U–Pb dating of magnetite from the Kinsman Quartz Monzonite, New Hampshire, USA: Implications for dating natural remnant magnetization

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Introduction

We have studied the U–Pb systematics of magnetites separated from the Acadian Kinsman Quartz Monzonite (KQM) in the northern Appalachians, USA. The main objective of the present study was to investigate the U–Pb geochronology of magnetite and to evaluate its potential for constraining the timing of magnetic acquisition in rocks. This may prove to be helpful in the reconstruction of apparent polar wander paths (APWP) for use in plate tectonic reconstruction (e.g., van der Voo, 1993) and may also shed light on the nature of remagnetization events. A few attempts have been made recently to date metamorphic and ultramafic magnetite directly using the $^{40}Ar/^{39}Ar$ method (e.g., Özdemir and York, 1990; 1992) and Pb isotopes (Gariépy *et al.*, 1990).

Previous studies have identified two major episodes of plutonism during the Acadian Orogeny in New Hampshire. The KQM belongs to the earliest phase of the plutonism and has been dated at ~410 Ma (Lyons and Livingston, 1977; Barreiro and Aleinkoff, 1985), whereas the second phase of plutonism (the Concord-type) took place at ~355 Ma (Harrison *et al.*, 1987). It has been suggested that the KQM is the product of syntectonic anatexis of metasediments at mid-crustal levels (Lathrop *et al.*, 1994).

Experimental methods

The magnetite fraction separated from the KQM was split into two aliquots, the first of which was completely dissolved in a combination of concentrated HCl and HF. The second aliquot was leached with successively stronger ultra pure HCl from 1N to 10N, and finally with aqua regia (for a total of ten samples). Following each leaching step, the supernate was separated from the residue by centrifugation. The supernate was then processed through ion exchange columns, and analyzed for Pb isotopic composition and concentration; seven of the samples were also analyzed for U concentration. All analyses were done on a VG-Sector thermal ionization mass spectrometer and a ^{235}U-^{208}Pb spike was used for isotope dilution. The Pb standard NBS-981 was run intermittently for the determination of a machine fractionation factor (1‰ per amu). The procedural blank was determined prior to, during and after the experiment, and was found to be less than 1% of most samples.

Results and discussion

Six out of the seven aliquots analyzed for both Pb and U show a linear relationship on the ^{206}Pb-^{238}U diagram (Fig. 1), with a slope of 0.60365 (York, 1969; Ludwig, 1980). This plot can be interpreted as an isochron yielding an age of 378 ± 4 (2σ) Ma with an initial $^{206}Pb/^{204}Pb$ ratio of 18.94 ± 0.05. These six samples also yielded a concordant 389 ± 41 Ma age on the ^{207}Pb-^{235}U diagram. When the seventh sample (8 N HCl leach) is included the ^{206}Pb-^{238}U age changes slightly to 371 ± 5 Ma, nevertheless, the fit of both ^{206}Pb-^{238}U and 207Pb-235U isochrons worsens and the isochrons are no longer concordant (yielding 371 Ma and 252 Ma 'ages' respectively). The nature of this particular aliquot is under further investigation. The leached magnetite fractions of all samples yield a ^{207}Pb-^{206}Pb age of 360 ± 40 Ma which is the same as the ^{238}U-^{206}Pb age within analytical error (Fig 2). The large errors of this isochron are caused

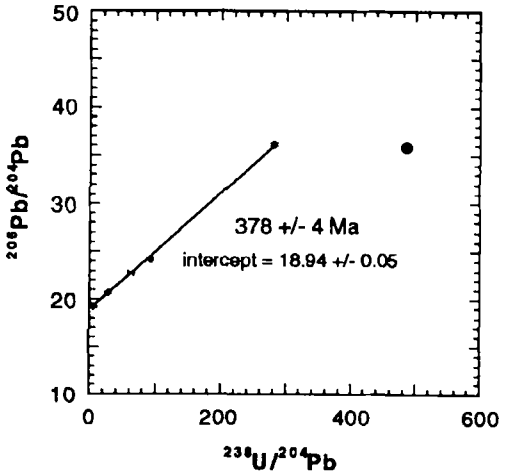

FIG. 1. ^{206}Pb-^{238}U isochron for magnetite from the KQM. All samples were obtained by leaching magnetites with successively stronger HCl acid (see text). The point plotting far off the curve is a 8N leach. Error bars indicate 2σ.

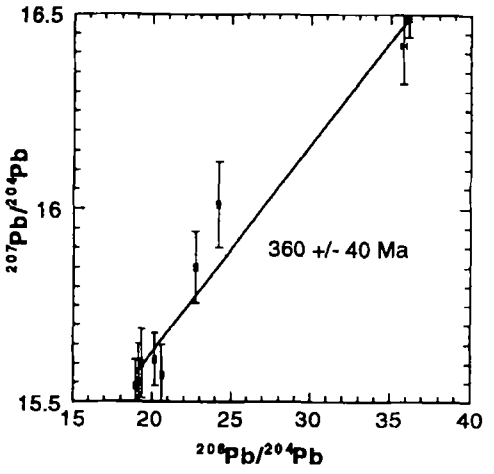

Figure 2: ^{207}Pb-^{206}Pb isochron of nine leaches of magnetite. Error bars indicate 2σ.

by the relatively large uncertainties compared to the small range of the $^{207}Pb/^{204}Pb$ ratios. The high initial $^{206}Pb/^{204}Pb$ (18.94) and $^{207}Pb/^{204}Pb$ (15.58) ratios are consistent with the high initial Sr and $\delta^{18}O$ values of the same rock unit as expected for the products of crustal anatexis of the KQM wallrocks (Lathrop *et al.*, 1994).

The 30 Ma age difference between the magnetite U–Pb isochron and the whole rock - garnet Sm-Nd isochron (Barreiro and Aleinkoff, 1985) can be explained either by slow cooling of the pluton between the closure temperature (T_c) of garnet (~750°C; Mezger, 1989) and magnetite (~500°C; Freer, 1980), or by subsequent resetting of the isotope system. Thermal modeling of the Acadian crust suggests that a cooling rate of ~8°C per Ma is quite reasonable for the KQM (Chamberlain and Sonder, 1990). Nevertheless, it is also possible that the 380 Ma age of the KQM magnetites actually records a partial resetting of the isotopic and magnetic systems caused by another episode of Acadian plutonism (e.g., Zartman, 1974). The resetting of the system could have been either a thermal process or the chemical process of dissolution and re-precipitation of magnetite resulting from infiltration of associated magmatic fluids (McCabe and Elmore, 1989). Work is underway to determine the nature and the causes of the resetting on the magnetite system in the KQM and adjacent rock units.

Conclusions

The U–Pb ages of magnetites from the Kinsman Quartz Monzonite reported in this study is the first step toward direct determination of the absolute age of the magnetic carriers which could provide a significant contribution to the interpretation of paleomagnetic data.

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