Constraining melt transport, storage, and chemical modification in monogenetic vents: Focus on the Auckland Volcanic Field

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Monogenetic vent fields are a major type of volcanism at many subduction settings (e.g., New Zealand, Cascadia, Trans-Mexican Volcanic Belt), and the dominant type of continental basaltic volcanism. Many monogenetic vent sequences display systematic stratigraphic variations in chemical and isotopic composition that may derive from time-variant magma generation and extraction processes (c.f., *Reiners*, 2002), or from varying degrees of crustal contamination (c.f., Paricutin Volcano; *McBirney & Taylor*, 1987). Understanding the origin and significance of temporal trends in monogenetic vents is central to several GeoPrisms themes, including "How are volatiles, fluids, and melts stored, transferred, and released through the subduction system?" and "What are the geochemical products of subduction zones, from mantle geochemical reservoirs to the architecture of arc lithosphere, and how do these influence the formation of new continental crust?" (GeoPrisms Draft Science Plan). In addition, several young, potentially active monogenetic vent fields are located in or near high-population-density areas (Auckland, Mexico City), and thus represent a significant but poorly characterized volcanic hazard. For example, several recent studies have examined volcanic hazards posed by the Auckland Volcanic Field (*Sandri et al.,* 2012), and challenges associated with monitoring this field using both ground deformation (*Kereszturi et al.*, 2012) and seismic monitoring (*Ashenden et al.*, 2011).

The Auckland Volcanic Field (AVF) contains approximately 50 late Pleistocene to recent eruptive centers scattered within and surrounding the Auckland metropolitan area (*Kermode*, 1992; *Allen & Smith*, 1994). Most of the volcanic cones are small (<0.05 km^3), but a few recent eruptions such as at Rangitotu volcano have been much greater in size (up to 2 km^3). Many AVF eruptive products are porphyritic and contain large phenocrysts of olivine with lesser clinopyroxene and plagioclase. Fractional crystallization thus appears to have played a important role in the evolution of some AVF lavas, with both shallow fractionation of olivine and deeper fractionation of clinopyroxene potentially generating much of the compositional variations observed in individual monogenetic vents (c.f., *Smith et al*., 2008). However, recent U-Th-Ra studies suggest that mixing of melts from distinct mantle sources is also important (*McGee et al.*, 2011). Pronounced ^{226}Ra excesses in eruptive products from Rangitoto volcano (~500 BP, AVF) also constrain the maximum duration of crustal melt storage prior to eruption.

Because of the large population of the Auckland metropolitan area (~1.46 million inhabitants), volcanism within the AVF presents a significant volcanic hazard (c.f., *Sandri et al*., 2012). Understanding the conditions of magma storage preceding AFV vent eruptions can aid the development of methods for detecting magma ascent or injection that precedes volcanic eruptions within the field. For example, if sill emplacement shortly precedes the eruption of many monogenetic vents, then possible loci of future eruptions might be determined through remote sensing of land surface deformation that would accompany this emplacement (*Kereszturi et al.*, 2012). However, the magnitude and spatial distribution of surface deformation will be strongly influenced by the depth of magma injection and the volume of stored melt.

We propose that a more complete understanding of the processes of melt generation, transport, and pre-eruptive storage leading to monogenetic vent eruptions can be gained by integrating ongoing geochemical studies of temporal geochemical variations in individual monogenetic vent sequences with numerical modeling of melt transport and sill injection/deflation processes and focused geophysical investigation of the structure of the mantle and crust beneath the AVF. Several questions regarding melt generation and transport that have implications for not only our understanding of melt generation and evolution, but also for assessment and monitoring of volcanic hazards, include:

1) Do systematic compositional variations in monogenetic vent sequences primarily reflect variable melt/crust interaction, or mixing of discrete parental melts derived from heterogeneous mantle?
2) What are the pre-eruptive volatile contents of monogenetic vent magmas, and how do these influence eruptive style?
3) What is the spatial and temporal distribution of melt in the mantle and crust beneath active monogenetic vent fields?
4) Where and for how long are monogenetic vent magmas stored in the crust prior to eruption?
5) How can insights gained from geochemical and geophysical studies on the processes of melt generation, transport, and storage related to monogenetic vents be utilized to improve volcanic risk assessment and monitoring of active or potentially active monogenetic vent fields?

Community efforts that could be coordinated to address these questions include: FTIR study of melt inclusions and phenocryst phases to constrain pre-eruptive volatile contents and depths of magma storage; numerical modeling of ground response to magma emplacement at depths appropriate for the AVF; constraints on the duration of crustal melt storage from crystal size distributions and U-Th-Ra disequilibria; optimized seismic studies designed to constrain spatial (and temporal?) variation in melt fraction within the mantle and crust beneath the AVF; utilization of temporal geochemical variations in monogenetic vent sequences to constrain quantitative models of melt migration and storage.

