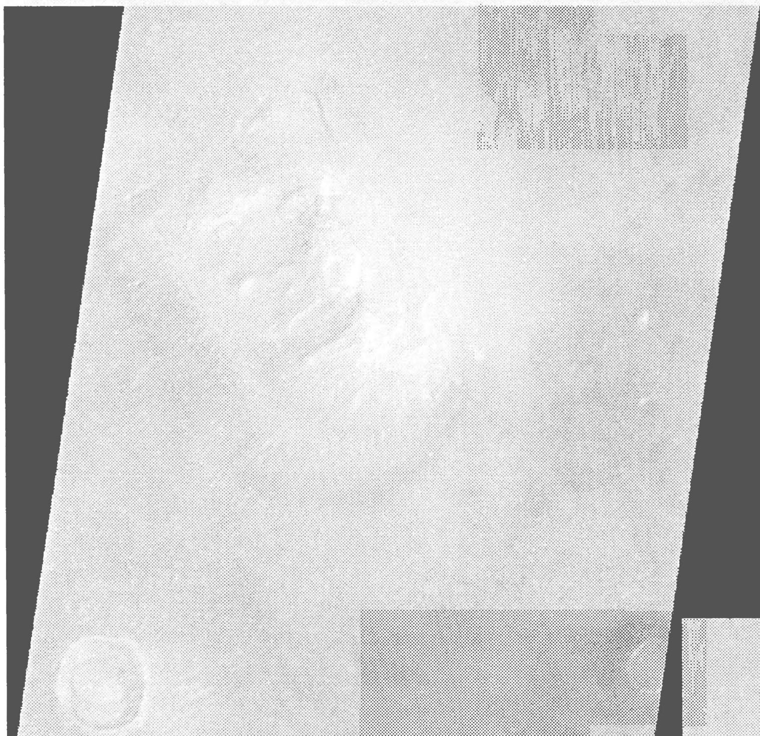
Lunar and Planetary Information

BULLETIN

Spring 1998/NUMBER 84 • LUNAR AND PLANETARY INSTITUTE • UNIVERSITIES SPACE RESEARCH ASSOCIATION

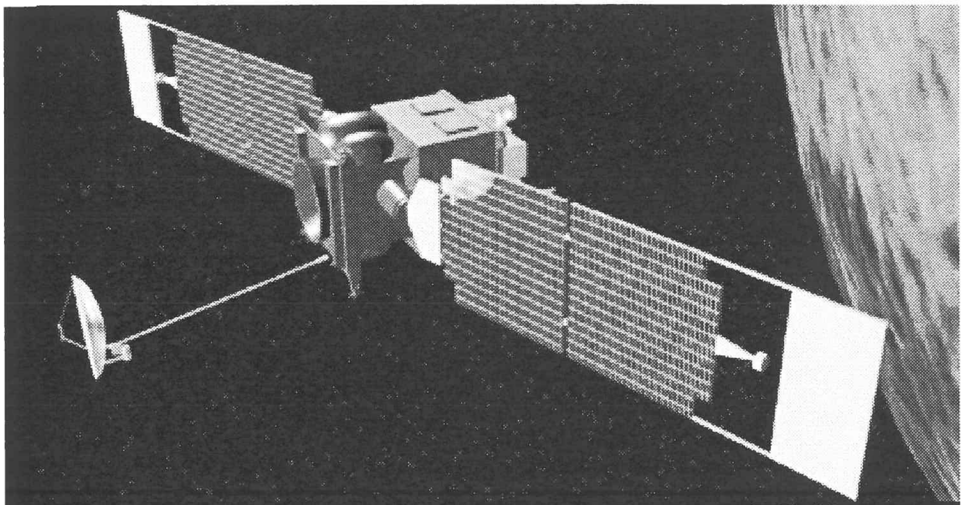
THE MANY FACES OF MARS:

A Portfolio of Global Surveyor Images



Mars Global Surveyor Image, 1998

Viking Orbiter 1 Image, 1976



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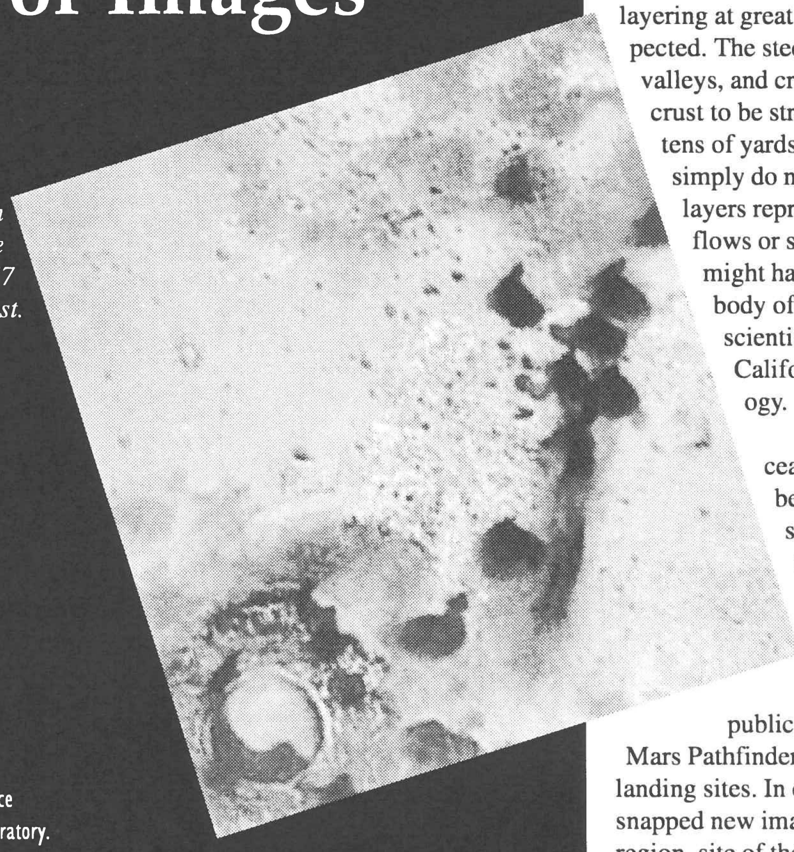


Rare tear-shaped dark dunes in this 6.4 × 7.0-kilometer image (frame 10004) centered near 47 degrees south, 341 degrees west.

