MEETING AMERICAN GEOPHYSICAL UNION

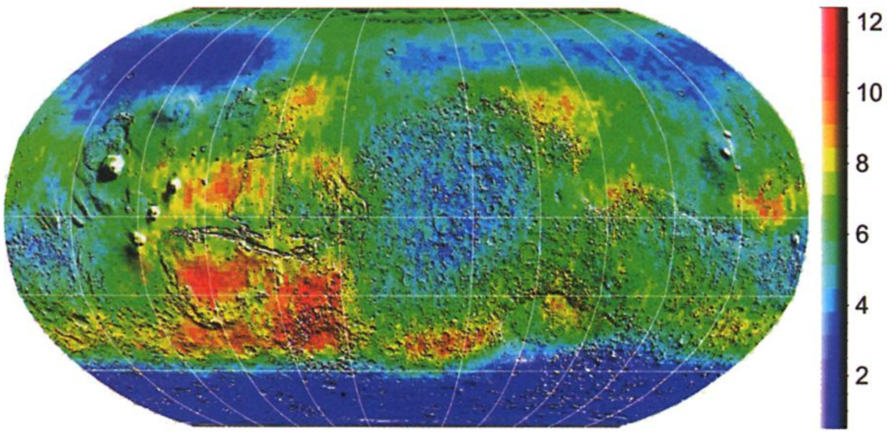
Of Mars Water, Old Cold, And Deep Talk

WASHINGTON, D.C.—The 3500 attendees of last month's meeting of the American Geophysical Union couldn't complain about the variety offered among the 2200 presentations. It included yet more water on Mars, garrulous volcanoes off Japan, and the depths of the Little Ice Age.

Dry Water on Mars

Planetary scientists "following the water" in pursuit of martian life hit a major lode of the icy stuff late last month in data returned by the Mars Odyssey spacecraft. But all the speculation about an ocean of water and media talk of quenching the thirst of astronauts overlooked an even more intriguing water find on the desert planet. In its search for water, Odyssey measured the abundance of hydrogen, the H in H_2O, plotting areas of particular hydrogen abundance in shades of blue. Between the ocean-blue high-latitude caps denoting ice-rich dirt are two huge splotches of light blue. They too can denote water: water that is bound to rock, or at least rock that has reacted with water. By recording the interaction of rock and water over the eons, this water-altered rock might reveal far more about the history of water on Mars and the planet's suitability for life than the surface ice ever will. At first blush, however, the newly recognized distribution of watery minerals across the martian landscape is proving frustratingly inscrutable.

Researchers accomplished the first global mapping of hydrogen in the surface of Mars by keeping track of the subatomic debris produced by the high-energy cosmic rays battering the planet. On impact, the cosmic rays send off a splattering of neutrons that ricochet like pinballs within the top meter or so of rock, dust, and dirt before escaping. Some of them are then picked up by Mars Odyssey's neutron spectrometer, which is operated by planetary scientist William Feldman of the Los Alamos National Laboratory in New Mexico and Odyssey team members. The energy of these scattered neutrons reflects how often they hit hydrogen before escaping the surface. And at latitudes within about 40° of Mars's equator—where the combination of relative warmth and thin atmosphere rules out liquid or frozen water—the only hydrogen they're likely to encounter would be in water chemically or physically bound to minerals or in minerals that have combined with oxygen and hydrogen from water to form hydroxides.



Martian blues. Deep blue (denoting high neutron counts per second) maps out ice-rich dirt, but the light-blue splotches are water-altered rock, possibly from ancient, wetter days.

Researchers expected to see bound hydrogen in at least a few areas from Odyssey's orbital perch. In 1976 the two Viking landers caught a whiff of water from midlatitude soil they scooped up and heated. And orbiters have seen suggestive spectral signatures of spots of mineral-bound water. But, as Feldman and colleagues reported at the meeting and in a paper published online by *Science* on 30 May (www.sciencemag.org/cgi/content/abstract/1073541), Odyssey discovered a huge, roughly circular area of enhanced hydrogen that spans nearly one-quarter of the planet's circumference, a surprisingly broad region of hydrogen. The circle is centered near the prime meridian and stretches across the tropics and subtropics (center of map). A second, more irregular region lies on the opposite side of Mars (right and left edges of map), mostly south of the equator. Taking the soil at the Viking 1 lander site to be 1% water, the soil in these two light-blue regions would contain 3% to 4% water (if the hydrogen is in the form of water). That's far less than Odyssey found as ice at high latitudes, but that ice might have simply "snowed out" on falling dust particles in the recent—and dry—geological past, whereas the low-latitude hydrogen might record ancient water from an earlier, wetter Mars more hospitable to life.

