Random Walk

When the satellite steam plant was built, it was given a blue tile dome to match the domes of Kerckhoff and North Mudd. In March, a new blue dome suddenly sprouted behind the gate (top). Under this tarp, the Cosmic Background Imager (see *E&S*, 1996, No. 4) is taking shape (right). (That's Steve Padin, chief scientist for the Cosmic Background Imager, on the ladder.) The framework (above) will support 13 one-meter radio telescopes. Assembly and testing will continue through August or so, after which it will be dismantled and rebuilt at its permanent home in northern Chile, where it will search for the seeds of the very first galaxies. "We'll actually make some observations right here while we're doing the final testing," says Anthony Readhead, professor of astronomy. "The first-year graduate students are very excited about that."

Earthquakes Can Generate Enough Heat to Melt Plates

Humans have probably known since the days of loincloths and clubs that the ground sometimes shakes from earthquakes. But only recently has it become clear that at least some earthquakes can also turn up the heat.

In the February 6 issue of *Science*, Hiroo Kanamori, the Smits Professor of Geophysics; Tom Heaton, professor of engineering seismology; and Don Anderson, the McMillan Professor of Geophysics (see page 39) reported that a powerful 1994 earthquake in Bolivia let loose heat at a rate of 35 billion megawatts during the 40 seconds when the rocks slipped about 400 miles under the surface. The earthquake released about as much heat as is generated by the entire United States in two months.

The 8.3 Bolivian earthquake not only sent out some truly prodigious seismic waves, but it also generated enough heat in the region of the plates to at least partially melt them and let them slide together more easily. The 1994 earthquake was the largest deep earthquake ever detected. It was felt as far away as Canada, but caused little or no property damage even at the epicenter because of its depth.

The thermal energy generated by the earthquake is especially interesting because it allowed the plates to turn molten, says Kanamori, the lead author of the paper. And if the plates were molten, they could slide together more easily.

"There are lots of implications," he says, "but mainly it allows us to understand better the basic physics of earthquakes—and more pointedly to better understand the mechanics of the slipping of the surfaces themselves."

The results also help to answer a basic question that has been around for many decades, adds Heaton. "There are some fundamental mysteries of how an earthquake can occur at such depths in the first place," he says. "At a depth of 400 miles, you have truly gigantic pressures that ought to pack the plates to-

Wired!

Caltech students have often been noted for their wired appearance (partially due to the massive caffeine intake). But now, Caltech itself is being acknowledged for its digital appeal. In their May 1998 issue, *Yahoo! Internet Magazine*—with more than 400,000 readers nationwide—named Caltech the seventh most wired school in the country. More than 400 schools were surveyed, and Yahoo's results showed that half of all students at Caltech have computers, 75 percent have home pages on university Web space, and 50 percent of classes use the Net to post study aids and other materials. Students can also sign up for high-bandwidth cable modem access to the Net, which means faster and more direct access to campus network resources. □—*RP*

gether so tightly that they just wouldn't be able to slide. The Bolivian earthquake happened at a depth where the pressure is equivalent to about 200,000 atmospheres. But this frictional melting might have allowed the plates to slide more easily."

A good analogy is an ice skater, Heaton says. While the friction between a steel skate blade and frozen ice would normally be rather high, the frictional energy of the heavy skater allows a thin film of water to greatly reduce the resistance between skate and ice. Therefore, at the depth of the Bolivian earthquake, the plates were solid before the shaking began, even though they were quite hot. The frictional energy of the earthquake then raised the temperature in the vicinity of the plate surfaces from their original ambient temperature of about 1,200 to 1,800 degrees Celsius to a point far above the melting point of the olivine materials.

Kanamori says that it's impossible to tell precisely how hot things got at the frictional points of the plates without knowing precisely how much material was available for the 35 billion megawatts of energy to diffuse through. If there was a comparatively small amount of material, he says, the plate surfaces could have quickly reached 50,000 degrees Celsius, which is much hotter than the surface of the sun. Regardless of the temperature, though, there was more than enough energy to turn the plate surfaces molten, he says.