Cover images courtesy NASA and Malin Space Sciences and NASA and Jet Propulsion Laboratory.

Since July 1997, the orbital spacecraft known as *Mars Global Surveyor* has been transmitting an array of revealing images that are helping scientists to unravel the mysteries of Mars' early history, its interior processes, and its atmosphere. The spacecraft has captured the evolution of a martian dust storm (for the first time ever) as well as images of deeply layered terrain and highly magnetized crustal features.

The first set of formal results comes from data obtained in October and November 1997, when the spacecraft was just beginning to use the drag of Mars' upper atmosphere to lower and circularize its highly elliptical orbit in a process called aerobraking. At the time, a dust storm was brewing on Mars and had grown to about the size of the South Atlantic Ocean.

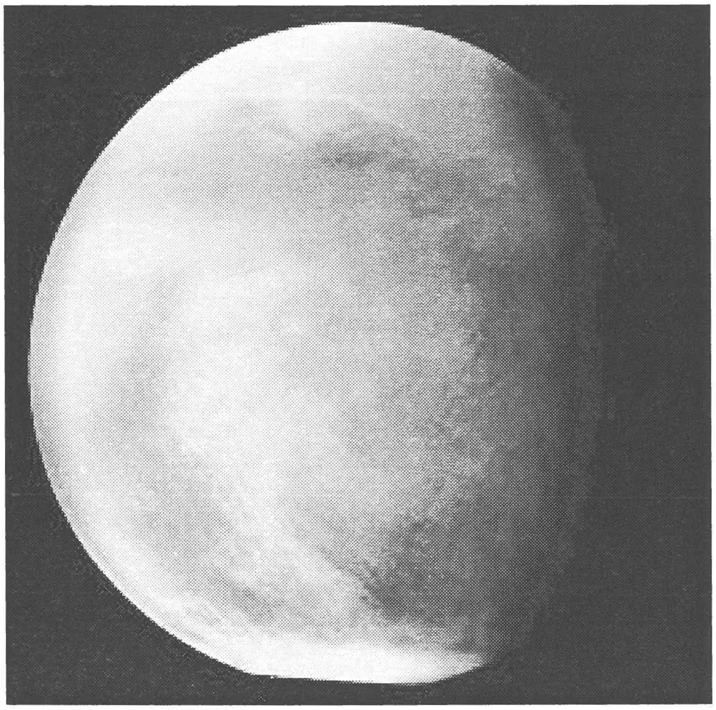
High-resolution images of dunes, sandsheets, and drifts are helping to reveal earlier chapters of martian history. Landforms shaped by erosion appear to be common, and dust spilling down the slopes of these ridges has invited comparisons to the snow-covered Rocky Mountains of Colorado.

The martian crust also exhibits more layering at great depths than was expected. The steep walls of canyons, valleys, and craters show the martian crust to be stratified at scales of a few tens of yards. "At this point we simply do not know whether these layers represent piles of volcanic flows or sedimentary rocks that might have formed in a standing body of water," said mission scientist Arden Albee of the California Institute of Technology.

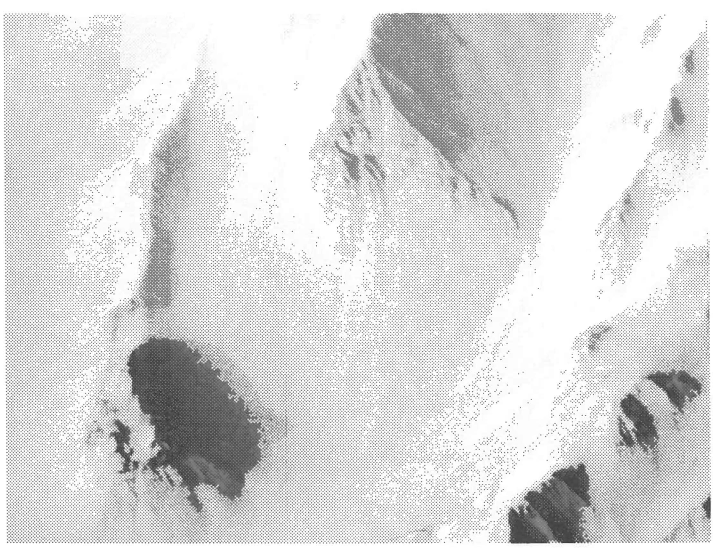
In March, *Surveyor* ceased aerobraking and began its summer-long session of observations from an interim elliptical orbit. During these passes, *Surveyor* will attempt to take images of several features of public interest, including the Mars Pathfinder and Viking mission landing sites. In early April, *Surveyor* snapped new images of the Cydonia region, site of the controversial feature known as the "Face on Mars."