The recognition of great swaths of water-altered minerals on Mars is both enticing and frustrating. Both of the preferred landing sites for the next two U.S. Mars rovers happen to fall in these regions—the so-called hematite site, where the roots of a hot-spring system might be exposed, and Gusev crater, which holds a former lakebed (*Science*, 10 May, p. 1006). Finding water-altered minerals would seem to make them even more attractive targets for landers. But planetary geologists are having trouble making sense of the patterns of hydrogen-rich minerals in the context of what they already know about Mars. The hydrogen signature extends willy-nilly beyond the lander targets across any number of geologic terrains. The regions are "very hard to reconcile with what we know about geology or topography," says planetary scientist James Bell of Cornell University. They don't fit the distribution of particular rock types, rock abundance, dust, or even atmospheric water vapor, notes planetary scientist Bruce Jakosky of the University of Colorado, Boulder.

The U.S. landers and a European lander might help sort out the nature of the water-altered rock, as could element- and mineral-identifying spectrometers on Odyssey. But the near-infrared mapping spectrometer aboard the 2005 Mars Reconnaissance Orbiter should provide "the definitive data set" identifying the minerals involved, says Bell, and thus help unravel the history of water on Mars.

Chatty Volcanoes

In recent years, seismologists have begun eavesdropping on conversations among faults. Faults can tell each other when to fail, communicating across hundreds of kilometers through the stress changes earthquakes induce. If faults can talk, why not volcanoes? A group of geophysicists reported at the meeting that they seem to have overheard one side of a conversation between two Japanese volcanoes as one of them prepared to erupt. The discovery offers the prospect of understanding how groups of volcanoes

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work and, as with faults and their earthquakes, forecasting future behavior.

Geophysicists didn't mean to eavesdrop on volcanoes. The Japan Meteorological Agency (JMA), the organization responsible for earthquake monitoring in Japan, had deployed strainmeters in deep boreholes around the southeast portion of the main Japanese island of Honshu to watch for the great quake expected to strike offshore. But one of the strainmeters, which measure the subtle squeezing and stretching of the crust, was installed in 1981 on the small island of Izu-Oshima, the northernmost of a string of volcanic islands. In 1983, Miyake-jima, a volcano in the chain 70 kilometers south of Izu-Oshima, erupted.

The erupting volcano had no strainmeter, but the one on Izu-Oshima seemed to know what was going on, according to geophysicists Alan Linde and Selwyn Sacks of the Carnegie Institution of Washington's Department of Terrestrial Magnetism in Washington, D.C., and their colleague Osamu Kamigaichi of JMA in Otemachi. On three different time scales, the way the crust was deforming at the distant strainmeter changed at the time of the eruption, they reported. The rate at which the crust was being slowly squeezed had been constant for 2 years but dropped dramatically 2 days before the eruption. The extent to which the crust yields to the daily tidal kneading of the moon and sun had been increasing rapidly but slowed abruptly at the eruption. And the frequency of as-yet-mysterious squeezings lasting an hour or two jumped from one or two a year to three or four a month 6 months before the eruption and stopped entirely just before it.

The striking coincidence of deformation changes and distant eruption means that "there's probably some important Earth physics happening" between the two volcanoes, says Linde. Their best guess is that, perhaps 40 or 50 kilometers down, a deep-seated channel of magma mush connects the shallow magma reservoirs that feed the two volcanoes. Seismic probing has found such a deep channel beneath the similar volcanic chain of northern Honshu, the group notes. Pressure variations beneath one volcano could then travel to the other in a matter of days. Some of those communiqués, such as the mysterious abrupt squeezings, might herald a coming eruption, notes Linde. Deep connections might even explain the habit of some pairs of volcanoes to erupt one right after the other, says Sacks.