The scientists reached their conclusions by computing the minimum strain energy change in the materials and then subtracting out the amount of seismic energy detected as ground shaking by surface sensors. Thus, most of the energy that could not be accounted for in the seismic waves could only have been converted to heat energy.

"This was a very good earthquake for computing the minimum strain energy change in this type of problem," Heaton says. "If you know the size of the slip in the earthquake, and you know how stiff the rocks are, then you can estimate the minimum energy necessary to put that much slip into that stiff a rock."

As for practical implications for those living in earthquake country, there may be no clear ones at present, Heaton and Kanamori say. In the case of Southern California, there are no deep earthquakes at all. Such earthquakes typically occur at subduction zones where old ocean floor is being returned into Earth's interior, such as in the plates of South and Central America, Alaska and the Aleutians, the South Pacific, and Japan.

But the results nonetheless underscore a nagging question that has existed for some time, Heaton says. Based on the amount of energy available and the pressures involved, there should be a bit of melting in most earthquakes, even the shallow ones of the San Andreas fault. But fault zones exposed to the surface by erosion show little or no melting.

"Since people don't see much melt, there is probably some other low-friction influence at work," Heaton says. "But we'd like to understand why this is so, and these results could help us better understand the physics of how even Earth's shallow insides move around." □
—*RT*

SURF's Offspring Make Waves of Their Own

They tried and tried, but couldn't find a water-related acronym for Caltech's newly named Office of Student-Faculty Programs, formerly the SURF office, which handles Caltech's popular SURF (Summer Undergraduate Research Fellowship) program, in addition to other student-focused research programs. SURF has come a long way since its inception in the summer of 1979, when the first batch of SURFers totaled only 18. Today, on the eve of its 20th anniversary, SURF is stronger than ever, enrolling more than 200 students each summer. In fact, the majority of Caltech undergraduates apply for at least one SURF at some point in their four years at the Institute, drawn by the opportunity to perform independent research under the guidance of a faculty, postdoc, or graduate-student mentor in their field. And, as a testament to its success, SURF has spawned a number of related programs, the most recent of which are Frosh SURF and JPLUS.

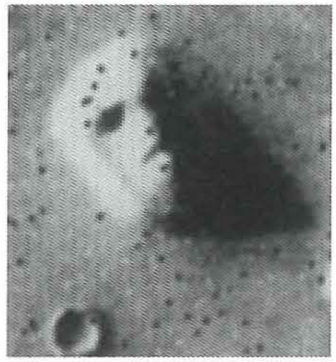
Frosh SURF, as its name implies, offers the chance for students to participate in the SURF program in the summer before they are matriculated. The program is offered as an incentive to the most academically talented students admitted to Caltech, in addition to the traditional merit scholarship. This summer will be Frosh SURF's first offering. On the other hand, the JPLUS (Jet Propulsion Laboratory Undergraduate Scholars) program provides opportunities to the top student at each of the 25 community colleges closest to JPL and Caltech. JPLUS offers a $500 merit scholarship for each of a student's first two years at the community college, and the students are also encouraged to apply for a regular SURF at Caltech or JPL during the summer.

The JPLUS program was founded in May 1997 by JPL's Office of Educational Affairs, with funds provided by Caltech. The funds were part of a NASA bonus that the Institute received as a reward for its stellar administration of JPL. Fred Shair—manager of Educational Affairs at JPL and one of the original architects of SURF—teamed up with Richard Alvidrez (also of JPL's Educational Affairs Office) to come up with the idea for JPLUS. "Many very good students start their education in the community colleges," says Alvidrez, "and this program will recognize them." At the first annual award banquet to honor the 25 awardees (18 of whom were underrepresented minorities), every one of the participating college presidents attended the banquet.

