Isotopic studies (Sr, Nd, Pb, Os, O) of the Jurassic Ferrar flood-basalt province of Northern Victoria Land, Antarctica: Evidence for three stages of petrogenetic evolution?

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Introduction

The Jurassic Ferrar flood-basalt event in Antarctica produced voluminous flows and sills with a unique geochemical character. They are enriched isotopically, and show a moderately enriched primitive mantle normalized spider diagram pattern, except for Nb, P and Ti. Compositions range from basaltic andesite to rare dacites. Prior studies attributed these distinct features (i) to an enriched mantle lithosphere where source contamination may be related to prior subduction of oceanic crust (Hergt *et al.*, 1989, Kyle *et al.*, 1983) or (ii) to assimilation of crustal material during magma chamber processes (recharge, assimilation, fractional crystallization, tapping) (Faure *et al.*, 1982, Elliot *et al.*, 1972). In addition, low temperature alteration has significantly (and quite variably) modified the bulk rock compositions during a pervasive alteration event around 70 Ma after emplacement (Fleming *et al.*, 1993, and own unpublished data). In order to distinguish between these petrogenetic processes we have measured major and trace element concentrations of whole rocks as well as isotopic compositions (Sr, Nd, O, Os) of samples from the Prince Albert Mountains in Northern Victoria Land. To exclude the effects of alteration, hand-picked mineral separates (plagioclase, clinopyroxene) of these samples were also analysed for Sr-, Nd-, Pb- and O-isotopes

To characterize the lower crust we have done isotopic analyses on hand-picked mineral separates from lower crustal gabbroic cumulates. These cumulates were brought to the surface as xenoliths within the Cenozoic volcanoes related to the Ross Sea Rift. Such cumulates could either be related directly to the flood basalt magmatism via accumulation in deep magma chambers or could represent the lower crust in assimilation models.

Results of isotopic analyses

Initial ε_{Nd} values vary from −0.6 to −5.5 for Ferrar whole rock samples, while plagioclase separates range from ε_{Nd} = −2.5 to −7.8. By contrast, clinopyroxenes show only minor variations from ε_{Nd} = −2.1 to −5.1. Initial $^{87}Sr/^{86}Sr$ ratios show a wide variation for all samples: whole rocks = 0.70930 to 0.71187, plag = 0.70988 to 0.71754, cpx = 0.70953 to 0.72000. The $\Delta^{18}O$ ratios range, for whole rocks, from 4.8 ‰ SMOW to 8.0‰, while plagioclases show a larger range at higher values (6.0‰ to 13.3‰). Clinopyroxenes gave more consistent ratios; typical of mantle values (5.2‰ to 7.0‰). Pb-isotope data of plagiclases also show enriched ratios ($^{206}Pb/^{204}Pb$ = 18.6–18.8, $^{207}Pb/^{204}Pb$ = 15.59–15.72, $^{208}Pb/^{204}Pb$ = 38.3–38.8).

This is the most complete isotopic data set on Ferrar whole rocks and mineral separates presently available and from these we conclude that whole rocks and plagioclase separates give (and have in past studies given) erroneous isotopic results. Clinopyroxene separates are robust against alteration and give magmatic isotopic values. The lowest $^{87}Sr/^{86}Sr$ ratios and $\Delta^{18}O$-values of the Ferrar-rocks were found in one whole rock sample and clinopyroxene separate from the Brimstone Peak locality. This sample also belongs to the rare high-TiO_2 suite of the Ferrar province.

Os-isotopic work is in progress. However, the first Os-isotopic analyse of the one of the most mafic whole rock samples provides evidence for a crustal contribution ($^{187}Os/^{186}Os$ = 2.6).

One gabbro cumulate gave a whole rock ε_{Nd}

value of +4.0 and a $^{87}Sr/^{86}Sr$ ratio of 0.70352 (both present-day ratios). The present day ε_{Nd} values for the mineral separates vary between +4.5 and +5.0 for the plagioclases and between +4.5 and +6.5 for the clinopyroxenes. The $^{87}Sr/^{86}Sr$ ratios for the plagioclases range from 0.70310 to 0.70355 and for the clinopyroxenes from 0.70290 to 0.70347. Two plagioclase samples have the following Pb isotopic ratios: $^{206}Pb/^{204}Pb$ = 19.2–19.5, $^{207}Pb/^{204}Pb$ = 15.27–15.83, $^{208}Pb/^{204}Pb$ = 37.9–39.3. Obviously, there is an extreme isotopic contrast between the Ferrar rocks and the lower crustal cumulate gabbros.

Conclusion

Trace elements and the various isotopic systems give conflicting evidence with regard to the sources and genesis of Ferrar magmas. While trace element signatures, Sr, Nd, and Os isotopes indicate a large crustal contribution, the O-isotopes are more mantle like.

According to these results we propose a three-stage petrogenetic model of the Ferrar-flood basalt. Source contamination (via subducted sediments) has influenced the Ferrar source resulting in radiogenic Sr and Nd and mantle like O-isotope ratios. Subsequently, after ascent into the crust the primary magma became contaminated by crustal material due to AFC, MASH, or RAFT processes (Aitcheson & Forrest, 1994, in press). These processes shifted the isotopic compositions towards even more crustal ratios. Subsequently, highly variable and even more enriched whole rock and plagioclase isotopic compositions are caused by surface alteration during an event of thermal (?) overprinting of the Ferrar-rocks in Northern Victoria Land 115 Ma ago (Molzahn *et al.*, unpublished data).

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