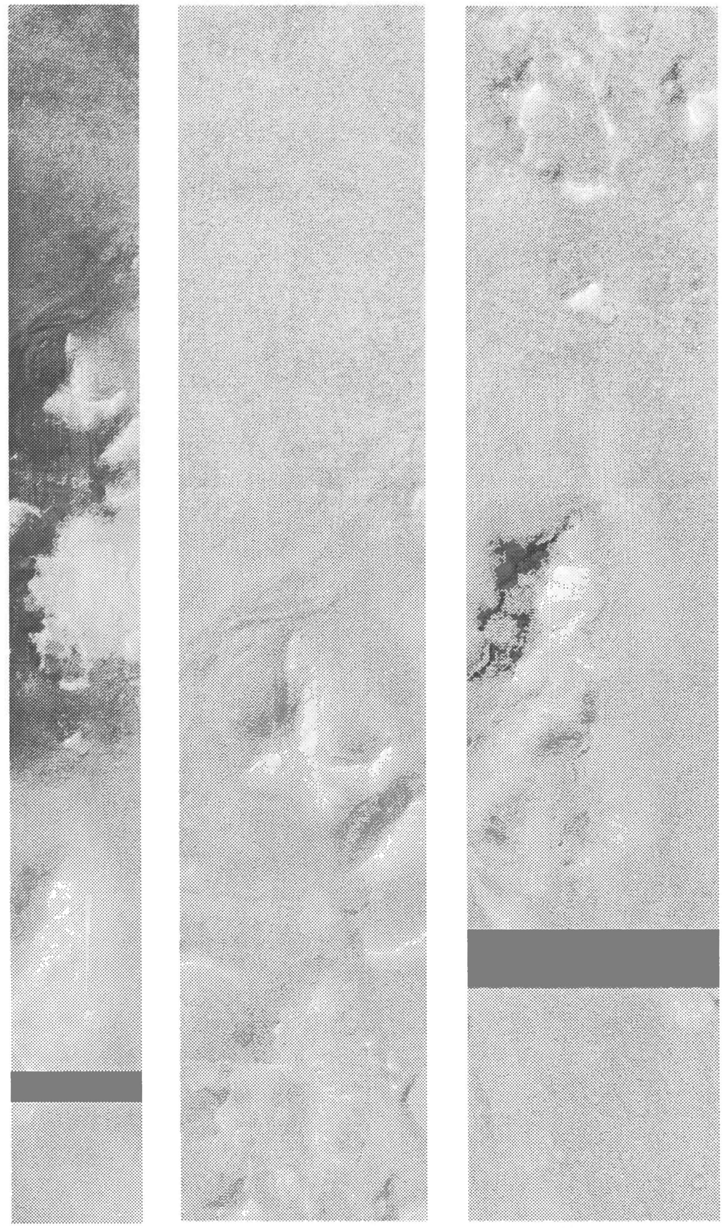
"Most scientists believe that everything we've seen on Mars is of natural origin," said Carl Pilcher, acting science director for Solar System Exploration in NASA's Office of Space Science. "However, we also believe it is appropriate to seek to resolve speculation about features in the Cydonia region by obtaining images when it is possible to do so."

Capturing images from the two landing sites may prove more difficult, since the locations of the sites are not precisely known and because the landers are so small. The spacecraft is scheduled to resume aerobraking in September and continue braking until March 1999, when it will settle into a final, circular orbit for its prime mapping mission.



Extensive wind-swept plains of the Medusae Fossae formation on Mars. This southern subframe image, frame 33104, is of a 3.0 × 4.7-kilometer area centered near 2.0 degrees north, 163.8 degrees west.





(Above) The first image shows the full processed swath of the Cydonia region viewed by Mars Global Surveyor at 14:02:17 UT (10:02:17: AM EDT) on April 14, 1998, on orbit 239. The second and third images show the top and bottom of the swath.

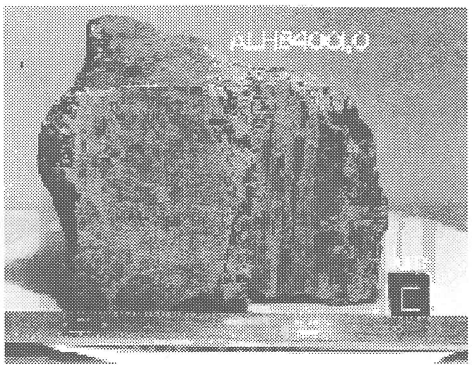
(Left) Layered features in Valles Marineris *— Most remarkable about this Mars Orbiter Camera image is the discovery of light and dark layers in the rock outcrops of the canyon walls. In the notable, triangular mountain face (at center), some 80 layers, typically alternating in brightness and varying in thickness from 5 to 50 meters (16 to 160 feet), are clearly visible. This sheer mountain cliff, over 1000 meters (3200 feet) tall, is only one of several outcrops that, together, indicate layering almost the entire depth of the canyon.*

This type of bedrock layering has never been seen before in Valles Marineris. It calls into question common views about the upper crust of Mars (for example, that there is a deep layer of rubble underlying most of the martian surface), and argues for a much more complex early history for the planet.

More Recent Research on ALH 84001

with More Insightful and Totally Objective Commentaries

by Allan Treiman, LPI Staff Scientist



Work continues apace on the ancient martian meteorite known as ALH 84001. In this article, the author updates his survey of recent research on the question of ancient fossil life in the meteorite to help nonspecialists keep abreast of the debate. Each entry includes a first-paragraph capsule summary of the work followed by a few paragraphs of extended description. Finally, the author adds his own comments and perspectives in italic type.

