The Columbia River Basalts: Volatile Fluxes During Flood Basalt Emplacement

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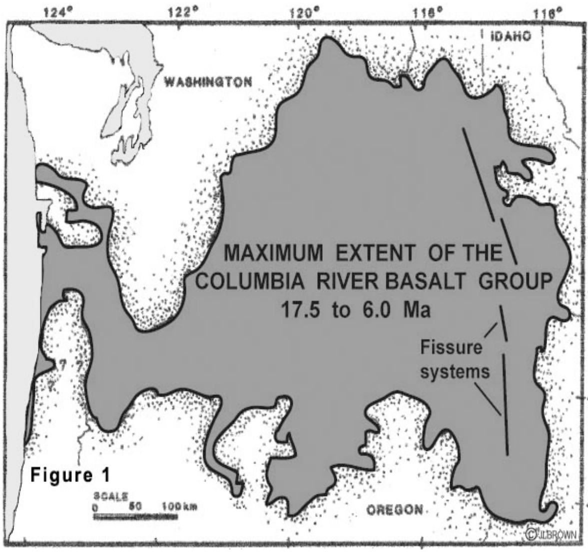
Flood basalt emplacement is a spectacular expression of terrestrial volcanism characterised by very high rates of lava emplacement. Volatiles released during such events are of particular interest as they are implicated in global climatic changes. Scaling the effects of historic eruptions that affected climate (cf. Laki 1783, Holuhruan 2014) has led to considerable effort to model the impact of volcanic volatile interaction with the hydrosphere and atmosphere (McCormick et al 1995, Wignall 2001, Self et al. 2006).



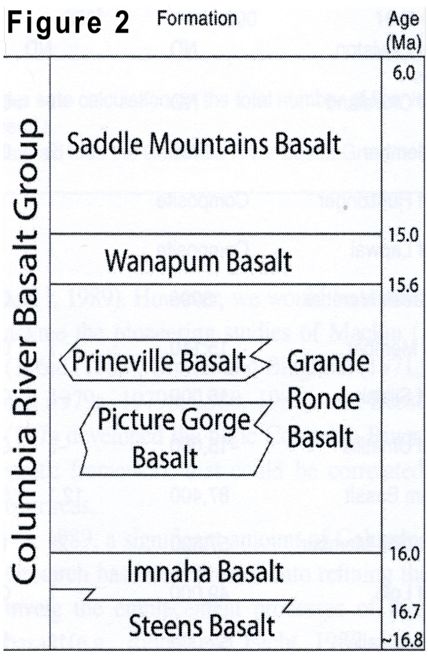
However, the accuracy and predictive power of any model is fundamentally dependent on the quality and accuracy of input parameters. In the case of volcanic volatiles & climate interaction, key parameters, among others, are the *frequency*, *rate* and *magnitude* of volatile release. This project will develop a high-resolution record of volatile release during emplacement of a mid-Miocene flood basalt province that can directly inform climate models.

The Columbia River Basalt Group (CRBG) is the youngest and one of the best-preserved continental flood basalt provinces on Earth, covering over 210,000 km^2 in the NW US (Figure 1). Since CRBG emplacement, the N. American plate has moved west-southwest, leaving a trail of age-progressive volcanism across southern Idaho that terminates beneath Yellowstone National Park volcano in northwest Wyoming.

Geochronology of a flood basalt event - Numerous geochronological studies have applied radiometric (K-Ar, $^{40}Ar/^{39}Ar$) and magneto-stratigraphic approaches to the CRBG (Barry et al. 2013). The $^{40}Ar/^{39}Ar$ method is suited to dating basalts due to simple cooling histories of flows, retention of radiogenic Ar and the presence of sufficient potassium (McDougall & Harrison 1999). Prior radiometric determinations suggest that the CRBG was active from 17 to 5 Ma, with the largest pulse (Grande Ronde) emplaced between 16 and 15 Ma (Fig. 2 –CRBG stratigraphy; Riedel et al. 2013).

Age differences between flows and the precision of ages determined for flows give measures of magma emplacement rates, key factors in determining the volatile flux to the surface. Precision of published CRBG $^{40}Ar/^{39}Ar$ ages are typically ±1%. This translates to a ~ 300,000 year window during which a given lava flow may have erupted, so a sequence of basalts would be inferred to degas over hundreds of thousands of years. Better age precision can narrow that window.

Advances in mass spectrometry (Mark et al. 2009), sample preparation, the accuracy of decay constants, and ages of standard minerals (Renne et al. 2010) have improved the accuracy and precision of $^{40}Ar/^{39}Ar$ ages with ±0.1% (1□) now achievable.



Melt inclusions and volatile history - Volatiles are key drivers of volcanism and, via volume changes and buoyancy forces, are responsible for a wide range of observed phenomena such as ascent of magma through the lithosphere, emplacement at the surface and transport in the atmosphere. Melt inclusions provide a record of volatile contents of magma prior to degassing near the surface. Melt inclusions can be complex entities composed of

any combination of glass, crystals or gas bubbles, and may or may not be open systems. Nevertheless, decades of research have shown that melt inclusions yield reliable and quantitative data on volatiles (Lowenstern 2003).
This doctoral project will focus on characterizing both the earliest and the most voluminous phases of CRBG volcanism. Achieving a high precision record from this flood basalt province will prove invaluable for climate modelling studies and for comparisons to climate records that suggest perturbations to, for example, the global carbon cycle during the mid Miocene (Armstrong-McKay et al. 2014).
Melt inclusions also provide an avenue to tackle one of the problems in determining sources of the CRBG. Many of these lavas demonstrate substantial geochemical heterogeneity, but melt inclusions provide a means to isolate the different sources contributing to composite basaltic eruptions (Maclennan 2008). Laser-ablation ICP-MS analysis of melt inclusions will be used to try and resolve both the character of the sources contributing to CRBG and how the involvement of those sources influences the heterogeneity of individual flows.

Field Work - The CRBs are spectacularly exposed across the Columbia basin due to repeated ice age mega-floods that scoured vast canyons into the bedrock. Outcrops and accessibility are excellent and preservation is exceptional due to the relative youth of the province and the arid conditions that prevail in the region. Careful sample collection in collaboration with Washington State University (Prof. J. Wolff) and the British Geological survey (Dr. C. Vye-Brown) will be used to obtain the best possible materials for $^{40}Ar/^{39}Ar$ and melt inclusion study.

Petrology - Characterisation will centre on the preservation and nature of the crystal cargo in the CRB units studied, essential for both the melt inclusion aspect of the study as well as the geochronology effort.

Project aims & objectives:

- **High-precision Ar/Ar chronology of CRBG with goal of 0.1% (or better) precision**
- **Melt inclusion trace element and volatile content determinations**

References & Further Reading

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