sequences of the *phn* genes of the C–P lyase pathway have been reported[8], but Dyhrman *et al.*[3] have taken their investigations several steps further. The introduction of genetic material during horizontal gene transfer from one bacterial species to another does not guarantee that it will be functional in the recipient species. So Dyhrman *et al.* studied the expression of the phosphonate genes in *Trichodesmium* cultures grown under different conditions. Their results showed that genes of the C–P lyase complex are expressed only under conditions of phosphate starvation, similar to those found in nutrient-poor waters. Dyhrman *et al.* also looked for, and detected, *phn* gene expression in populations of *Trichodesmium* collected from the nutrient-depleted western North Atlantic.

It seems, then, that *Trichodesmium* has different strategies for exploiting a wide range of phosphorus compounds as nutrients, including phosphonates (Fig. 1). The limited information that exists suggests that phosphonates may be ubiquitous in the oceans[9], making them a valuable phosphorus source for some phytoplankton. As dissolved organic phosphorus often constitutes the largest reservoir of this nutrient[10,11], drawing from this pool may give *Trichodesmium* an ecological advantage over other phytoplankton (including another oceanic diazotroph, *Crocosphaera watsonii*) that can apparently use only monophosphate esters or inorganic phosphate (Fig. 1). This may be an evolutionary adaptation to conditions in the nutrient-poor ocean gyres that are far from continental sources of nutrients. *Trichodesmium* species can form extensive blooms, up to some 300,000 km^2 in extent[12]. Such blooms may in part be made possible by their unique ability to exploit a nutrient source that is not available to other nitrogen-fixing organisms.

As to remaining questions, it is still unclear what fraction of the phosphorus required by *Trichodesmium* is provided by phosphonates; even under extreme inorganic phosphorus limitation, phosphonates may be a relatively small part of the phosphorus budget. And it would be informative to include sequence data from a recently discovered unicellular nitrogen-fixing cyanobacterium[13] in Dyhrman and colleagues' phylogenetic analysis. Because single cells may have lower nutrient requirements than do colonies such as *Trichodesmium*, it will be of interest to know whether or not these unicellular diazotrophs have the genetic capability for phosphonate uptake.

Further research on the cycling of phosphonates in marine systems is also called for, but that won't be an easy enterprise. Phosphonates were discovered in pre-concentrated high-molecular-weight organic matter in marine systems only eight years ago[14]. Although the presence of phosphonates and phosphorus esters can be determined using nuclear magnetic resonance spectroscopy[9,14], there is no available method for quantifying phosphonates in sea water. The relative importance of this nutrient type under variable oceanographic conditions cannot be assessed without such measurements.

Finally, Dyhrman and colleagues' findings point to yet another role for *Trichodesmium* colonies in the open ocean. Just as the atmospheric nitrogen that they have fixed becomes available to other organisms, so those organisms may also benefit from the extra reactive phosphorus that *Trichodesmium* releases in excretory products or when it dies. ■

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VOLCANOES

Interpreting inclusive evidence

Julia E. Hammer

Crystallization of ascending magma may affect the style of volcanic activity. Pockets of melt incorporated into crystals provide windows on processes that occur several kilometres below Earth's surface.

Most volcanic activity on land occurs above subduction zones, where one tectonic plate dives beneath another. When a subduction-zone volcano erupts, magma containing abundant dissolved H_2O ascends from a reservoir 8–14 km below the Earth's surface: it is the fate of H_2O vapour bubbles boiling out of the rising melt that largely determines whether the magma emerges with a bang or a whimper. Mount St Helens in Washington state displayed an impressive repertoire of eruptive styles in the early-to-mid 1980s. A magma intrusion produced a bulge on the volcano's flank in March 1980; eruption intensity peaked on 18 May with a sustained, explosive eruption of ash and pumice; and an uneasy denouement of brief explosions and lava extrusions characterized activity for the subsequent half-dozen years.