Volcano communication "is a good idea that needs more work," says volcanologist Michael Ryan of the U.S. Geological Survey in Reston, Virginia. "I've done theoretical models of volcano interactions before, and you don't get much 'news' more than 10 or 15 kilometers down the line" from major deformations. Linde and his colleagues should show how 70-kilometer communication could possibly work, says Ryan, before he's convinced.

Big Chill From Sun and Volcano

Anything as fiery as the sun or an erupting volcano would seem an unlikely agent of global cooling. But researchers are accumulating evidence that the sun and volcanoes ganged up on Earth's climate system 300 years ago to give Europeans, at least, a major chill. The sun became exceptionally quiet in the second half of the 1600s just as an unusual number of volcanoes popped off, a combination that a growing number of climate models suggests could have triggered intensely cold winters in Europe. The trick might have been the ability of a dimming sun to shift atmospheric circulation patterns over the North Atlantic.

Winter wonderland. A dimming sun and volcanic haze might have combined to chill late-17th-century Europe.

The apparent progress in understanding at least a few decades of paleoclimate comes after climate researchers sharply narrowed their focus. Paleoclimatologists had long pondered the 3-century-long Little Ice Age, a time of frequent cold spells that ended around 1850 (*Science*, 25 June 1999, p. 2069), but its ultimate cause remained unclear. At the meeting, a morning session was devoted to a single cold spike, particularly well documented in Europe, that spanned from 1670 to 1710. That was just after sunspots nearly disappeared from the face of the sun for more than half a century. The event, called the Maunder sunspot minimum, is unique in the past millennium. By studying shorter term behavior of the sun and sunlike stars and indirect records of solar activity, scientists have estimated that during the Maunder minimum the sun grew a few tenths of a percent dimmer than it is today.

The coincidence of an extreme climate event and a possible solar dimming—a driver of climate change—proved an irresistible target for climate modelers. At the meeting, modeler Drew Shindell of NASA's Goddard Institute for Space Studies (GISS) in New York City and his colleagues reported that the GISS general circulation model, the sort of complex climate model used to predict greenhouse warming, cooled the globe as a whole a modest 0.3° to 0.4°C in response to the solar dimming of the Maunder minimum. The model's cooling agrees with the sketchy temperature record from historical accounts and paleoclimate proxies such as tree rings. But in the model, as in the real world, the extreme cold of the late Maunder minimum—1° to 2°C of cooling—was localized, primarily over Northern Hemisphere continents in winter.

The GISS results offer resolution of a paleoclimate quandary: how such a modest dimming of the sun could drive such a strong response. In the GISS model, the dimming doesn't cool the globe as much as redistribute heat around the globe. It weakens the westerly winds of the Arctic Oscillation (also called the North Atlantic Oscillation) that blow across the North Atlantic. The weaker westerlies pick up less heat from the Atlantic and thus carry less heat into Europe to moderate its winters. So a dimmer sun could mean more ice skating, at least on the canals of Europe. Rising greenhouse gases might be driving the Arctic Oscillation the other way and warming northern continents (*Science*, 9 April 1999, p. 241).

Shindell also tested the effect of the volcanic eruptions of the time as recorded in ice cores. The debris spewed into the stratosphere by volcanoes cools the surface by reflecting some sunlight back into space. "The volcanic signals help improve the agreement" of model and climate record, said Shindell. For example, in the model, solar dimming alone made Iceland warm, although some historical records say it experienced disastrous cold. Adding volcanoes to solar dimming chilled Iceland, as observed.

Other modelers presenting in the session reached similar conclusions. Both Ulrich Cubasch of the Max Planck Institute for Meteorology in Hamburg, Germany, running a different state-of-the-art greenhouse model, and Eva Bauer and her colleagues at the Potsdam Institute for Climate Impact Research in Germany, running a model of intermediate complexity, reported that both solar variations and volcanoes are needed to best simulate the climate late in the Maunder minimum. So a deep European chill might require a double whammy, at least.

—RICHARD A. KERR

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