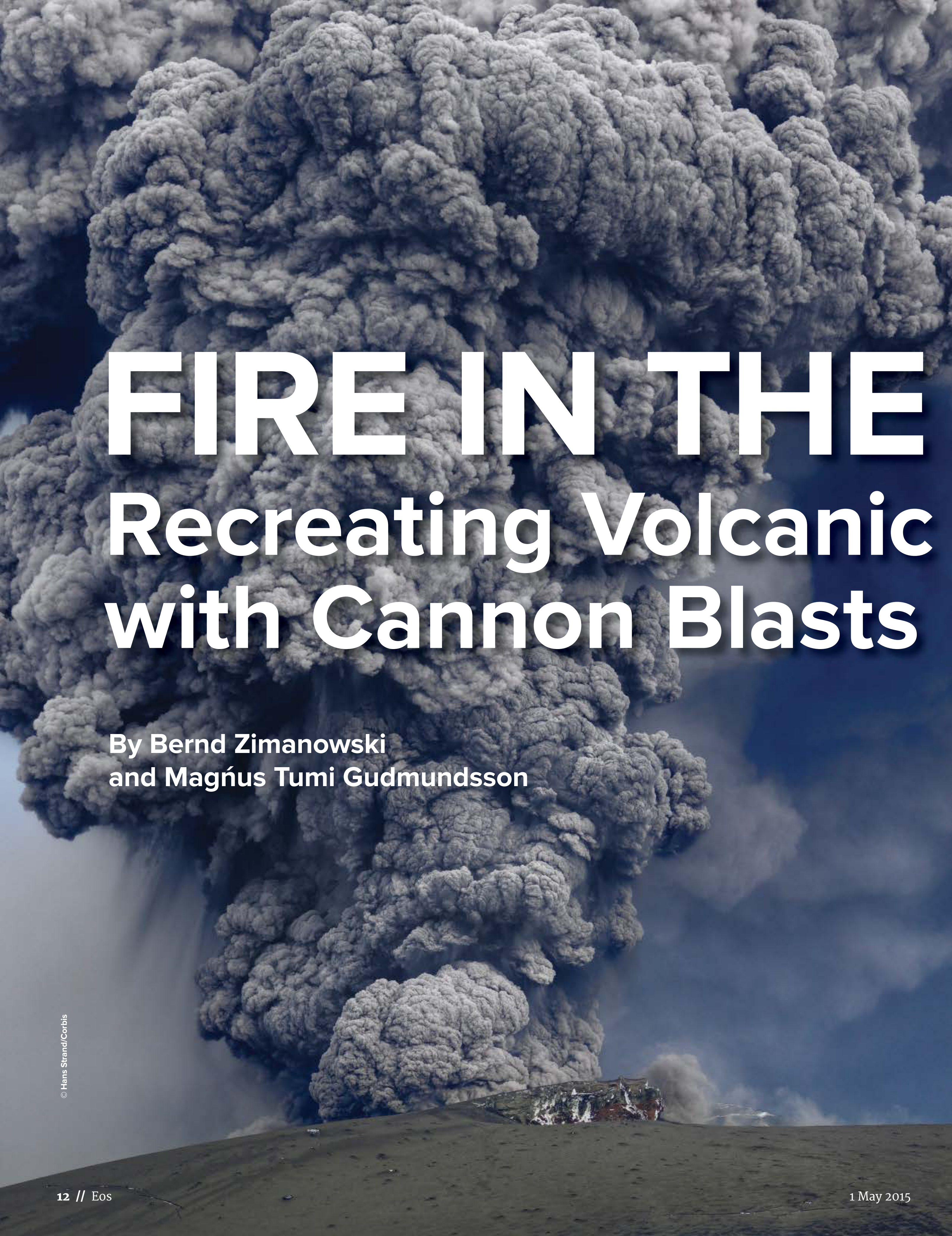

FIRE IN THE
Recreating Volcanic with Cannon Blasts

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HOLE Eruptions

As the volcano Eyjafjallajökull erupted from beneath the glacial ice cap of southern Iceland in April and May 2010, it burst through 200 meters of ice and spewed 270 million cubic meters of ash into the stratosphere. Thanks to an unusually stable jet stream, this moderate-sized eruption darkened the skies of Europe with glass-rich ash, grounding flights in one of history's biggest disruptions to air travel [*Gudmundsson et al.*, 2012].

The threat from such ash plumes has not gone away. A much stronger eruption of Grímsvötn volcano in 2011 raised the alarm again, but fortunately, the weather kept Europe's skies mostly clear.

The much larger effusive lava eruption in the vicinity of the ice-covered volcano Barðarbunga lasted for 6 months (from September 2014 to February 2015). Scientists closely monitored the eruption for signs whether the volcanic fissure would migrate under a nearby ice cap, which would have turned it into a major explosive, ash-forming event. Fortunately this did not happen, but the area is still under close surveillance for possible renewed activity.

To address this threat, a new project is testing high-resolution ash monitoring systems in an unconventional way: by firing cannons packed with ash collected from the Eyjafjallajökull eruption and monitoring how the artificial ash clouds evolve over time.

Wanted: The Volcano's Mass Eruption Rate

Since October 2012, the European Union has funded the FUTUREVOLC project, charged with developing a comprehensive system to monitor future eruptions in Iceland. A main goal of this project involves better understanding the amount of ash such ice-bound volcanoes produce and push into the atmosphere per unit time—also known as the mass eruption rate.