In a report in *Geology*, Blundy and Cashman[1] present new analyses of the products of Mount St Helens' activity during 1980. They interpret the compositions of frozen melt trapped within large crystals as snapshots captured through time during the magma's ascent, and ascribe variations in those compositions to sequential H_2O vaporization and crystallization of the melt. The authors suggest that crystallization occurs in response to decompression caused by degassing of the magma in isothermal conditions. They further propose that crystallization influences eruptive intensity through the resulting increase in magma viscosity.

The amount of H_2O that molten rock (a silicate melt) can hold depends strongly on pressure. If melt ascends from depth and decompresses, all H_2O in excess of the saturation value enters a vapour phase. If the bubbles do not decouple from the melt and escape, their expansion causes magma to accelerate upwards. The result is further decompression, H_2O vaporization, magma expansion and so on, perpetuating a feedback loop that culminates in eruption. The importance of H_2O doesn't stop with dictating the physical properties of magma. Melting and freezing points of silicate melt are depressed by addition of H_2O, and this provides a thermodynamic driving force for solidification during magma ascent. For example, magmas at typical reservoir temperatures (about 850 °C) are only moderately crystalline when saturated with H_2O. If the melt dries out, extensive crystallization must occur to bring the system back into chemical equilibrium.

Plagioclase is a common crystalline mineral produced by magmas, and its stability is particularly sensitive to the amount of H_2O dissolved in the melt — the less H_2O, the more stable plagioclase becomes. Thus, plagioclase should crystallize in decompressing magmas. The importance of isothermal crystallization during volcanic eruptions is demonstrated by studies of volcanic materials[2,3] as well as laboratory experiments[4–6]. However, most work has focused on the formation of new crystals rather than the growth of existing ones[7]. In these studies, the usual assumptions have been that small plagioclase crystals (microlites) are created during an eruption[8], whereas larger, compositionally heterogeneous crystals (phenocrysts) are inherited from the magma reservoir. In an earlier paper[9], Blundy and Cashman questioned these assumptions: they proposed that

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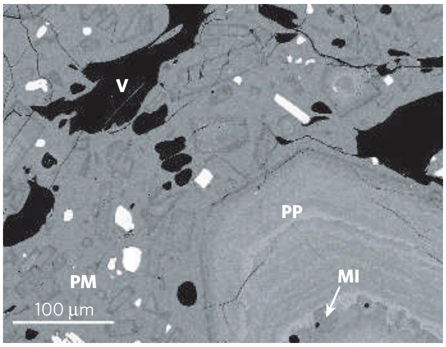

Figure 1 | Photomicrograph of a plagioclase phenocryst with a melt inclusion. This backscattered electron image shows the microtexture of a Mount St Helens lava-dome sample erupted in September 1981. PM, plagioclase microlite; PP, plagioclase phenocryst; MI, melt inclusion; V, vesicle (relict vapour bubble).

plagioclase phenocrysts form in a magma reservoir but then grow considerably during an eruption. In their new paper[1], they support and expand this idea with analyses of the melt inclusions found in phenocrysts (Fig. 1).

Melt inclusions are intriguing aberrations of 'normal' crystal growth. They preserve information about the history of the phenocryst, but are difficult to interpret because the conditions in which they form are unknown, the degree of chemical communication with the outside melt may vary, and post-entrapment processes can modify the original compositions. To address these problems, Blundy and Cashman[1] analysed more than 100 inclusions from six eruptions of Mount St Helens during 1980 that varied in intensity from quiescent lava effusion to sustained explosive activity.

They interpret a large range in observed H_2O contents (0.3–6.4 wt%) as representing saturation at pressures ranging from those at reservoir level all the way up to those near the surface. They also recognize a consistent relationship between the compositions of melt inclusions and the style of eruption that brought material to the surface. A key observation is that melt inclusions in lavas and other products of low-intensity eruptions preserve H_2O concentrations that correlate inversely with an 'incompatible species', potassium oxide (K_2O). Blundy and Cashman's finding that depressed H_2O is paired with elevated K_2O corroborates the notion that degassing and crystallization occur in concert. This trend among the melt inclusions suggests that connections to the surrounding melt persisted until the magma reached shallow levels; tube-like channels are in fact visible in some phenocryst cross-sections. What held these channels open initially, and what change in conditions triggered their closure, are grist for future studies.