Jull A. J. T., Courtney C., Jeffrey D. A., and Beck J. W. (1998) Isotopic evidence for a terrestrial source of organic compounds found in Martian meteorites Allan Hills 84001 and Elephant Moraine 79001. *Science, 279,* 366–369.
Jull and coworkers measured the abundances of stable and radioactive isotopes of carbon in ALH 84001. Most of the carbon in ALH 84001 is from its carbonate mineral globules (as reported previously). Most of the remaining carbon is from Earth organic material, i.e., terrestrial contamination. A small fraction of the carbon (~8%) is too old to be Earth contamination, and is not (in chemistry and carbon isotopes) like carbon from the carbonate minerals. This carbon may be from organic material formed on Mars, or possibly a rare inorganic mineral (also from Mars).

Part of McKay et al.'s (1996) argument for traces of martian life in ALH 84001 is that the meteorite contains organic material, rich in PAH compounds, associated with its carbonate mineral globules. However, Becker et al. (1996) argued that this organic material is actually terrestrial contamination. To help resolve this issue, Jull and coworkers analyzed the isotopic composition of the carbon in the organic matter and the carbonate minerals of ALH 84001 (following Jull et al., 1997).

The principal clue used by Jull is the abundance of the radioactive isotope of carbon, carbon-14, in the organic material. Carbon-14 is used as an age-dating tool for archaeological and cultural artifacts (like the Shroud of Turin). Carbon-14 forms continuously and abundantly in the Earth's atmosphere. As soon as a carbon-bearing compound is isolated from the atmosphere (e.g., a tree dies and stops absorbing CO_2 from the air), its carbon-14 starts decaying away with a half-life of 5730 years. *Most* of the organic matter in ALH 84001 contains significant amounts of carbon-14 — which means that it is terrestrial contamination (there is no reasonable extraterrestrial source of so much carbon-14). Also, the carbon-14 gives an average age near 6000 years, which is approximately 7000 years after ALH 84001 fell to Earth. So, there is little doubt that most of the organic carbon in ALH 84001 is terrestrial contamination. In addition, the relative abundances of carbon-12 and carbon-13 (the $\delta^{13}C$ value) in the ALH 84001 organics are typical or carbon from living things on Earth.

The carbon in carbonate minerals in ALH 84001 is clearly not terrestrial — it has little or no carbon-14, and a $\delta^{13}C$ value much higher than typical for Earth carbonates. Earlier, Jull et al. (1997) got similar results for carbonate minerals in a different sample of ALH 84001, although that sample had enough carbon-14 to suggest some chemical exchanges with Earth water.

However, a small part of the carbon in ALH 84001 might be martian organic material. This carbon was not dissolved away during acid treatment designed to remove carbonate minerals, so it is either organic or some (unknown) resistant mineral. This batch of carbon has no carbon-14, meaning that it is very old. Jull and coworkers take this ancient age to mean that this batch of carbon did not form on Earth — it is martian.

This work appears to be carefully done, adequately documented, and carefully presented. It does not directly refute McKay et al.'s (1996) hypothesis of martian biological activity in ALH 84001, but it is not much of a confirmation, either. I have two comments about this work and possible evidence of martian biological activity in ALH 84001.

ALH 84001 contains hundreds of parts per million organic carbon, much more than other martian meteorites except EETA79001 (which Jull also analyzed in this paper). This high abundance of organic matter has been used to support claims of fossil martian biology in ALH 84001. However, ALH 84001 contains the same amount of organic carbon as do typical basalt meteorites from asteroids, even those found in Antarctica (Grady et al., 1997). Just as Jull and coworkers showed that most of the organic carbon in ALH 84001 is terrestrial contamination, Grady et al. (1997) showed that most of the carbon in asteroidal basalt meteorites is terrestrial contamination. In this way, ALH 84001 is quite average and was not *contaminated any more than normal for a meteorite.*

The most intriguing part of Jull's work, at least to me, is the extraterrestrial organic (?) material they found in ALH 84001. They found this carbon in a sample of ALH 84001 that had been treated to remove all of its carbonate minerals. At lower temperatures (<450°C) this treated sample released the same terrestrial carbon (both ^{14}C and $\delta^{13}C$) as the untreated sample. But at higher temperatures, the treated sample released some carbon without any carbon-14, meaning it was pre-terrestrial. This high-temperature, noncarbonate carbon could be organic matter, or could possibly be a rare, acid-resistant, as-yet-unidentified inorganic mineral. Many different kinds of organics can be released at these higher temperatures, including material like kerogen, graphite, and PAHs. So, it is tempting to say that Jull and co-workers detected the same PAHs that McKay et al. found (and probably also other high-temperature organic compounds). But most meteorite basalts from asteroids also contain similar amounts of high-temperature carbon (10–30 parts per million; Grady et al., 1997). Could it be that basalts in the solar system just have this many high-temperature carbon compounds, whether or not life was present?

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Becker L., Glavin D. P., and Bada J. L. (1997) Polycycic aromatic hydrocarbons (PAHs) in Antarctic Martian meteorites, carbonaceous chondrites, and polar ice. *Geochim. Cosmochim. Acta, 61,* 475–481.

Grady M. M., Wright I. P., and Pillinger C. T. (1997) Carbon in howardite, eucrite, and diogenite basaltic achondrites. *Meteoritics Planet. Sci., 32,* 863–887.

Jull A. J. T., Eastoe C. J., and Cloudt S. (1997) Isotopic composition of carbonates in SNC meteorites, Allan Hills 84001 and Zagami. *Jour. Geophys. Res., 102,* 1663–1669.

