

The Maymecha-Kotuy area of the SFV province ( $\sim 500$  km E-NE of Noril'sk) has been a source of interest because of the occurrence of a meimechite sequence (Arndt et al. 1995; Fedorenko and Czamanske, 1997) and because much of the  $\sim 3000$  m lava sequence is apparently younger than any lavas in the Noril'sk area.

The Arydzhangsky Suite, the oldest in the Maymecha-Kotuy area, is considered correlative in its lower part to the oldest, Ivakinsky Suite of the Noril'sk area; both suites rest unconformably upon Permian Tungusskaya Series sandstones, argillites, and coal. To establish the time of initiation of Siberian flood volcanism, a mela-nephelinite sample in the Kotuy River basin was collected  $\sim 200$  m above the base of the Arydzhangsky Suite. Perovskite (CaTiO<sub>3</sub>), which contains high concentrations of U and Th, was recovered and may prove to be a useful geochronometer for dating alkaline volcanic rocks. Nine concordant and overlapping data points give a U-Pb perovskite concordia age of  $252.1 \pm 0.4$  Ma ( $2\sigma$ ). A weighted mean model <sup>232</sup>Th/<sup>208</sup>Pb age of  $250.5 \pm 0.4$  Ma and a <sup>232</sup>Th-<sup>208</sup>Pb isochron age of  $254.5 \pm 5.8$  Ma were determined. Ongoing analytical work may improve the precision on the latter age. High Th/U of 19 to 23, and hence a larger proportion of radiogenic Pb, makes the <sup>232</sup>Th-<sup>208</sup>Pb system in perovskite a potentially more precise and accurate geochronometer than U-Pb for this mineral. However, due to possible inaccuracies in the Th decay constant and consequent errors in these ages, we here limit ourselves to consideration of the U-Pb ages.

Ages for two trachyrhydacite samples from the Delkansky Suite of the Maymecha River basin, stratigraphically  $\sim 2000$  m above the Arydzhangsky Suite mela-nephelinite sample, provide an estimate for the time of the waning stages of SFV, as the Delkansky Suite lavas are interpreted to be younger than any in the Noril'sk area (Fedorenko and Czamanske, 1997). These give

an age of  $251.1 \pm 0.5$  Ma, within error of the U-Pb zircon/baddeleyite age of  $251.2 \pm 0.3$  Ma for the Noril'sk I intrusion (Kamo et al., 1996), which cuts the lower third of the lava sequence at Noril'sk. The trachyrhydacite age establishes an upper limit for the time of a magnetic reversal between deposition of normally-polarized Onkuchaksky Suite lavas and those of the overlying, reversely-polarized Tyvankitsky Suite, which lies immediately below the Delkansky Suite.

The Guli intrusive-volcanic complex (Fedorenko and Czamanske, 1997; and references therein) is composed largely of ultramafic and alkaline rocks, but hosts two carbonatite stocks; it clearly cuts the Onkuchaksky Suite and most probably the Delkansky Suite. Baddeleyite (ZrO<sub>2</sub>) extracted from one of the carbonatites gives five overlapping data points with a weighted mean <sup>206</sup>Pb/<sup>238</sup>U age of  $250.2 \pm 0.3$  Ma, and distinctly older, weighted mean <sup>207</sup>Pb/<sup>235</sup>U and <sup>207</sup>Pb/<sup>206</sup>Pb ages of  $252.7 \pm 0.3$  Ma and  $278 \pm 4$  Ma, respectively. Geological relations, in combination with the accurately dated Delkansky trachyrhydacites, rule out the possibility that the <sup>207</sup>Pb/<sup>235</sup>U and <sup>207</sup>Pb/<sup>206</sup>Pb ages are geologically meaningful. These results may indicate the presence of excess <sup>207</sup>Pb, possibly due to disequilibrium amounts of <sup>231</sup>Pa.

A late, distinct phase of magmatism in the Noril'sk area of north-central Siberia is recorded by the intrusion of the Bolgotokh granodioritic stock. Zircon analyses give concordant data, with weighted mean <sup>206</sup>Pb/<sup>238</sup>U and <sup>207</sup>Pb/<sup>235</sup>U ages of  $228.9 \pm 0.3$  and  $229.2 \pm 0.6$  Ma, respectively.

Bowring et al. (1998) reported a precise U-Pb zircon age of  $251.4 \pm 0.3$  Ma for an ash immediately preceding the paleontologically defined, P-Tr boundary at Meishan, southern China. Thus, our study has 1) established that the waning stages of Siberian flood volcanism, emplacement of the Noril'sk I intrusion, and the P-Tr boundary are statistically indistinguishable in age, and 2) established directly and precisely that most of  $\sim 4 \times 10^6$  km<sup>3</sup> of lava was erupted in  $\sim 1$  m.y.

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