and augment visualization output options. G3 will increase every researcher's ability to use Giovanni for accurate analysis and effective presentation of Earth remote-sensing data.

For more information, visit the Web site: http://giovanni.gsfc.nasa.gov/

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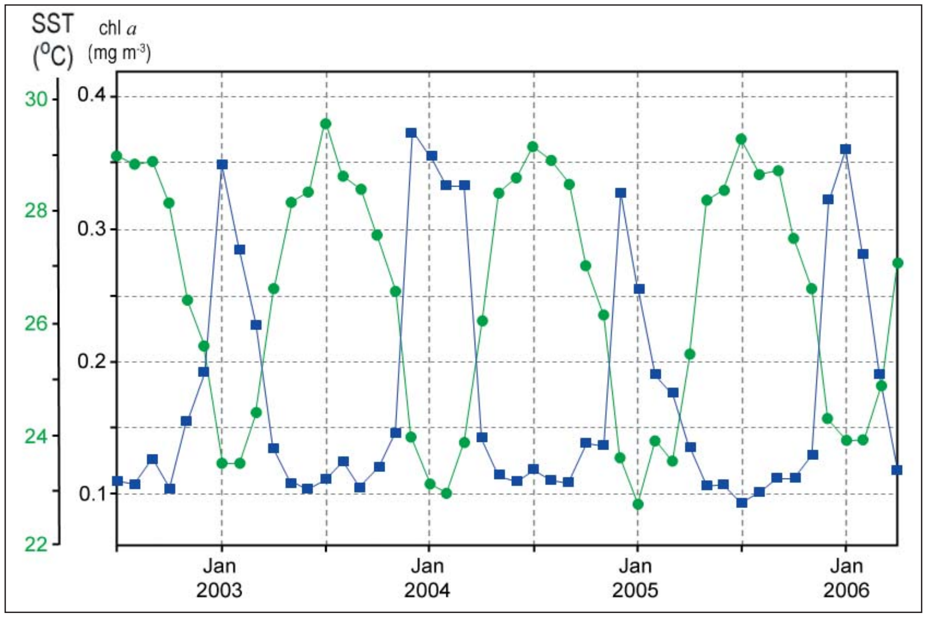

Fig. 3. MODIS-Aqua chlorophyll a *concentration (black) and 11-micron night sea surface temperature (SST; green) in the Luzon Strait north of the Philippine Islands for the period July 2002 to April 2006. Chlorophyll* a *concentrations are driven by upwelling in the winter months, so chlorophyll concentrations and SST in this region are strongly anticorrelated. This figure is only slightly modified from the original Giovanni output, in a manner similar to the requirements of research publications.*

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MEETINGS

Mount St. Helens Petrology Workshop

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Following seismic activity in late September 2004, the current eruption of Mount St. Helens began with an explosive steam and ash emission on 1 October 2004, with hot dacite emerging from the crater floor on 11 October 2004. Nearly two years later, with more than 80 million cubic meters of erupted dacite, accompanied by rare explosions and predominantly shallow seismicity, questions still remain about what initiated and what is sustaining the eruption.

The U.S. Geological Survey's (USGS) Cascade Volcano Observatory (CVO) hosted the 2006 Mount St. Helens Petrology Workshop in Vancouver, Wash., on 27–30 August 2006. With many of the more than 40 workshop participants finalizing contributions to a USGS Professional Paper on the current Mount St. Helens eruption, the workshop was a timely opportunity to share results, reconcile interpretations, and plan future research.

Fundamental questions about the ongoing eruption included whether recharge from a deep crustal source was occurring and what petrologic evidence supports the presence of 'new' magma, rather than residual dacite from the 1980–1986 eruptions, a question critical to understanding the driving forces and longevity of the eruption. Presentations addressed both shallow and deep processes in the magmatic plumbing system beneath the volcano. New evidence indicates magma convection within the seismically imaged magma reservoir at depths of 5–12 kilometers, and much of the discussion focused on this topic, on the origin of mineral and isotopic heterogeneity despite the bulk rock homogeneity, and on questions related to ascent time and path of the dacite.

Talks by USGS scientists updated participants on recent findings and monitoring efforts. Mike Lisowski (CVO) presented deformation data that show less deflation than expected. He showed that volume loss at depth appears to be less than a quarter of the volume of erupted dacite. This could be explained either by recharge or by reservoir expansion. Magma compressibility and the presence of bubbles (estimated by Terry Gerlach at about two percent of the volume at eight kilometers, and as much as 10 percent of the volume at five kilometers) was discussed by Larry Mastin (CVO).

