International Climate Change Assessment Highlighted at Workshop

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With the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) still more than a year from completion in 2007, organizers are attempting to keep the process open and to respond to criticism of some of its contents, including uncertainty in climate models, that was received after release of the 2001 report.

Since 1990, the IPCC has produced three assessments of the scientific and socio-economic information relevant to understanding human-induced climate change, the potential impacts of climate change, and options for mitigation and adaptation. AR4 will contain an evaluation of the current understanding of climate change, based on peer-reviewed science that has been published or is in press by December 2005.

During a 14 November session of the workshop "Climate Science in Support of Decision Making"—which took place in Arlington, Va., and was held to develop priorities for the U.S. Climate Change Science Program—the IPCC process was lauded by several speakers and attendees for its openness and transparency, particularly in the final plenary that brings together government representatives to create the executive summary.

"This [report] is really the nexus of science and policy," Dan Reifsnyder, of the Office of Global Programs at the U.S. Department of State, said at the workshop. Unlike the underlying report that is written mostly by scientists, the "much heavier hand of government" can be seen in the executive summary, Reifsnyder noted. However, he said that the negotiation in the final plenary is necessary to make governments take the process and the report seriously.

Susan Solomon, co-chair of IPCC working group 1 (there are three working groups) which is looking at the physical basis of climate change, told *Eos* that the claims of a lack of transparency in the process that created the third assessment, and particularly its executive summary, were unfounded. However, she said that when discussing AR4, she does stress that IPCC rules make the assessment process very open and that everything, including public comments and the responses to them, is archived.

Solomon, who is a senior scientist in the chemical sciences division in the U.S. National Oceanic and Atmospheric Administration's Earth System Research Laboratory in Boulder, Colo., has also tried to address other criticism from the third report, including comments about uncertainty in the climate models. In response, AR4 will include a chapter on model evaluation that describes each of the 23 models and compares them, for example, by assessing radiant transfer and cloud behavior across all of the models.

At the workshop, attendees favorably noted that working group 1 has included a broad range of participants in the creation of that section of the report. Of the 140 authors from 32 countries, 75 percent were not authors on the third report, 25 percent are younger scientists (who received their highest degree in the last 10 years), and 27 percent are from developing countries or countries with economies in transition.

In spite of these efforts, Reifsnyder expects AR4 to come under attack when it is released in 2007. "It is not easy to get this relationship between scientists and policymakers right," he said.

Solomon said that the IPCC process is an important tool for making climate change science "understandable to the outside world," and that the process should be kept separate from other issues, such as creating funding agendas. However, at the workshop, she stressed that "scientific judgment has to be the final arbiter in the process."

External reviews of the first drafts from working groups 1 and 2 (impacts, adaptation, and vulnerability) were completed this fall, and the revised drafts will undergo government and expert review in 2006. The first draft from working group 3 (mitigation of climate change) is undergoing external review from 28 November 2005–20 January 2006. For more information, visit the Web site: http://www.ipcc.ch.

—Sarah Zielinski, Staff Writer

MEETINGS

A New Eruptive Cycle at Mount St. Helens?

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What triggered the recent and ongoing eruption of Mount St. Helens? Is it new magma or just leftovers from the 1980s? How long will the eruption continue? Will the magma composition change, and will it become more explosive?

The U.S. Geological Survey's (USGS) Cascades Volcano Observatory (CVO) hosted a three-day workshop at which 25 petrologists addressed these fundamental questions. The workshop began with a review of monitoring data by CVO staff and was followed by presentations and discussions of new petrologic data.

The eruption started with seismic activity and uplift of the crater floor in late September 2004 and was followed by explosions of steam and ash, and the extrusion of a new lava dome starting in early October 2004 and continuing to the present. Helicopter dredging (Figure 1) was used to acquire more than 20 age-controlled samples from the hot and steep-sided dome; because of occasional explosions and frequent collapses, this area has been unsafe to approach on the ground.