In contrast, magmas that ascended rapidly during the explosive event of 18 May 1980 contain melt inclusions that have uniform K_2O yet variable H_2O. Blundy and Cashman interpret the few H_2O-rich inclusions in these magmas as snapshots of magma reservoir conditions, and the remainder as the result of the eruption itself in which partial degassing of the melt happened too quickly for crystallization to occur. There is an alternative interpretation, however, that is consistent with the traditional understanding of plagioclase phenocrysts. Variable H_2O may arise from fluctuations in the CO_2 and H_2O content of magma within the reservoir. Such fluctuations would corroborate the view of the reservoir as an open system subject to periodic influxes of new magma[10].

Most importantly, Blundy and Cashman's interpretation of the melt-inclusion data reinforces the idea that crystallization during an eruption affects the style of intermediate-intensity eruptions[8,11]. The correlation between crystallinity and melt-inclusion H_2O content raises an intriguing chicken-and-egg issue, however. Does degassing-induced crystallization occur only when ascent rates and flow regimes in the magma conduit produce conditions favourable for rapid crystal growth? Or through its influence on magma viscosity, can the solidification process reduce the intensity of an eruption already in progress?

Events at Mount St Helens in 1980 have inspired many studies, the latest being this report[1] detailing changes in melt chemistry at unprecedented spatial and temporal resolution. With the volcano again obliging investigators with new magma since early 2004, a renewed effusion of research is sure to follow. ■

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BIOLOGICAL PHYSICS

Harmonies from noise

Michael Springer and Johan Paulsson

Do random environments make for random responses to them? Mathematical models suggest that this is not always the case — adding noise could create synchronous oscillations in cell–cell signalling systems.

Noise in communication devices is a familiar nuisance. In most Hollywood war films, radio static seems to botch up any attempt at coordinated action, to the frustration of the troops in the trenches. Cells face much the same problem: their signalling is garbled by chemical noise — random fluctuations in the concentrations of different molecular constituents — both inside and outside the cell. This noise could in turn compromise the cell's ability to grow and reproduce — or so one might think.

But two things here are worth considering more carefully. First, chemical fluctuations are always to some degree correlated, so different noise-afflicted cells may see the same random ups and downs. Second, in nonlinear systems (such as those underlying cell development, the cell cycle and circadian oscillators) the effects of the ups and downs do not cancel out; this in turn can qualitatively change the dynamics of the system. Writing in *Physical Review Letters*, Zhou *et al.*[1] propose a model for how the combination of these two effects can create regular and synchronized oscillations in an otherwise non-oscillatory cell system. This is an example of how noise in a biological process can have counterintuitive effects, even suppressing other noise or generating new, coherent behaviours.

The investigations of Zhou *et al.* were inspired by a communication system between bacterial cells known as quorum sensing. Many bacteria produce a small 'autoinducer' molecule that, diffusing in and out of cells, promotes its own synthesis wherever it goes. This provides a population-wide positive-feedback loop that allows individual cells to count their neighbours and take synchronous action: when the population reaches a high enough concentration, the cells collectively switch from a low-production state, with minimal autoinduction, to a fully induced, high-production state.

The effect of changes in the design of quorum-sensing networks has been explored in several models. One proposal is to add a negative-feedback loop through an 'autoinhibitor' molecule that, again diffusing in and out of cells, inhibits its synthesis wherever it goes. This additional loop creates a network similar to a circadian oscillator, in which concentrations go up and down in stable temporal waves; communication between cells by means of a diffusive autoinducer molecule could then allow these oscillations to be