Long-term deformation monitoring did not detect magma recharge from 1997 to 2004, and seismicity and gas emissions at Mount St. Helens provide only limited support for recharge. Seth Moran (CVO) showed that few earthquakes associated with the current eruption have occurred at depths greater than approximately three kilometers. In contrast, deeper earthquakes (3 to 9 kilometers) from 1987 to 2004 had focal solutions consistent with pressurization of the magma reservoir, and one of these swarms (in 1998) was accompanied by magmatic carbon dioxide (CO_2) emissions. Gas data for the current eruption, collected and analyzed by CVO scientists Mike Doukas, Ken McGee, and Terry Gerlach and presented by Taryn Lopez (CVO volunteer), indicate that the new dacite is relatively poor in excess volatiles compared with the 1980–1981 dacite, with a mean CO_2 and sulfur dioxide (SO_2) emission rate of 688 and 86 tons per day, respectively. While the CO_2/SO_2 ratio (8 to10) is similar to that from 1980–1981 of about 9 to15, the ratio of chlorine to sulfur ranges from 1.1 to 2, significantly greater than a ratio of 0.42 measured during 1981. There is no 'smoking gun' in the gas emission data for the introduction of new gas-rich dacite to the magma reservoir, but these data do not rule out earlier recharge or recharge by a gas-poor magma.

Meeting report co-author John Pallister (CVO) provided an overview of the petrology and geochemistry of the ongoing eruption. He stressed the remarkable homogeneity of the bulk composition of the 65% silicon dioxide (SiO_2) dacite: Through the two-year-long, >80 million cubic meter eruption, most major and trace element compositions vary less than analytical uncertainty. A yet unanswered question is: What triggered the eruption? Pallister proposed two hypotheses concerning the pressurization of the magma chamber: (1) magma recharge into the base of the reservoir (more than 12 kilometers), or (2) cooling and ascent accompanying convection, which resulted in second boiling and pressurization. Richard Iverson's (CVO) model for seismogenic extrusion, however, indicates initial conditions were likely not far from equilibrium, as much higher extrusion rates would have been present initially.

The presence of juvenile dacite, chemically or petrologically distinct from that erupted from 1980 to 1986, was a point of debate among workshop participants. Every petrologic presentation identified textural, chemical, and isotopic variability of phases within the dacite lava. How then should a 'juvenile' dacite that is clearly a heterogeneous mixture of various crystal populations be defined? Uranium (U)-series analyses of plagioclase separates by Mark Reagan (University of Iowa, Iowa City) and Kari Cooper (University of Washington, Seattle/University of California, Davis) indicated that the current eruption is sampling a mixture of plagioclase components, including a component not seen in the 1980–1986 eruptions. Based on lead-210/radium-226 ($^{210}Pb/^{226}Ra$) ratios and assuming plagioclase separates are a mixture of old (>8000 years) and zero-age plagioclase, up to 40% zero-age plagioclase is present. These calculations suggest that while plagioclase is crystallizing during the eruption, a significant fraction of older grains also is present.

Using transmitted light and Nomarski imagery, Martin Streck (Portland State University, Ore.) identified three to four distinct plagioclase populations, and he showed that plagioclase textural populations are distinct from 1980 to 1986. Streck suggested that resorption surfaces and increasing anorthite content resulted from recharge of hotter dacite into the 1980–1986 reservoir, consistent with a reservoir model proposed by Mac Rutherford (Brown University, Providence, R.I.). Similar to Streck's groupings, Garrett Hart (Washington State University, Pullman) presented strontium isotope and trace element variations in plagioclase phenocrysts indicating up to four different reservoirs mixed to produce the erupting dacite.

Rutherford presented compelling experimental evidence of convection. His experiments indicate that high-aluminum amphiboles (≥13 weight percent aluminum oxide) crystallized at P_{H2O} = 300 megapascals and 900°C and that low-Al amphiboles crystallized at P_{H2O} = 200 megapascals and 860°C, while labradorite to andesine plagioclase (An_{65-32}) crystallized between 900º and 860°C and 200–130 megapascals. From copper and lithium concentrations in amphibole and feldspar, meeting report co-author Michael Rowe (Oregon State University/University of Texas at Austin) similarly suggested crystallization or diffusion over a range of pressures, concurrent with volatile exsolution and migration. Rutherford, Streck, and Carl Thornber (CVO) also identified cyclic zoning in amphibole, hypersthene, and plagioclase, and they suggested at least two cycles of zonation likely produced in a convecting magma chamber.

