1.3 Ga mafic magmatism of the St. Francois Mountains of SE Missouri: implications for mantle composition beneath mid-continental USA

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Introduction

The St. Francois Mountains area of SE Missouri lies on the southwestern flank of the Eastern Granite-Rhyolite Province of central U.S.A. and consists mainly of 1480 Ma silicic volcanic rocks and epizonal granite intrusions (Van Schmus *et al.*, 1987). In addition to the silicic rocks, minor mafic intrusions occur; these were divided into two suites by Sylvester (1984). The older suite, Silver Mines, is considered coeval with the silicic rocks, whereas the younger suite, Skrainka, represents, as judged from field relations, a later separate magmatic episode. The crystallization ages of the different mafic suites were, however, not determined. We have carried out a U-Pb and Nd-Sr-Pb isotopic study on the Skrainka suite. Our results confirm that the suite postdates the silicic magmatism in the area, and provide constraints on the isotopic composition of the subcontinental mantle.

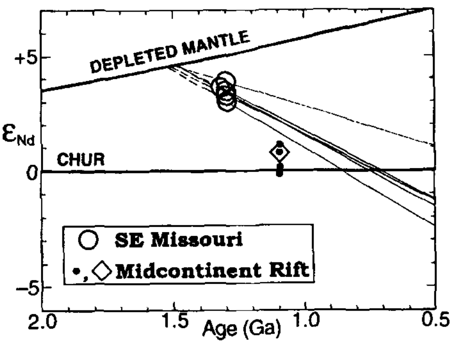

FIG. 1. ε_{Nd} *vs.* age diagram showing the initial Nd isotopic composition of the 1.3 Ga mafic rocks of SE Missouri and those of the 1.1 Ga high-Ti tholeiites (dots; Nicholson and Shirey, 1990) of the Midcontinent Rift and an inferred composition (diamond; Paces and Bell, 1989) of the mantle beneath the Midcontinent Rift. Evolution lines of CHUR (Chondritic Uniform Reservoir), depleted mantle (DePaolo, 1981), and the Missouri samples are also shown.

Sampling and analytical methods

We report U-Pb baddeleyite ages on two samples and Nd-Sr-Pb data on five samples of the Skrainka suite. The isotopic analyses were made at the Unit for Isotope Geology, Geological Survey of Finland. Analytical procedures are described in detail by O Brien *et al.* (1993) and Vaasjoki *et al.* (1993).

U-Pb chronology

Single baddeleyite fractions were analyzed from

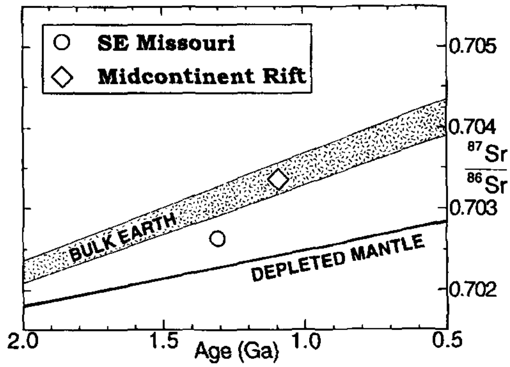

FIG. 2. $^{87}Sr/^{86}Sr$ *vs.* age diagram showing the initial Sr isotopic composition of the 1.3 Ga mafic rocks of SE Missouri and the inferred mantle composition beneath the 1.1 Ga Midcontinent Rift (Paces and Bell, 1989). Evolution of bulk earth and a Rb-depleted mantle (Bell *et al.*, 1982) are also shown.

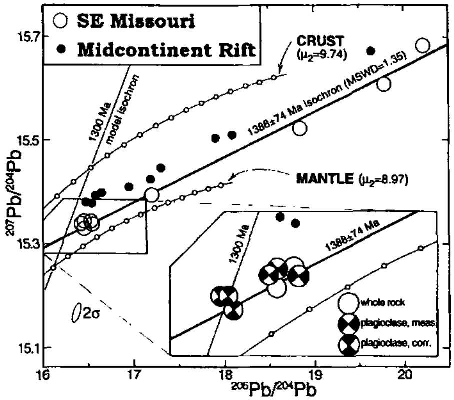

FIG. 3. $^{207}Pb/^{204}Pb$ *vs.* $^{206}Pb/^{204}Pb$ diagram showing the Pb isotopic composition of the 1.3 Ga mafic rocks of SE Missouri and tholeiites of the 1.1 Ga Midcontinent Rift (Nicholson and Shirey, 1990). Crowth curves for average crustal Pb (Stacey and Kramers, 1975) and plumbotectonics model mantle (Doe and Zartman, 1979) as well as a second-stage 1300 Ma model isochron, calculated according to the two-stage evolution model of Stacey and Kramers (1975), are shown.