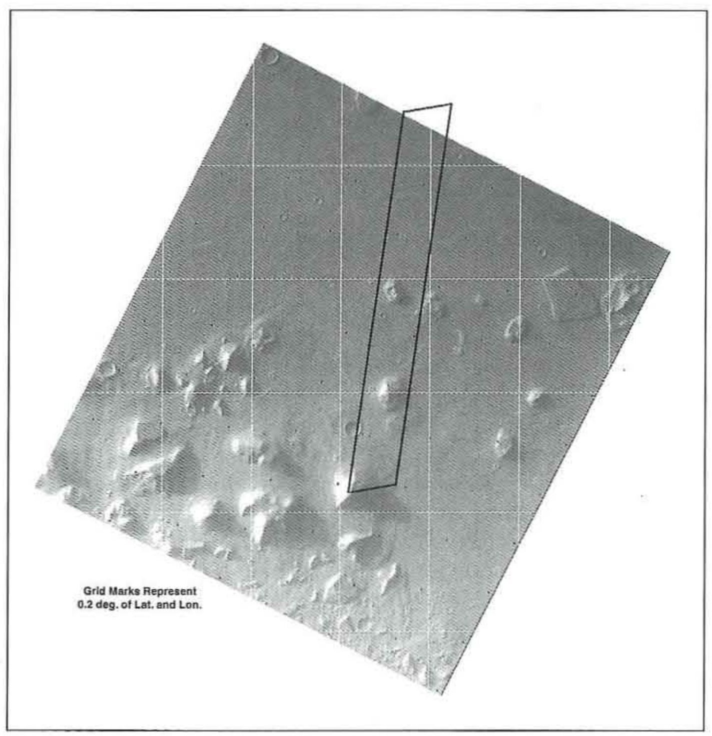
JPLUS is dedicated to the memory of Robert B. Leighton, a renowned physicist and astronomer at Caltech who began his undergraduate career at Los Angeles City College before transferring to the Institute, where he earned his BS in electrical engineering, as well as his MS and PhD in physics. Leighton's many contributions to science include designing and building equipment for imaging the planets in the pre-space-exploration era, serving as team leader at JPL in the mid-'60s for the Mariner 4, 6, and 7 missions to Mars, serving as chair of Caltech's Division of Physics, Mathematics and Astronomy, and editing the famous *Feynman Lectures in Physics*.

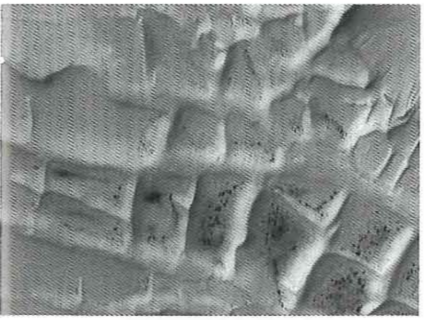
Other programs that the Office of Student-Faculty Programs coordinates include the MURF (Minority Undergraduate Research Fellowship) program, which brings minority students who are not attending Caltech to the campus for the summer; and TIDE (Teaching and Interdisciplinary Education), which provides an opportunity for students who want to work on education-focused (rather than research) projects. □
—*RP*

Mars Global Surveyor Loses Face



Faithful readers of the *Weekly World News* will be disappointed by the photograph of the mile-wide "face" on Cydonia taken by JPL's Mars Global Surveyor (MGS) in April. The Viking 1 orbiter took the above left picture on July 25, 1976. The speckles peppering the image are missing data bits; a fortuitous few became the nostril, dimpled chin, and helmet visor, while shadows formed the other features. The MGS image (above right), taken with the sun at a different angle (and with 10 to 20 times better resolution), shows no monument to ancient astronauts—although, with some imagination, the rock formation looks vaguely like the mask of Greek tragedy. The graphic below shows the MGS mapping swath.

