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Stable-Isotopic Investigation of Plutons Intruded at High, Polar, Latitudes During the Mesozoic: Low-^{18}O Melts or Interactions with Light Polar Waters?

Robert C. R. Willan[1], **Adrian J. Boyce** (a.boyce@surrc.gla.ac.uk)[2] &
Anthony E. Fallick (t.fallick@surrc.gla.ac.uk)[2]

[1] Geosciences Division, British Antarctic Survey, Cambridge, CB3 0ET, UK
[2] Isotope Geosciences Unit, S.U.R.R.C., East Kilbride, UK

Introduction

Plutons generally have a narrow δ^{18}O range, from mantle values (+6 permil) to values indicating assimilation of ^{18}O-enriched sedimentary material (>+10 to +15 permil). In addition, altered plutons can have very low δ^{18}O (to -5 permil) and δD (to -150 permil), which correlate with local meteoric groundwaters. The origin of low-^{18}O values in *unaltered* plutons (< +7 permil), i.e. existence of low-^{18}O *magma* is controversial and may be due to incorporation of altered oceanic crust in melt regions (Gilliam and Valley, 1997). Hence, the rarity of low-^{18}O magmas in arcs is surprising given the large volume of altered oceanic crust available as a source and the extensional tectonic environment of many arcs.

The Antarctic Peninsula magmatic arc: 220 m.y. of high-latitude magmatism

The Antarctic Peninsula (61º to 76º S) is the remnant of a continental-margin magmatic arc of late Triassic to late Tertiary age. Numerous Andean plutons, dated between 230 and 10 Ma, crop out for 2000 km along strike and across a maximum width of 480 km. The oldest plutons have an 'S'-like geochemical signature related to the presence of continental basement, whereas the youngest plutons have increasingly primitive, mantle-type signatures. Magmatism was accompanied by extension in the early Jurassic, late Jurassic-early Cretaceous and mid to late Tertiary.

The arc evolved at a high palaeo-latitude (55 to 75 ºS), however palaeofloras indicate that the climate approached subtropical in the mid Cretaceous, and Palaeocene-early Eocene greenhouse events, with cool, possibly glaciated, intervals in the Aptian-Cenomanian and Maastrichtian. Following continental breakup at 30 Ma and establishment of a deep, circum-continental polar current, the climate deteriorated to polar-glacial conditions. Hence because of the dependence of meteoric-water compositions on latitude, Antarctic Peninsula plutons offer an outstanding opportunity to investigate the origins of low-^{18}O and -δD melts, lithosphere-hydrosphere interactions in the past and the variation of meteoric-water compositions with global climate. Previous studies of plutons and hydrothermal systems have been mostly limited to Tertiary systems within 40 to 50 latitude of the modern-day equator.

Previous stable-isotopic studies

Previous δ^{18}O work (Hole, 1986) reveals Jurassic and Cretaceous plutons (low εSr_i and high εNd_i) with a wide range in δ^{18}O (+6 to +11 permil) suggesting a mantle or mafic lower-crustal source and upper crustal contamination. Palaeocene plutons have very low δ^{18}O values (+1 to +5 permil) attributed to low-temperature alteration. By contrast, Cretaceous plutons in Marie Byrd Land have very variable and low δ^{18}O (-8.7 to +10.4 permil) and δD (-160 to -151 permil), attributed either to interaction with polar meteoric waters in the Aptian-Cenomanian cool period, or to assimilation of low-^{18}O country rocks (Blattner et al., 1997). Recent work on middle Jurassic rhyolites in the Antarctic Peninsula (quartz δ^{18}O = +5.4 to +10.6 permil) may indicate low-^{18}O melts (Riley et al., 2000).

Results and discussion

Our preliminary study of unaltered, well-dated Jurassic and Cretaceous granitoid plutons at 69-70 ºS in northern Palmer Land reveals large variations in δ^{18}O (-7.3 to +10 permil) and δD (-158 to -75 permil) that are well outwith the normal magmatic range. Some felsic plutons have extraordinarily low δ^{18}O in all minerals (<5 permil) with quartz, normally most resistant to low-temperature isotopic exchange, as low as +3.9 permil. Biotite δ^{18}O compositions (-7 to +3 permil) are as light as meteoric-hydrothermal minerals in the largest porphyry-copper deposits. Preliminary assessment of mineral-mineral equilibria indicates isotopic equilibration at near-magmatic temperatures (700 to 400 ºC), similar to the layered gabbros of the North Atlantic Tertiary Province. Other mineral pairs give temperatures of 400-100 ºC, typical of hydrothermal systems. A third of mineral pairs give unrealistic temperatures or isotopic reversals, indicating that interaction with external waters has occurred at high water/rock ratios, despite there being little mineralogical alteration.

