In Vulkan's Forge

Experimental geoscience began in the furnaces, kilns, and crucibles of the glass workers and metallurgists of the industrial revolution[1]. Pioneers of experimental petrology and geochemistry worked with industrialists and artisans who had the craft-knowledge and skill to manipulate silicates at high temperature[1,2]. These early encounters between geoscientists and glass workers spawned diverse disciplines that are now central to geoscience research. This rich heritage of knowledge exchange is of great benefit to artisans as well as geoscientists. In particular, the conditions and processes of volcanic interiors are found in glass art studios every day. We advocate that every volcanologist should enter a glass workshop – take a step into *Vulkan's forge* – to develop a visceral understanding of the materiality of magma.

Artists manipulating hot glass in their workshops exploit the same processes that occur in natural melts: viscous flow, brittle glass phenomena, bubble dynamics in melts, viscous threading, welding and sintering. In nature these processes are a mechanical consequence of magma transport and are seen in the textures and morphologies of volcanic products. In the glass studio these processes are deliberate, forming the elements of the glass artist's tool kit, and their mastery is the essence of the glass artist's skill.

The behavioural similarity of magma and studio glass arises chiefly from similarity in their viscosity, and its dependence on temperature. On eruption, magma viscosity ranges from approximately 100 Pa.s, typical of a basaltic eruption[3], to more than 10^8 Pa.s, typical of silicic eruptions[4]. In the workshop, glass has the same viscosity range, and artists melt, gather, and work studio glass at viscosities of magmatic liquids. The chemical composition of most magma is more complex than that of industrial glass used in the workshop, but the physical properties determining flow behaviour are remarkably similar.

With effective knowledge-exchange, practices can translate between laboratories and workshops. Indeed, some new discoveries in volcanology are already common-knowledge in glass studios. For example, the phenomenon of bubble shrinkage and resorption during slow cooling of bubbly liquids has long been used in glass workshops to remove unwanted bubbles from large batches of glass. However, it has only recently been invoked as a key phenomenon in volcanoes in nature[5].

The makers who create our material culture correspond with the material itself through their practice. Making is not simply an algorithmic process of producing an object from a blueprint in their minds[6]. We suggest that the communication between a glass worker and the glass, as it cools, flows, breaks, deforms and reforms, is an essential tool for building a physical intuition about glass behaviour. This same intuition could be transformative for volcanologists, not least because the behaviour of hot glass and magma is not a component of our everyday experience, and can confound our expectations. In the design and testing of hypotheses in physically grounded research, intuition is key to negotiating the way to insight and discovery[7]. Working in a glass workshop would expose volcanologists to phenomena that go beyond what they might imagine in their laboratories, or could get close enough to witness during eruptions.

The communication between glass artists and volcanologists advocated here is bilateral and mutually beneficial. There is direct evidence for the two-way nature of the inspiration and experimentation that can be born of looking at studio glass as a pseudo-magmatic phenomenon, and at magma as a source of glass art (Figure 1). Correspondence between volcanologists and glass on a large scale could be an untapped resource for understanding volcanic phenomena.

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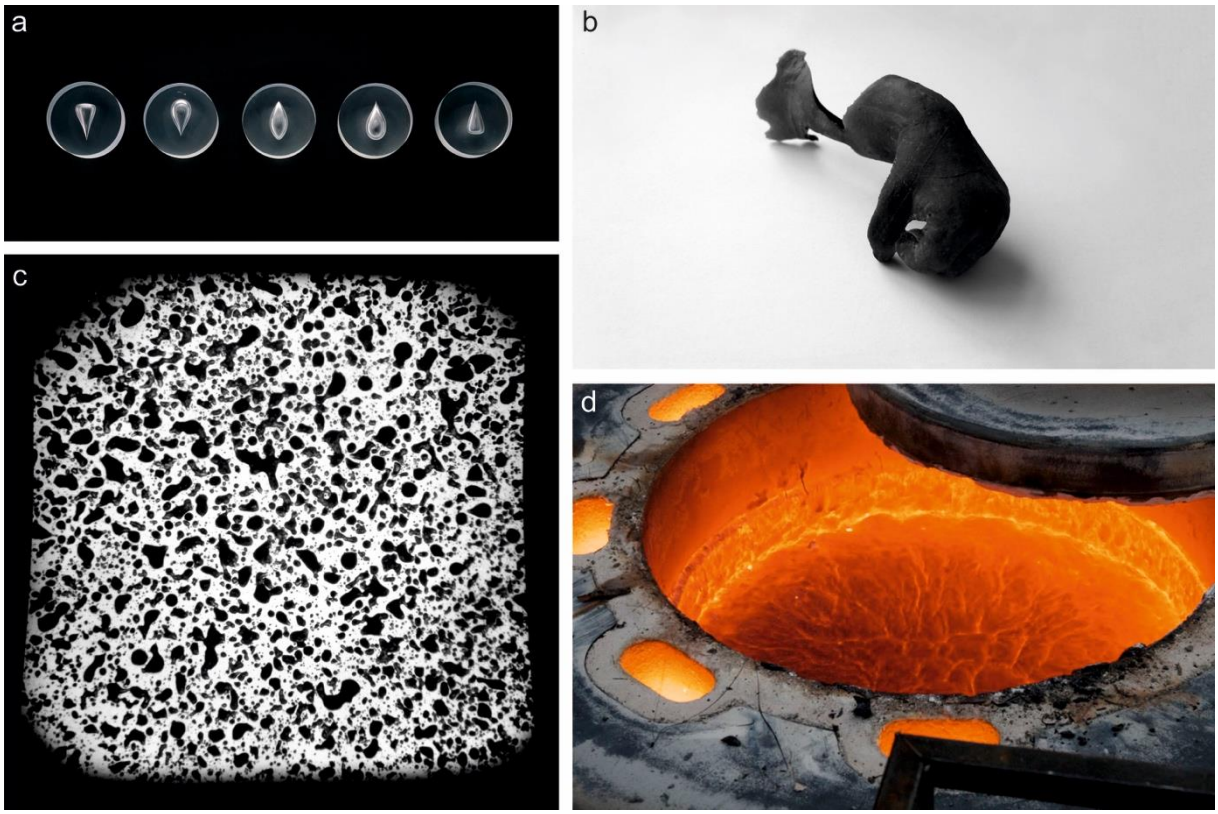

Figure 1. Art inspired by volcanoes and produced in collaboration with volcanologists. Studio glass and natural magmas share similar physical properties, such as viscosity. Through collaboration, volcanologists gain a visceral understanding of glass and magma and artists gain inspiration to create. **a** – 'Progression' by Colin Rennie is a set of vesicles deformed by hand while hot in blown glass. **b** – 'PEDM' by Alistair Mackie uses sintered fragments of crushed Hrafntinnusker volcanic obsidian, cast moulded by pate de verre. **c** – Helen Petersen softened and sintered[8] volcanic ash from the AD79 Vesuvius eruption onto glass. Once cooled, it is projected using a light source. **d** - The furnace from the Lava Project at Syracuse University that brings artists such as Robert Wysocki together with volcanologists for mutual benefit.