Down under the volcano

Jonathan Fink

IN the past two years, more geologists have been killed studying active volcanoes than ever before. It was perhaps fitting then that a recent meeting* of over 600 volcanologists was held in the relative calm of Australia, a continent that has seen no eruptions in historic times. Under the theme of "Ancient Volcanism and Modern Analogues", speakers discussed novel ways to learn about the normally inaccessible interiors of incendiary pyroclastic flows and giant submarine landslides, in order to improve prediction of their behaviour and reduce the associated loss of life.

In Japan, the collapse of Mount Unzen's lava dome on 3 June 1991 sent a cascade of intensely hot magma fragments down the flank of the volcano. Although the most extreme conditions occurred within the dense, concentrated pyroclastic flow, most of the victims were killed or injured by the cooler, more dilute pyroclastic surge cloud. Harrowing accounts provided by the handful of survivors formed the basis for an unusual study (S. Aramaki, Hokkaido University). From observations such as "Mr A heard a noise in his yard, opened the front door, and was immediately knocked on to his rear end", and "Racing away from the eruption, Mr C saw red glowing pumice lumps bouncing on the hood of his car", it was possible to map out the overpressures and temperatures within the ash cloud. The fact that nearly all who perished were outdoors and enveloped by the more extensive surges rather than the hotter but more restricted pyroclastic flows prompted a recommendation that numerous concrete shelters be built around the base of the volcano as shields against these more widespread dangers.

Recordings

If Mr A and Mr C had intended to be in the path of a pyroclastic cloud, they could have been outfitted with asbestos suits, thermocouples and pressure gauges to quantify conditions hidden within the infernal avalanche. A safer approach (M. Sumita, University of Kiel, and J. Oikawa, University of Tokyo) relies on the latest acoustic technology to record precisely the sounds made by pyroclastic flows. Comparing frequency spectra of the whooshes, clinks and crashes made by colliding pumice fragments with data from experiments in which steel balls of different sizes were poured down a slope, Sumita calculated that average particle diameters decreased by 30 per cent during 30 seconds of travel. This kind of information provides new constraints on how pyroclastic flows are generated and advance.

Although the Unzen eruption has continued for nearly three years, most residents of nearby Shimabara have been only slightly inconvenienced. Not so the Mayans living 1,400 years ago in Ceren, in what is now El Salvador. New archaeological and volcanological findings (C. D. Miller, U.S. Geological Survey), show that a rapid series of explosive eruptions took place within 2 kilometres of the village when rising magma encountered ground water. Buildings were burned, blasted down and then buried by up to 5 metres of ash and pumice which preserved details of Mayan life rivalling the Roman ruins at Pompeii. Dirty dishes, pots full of food, the remains of a duck still tethered to a stake, and footprints in ash all suggest a precipitous evacuation of the town, yet so far no corpses have been found. It is not known if the citizens of Ceren understood volcanic unrest well enough to respond to its precursory signs, or whether future excavations will show their remains lying in some as yet undiscovered tomb.

Pyroclastic flows like those at Unzen and Ceren are driven in large part by gravity. Work at two of the world's most active volcanoes, Kilauea and Etna, has shown that gravitational effects can sometimes be far more catastrophic (from the standpoint of the volcano) than those associated with such pyroclastic flows. Studies using the Global Positioning System satellites have shown that entire mountains can be torn apart when magmatic injection causes flanks to slide off towards the ocean; the giant landslides can involve huge amounts of material covering thousands of square kilometres, and can cause very large tsunamis and earthquakes.

Before now, the factors controlling the speed of this slumping have been elusive. New petrological examination of samples from the submarine extension of Kilauea's East Rift Zone (D. Clague and R. Denlinger, U.S. Geological Survey) indicates that the giant landslide is slipping on an unusually concentrated slurry of olivine crystals that precipitated out of the basaltic magma to make a basal lubricating zone "as fluid as duck droppings". This surprising result suggests that the sides of the most active volcanoes can spread like glacial ice advancing into the sea.

Similar collapse has also been recognized at Mount Etna, where the Valle del Bove represents the scarp of a massive landslide that extends eastwards into the Mediterranean. Detailed structural and geophysical mapping (W. McGuire and colleagues, University College London) has revealed a series of small, seaward-sloping faults that act as brakes on the larger-scale movement. When these faults are free to slip, the volcano sags, allowing more voluminous eruptions from the summit and rift zones. When friction causes the faults to lock, eruptions are suppressed and intrusive injection extends to more distal parts of the volcanic edifice. Thus settling of crystals and movement along seemingly minor faults may be competing influences on the efforts of gravity to reduce huge volcanoes to piles of submarine rubble.

Volcanic sediments

At some stage in the development of all volcanoes, gravity wins and the many types of rock that make up the construct are broken apart and transformed into sediments. Most volcanologists have assumed a simple correspondence between individual volcaniclastic layers and discrete eruptive events. But the conversion of a coherent volcano into an assemblage of loose sediments had never been fully documented until P. Kokelaar (University of Liverpool) took an interest, looking at White Island in New Zealand and Stromboli in Italy.

Combining data from submersibles, scuba dives, dredging and sonar, Kokelaar mapped out the exceedingly complex path by which lava, ash and pumice fragments first become comminuted as they roll downhill, are winnowed as they pass through the filtering effect of the shoreline, then become ponded in offshore stores where reworking by storms is common, and finally become consolidated in deeper deposits. Demonstrating how this perspective can radically alter interpretations of submarine volcanic sequences, he showed how a previously mapped debris fan off the coast of Stromboli is three times larger than the concavity that was its apparent source, and concluded that the deposits were formed by three discrete events.

After the latest research conclusions are reported, volcanological meetings inevitably turn to consider ways to reduce the societal impact of future eruptions. This year such concerns were overshadowed by questions about how the safety of volcanologists themselves can be better guaranteed. Although participants admonished each other to think twice about taking nonspecialists into potentially active craters, there was general recognition that substantial risks will remain for volcanologists in the field as long as we know so little about the factors controlling so wide a range of hazardous volcanic processes. □

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