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Numerical modeling of mafic dyking zones during plume-induced continental rifting

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The Early Paleoproterozoic ca 2.45 Ga mafic–ultramafic dykes and layered intrusions are widespread within Karelian protocraton and associated with mantle plume [Puchtel et al., 1997]. Geological and geochemical data indicate that 2.4-2.2 Ga dolerite dykes of the Karelian protocraton reflected the intraplate magmatism [Stepanova et al., 2015]. Paleoproteorozoic ca 2.1 Ga MORB-type tholeiitic dykes mark the final break-up of the Archean lithosphere within the Karelian protocraton [Stepanova et al., 2015].

In order to correctly interpret the time of magnetization, it is necessary to know the rate and depth of rocks cooling. We present results of 2D numerical modeling of sequential formation of mafic dykes zones during plume-induced continental rifting before the supercontinent break off at lithospheric thickness of 140 km with variable crustal thickness, extension rate and depth of plume. The numerical experiments cover the range of depth of plume from 40 km to 80 km, the upper mantle temperature exceeded the modern temperature by 0–150°C.

The numerical modeling has shown that the thermal influence of the plume provokes the mafic melt which is embedded into the base of the continental crust. Due to the general extension, weak zones in the crust are developed, through which melt with a temperature of 700–900°C is embedded and the mafic intrusions are formed. Repeated intrusions occur in the same or close zones. The cooling time of intrusive bodies ranges from the millions to the tens of millions years, depending on the size and relative location.

Similar structures and the sequence of their formation occur in a range of parameters: the extension rate of 0.2–2 cm/year, the crustal thickness of 30–45 km and the upper mantle temperature exceeded the modern temperature by 50–150°C which corresponds to the conditions of the Precambrian. In the case of an extension rate of 0.2 cm/year the duration of the dykes formation is up to 70 million years.

In the case of a plume depth of 40–60 km intrusions embed symmetrically, from the edges of the zone to its central parts. Then a new oceanic crust forms in the extension zone, the continental crust is fragmented, and its remnants gradually disappear. In the case of a plume depth of 70–80 km intrusions embed asymmetrically, a trend and some "pulsations" in the spread of intrusions are detected. In this case, it is possible the retention of continental blocks (up to 100 km wide) with felsic crust.

Thus, the results of numerical modeling provide a possible explanation for the sequential formation of the intrusive bodies of the Karelian craton during plume-induced continental rifting.

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Reference.

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