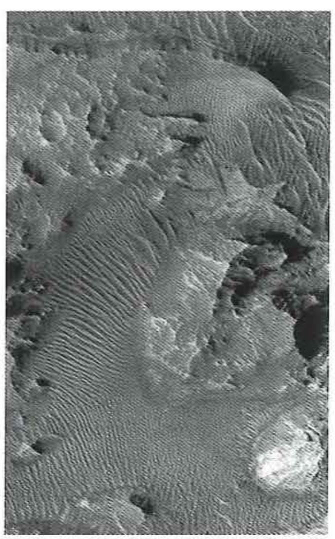




MGS is seeing a lot of other strange and wonderful things, however. Above, left: This view of the south polar region shows a gridlike system of intersecting ridges, spaced at intervals of a few miles—a giant alien ice-cube tray, perhaps?

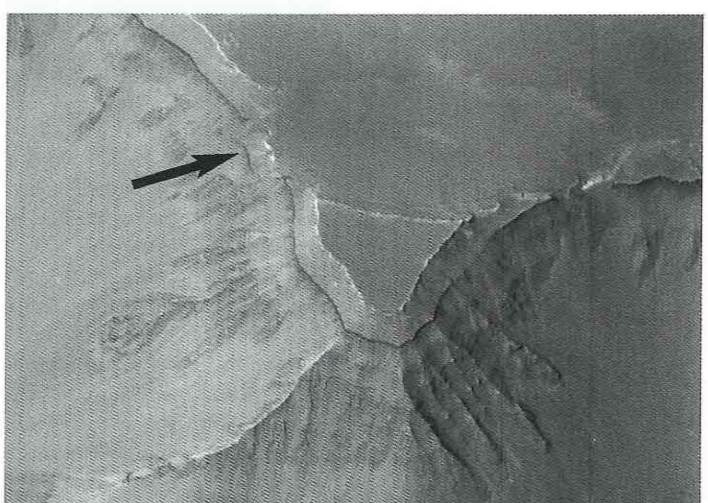
Above, right: This photo of Nanedi Vallis resolves features as small as 12 meters—the length of a boxcar. The terraced walls and the 200-meter-wide channel on the canyon floor, best visible near the top of the frame, may indicate the canyon was cut by running water.

Below: Like waves in an estuary, dunes lap against rocky outcrops on the floor of Hebes Chasma.

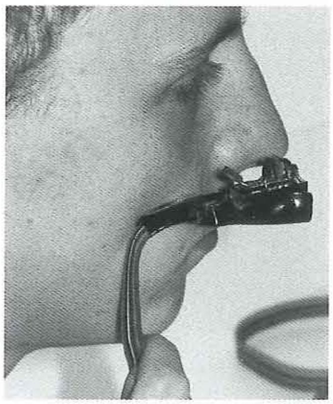


Right: This swath through Coprates Chasma, one of the main canyons that make up the central portion of the 6,000-kilometer-long Valles Marineris system, captures details as small as six meters—the length of a full-sized station wagon. The gray-scale MGS image has been combined with a Viking orbiter color view of the same area. Multiple rock layers, varying from a few meters to a few tens of meters thick, are visible in the steep slopes near the top and bottom of the frame.

Below: In this close-up, you can see where a graben—a depression caused by subsidence between two faults—has offset the strata (arrow).



Olfactory Worker



Mike McGrath shows that Nate Lewis (as he appeared in *E&S*, No. 3, 1996) isn't the only human with two noses.

"This is a high-school science project," a passerby noted to Nathan Lewis, Caltech professor of chemistry, when examining the experimental procedures for Lewis's electronic nose. [See *E&S,* No. 3, 1996] Well, Mark McGrath, a high-school junior in Hilton Head Island, South Carolina, has made good on that assertion.