A variety of ground-based instruments could be used to estimate mass eruption rates in explosive eruptions. However, they need better calibration to obtain reliable data that can fulfill scientific and operational needs.

The FUTUREVOLC consortium decided to use the well-documented 2010 eruption of Eyjafjallajökull as a case study for benchmarking purposes. Eruptions of this type typically eject ash in explosive pulses, merging into a continuous plume about 100 meters above the volcano [*Dellino et al.*, 2012]. The consortium posed the question, What if the rough dynamics of the eruption could be replicated on a small scale?

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As part of the FUTREVOLC effort, scientists on the campus of Universität Würzburg in Germany have succeeded in doing just that in a remote area well apart from traffic and power lines.

The goal was to observe miniaturized volcanic blasts with known mass eruption rates and then observe details of artificial plumes to determine whether their properties could allow scientists to work backward to estimate these rates. If the mass eruption rate can be estimated this way, scientists can, in theory, quickly assess eruption patterns as the plume develops and potentially warn downwind communities of the amount of ash coming their way.

Fine Ash and Big Cannons

Scientists collected the ash for their experiments a few weeks after the Eyjafjallajökull eruption, a few kilometers

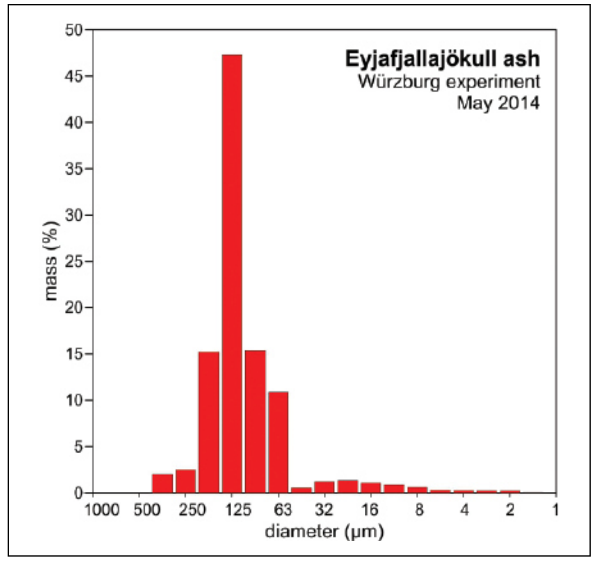

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Fig. 1. Grain size distribution of the ash used in the experiments.

to the east of the volcano's vents. Thus, the ash contains material from both of the main explosive phases of the eruption. The experiments only used particles smaller than 500 micrometers across. Thus, the grain size distribution of the ash used (Figure 1) was broadly similar to that sampled 20–60 kilometers away from the vents in the first explosive phase of the eruption (14–18 April 2010) [*Gudmundsson et al.*, 2012], making it more representative of the eruption clouds threatening aircraft.

A joint team from Universität Würzburg, Bari University in Italy, and the University of Iceland conducted the experiments at Universität Würzburg in May and August 2014. To recreate the explosive volcanic plumes, the team developed three specially designed gas impulse cannons. In each one, pressurized gas rushes through nozzles into a bed of ash particles at the bottom of a tube roughly 1.5 meters high. The tube serves as the artificial vent [see *Dellino et al.*, 2010].

FUTUREVOLC utilized a three-cannon setup (Figure 1). Each cannon was charged with 5 kilograms of ash, of which about 3.2 kilograms went into the plumes, which rose as high as 20 meters.

In the first runs, all three guns fired simultaneously, creating the first volcanic ash plume ever seen in Bavaria. Then, the guns were fired with equal time intervals between the shots to represent the explosive pulses seen during the 2010 eruption [*Dürig et al.*, 2014]. Finally, the amount of ash was varied to simulate different mass eruption rates.

Monitoring the "Eruptions"

Several research groups from across Europe monitored the eruptions, each using various methods [e.g., *Mather and Harrison*, 2006; *Prata and Bernardo*, 2009; *Vöge and Hort*, 2009; *Ripepe et al.*, 2013]. Some used high-resolution cameras, with a few operating in the infrared or at very high frame rates. Some also included Doppler radar, acoustic measurements from microphones detecting rumbling frequencies lower than humans can hear, and measurements of the plumes' electric field. By running

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Fig. 2. Getting ready for the first experimental run: Scientists check the impulse cannons (left side in the foreground). An electrical field sensor is prepared by the team from the UK Met Office and National Centre for Atmospheric Science (right side in the background).

these systems simultaneously, the teams were able to test and intercalibrate them so that measurements of the next explosive eruption in Iceland will be more accurate.

The teams also came away from the collaboration with a better understanding of the methodologies and technical aspects of each other's techniques. The consortium created a joint database of the results and presented the results obtained from individual sensors in a joint workshop immediately following the experiments.

Scientists are now poring over the data to see if they can tease out any patterns from the plumes that hint at the known mass eruption rates. If they succeed, they could help improve real-time observations of mass eruption rates and provide much better predictions of how volcanic plumes rise and disperse. Both may help reduce the disruption to air travel the next time an Icelandic volcano pumps ash into the skies over Europe.

Acknowledgments

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