Two δ^{18}O-δD compositional groups are present. A low-δD group, similar to the fossil meteoric-hydrothermal systems in gabbros of the North Atlantic Tertiary province, suggests high-temperature exchange with evolved meteoric waters at low water-rock ratios. Alternatively, they could be derived from a low-D melt, by assimilation of low-D crustal rocks, or from highly degassed magmas. A low-^{18}O group suggests a large influx of isotopically light meteoric waters into the hot melt, by an unknown mechanism. Such light values also require buffering by ^{18}O-depleted basement along the flow path in order to preserve the light meteoric signature of the waters. Alternatively, assimilation of altered, low-^{18}O host rocks requires major, near-surface, hydrothermal activity. There are no stable-isotopic data for Antarctic Peninsula basement or cover sequences to test these hypotheses.

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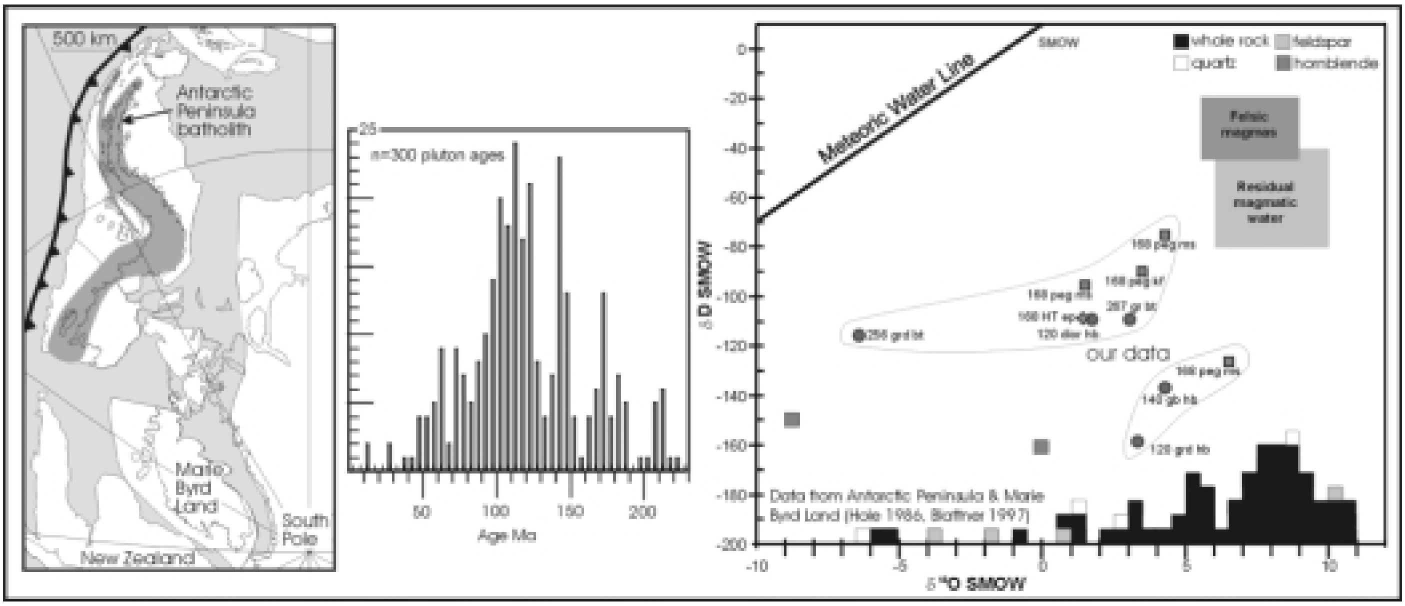

Figure: Location of Antarctic Peninsula at about 100 Ma, and summary of stable-isotopic data for plutons in the Antarctic Peninsula and Marie Byrd Land.

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