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VOLCANIC ERUPTIONS AND WHAT TRIGGERS THEM

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Gordon E. Brown Jr.

The north slope of Mount St. Helens erupted catastrophically at 8:32 a.m. on 18 May 1980 in southern Washington state, about 50 miles northeast of Portland (Oregon, USA). This eruption was preceded by a magnitude 5.1 earthquake and a subsequent landslide that are thought to have triggered the main eruption. Although relatively "minor" compared to other US eruptions (e.g. Yellowstone Supervolcano in Wyoming, USA), Mount St. Helens was the deadliest and most economically destructive eruption in United States' history (Tilling et al. 1990): it killed 57 people, including U.S. Geological Survey (USGS) volcanologist Dr. David A. Johnston who was monitoring the volcano 6 miles north of Mount St. Helens. It's somewhat ironic that Dave Johnston was killed "by an unusual eruptive event that was largely unanticipated, in magnitude or style, except perhaps by Dave himself" (Hildreth 1980).

Several months before the May eruption, there were at least four warning signs that major changes were occurring beneath Mount St. Helens (Tilling et al. 1990). These changes included (1) increased seismic activity; (2) increased volcanic activity, including the formation of a bulge on the north flank of Mount St. Helens; (3) phreatic and other minor eruptions; and (4) changes in gas composition. As a result of these warning signals, Johnston and USGS coworkers were able to convince civil authorities to close Mount St. Helens to the public prior to the May eruption, which undoubtedly saved many lives. According to USGS volcanologist Wes Hildreth, Dave Johnston hoped that "systematic monitoring of fumarolic emissions might permit detection of changes characteristically precursory to eruptions" (Hildreth 1980).

I remember the Mount St. Helens eruption vividly for several reasons. One was that I met Dave Johnston several years before the eruption, when he interviewed for a faculty position in the Department of Geology at Stanford University (California, USA). I remember his interview talk, his stage fright, and how enthusiastic he was about his PhD work on the Cimarron Volcano in southwest Colorado (USA). The second reason was that I was teaching an introductory geology class to about 175 Stanford undergraduates during spring 1980. I had given a lecture on volcanoes the Friday before the Mount St. Helens eruption, including the Cascade Range volcanoes—talk about almost perfect timing! Most mornings, about 100 students would be in their seats awaiting the start of the 8 a.m. lecture, and another 60 or so would stumble in over the next 15-20 minutes, many still half asleep. However, at 8:00 a.m. on Monday, 19 May 1980, all 250 seats in the lecture hall in "Geology Corner" were occupied. I started that class by telling the students that what little I knew about the Mount St. Helens eruption largely came from talking with several USGS friends at the Menlo Park (California) office, and reiterating that this volcano, which had been inactive for the past 123 years, was part of the Cascade Range of mostly andesitic stratovolcanoes that have been active over the last 37 My because of subduction processes. These tend to erupt violently because of the higher viscosity and water content of their magmas, in contrast to basaltic shield volcanoes, such as in Hawaii.

The third reason the eruption of Mount St. Helens continues to occupy a prominent location in my memory is that my son, Michael, and his wife and two of my grandkids live in Bend (Oregon, USA) near Mount Bachelor and the Three Sisters Volcanoes (North, Middle, South), which are also part of the Cascade Range. South Sister has recently shown signs of tectonic uplift and, thus, may still be active (Dzurisin et al. 1997).

It's been 36 years since Mount St. Helens erupted catastrophically, yet volcanologists still have a way to go in understanding how to predict volcanic eruptions and what triggers them. After reading the six articles in this issue of *Elements*, however, I see that significant progress has been made over the past 36 years in understanding the mechanisms of volcanic eruptions relative to the earlier views that I had (and taught) of magma accumulation, storage, and transport in Earth's crust back in 1980. Bruce Marsh's magma "mush column" hypothesis (Marsh 1981) and its application to large silicic systems (Bachmann and Bergantz 2004; Hildreth and Wilson 2007) represent major advances in our understanding of magma accumulation and rheology, as does the new understanding of the roles that magma storage and volatile phases play in triggering eruptions of different types. Moreover, the articles in this issue review ways of testing hypotheses about various triggering mechanisms based on integrated geological, geochemical, mineralogical, petrological, and geophysical studies both of ancient eruptions and of active volcanoes. In addition, the use of modern satellites to monitor deformation of volcanoes worldwide at millimeter to meter spatial resolution represents a major technological advance. There appears to be significant hope for developing new quantitative, and predictive, approaches to volcanic eruptions because we are understanding better the processes that trigger them. However, as pointed out by one of the articles in this issue, and the Perspective column, point to the "unknown unknowns" about how volcanoes work, and these will test our current understanding with regard to predicting the timing and style of future volcanic eruptions.