Bada J. L., Glavin D. P., McDonald G. D., and Becker L. (1998) A search for endogenous amino acids in martian meteorite ALH84001. *Science, 279,* 362–365.

Bada and coworkers analyzed ALH 84001 for amino acids, chemicals that are essential in life as we know it on Earth. In the meteorite's carbonate globules are small amounts of amino acids, which are nearly identical (in proportions of acid species and in their chemical handedness) to amino acids in Antarctic ice. So, Bada and coworkers conclude that (essentially) all the amino acids in ALH 84001 are terrestrial contamination, carried into the meteorite by melted Antarctic ice.

Part of McKay et al.'s (1996) argument for traces of martian life in ALH 84001 is that the meteorite contains organic material mixed with its carbonate mineral globules. Last year, Bada's research group claimed the organic material is terrestrial contamination (Becker et al., 1996). Continuing this work, Bada and coworkers analyzed ALH 84001 and its carbonate minerals for amino acids. Amino acids are small organic molecules, the building blocks of proteins and enzymes in all living things on Earth. Earth life only uses a few of the many possible amino acids in fairly characteristic relative abundances, and only uses the L form of those amino acids. With these distinctive characters, amino acids are a sensitive test for Earth organic contamination in meteorites.

To analyze for amino acids, Bada and coworkers used a very sensitive technique developed in their laboratory. McKay et al. suggested that the signs of ancient martian life were associated with carbonate minerals in ALH 84001, so Bada and coworkers used a chemical extraction to separate amino acids in the carbonate globules from those elsewhere. First, they rinsed the samples of ALH 84001 in distilled water, and that extracted no amino acids at all. Then, they reacted the samples with weak hydrochloric acid, which should dissolve the carbonate minerals in the rock and release any amino acids associated with them. This acid solution was dried and part of it analyzed for free amino acids (those not chemically bound to anything else). Another part of the solution was dried and treated to liberate amino acids that were bound to other molecules (for example, this treatment would break proteins into their constituent amino acids). And finally, they analyzed the remainder of the meteorite that was not dissolved in acid (including the pyroxene and chromite mineral grains) for bound amino acids.

Bada and coworkers found that the amino acids in ALH 84001 were most abundant as bound acids associated with the carbonate minerals. There were almost no amino acids in the distilled water wash, the acid-insoluble residue, or as free amino acids in the acid solution. The part of ALH 84001 that dissolved in acid contained about 10 parts per million total amino acids (almost all chemically bound), while the rest of the rock contained only 75–100 parts per billion of amino acids.

The amino acids in ALH 84001 are almost exactly in the same proportion as in the Antarctic ice — the proportions of DL-serine to glycine to L-alanine are approximately 3:3:1. In addition, there is a little D-alanine in Antarctic ice and in ALH 84001 *[author's note: possibly from micrometeorites in the ice?]*. This similarity of terrestrial and ALH 84001 amino acids leaves little doubt that they are primarily terrestrial contamination, derived from amino acids in the ice that was around ALH 84001.

The amino acids that Bada and coworkers found in ALH 84001 are from the Antarctic ice. But this fact is not a deathblow to the hypothesis that ALH 84001 contains traces of ancient martian life (McKay et al. 1996). Despite an exuberant press release from Scripps Oceanographic Institution, Bada's work is not *a conclusive test of McKay's hypothesis. McKay et al. (1996) did not talk about amino acids, so the absence of preterrestrial amino acids does not refute their hypothesis at all. Of course, if Bada and coworkers had found abundant preterrestrial amino acids, it would have been strong support* for *McKay et al.'s hypothesis.*

Two aspects of Bada's experiments are puzzling (although probably not very important). First, their acid treatment was designed to dissolve carbonate minerals, but it *dissolved 20% of their carbonate-free sample of lunar rock. What actually dissolved from the lunar rock? Possibly feldspar? Could feldspar (or whatever) also have dissolved from ALH 84001, and would this change the conclusions? Second, their acid treatment seems to have increased the masses of their samples. For instance, sample 2 of ALH 84001 started at 463 milligrams, and ended up as 472.5 milligrams (text and Table 1). What is this extra mass? Could it be lab contamination that might carry amino acids?*

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Bradley J. P., Harvey R. P., and McSween H. Y. Jr. (1997) No 'nanofossils' in martian meteorite orthopyroxenite. *Nature 390,* 454.

McKay D. S., Gibson E. K. Jr., Thomas-Keprta K., and Vali H. (1997) Reply to "No 'nanofossils' in martian meteorite orthopyroxenite." *Nature, 390,* 455–456.

Bradley et al. claim that the possible nanofossils found by McKay et al. (1996) in martian meteorite ALH 84001 are actually irregularities in the surfaces of mineral grains. These irregularities were accentuated by the metal coating that had to be put on the samples for electron microscope examination. So, Bradley and coworkers reject the hypothesis that ALH 84001 carries nanofossils of ancient martian life. In response, McKay et al. say that they also found the same surface irregularities, and that they are not possible martian nanofossils. The metal coating on the samples did not interfere with their identification of objects as nanofossils, because they did control experiments on metal coatings and know what the coating does. (G. J. Taylor has posted a nice summary of these letters on the World Wide Web at http://www.soest.hawaii.edu/PSRdiscoveries/Dec97/LifeonMarsUpdate2.html.)