two gabbro intrusions (Muddy Knob and Skrainka Quarry) and yielded $^{207}Pb/^{206}Pb$ ages of 1316 $\pm$ 6 and 1300 $\pm$ 10 Ma, respectively. Both are discordant , but at a concordancy degree of 97.3%, the Pb-Pb age for Muddy Knob can be regarded as a fair estimate of the true age. The Skrainka Quarry baddeleyite is more discordant (84.4%) and the Pb-Pb age should be considered a minimum. Both baddeleyites exhibit unusually high U contents (983 and 693 ppm) and particularly large common Pb contents (measured $^{206}Pb/^{204}Pb$ 631.5 and 231.8). The decay-corrected plagioclase Pb isotopic compositions, rather than tabulated model values, were used for the common Pb correction.

Nd-Sr-Pb isotope geochemistry

The Nd-Sr-Pb isotopic data are presented in Figs. 1 to 3. All samples are enriched in LREE relative to chondritic composition, but show a depleted long-term signature (initial $\varepsilon_{N}d$ values range from +3.1 to +3.9). The Sr isotopic data show considerable scatter implying that the Rb-Sr system was disturbed after crystallization. However, the two apatite fractions, with their low $^{87}Rb/^{86}Sr$ and high Sr contents, provide reasonable estimates of the initial $^{87}Sr/^{86}Sr$ of the Skrainka suite (mean $^{87}Sr/^{86}Sr$ 0.7026). In a $^{87}Sr/^{86}Sr$ *vs.* age diagram (Fig. 2) this initial composition falls between the evolution of the Bulk Earth and a Rb-depleted mantle. In a $^{207}Pb/^{204}Pb$ *vs.* $^{206}Pb/^{204}Pb$ diagram (Fig. 3) the data on the Skrainka suite falls close to the evolution of the plumbotectonics model mantle and defines an isochron of 1388 $\pm$ 74 Ma (2σ). The decay-corrected Pb isotopic ratios of the three plagioclase fractions are identical within the experimental error (Fig. 3). They also conform to the two-stage Pb evolution model of Stacey and Kramers (1975), with average μ_2 of 9.24 ($^{206}Pb/^{204}Pb$ = 16.25, $^{207}Pb/^{204}Pb$ = 15.32) and model age of 1300 Ma.

Discussion and conclusions

The analyzed samples are evolved Fe-rich tholeiites that span a range of mafic magma evolution (Mg numbers vary from 56 to 29). However, their initial isotopic compositions, those of Nd and Pb in particular, are almost constant. This suggests that the initial isotopic compositions measured on the Skrainka suite approach those of its mantle-derived parental magma. Sylvester (1984) interpreted the phenocryst assemblage (olivine + plagioclase) in the Skrainka suite as indicative of equilibration at relatively high pressure (> 5 kb), i.e., having occurred in the lower crust or at the crust-mantle interface.

In Figs 1, 2, and 3, the isotopic data on the Skrainka suite are compared to those of similar tholeiites thought to represent the isotopic composition of the mantle beneath the 1.1 Ga Midcontinent Rift (Paces and Bell, 1989; Nicholson and Shirey, 1990). The two suites are distinct in terms of their Nd, Sr, and Pb isotopic compositions. The Midcontinent Rift tholeiites are indicative of a mantle with nearly chondritic Nd, bulk earth Sr, and overall U/Pb half way between average crust and plumbotectonics model mantle, whereas the SE Missouri tholeiites point to a mantle clearly depleted in *LREE* and Rb and with an overall U/Pb close to the model mantle. Paces and Bell (1989) and Nicholson and Shirey (1990) ascribe the isotopic systematics of the Midcontinent Rift tholeiites to an enriched lithospheric mantle source or, alternatively, to an upwelling asthenospheric (non-depleted) plume. Decompression melting of an upwelling plume is favoured by the huge volume of mafic magma emplaced in the Midcontinent Rift (Nicholson and Shirey, 1990). Volumetrically, the 1.3 Ga SE Missouri mafic magmatism is smaller than that of the Midcontinent Rift and involved a much smaller-scale thermal perturbation of a depleted domain in the subcontinental lithosphere.