New chemical and microscopic analyses of the samples, reported by article author John Pallister and Carl Thornber of CVO, showed that the lava dome is composed of crystal-rich dacite (65 wt % silicon dioxide (SiO_2)), which has varied little in composition over the past year despite an eruptive volume of >70 million cubic meters.

Experiments discussed by Mac Rutherford of Brown University showed that shortly before eruption, the magma was at 850ºC and pressures of 100–120 megapascals (MPa), equivalent to depths of 4–5 kilometers (50ºC cooler and three kilometers shallower than at the time of the 1980 eruption). As pointed out by Seth Moran of CVO, these shallower depths are similar to those defined by earthquake swarms under the volcano during the period between the 1980–1986 and 2004–2005 eruptions [e.g., *Moran,* 1994].

Terry Gerlach of CVO explained how measurements of gases emitted by the volcano constrained the extent and timing of magmatic degassing. Measurements of carbon dioxide and sulfur dioxide emissions are significantly lower than levels during most 1980s dome-building episodes. However, in both cases more gas had been emitted than can be accounted for by the volume of magma erupted, indicating saturation of the magma with a separate vapor phase prior to ascent.

Evidence of gas fluxing comes from measurements of lithium (Li) and lead-210 (^{210}Pb), the latter of which is a product of uranium-series decay that involves the volatile element radon [*Berlo et al.,* 2004]. Adam Kent of Oregon State University showed that crystals of the mineral plagioclase in the dacite that erupted during October 2004 have surprisingly high lithium contents, attributed to the addition of Li by gas fluxing during the earliest phase of the eruption. In contrast to 1980 samples, however, Mark Reagan of the University of Iowa and Kari Cooper of the University of California at Los Angeles showed that the 2004 Li-enriched samples are not also enriched in ^{210}Pb, indicating that the gas fluxing took place over a relatively short time (months to years).

Kathy Cashman of the University of Oregon presented textural evidence of extensive crystallization of the melt phase of the magma,

resulting in the creation of a solid plug of hot dacite at shallow levels beneath the vent [*Pallister et al.,* 2005]. Presence of the minerals tridymite and quartz constrained this latest crystallization to pressures <20 MPa (equivalent to a depth of <1 kilometer below the vent [cf. *Blundy and Cashman,* 2001]).

Shallow solidification of the dacite was confirmed by Charlie Mandeville of the American Museum of Natural History, who used a Fourier transform infrared spectrometer to measure 1.87 ±0.17 wt % H_2O and <20 ppm CO_2 in a rare glassy lava fragment from October 2004. This amount of water is the maximum that could be dissolved in the dacite at pressures of 26–30 MPa, yielding a maximum solidification depth of 1.2 to 1.4 kilometers.

Analyses of the iron-titanium (Fe-Ti) oxide minerals were discussed by Pallister and Rutherford. The oxide minerals, which are sensitive to temperature and oxygen in the melt, showed that the earliest erupted 2004 lava was at about 850ºC, whereas later samples have unusual zoned oxides (in which abundances of Fe and Ti vary). These zoned oxides recorded apparent temperatures that range from 850ºC to greater than 950ºC. As zoned oxides in laboratory experiments homogenized over a period of hours to days [e.g., *Venezky and Rutherford,* 1999], the observed oxide zoning indicated transient and recent heating, either by contact with much hotter magma or, as suggested by Cashman, from latent heat evolved during the rapid and extensive shallow solidification.

As a consequence of shallow solidification beneath the vent, the magma erupted as solid spines mantled by meter-thick fault gouge (pulverized and striated dacite), which was likely produced by repeated fault movements accompanying the roughly one million small, repetitive earthquakes that have occurred at the volcano since October 2004. Preliminary results from deformation experiments on the dacite, reported by Kelly Russell of the University of British Columbia, demonstrated that even at high temperatures (1000ºC), a substantial component of strain is accommodated by brittle failure rather than by viscous flow.

Taken together, these data on the depth of solidification and rheological properties of the erupting magma provided evidence that a shallow (≤1 kilometer) plug of near-solid dacite has been continuously forming beneath the vent, consistent with a new dynamical model of stick-slip gouge formation during steady state eruption [*R. M. Iverson et al.,* manuscript in review, 2005].

