Island Arc Magmatism: Santorini

The Crystal Fractionation experiment

Dr Steve Blake:
The compositional diversity of Santorini's magmas, which range from basalt through andesite to rhyodacite, is generally attributable to crystal fractionation. Crystal fractionation is a process which is quite common in many island arc volcanoes. You should be familiar with some of the geochemical arguments that allow us to interpret chemical data in terms of crystal fractionation, but understanding exactly why and how crystal fractionation occurs in a magma chamber is a problem that we can address in the laboratory.

Narrator:
The experiment we're going to do simulates the magma chamber of a volcano. We use a house-shaped tank filled with sodium carbonate solution and cool it by means of heat exchangers in the roof. This set-up is in the Geophysical Fluid Dynamics Laboratory at the Australian National University in Canberra. The experimental magma chamber has windows, so we can record what happens. Here it's set up for time-lapse photography with a stop clock and tracing paper screen. Look hard at the edges of the tank. We've just begun the cooling experiment and convection has started with cold liquid descending from the roof. As the temperature drops further, crystals have started to grow on the coldest part of the roof. Look very hard indeed close to the surface and you can see a thin up-flow. You may have to re-run this sequence several times to spot it. As the crystals come out of solution the residual liquid becomes less dense. This rises and forms a series of stratified layers coming down from the apex of the tank. This segregation of the residual liquid from the crystals is called convective fractionation. As time passes, more and more crystals grow, and the complementary pool of fractionated liquid at the top of the chamber gets deeper. The lightest, most watery solution sits at the apex and is underlain by slightly denser solutions which have more sodium carbonate. In other words, the fractionated cap has become compositionally zoned as a result of convective fractionation. Dye injected in from the roof illustrates that there are two very different kinds of liquid in the chamber. Crystals which have fallen to the floor drive turbulent convection in the lower half, while stratified and fractionated layers remain at the top. The longer the experiment lasts, the more fractionated the zoned liquids become. A stimulating experiment. We hope that you can find several parallels between it and the petrology of Santorini's magmas. It's tempting to see the crystalline encrustation on the chamber roof as the source of some of the coarse-grained xenoliths caught up Santorini's lavas. And what about the effects of time? A long period of volcanic inactivity should allow large volumes of evolved, possibly compositionally zoned, magma to accumulate. Perhaps this is how the rhyodacite and andesite of the Minoan eruption were formed during the 14,000 years which separates it from the previous major eruption. So, plenty of things to think about. This is the kind of volcano that invigorates the geologist.

Dr Richard Thorpe:
Well we both agree that Santorini is a very exciting island arc volcano. Most of the products are explosive in origin, and they include a superb variety of pyroclastic fall and pyroclastic flow deposits. Now the rocks themselves range in composition from basalt through andesite and dacite to rhyolite. We think this range of rock compositions is developed in a magma chamber below Santorini. Well, we also think that the parental magma that went into the magma chamber to create those compositions was basalt, formed by melting of mantle a long way below Santorini, as a result of dehydration of oceanic lithosphere descending from the trench. Now, within the magma chamber, the major process we think responsible for the diversification of the magmas was fractional crystallization, but there's also evidence for magma mixing. So what I'd like to think about are what magmatic processes are taking place in the chamber below where I'm standing? And finally, it's nice to speculate about when Santorini might erupt again.