Amphibole and mid-crustal differentiation: Evidence from a Jurassic arc section, Vancouver Island, BC

JEFF LAROCQUE AND DANTE CANIL

School of Earth and Ocean Sciences, University of Victoria,
Victoria, BC, Canada (larocque@uvic.ca)

Island arcs are a key ingredient in models of continental growth, and appear to exert a dominant influence on the composition of the continents [1]. The pathways along which arc magmas evolve are therefore important to our understanding of the evolution of continental crust. A window into the deeper level differentiation of island arcs is preserved on Southern Vancouver Island in the exhumed Bonanza arc, active from approximately 195 Ma to 165 Ma.

The central role of amphibole in the differentiation of the Bonanza arc is attested to by petrography, and by major and trace element systematics, including Sc, Dy/La ratios, and Cr. Ultramafic bodies occurring in the plutonic section of the arc consist of cumulus olivine (up to Fo_{82}), poikilitically enclosed by amphibole and/or orthopyroxene, with minor post-cumulus plagioclase, biotite, and rare clinopyroxene. Amphibole inclusions in olivine are also noted. The olivines are embayed, and are interpreted to have been in a reaction relationship with amphibole. These cumulates form the geochemical complement to the gabbroic and gabbro-dioritic compositions of the arc, which are dominantly plagioclase-, amphibole-, biotite-, and quartz-bearing, and lack olivine and pyroxenes.

The very high Cr contents of the amphibole oikocrysts, as well as the presence of amphibole inclusions in cumulus olivine, suggest that amphibole appeared very early in the crystallization sequence, at or near to the liquidus. Experimental work on basaltic compositions at the relevant fO_2 conditions (~NNO+1) for arc magmas reveals that amphibole can, under H_2O-saturated conditions, replace olivine as the liquidus phase, at pressures above 7-8 kbar [2], [3]. The liquidus temperature under such circumstances corresponds to amphibole's maximum thermal stability, ~1050ºC. Experimental work also documents a reaction relationship between olivine, pyroxenes, and amphibole.

The Bonanza arc reflects magma differentiation at mid-crustal depths, where amphibole is a near-liquidus phase in basaltic compositions, and exerts a dominant influence on the evolution and water budget of intermediate magmas.

[1] Hawkesworth & Kemp (2006) *Chemical Geology* **226**, 134-143. [2] Barclay & Carmichael (2004) *Journal of Petrology* **45**, 485-506. [3] Grove *et al.* (2003) *Contrib. Mineral Petrol* **145**, 515-533.

The abiotic synthesis of nucleosides, nucleotides and RNA in hydrothermal systems

D.E. LAROWE*, A.W. DALE AND P. REGNIER

Department of Earth Sciences - Geochemistry, Utrecht
University, 3508 TA Utrecht, Netherlands
(*correspondence: larowe@geo.uu.nl)

Recent calculations have shown that the abiotic synthesis of nucleobases, ribose and deoxyribose from formaldehyde (CH_2O) and hydrogen cyanide (HCN) under hydrothermal conditions are thermodynamically favored [1]. Yet, to form the nucleosides, and ultimately by the addition of phosphate, nucleotides, that constitute RNA, a thermodynamic drive (positive chemical affinity) must also be available for the condensation reactions among these fundamental building blocks. In this study, the energy required for these condensation reactions and the polymerization of RNA at high temperatures and pressures has been quantified. Results reveal that none of these reactions are thermodynamically favored under the low concentrations of nucleobases, ribose and deoxyribose that would exist on the early Earth. A concentrating step of the building block molecules, likely driven by the steep thermal gradients that exist in some hydrothermal systems, is required to overcome this energetic limitation. Building on work by Baaske *et al.* [2], who calculate that nucleotides can be concentrated in hydrothermal environments through a combination of convection and thermal diffusion in narrow pore spaces, we show that nucleobases, ribose, deoxyribose and phosphate can be concentrated under hydrothermal conditions to sufficiently high concentrations to overcome this energetic barrier. Calculations of this kind strongly support the notion that hydrothermal systems played a fundamental role in the origin of life.

[1] LaRowe & Regnier (2008, submitted) *Orig. Life Evol. Bios.* [2] Baaske, P. *et al.* (2007) *PNAS* **104,** 9346-9351.