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The importance of being pillowed: using pillow lava as a paleo-climate proxie in glaciovolcanic settings

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Pillow lava may be the most abundant type of lava morphology on Earth throughout most of Earth's history. Pillow presence always implies eruption/emplacement of lava into (1) a medium with a significantly different viscosity than that of the lava, and (2) a medium in which heat can be removed efficiently enough from the lava/medium interface to prevent whole scale physical and chemical homogenization. Although the 'medium' is most commonly water, pillow-shaped lava can also form by intrusion into wet sediment or even emplacement into cooler, higher viscosity magma. During glaciovolcanic eruptions, pillow lava forms in a variety of different environments including (1) eruptions into water at variable confining pressures (e.g. pillow ridges/mounds), (2) intrusion into unconsolidated volcaniclastic materials (e.g. pepperite and pillowed dike margins), (3) eruption into water-filled, ice-confined tunnels, and (4) flow of subaerial lava into englacial lakes (e.g. pillow lava deltas).

Differentiating between different eruption environments can require the use of both field and laboratory techniques. Field observations of pillow mounds/ridges or individual pillows can help distinguish (1) from (3) based on morphologies indicative of large-scale confinement, or shapes of individual pillows (e.g. Skilling 2009). However, differentiating between pillows formed in (1), (3) or (4) can also be difficult based solely on field observations. Dense, non-vesiculated pillows could form by eruptions of 'wet' magmas at high confining pressures, from eruptions of 'dry' magmas at a range of confining pressures, or by flow of subaerial, degassed lava into water. Differentiating between these three scenarios may require measurements of volatiles from fresh, pillow rim glass and use of one of a variety of techniques for documenting the heterogeneity and concentrations of volatile species (e.g. Tuffen et al and Owen et al, this session), as well as estimation of volatile saturation pressures, which are model dependent (e.g. Edwards et al., 2009).

As demonstrated by many workers, close field and laboratory analysis of pillow lava has significant potential as a paleo-environmental proxie. Morphologies can be used to infer direct ice-contact. Volatile concentrations can constrain overlying ice/water thicknesses. The highest elevations of glaciovolcanic pillow lava constrain minimum ice thicknesses (e.g. Smellie 2000). Variations in vesicularity within pillow ridges can even be used to infer syn-eruption changes in confining pressures due to catastrophic water-drainage events (e.g. Hoskuldsson et al., 2006). Further refinements in our understanding of pillow lava formation will continue to improve the importance of being pillowed for using mafic glaciovolcanism as a climate proxie.

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