Prospective volcanologists reading this issue have much exciting work to look forward to.

Gordon E. Brown Jr.
Principal Editor

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ABOUT THIS ISSUE

Volcanoes are the powerhouses of nature that can, within minutes, transform a beautiful mountainscape into a desolate landscape devoid of life. Many of us know of singular historic volcanic events because of their impact on society: the 79 AD Mount Vesuvius eruption that resulted in the destruction of Pompeii and Herculaneum (Italy); the deadly 1883 eruption of Krakatoa (Indonesia) that was heard 3,100 miles away; the tragedy of the 1985 Nevada del Ruiz (Columbia) eruption, which resulted in a lahar that killed more than three quarters of the 28,700 inhabitants of Armero; or the costly eruption of Eyjafjallajökull (Iceland) in 2010, which caused more than 10 million air passengers to be stranded and cost the global economy an estimated US$ 4.7 billion. Whether eruptions are mild or catastrophic, volcanoes fascinate and captivate us.

As this issue goes to press (February 2017), there are 33 volcanoes erupting throughout the world, with another 1,500 active volcanoes slumbering until the conditions are right for an eruption. Some of those slumbering volcanoes have nasty histories, such as the supervolcano Campi Flegrei (near Naples, Italy) that is currently making headlines because it is seemingly approaching a "critical state". The articles in this issue present our current understanding of how such volcanoes work and give us a glimpse into the world of magma – how it is formed and how it is transported to the surface. Much remains unknown the plumbing systems of volcanoes or what triggers an eruption. But, as you will read, scientists are making significant progress in uncovering the secrets of these powerhouses, which ultimately helps our world to be a safer place to live.

THANKS GORDON

With this issue, Gordon Brown (Stanford University, California, USA) completes his three-year term as a principal editor of *Elements*. Gordon has been a vital part of our editorial team since 2014. During his tenure, he oversaw the following issues: "Kaolin" (v10n3), "Mineralogy of Mars" (v11n1), "Social and Economic Impact of Geochemistry" (v11n4), "Earth Sciences for Cultural Heritage" (v12n1), "Deep-Mined Geological Disposal of Radioactive Waste" (v12n4), and "Volcanoes: From Mantle to Surface" (v13n1). In addition to working closely with our guest editors and handling manuscripts, Gordon actively solicited contributions to our Perspectives column and wrote editorials to give us a historical context for today's science. Thank you, Gordon, for all your hard work and the time you committed to *Elements*.

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INTRODUCING NANCY L. ROSS, PRINCIPAL EDITOR 2017–2019

We are delighted to announce that Nancy L. Ross has joined the *Elements* team as a principal editor, replacing Gordon Brown (2014–2016), whose three-year term comes to an end with this issue. Nancy is currently Professor of Mineralogy and Head of the Geosciences Department at Virginia Tech (USA).

Nancy has been a pioneer in the study of the crystalline structures, elastic properties, and stabilities of Earth materials under the extreme pressures and temperatures of Earth's lower crust and mantle. More recently, she has studied the thermodynamic properties and effect of surface hydration on metal-oxide nanoparticles. She uses a combination of theoretical modeling and experimental techniques (such as X-ray and neutron diffraction; Raman spectroscopy and inelastic neutron scattering) to determine the structure relations of crystals and vibrational properties of minerals that govern their thermodynamic properties.

Nancy is active within our scientific community. She was elected fellow of the Mineralogical Society of America (MSA) (1991), honorary fellow of the Societá di Mineralogia e Petrologia (2014), and fellow of the Geological Society of America (2016). She served as President of MSA (2009–2010) and as MSA's Distinguished Lecturer (2011–2012). She has served on a number of commissions and councils. She has also been on advisory groups for funding agencies [e.g. the Natural Environment Research Council (UK) and the National Science Foundation (USA)] and government laboratories [e.g. Oak Ridge National Laboratory (Tennessee, USA) and Los Alamos National Laboratory (New Mexico, USA)]. She served on the *Elements* advisory board 2005–2008.

The *Elements* editorial team is delighted that Nancy has accepted our invitation to become a principal editor, and we look forward to working with her. She is already hard at work on our October 2017 issue ("Boron: Light and Lively").

Gordon Brown, **Bernie Wood**, **Friedhelm von Blanckenburg**, **Nancy Ross**, and **Jodi Rosso**

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