Bradley and coworkers examined fracture surfaces of ALH 84001 using nearly the same methods that McKay et al. (1996) used. They found sausage-shaped surface features, approximately 100–400 nanometers (billionths of a meter) long, that looked (to them) similar to the possible nanofossils in the McKay et al. (1996) paper and in later magazine articles and press briefings. Bradley found these sausage-shaped features on the carbonate minerals (as McKay's "nanofossils" were) and also on the host silicate minerals. By observing the sample from many angles (in their electron microscope), Bradley found that the "sausages" were not sitting on the host minerals, but were actually ridges poking out of the host minerals.

Bradley also did a few experiments on how the metal coating on the samples changes the shapes of surface features. They found (as have others) that metal coatings tend to make surface features look segmented (the thicker, the more segmented) — an appearance that McKay's group had suggested might reflect cell boundaries.

McKay et al. respond that they have also seen ridges on minerals' surfaces that Bradley et al. found — same sizes, shapes, and textures. McKay and coworkers suggest that the ridges are grains of clay minerals formed during "incipient" alteration of the host minerals. But these surface ridges, say McKay et al., are not the possible nanofossils they described in 1996 and subsequently. Their possible nanofossils differ from the Bradley ridges by not being parallel with each other, by intersecting with each other at distinct angles, by being curved, and by being rather isolated from each other.

McKay and colleagues also dispute that their identifications of possible nanofossils (here and earlier) were compromised by metal coatings on the samples. They reiterate that they did control experiments on the effects of metal coatings, and that the nanofossil morphologies do not result from coating. McKay also notes that some of Bradley's samples were coated with gold alone, rather than a gold-palladium alloy, and that gold coatings are known to make larger artifacts (artificial structures) than are gold-palladium.

This exchange focuses on two important issues about the possible martian nanofossils in ALH 84001: (1) How can you recognize a nanofossil? and (2) How does laboratory preparation change the surfaces of the samples? Unfortunately, short "correspondence and reply" tidbits cannot carry enough scientific "meat" to resolve these issues.

(1) How can you recognize that a shape in ALH 84001 is a martian nanofossil? In 1996, McKay et al. cited ". . .regularly shaped ovoid and elongate forms ranging from 20 to 100 nanometers in longest dimension" as possible nanofossils (their Figure 6 and Kerr, 1996). At their big NASA press conference, McKay and colleagues also presented an image of aligned sausage-shaped objects in a grid formation as being possible nanofossils (http://cass.jsc.nasa.gov/lpi/meteorites/s96-1229.gif). Bradley et al. found features that matched these characteristics and showed that they were not biological.

Here, McKay et al. seem to have changed their definition of martian nanofossils. Nanofossils are still elongate and ovoid. Now, however, they do not appear in parallel, but display "intersecting alignments"; they are relatively isolated from each other; they are significantly curved (their Fig. 2c); and they are much larger, up to 750 nanometers long. With these new criteria, many of McKay's own objects may not qualify as nanofossils: the ovoids of Figure 6a in McKay et al. (1996); the famous segmented worm shape (http://cass.jsc.nasa.gov/lpi/meteorites/Photomicrograph.gif; Kerr, 1996); and the aligned sausage-shaped objects (http://cass.jsc.nasa.gov/lpi/meteorites/s96-1229.gif).

(2) How does the metal coating (for electron microscopy) affect the surfaces of minerals in ALH 84001? This question has been argued, mostly in private, since McKay et al. (1996) was published. In other words, are some of the "nanofossils" in ALH 84001 completely artificial, made during

metal coating, and completely irrelevant to life on Mars? Believable answers to these questions will only come from carefully controlled experiments, where fragments of ALH 84001 are coated with various thicknesses of different metals and alloys. Bradley et al. report that they did a few experiments in this program; McKay et al. report that they did a series of experiments on a different sample (a lunar glass). Unfortunately, neither set of experiments has been reported in any detail, and I am still not sure of what metal coatings (gold or gold/palladium) do to surface morphology at these very small sizes.

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Murty S. V. S. and Mohapatra R. K. (1997) Nitrogen and heavy noble gases in ALH 84001: Signatures of ancient Martian atmosphere. *Geochim. Cosmochim. Acta, 61,* 5417–5428.

About 4 billion years ago, traces of noble gases and nitrogen from the martian atmosphere were trapped in ALH 84001. The isotopic compositions and relative abundances of the heavy noble gases xenon (Xe) and krypton (Kr) are similar to the present-day martian atmosphere. So, Mars' unusual Xe and Kr compositions and abundances were set earlier than 4.0 billion years ago. Argon trapped in ALH 84001 has less ^{40}Ar from radioactive ^{40}K (potassium) than Mars' present-day atmosphere, suggesting that it has continued to gain ^{40}Ar over time *[author's note: e.g., by volcanic outgassing].* Nitrogen trapped in ALH 84001 has much less of the heavy isotope ^{15}N, consistent with loss of the light isotope ^{14}N (and other lightweight gases) from Mars' atmosphere over the last 4 billion years.

The elemental and isotopic composition of the martian atmosphere has been a real puzzle. It is greatly depleted in the light stable isotopes of all gas elements, from hydrogen to xenon. For instance, the abundance ratios of light to heavy xenon isotopes (e.g., ^{128}Xe/^{136}Xe) are approximately 0.7 times that in the Sun (Zahnle, 1993). It is a mystery how and when the lightweight isotopes were removed, but a separate process must have acted for each element (Pepin, 1994). Any process strong enough to remove a lot of, say, ^{128}Xe compared to ^{136}Xe, would certainly have removed all of the lighter gaseous elements completely (like krypton, argon, and nitrogen). Similarly, any process capable of separating ^{36}Ar from ^{38}Ar to the extent seen in the martian atmosphere would have removed essentially all of its nitrogen.

