Continental surface temperatures inferred from the investigation of fossil hydrothermal systems

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Plutonic and sub-volcanic igneous rocks have been shown to be a promising source of data relevant to paleo-temperature reconstruction. A first Antarctic terrestrial record of climate variations through the Cenozoic has been recently published, based on the hydrogen isotope composition of hydrothermally altered minerals of intrusive rocks from the coastal areas of the Wilson Terrane, Northern Victoria Land, Antarctica (Dallai & Burgess, 2011). Cenozoic land surface temperature data for this remote area located at 73-74°S latitude are poorly known but may be crucial to understand how and possibly why, the climate changed in continental Antarctica before and during the Eocene-Oligocene transition. In this investigation, the variations of hydrogen isotope composition of hydrothermal waters have been studied in detail. By dating the minerals formed upon hydrothermal alteration, a record of meteoric-hydrothermal water compositions has been reconstructed, enabling the atmospheric conditions during the Cenozoic era to be inferred. This continental record of polar climates in Antarctica is in reasonable agreement with the global climatic records derived from oceanic deep cores and with the model curve for atmospheric pCO_2. These observations give insights into the climatic evolution of continental areas in an important region over a critical time interval suggesting that temperature fluctuations as large as 20°C occurred repeatedly during the Eocene. The aim is to determine continental paleo-temperatures for different periods of the Cenozoic and to merge data from hydrothermal systems from high latitude regions of both hemispheres to define bi-polar climatic conditions through geological time. Preliminary data of hydrothermal systems from high latitude regions of the Northern Hemisphere fit the hydrogen based paleo-temperature curve, thereby implying that extending this study to other Cenozoic (and older) intrusive bodies may better constrain continental paleo-temperature records both in space and in deeper times.

References

Dallai L., & Burgess R., 2011. A record of Antarctic surface temperature between 25 and 50 million years ago. Geology **39**, 423–426.

Evolution of silicic magmas and the origin of the Daly Gap at Santa Barbara volcano, Terceira, Azores

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The origin of compositional gaps (e.g. the Daly Gap) and high volumes of silicic rocks among volcanic deposits in ocean islands have remained controversial subjects. Although silicic magmas can be produced by fractional crystallization of parental basalts, the paucity of intermediate compositions and the relatively large volumes of silicic compositions amongst erupted materials are difficult to explain by this mechanism. Several hypotheses have been proposed for the scarcity of erupted intermediate rocks, including development of physical/chemical properties (density, viscosity and/or volatile content) that may inhibit them from erupting [1]. Alternatively, melting of altered mafic crust may produce bimodal volcanism without formation of intermediate magma compositions, and can potentially explain large volumes of silicic deposits [2].

Santa Barbara volcano (Terceira, Azores) is an ideal locality for investigating these problems. Terceira has an uncommonly high percentage (~50%) of silicic volcanic rocks relative to mafic compositions [1], and Santa Barbara exhibits a well defined Daly Gap from 54 to 64 wt.% SiO_2 amongst eruptive products, including flank basalts and trachytes erupted from the central vent [3]. However, we show that the compositional gap closes if plutonic nodules contained in air fall deposits from Santa Barbara are considered.

We have performed petrographic, major and trace element, and Sr–Nd-Pb isotopic analyses on eruptive products from the relatively recent (<2ka) Santa Barbara-G trachyte deposit [4], as well as flank basalts [5] and plutonic nodules collected from older trachytic air fall deposits from Santa Barbara. These data demonstrate an essentially continuous compositional variation from 45 to 69% SiO_2, with the plutonic nodules ranging from 45 to 65 wt% SiO_2, and thus effectively filling in the compositional gap defined by the bimodal basaltic-tracyhtic volcanic products. Trace element systematics indicate that the plutonic nodules are genetically related to the basalts and trachytes, following a common fractional crystallization path. The plutonic nodules exhibit large (~4- to 10-fold) variations in concentrations of trace elements including highly incompatible elements (Hf, Nb, and Zr) and compatible elements (Ba and Sr). Most significantly, some of the plutonic nodules have incompatible element concentrations equal to those in the Santa Barbara G trachytes. Together, these data suggest that the plutonic nodules represent liquid rather than cumulate compositions, as inferred for syenites from Fogo volcano (Sao Miguel, Azores; [6]).

These results indicate that intermediate magma compositions are produced during fractional crystallization from parental basalts to trachytes, and that these intermediate magma compositions generally fail to erupt as volcanic products. Ongoing Sr-Nd-Pb and planned U-series isotopic analyses of the plutonic nodules will further constrain their genetic relationship to the Santa Barbara basalts and trachytes, and potentially allow evaluation of their crystallization ages.

[1] Mungall & Martin (1995) *Contrib. Mineral. Petrol.* **119(1)**, 43-55 [2] Bindeman et al. (2006) *Earth and Planet. Sci. Lett.* **245**(3-4), 245-259 [3] Self (1976) *J. Geol. Soc. of London* **132**(6), 645-666 [4] Daly et al. (2010) Goldschmidt [abs.] A204 [5] Yu & Widom (2010) Goldschmidt [abs.] A1191 [6] Widom et al. (1993) *J. Pet.* **34,** 929-953