A fundamental unknown that was addressed by attendees is the origin of the magma that is feeding the growing dome. Major and trace elements of the 1980–1986 and 2004–2005 magma batches are similar, leading to the initial interpretation that the dacite magma was "left over," i.e., remobilized from the conduit and magma reservoir that fed the 1980–1986 eruptions.

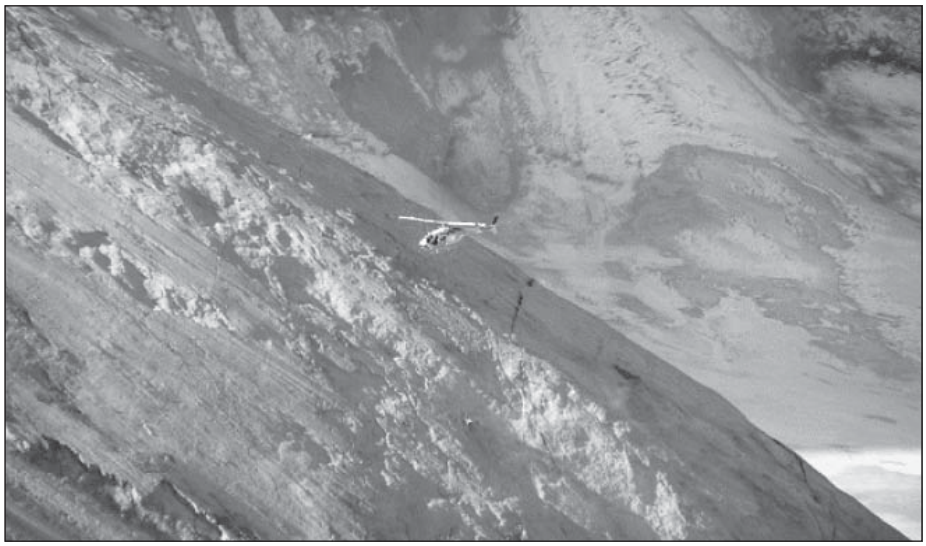

Fig. 1. Collecting samples of striated and granulated dacite (fault gouge) from the surface of the new lava dome at Mount St. Helens using a steel box dredge suspended 60 feet below a helicopter.

However, Cooper showed that thorium isotopes in the 2004 dacite are distinct from those measured in the 1985 dome. Additionally, Rutherford showed that the recent dacite contains some crystals of the mineral amphibole with aluminum oxide (Al_2O_3) contents of 12–15 wt%, too high to be in equilibrium with the dacite magma at pressures ≤220 MPa.

Similarly, Martin Streck of Portland State University showed that plagioclase crystals display multiple zoning populations, reflecting different cycles of rapid crystallization and dissolution during episodes of cooling (or decompression) and heating. In addition, the combined uranium-series data set of Cooper and Reagan show that the plagioclase crystals grew over a variety of timescales ranging from more than thousands of years to just a few years before eruption, and that they demonstrate a long and complex magmatic history for the dacite [cf. *Cooper and Reid,* 2003].

In spite of the complexity, the geochemical differences of this dacite with respect to 1980s lavas, the presence of high-aluminium amphiboles, and evidence of heating led meeting participants to question if the eruption might now be tapping new batches of gas-poor magma derived from relatively deep crustal levels. Pallister and John Eichelberger of the University of Alaska suggested that recharge from the deep crust might be in response to unloading of the magmatic system in 1980.

Although the available data are not definitive with respect to magmatic recharge from the deep crust, the answer has significant implications and remains a 'hot' topic of research, as arrival of a new batch of magma could herald the beginning of a new long-term cycle of eruptive activity, which by comparison with past cycles could continue for many decades and be punctuated by more explosive eruptions than seen in 2004–2005.

The Mount St. Helens 2004–2005 Eruption Petrology Workshop was held 28–30 July 2005 at the USGS Cascades Volcano Observatory, Vancouver, Wa.

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