One way to help understand the martian atmosphere would be to learn how its composition has changed through time. Its present-day atmosphere (analyzed by Earth telescopes and the Viking landers) is the same as the atmosphere of 180 million years ago, as trapped in some martian meteorites (most notably EETA79001). Recognizing that ALH 84001 has retained noble gases (like argon) for 4 billion years, Murty and Mohapatra investigated whether it might contain trapped martian atmosphere from that time. They used standard techniques — separating the meteorite into its minerals by their density, heating the samples up in steps of 200°C (or more) to 1600°C, and collecting the gases given off by each sample in each temperature step. The gases were separated, and the isotopic composition of each element was measured with a mass spectrometer.

Murty and Mohapatra found that ALH 84001 contains significant quantities of nitrogen, argon, krypton, and xenon gases. Most gases (xenon, krypton, nitrogen, and argon^{36}) all were released by the samples at nearly the same temperatures, suggesting that they are from the same trapped atmosphere component. ALH 84001 contains a nitrogen component comparable to Mars "mantle"(the Chassigny meteorite) and a trapped component with δ^{15}N $\geq$ +85‰; the current Mars atmosphere has δ^{15}N $\approx$ +620‰. From the isotopic composition of the argon (in mineral and temperature and temperature separates), the authors estimate that the trapped gas has ^{40}Ar/^{36}Ar $\leq$ 1400, while the current Mars atmosphere has a value of 2400. The trapped gas in ALH 84001 has ^{14}N/^{36}Ar, about 60 times the value for the current Mars atmosphere. The Kr and Xe isotope compositions of most of the trapped gas are similar to the current martian atmosphere, or the current atmosphere as modified by groundwater processes.

Murty and Mohapatra infer that this trapped gas component is a sample of the martian atmosphere from 4 billion years ago, the age when argon gas was last lost from ALH 84001. The ancient and modern atmospheres have similar isotopes and relative abundances of xenon and krypton (the heaviest noble gases), which means that the hydrodynamic escape processes that set these abundances (Pepin, 1994) were complete by 4 billion years ago. The higher ^{40}Ar/^{36}Ar in the current atmosphere reflects production of ^{40}Ar from potassium over the history of Mars. And the decrease in ^{14}N/^{36}Ar may reflect loss of nitrogen (through sputtering) into space over the last 4 billion years.

This work is not directly related to the "life in ALH 84001" folderol. It is part of the long-term effort to learn about Mars' ancient environments through clues in the martian meteorites. The noble gases and nitrogen hold great promise in unraveling the evolution of Mars' atmosphere, particularly why it is so thin now (surface pressure of ~1/200 that of Earth) and where its water has gone. But this work, no matter how good, is not likely to be the final word on ALH 84001. The uncertainty here is not from Murty and Mohapatra's analyses, but in the inherent variability of samples of ALH 84001 and the many assumptions that must be made to unravel the noble gas story.

First, it appears that different samples of ALH 84001 contain different quantities, proportions, and isotope compositions of the noble gases and nitrogen. This is perhaps not too surprising, as the mineral proportions and chemical composition of ALH 84001 are rather variable, for instance potassium abundances (108 vs. 200 parts per million: Mittlefehldt, 1994b; Dreibus et al., 1994). For the noble gases, this variability can appear as differences in the proportion of ^{40}Ar that comes from radioactive potassium (this paper; Turner et al., 1997), and as differences in xenon isotope ratios (Fig. 9 of this paper vs. Fig. 2 of Swindle et al., 1995 and

Fig. 3 of Miura et al., 1995). Variabilities like these in elemental and isotopic abundances suggests that the gases in ALH 84001 came from many different sources and were not mixed well. It will be possible, eventually, to sort out the different sources (or components) of gas; now, it seems to be a muddle.

Second, interpretation of noble gas and nitrogen abundances is not simple and relies on some (fairly complex) correction schemes and underlying assumptions. Different research groups have not treated their data the same way, so when their results appear in conflict, it may be difficult for a nonspecialist (like me) to understand why. For instance, all groups so far have agreed that some of the argon in ALH 84001 comes from atmosphere trapped in the mineral grains. Turner et al. (1997) present evidence that this trapped gas is like argon from the Earth's atmosphere: $^{40}Ar/^{36}Ar = 295$. *Murty and Mohapatra infer that the trapped argon is ancient martian, with* $^{40}Ar/^{36}Ar \leq 1410$. *Miura et al. (1995) and Goswami et al. (1997) use the current martian atmosphere value of* $^{40}Ar/^{36}Ar \approx 2400$. *Swindle et al. (1995) do not infer a specific* $^{40}Ar/^{36}Ar$ *for the trapped component. Is each group justified, given their data and the intrinsic variability of ALH 84001, or have some (or all) of them made unjustified simplifications in their data treatment?*

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The authors measured the abundance ratio of sulfur isotopes ($^{34}S/^{32}S$) in minerals of martian meteorites to see if the sulfur in ALH 84001 had been processed by sulfate-reducing bacteria, as implied by McKay et al. (1996). They found no evidence for the action of sulfate-reducing bacteria in ALH 84001, and so reject the McKay et al. (1996) hypothesis that ALH 84001 contains traces of ancient martian life.