Decompression rims, illustrated by Thornber, on both resorbed and unresorbed amphibole grains are mostly five micrometers (μm) thick, although thicker rims on some grains suggest stalling between 2.5 and approximately 3.5 kilometers, and imply mixing before ascent. The 5-μm decompression rims indicate the magma ascended to about out kilometer in three to four days (375–625 meters per day minimum). A conduit radius of approximately 10 meters (at ~3.5–1 kilometer depth) would be consistent with this ascent rate and a first-year erupted volume of about 70 million cubic meters, similar to estimates by Dan Dzurisin (CVO), suggesting a fivefold increase in conduit radius from approximately 3.5–1 kilometers to the surface.

Deuterium/hydrogen ratios of amphiboles presented by Sandy Underwood (Montana State University, Bozeman) suggest the current dome growth has a dehydration signature similar to the 1980 cryptodome and in general reveal a constantly evolving plumbing system beneath Mount St. Helens. Calvin Miller and Lily Lowery Claiborne (Vanderbilt University, Nashville, Tenn.) proposed the use of Sensitive High-Resolution Ion Microprobe (SHRIMP) U-Pb and U-series ages and elemental concentrations and zoning patterns of zircons as long-term recorders of magmatic conditions and processes, such as the amount of storage time in crystal mush zones. Miller pointed out that zircon is present as a trace phase in the current dome and summarized preliminary SHRIMP data collected by Pallister from Mount St. Helens zircons.

As a result of the textural and chemical diversity identified in the erupting dacite, the need for a thorough examination of pre-2004 eruptive products has become increasingly apparent. Mike Clynne (USGS, Menlo Park, Calif.) presented a summary of the eruptive history of Mount St. Helens extending back to 300,000 years ago. Detailed field mapping, geochronology, petrography, and geochemistry show that Mount St. Helens is a fundamentally dacitic to andesitic volcano, although evidence of disequilibrium and magma mixing is common. Voluminous basalt was erupted from near the summit about 2000 years ago, implying that during at least that period, the supply of eruptible felsic magma in the reservoir was depleted.

Comparison of Mount St. Helens to Bezymianny

Russian and U.S. students and scientists from the U.S.-Russia-Japan Partnership in Volcanological Research and Education (PIRE) presented a comparison of Bezymianny and Shiveluch volcanoes in Kamchatka, Russia, with Mount St. Helens. Presentations of Bezymianny physical volcanology and eruptive history (Jill Shipman, University of Alaska Fairbanks) and 2005–2006 eruptions (Yury Bukatov, Kamchatcka State University, Russia) provided background and outlined the petrologic goals of the PIRE group.

An overview of volcano seismology and seismicity at Bezymianny was presented by Evgenii Gordeev (Petropavlosk-Kamchatsky, Russia), and Wes Thelen (University of Washington) discussed current and planned seismic monitoring. A comparison by John Eichelberger (University of Alaska Fairbanks) indicated that following sector collapse in 1956, regrowth of a dome inside Bezymianny has been more rapid than at Mount St. Helens.

Their work showed that while some features, such as the shallow seismicity, appearance of a gouge surface on the erupting lava (photographed in 1967), and overall appearance, are similar, Bezymianny offers clear evidence of ongoing basaltic recharge. This includes decreasing SiO_2 of the lava with time and ubiquitous basaltic inclusions. While visually similar to Mount St. Helens, the underlying causes for dome building at Bezymianny may be substantially different and consequently offer different insights into post-sector-collapse volcanism.

Field trips to the north and south sides of Mount St. Helens, led by USGS scientists Pallister, Clynne, Ed Wolfe, and Rick Hoblitt, provided opportunities to examine pre-2004 eruptive products. Helicopter flights (supported by the U.S. National Science Foundation) into the crater during the last day of the workshop allowed participants to get a firsthand look at ongoing dome building.

— Michael C. Rowe, University of Texas at Austin and Oregon State University, Corvallis; John S. Pallister, U.S. Geological Survey Cascade Volcano Observatory, Vancouver, Wash.; and Anita Grunder, Oregon State University, Corvallis.