AAPG Datapages/Search and Discovery Article #90295 ©2017 AAPG Asia Pacific Region GTW,
Influence of Volcanism and Associated Magmatic Processes on Petroleum Systems, Oamaru, New Zealand, March 14-16, 2017

Structures Controlling Permeability in Lava Domes

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ABSTRACT

Lava domes are the result of the extrusion of high viscosity lava, often extruding after the explosive climax of large eruptions. Although the explosive phase of the eruption may have waned, the lava which extrudes can be highly vesicular and permeable; this porosity and permeability evolves over the course of the eruption as structures such as shear zones destroy or create porosity and permeability. Lava dome structures are highly heterogeneous due to the many factors which control their development, including viscosity (itself controlled by water, silica and crystal content of the lava; e.g. Nakada et al., 1995; Dingwell et al., 1996), bubble growth, coalescence and collapse (e.g. Bull et al., 2012), the formation of shear and breccia zones (Hale and Wadge, 2008), palaeotopography and extrusion rate (e.g. Platz et al., 2007; Vallance et al., 2008). Since the viscosity of lava domes is so high, they rarely flow far from the vent site and therefore domes (and dome complexes) inevitably mark vertical conduits that are several kilometres in height; the variation in their structure, as well as their gas or fluid permeability, is not only horizontally variable, but also vertically so. Lava domes are built up from of a series of lobes, spines, breccia and talus, and can grow exogenously (as a result of extrusion of a spine or breakout flow from the rest of the dome; e.g. Vallance et al., 2008), or endogenously (through inflation of the core or an individual lobe from within; e.g. Nakada et al., 1995). Each of these methods of growth produces different internal structures such as flow bands (Stasiuk et al., 1996; Fink and Anderson, 2000), fractures, shear zones and breccia zones (e.g. Kendrick et al., 2014; Sahetapy-Engel and Harris, 2008), all formed during ductile or brittle deformation within a lava dome. The porosity of lava domes can vary from highly porous pumice (80% porosity) to dense obsidian (<10% porosity), although is generally low (<40%; Jaupart and Allegre, 1991; Klug and Cashman, 1996; Castro and Cashman, 1999; Mueller et al., 2005; Wright et al., 2009). As lava extrudes, bubbles form, grow and coalesce in the conduit, before deformation forces (such as shear) affects this network (Zhang and Sanderson, 1998; Laumonier et al., 2011; Lavallée et al., 2013). Shearing (i.e. ductile deformation) elongates bubbles and creates anisotropic permeability in the direction of elongation (Okumura et al., 2009; Wright et al., 2006), while compression may act to close bubbles and reduce permeability (Ashwell et al. 2015). As the lava dome cools, or as strain rates increase, brittle deformation can also increase permeability through thermal stresses (Fortin et al., 2011) or production of breccia zones (e.g. Ashwell, 2013).