McGrath, a devoted inventor (and, as it so happens, the grand-nephew of Robert M. McCurdy, who was the assistant city manager of Pasadena, and president of the Rose Parade), read an article about Lewis's electronic nose project in *Ties Magazine,* and contacted Caltech for more information. Using the *E&S* article as one of his references, McGrath set to work on making the nose for his high school science fair.

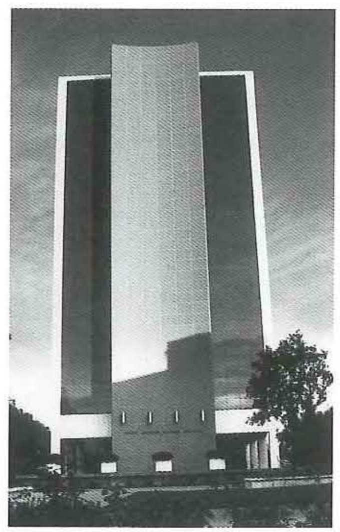
Like Lewis's nose, McGrath's project consists of a number of sensors, each made up of a different type of conducting plastic. Each sensor is exposed to a certain odor-producing agent, while an electrical current is passed through the sensor. By measuring the pattern of resistance for each sensor and odor, the nose can assign a chemical "fingerprint" to the smell.

McGrath's nose is also smelling the first whiffs of victory. At press time, McGrath's electronic nose had already taken first place at both McGrath's high school science fair and the regional science fair, and was on its way to the International Science Fair in Fort Worth, Texas, May 10–16.

McGrath is no stranger to fame. Through such inventions as the K-9 Cooler, a solar-powered pet carrier to keep pets ventilated while in a closed vehicle, and Scram Away, a warning device that puts out vibrations and unpleasant sounds to keep pets and small children away from glass windows (an invention which, incidentally, won fourth place and a $500 savings bond in the Duracell Competition for high school students), McGrath has attracted national attention.

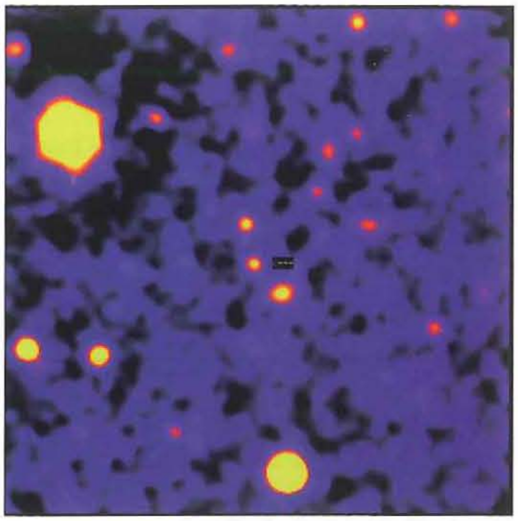
In addition to the numerous awards he's received, McGrath has also appeared on a number of television shows, including an appearance on *The Tonight Show* and a running clip on the Discovery Channel. The producers of *The Oprah Winfrey Show* even featured him in a show on child prodigies.

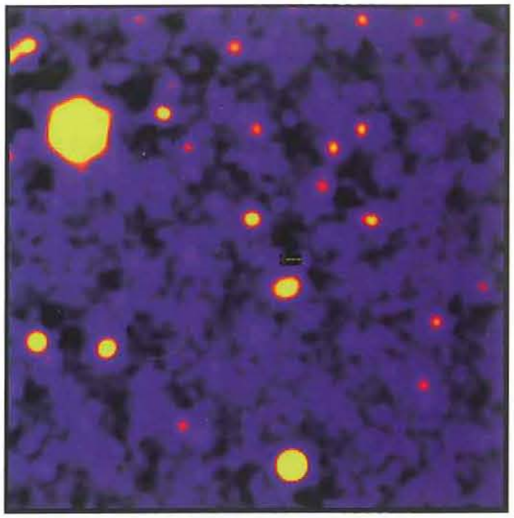
Perhaps his most prodigious accomplishment is the fact that McGrath has been successful in spite of having a learning disability. "Mark recognizes his strengths and weaknesses, but he doesn't allow either one to define him," says Hank Noble, his friend and former principal. Mark doesn't have time to bask in his glories, however. He's too busy sniffing out ideas for new inventions and working toward getting his pilot's license. □—*RP*