References:

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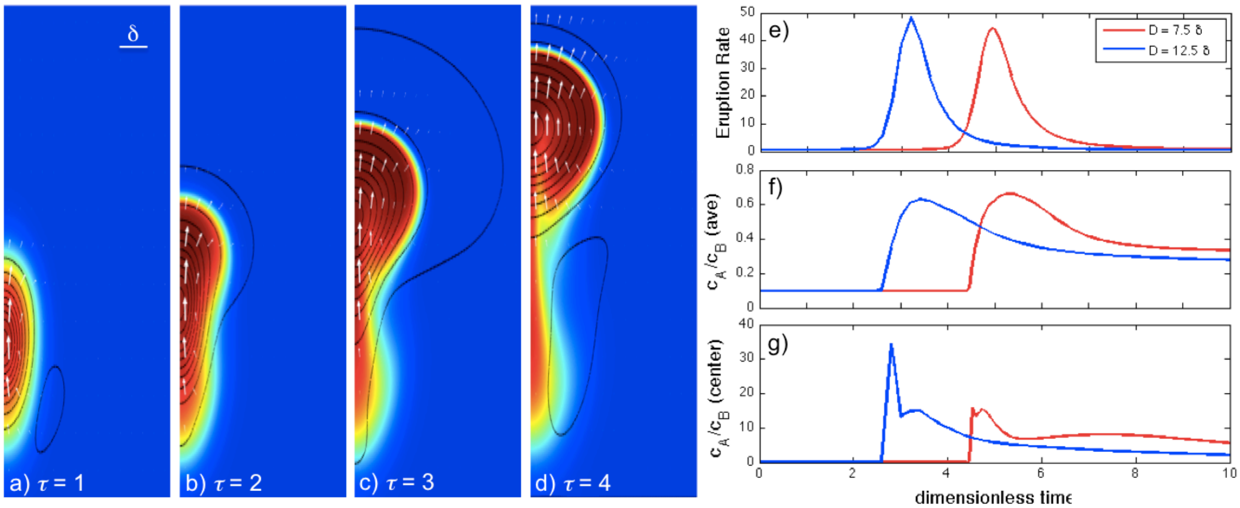

Figure 1. (a to d) Numerical simulations of an isolated pool of melt (left boundary is a symmetry axis), due to localized melting of a fertile heterogeneity, rising through an ambient mantle at very low melt fraction in a domain of 6 by 20 compaction length, δ. The black contours show the porosity normalized to the background, white arrows indicate melt velocity, and the color indicates the concentration of a tracer A introduced with the melt pool. (e to g) Evolution of the magma at the surface (top of simulation domain) for melting at two different depths. The melt composition in (f) is averaged over the entire top of the domain while (g) shows the more extreme variability at the center of the rising pool, i.e. the top left corner of the domain.

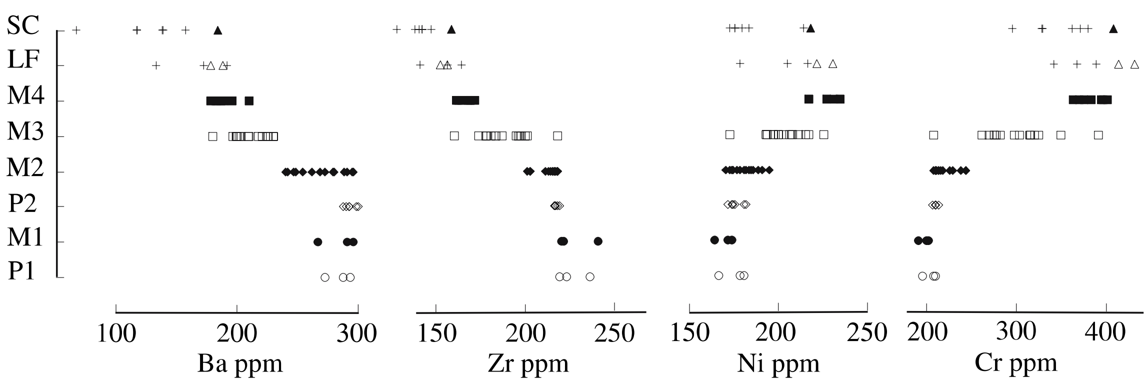

Figure 2. Stratigraphic variation in trace element abundance variations in the Crater Hill monogenetic vent sequence, Auckland Volcanic Field. From Smith et al. (2008). Similar chemical trends are observed in AVF vent sequences. Smith et al. (2008) argued for significant high-pressure clinopyroxene fractionation as a potential source of the chemical variations observed at Crater Hill. However, McGee et al. (2011) suggested mixing of eclogite- and peridotite derived melts generated the chemical variations observed at Motukorea Volcano, AVF.