Shaking Up the System

Unlike James Bond, southland residents are used to having their beverages (and everything else around them) shaken *and* stirred, when the buildings they are in respond to the massive force of an earthquake. But thanks to the extensive digital earthquake-monitoring system that the USGS (United States Geological Survey) recently installed in Caltech's nine-story Millikan Library, researchers from Caltech, USGS, and elsewhere will now have a first-rate testbed to gain a more comprehensive understanding of what happens to reinforced-concrete buildings during earthquakes. The new 36-channel system—which provides detailed information about the building's movements in real time—replaces a 10-channel system that recorded strong earthquake shaking on film, which then had to be developed before it could be analyzed. □—*RP*





It may be hard for most of us to tell, but these images show evidence of the most energetic event yet observed in the universe—a phenomenon that generated several hundred times more energy than a supernova and for a second or two was as luminous as all the rest of the universe. A gamma-ray burst, named GRB 971214, that had been discovered in December left a faint visible-light afterglow (arrow, far-left image), which was found by a team of astronomers from Columbia and Dartmouth Universities. When the afterglow faded about two months later, a Caltech team (under astronomy professors Shrinivas Kulkarni and George Djorgovski) at the 10-meter W. M. Keck II Telescope in Hawaii discovered a very faint galaxy in its place (right image, above). They measured the distance to this galaxy as 12 billion light-years and, from this distance and the observed brightness of the burst, calculated the amount of energy released—an amount that "staggers the imagination" and that most theoretical models cannot explain, according to Kulkarni.

Proposed Radioactive Dump Site May Be Seismically Active

Recent geodetic measurements using Global Positioning System (GPS) satellites show that the Yucca Mountain area in southern Nevada is straining roughly 10 to 100 times faster than expected on the basis of the geologic history of the area. And for the moment at least, geologists are at a loss to explain the anomaly.

In the March 28 issue of the journal *Science*, Caltech Professor of Geology Brian Wernicke and colleagues at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, reported on Global Positioning System surveys they conducted from 1991 to 1997. Those surveys show that the Yucca Mountain area is stretching apart at about one millimeter per year east-southeastward.

"The question is, why are the predicted geological rates of stretching so much lower than what we are measuring?" asks Wernicke. "That's something we need to think through and understand." The answer is likely to be of interest to quite a few people, because Yucca Mountain has been proposed as a site for the permanent disposal of high-level radioactive waste. Experts believe that the waste-disposal site can accommodate a certain amount of seismic activity, but they nonetheless would like for any site to have a certain amount of stability over the next 10,000 to 100,000 years.

Yucca Mountain was already known to have both seismic and volcanic activity, Wernicke says. An example of the former is the 5.4-magnitude "Little Skull Mountain" earthquake that occurred in 1992. And an example of the latter is the 80,000-year-old volcano to the south of the mountain. The volcano is inactive, but still must be studied according to Department of Energy regulations.

The problem the new study poses is that the strain is building up in the crust at a rate about one-fourth that of the most rapidly straining areas of Earth's crust, such as near the San Andreas fault, Wernicke says. But there could be other factors at work.

"There are three possibilities that we outline in the paper as to why the satellite data doesn't agree with the average predicted by the geological record," he says. "Either the average is wrong, or we are wrong, or there's some kind of pulse of activity going on and we just happened to take our data during the pulse." The latter scenario, Wernicke believes, could turn out to be the case. But if Yucca Mountain is really as seismically active as the current data indicate at face value, the likelihood of magmatic and tectonic events could be 10 times higher than once believed. □—*RT*