The element sulfur occurs as two stable (not radioactive) isotopes with masses of 32 and 34, ^{32}S and ^{34}S. Most sources of sulfur have abundance ratios of $^{34}S/^{32}S$ that are very similar to the average in the solar system. However, sulfur that has been processed by bacteria (or other life forms) can have distinctly different abundances of these isotopes. The greatest changes in S isotopes come from sulfate-reducing bacteria, which take sulfate ions (SO_4^{2-}) from water and convert them to sulfide ions (S^{2-}) in water or as solid sulfide minerals. Sulfate-reducing bacteria, when they have lots of sulfate in water around them, can form sulfide minerals with ~5% less ^{34}S than the sulfate in the water. This difference is easily detected, and has been used (on Earth) as a guide to the action of these bacteria.

To estimate the sulfur isotope ratio for bulk Mars, Greenwood et al. measured sulfur isotope ratios in the martian basalt meteorites (Shergotty, Zagami, EETA 79001, LEW 88516, and QUE 94201). The sulfur isotope ratios for these meteorites are within 0.3% of the solar system average. In ALH 84001, they first measured sulfur isotopes in millimeter-sized grains of pyrite (FeS_2), which are not associated with the possible traces of ancient martian life (Gibson et al., 1996; but see Shearer et al., 1997). The pyrite had variable and slightly "heavier" sulfur than the other martian meteorites, with $^{34}S/^{32}S$ from approximately 0.2 to 0.75% larger than the solar system average; this agrees with earlier work of Shearer et al. (1996). Finally, they analyzed the sulfur-rich outer zone of a single carbonate globule from ALH 84001 — iron sulfide minerals in the carbonate globules were claimed by McKay et al. (1996) to have formed through the action of martian biological organisms. The outer parts of the carbonate globules contain carbonate and oxide minerals in addition to the sulfides, so Greenwood et al. did not get as precise a result here as for the pure sulfide minerals. Also, they had to apply a small correction for pairs of oxygen atoms masquerading as sulfur. But the $^{34}S/^{32}S$ for the sulfide-rich region of the carbonate globule is identical to the nonbiological pyrite in ALH 84001: 0.6% larger than the solar system average.

The nonbiological and possibly biological sulfide minerals in ALH 84001 have nearly identical $^{34}S/^{32}S$ ratios. Greenwood et al. take this similarity to suggest that sulfur (in the possibly biological sulfides) in the carbonate globules was not processed by sulfate-reducing bacteria — that the McKay et al. (1996) hypothesis is wrong. Rather, they suggest that all the sulfides in ALH 84001 formed from a high-temperature fluid (too hot for life as we know it), probably generated by an asteroid impact onto Mars. The variations in sulfur isotope ratios suggest mixing of "light" and "heavy" sulfur, the former perhaps from igneous rocks, the latter perhaps from Mars' surface.

This paper is much weaker than it could have been because the authors did not document their experiments adequately. The analyses of sulfur isotopes in the pure sulfide minerals (pyrite and pyrrhotite) seem superb; they follow carefully described procedures, are based on good standards, and are repeatable. But the analysis of sulfur isotopes in the carbonate globule, the critical analysis for evaluating the hypothesis of ancient martian life (McKay et al., 1996), will be suspect until Greenwood et al. document it fully.

The problem with Greenwood's analysis for sulfur isotopes in the carbonate globule is that they did not analyze only sulfide minerals. Their instrument, an ion microprobe, shoots cesium ions at the sample, and collects ions from the sample that are sputtered off by the cesium. Sulfur come off as S^{2-} ions, both as the "light" $^{32}S^{2-}$ and the "heavy" $^{34}S^{2-}$. Two problems are possible when the sulfur is present as sulfides among other minerals, like carbonates and oxides.

If the sulfide minerals are mixed with oxide and carbonate minerals, the ion $^{16}O^{16}O^{2-}$ might be formed in abundance (from the carbonates and oxides) and might pass as $^{32}S^{2-}$, as both ions have the same masses and charges. If there were lots of $^{16}O^{16}O^{2-}$ passing for $^{32}S^{2-}$, the sulfur would appear "lighter" than it really is.

It is also possible that having sulfur-bearing minerals among other minerals influences the way that the sulfur sputters off the sample and into the analyzer. For instance, sulfur in sulfides mixed with carbonates and oxides might sputter more like a sulfate than a sulfide, and require a different corrective procedure.

Greenwood et al. were aware of these potential problems, and reported that they (1) corrected for the presence of $^{16}O^{16}O^{2-}$ (less than 0.2% in their value of $^{34}S/^{32}S$), and (2) did experiments to show that their sulfur isotope corrective procedures gave consistent results for $^{34}S/^{32}S$ with or without admixed carbonates and oxides. But they gave no details on the $^{16}O^{16}O^{2-}$ correction, and no results for the experiments on mixtures. Since we cannot see the details of their corrections, and the results of their experiments, we are really asked to take on faith that Greenwood did both properly. Some scientists, trusting the authors implicitly, will *take their work on faith. Others, who do not accept the conclusions of Greenwood et al., will point to these problems as cause for discounting the paper entirely. And those who wish to "trust, but verify" will merely be disappointed.*

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29th LPSC SETS NEW RECORDS

The 29th Lunar and Planetary Science Conference came to a close March 20, 1998, after four and a half successful days of technical sessions at the Johnson Space Center and Space Center Houston in the Clear Lake area of Houston, Texas.

The conference, cosponsored by NASA, the Lunar and Planetary Institute, and NASA Johnson Space Center, attracted 1033 participants, including 240 students, 26 members of the press, and 185 foreign participants from 20 different countries.

Abstract submissions far exceeded previous years for the conference, and the final abstract volume included a record-breaking 955 abstracts. The abstract volume was published solely in electronic CD-ROM format for the first time this year. Also for the first time this year, the Tuesday and Thursday night poster sessions, as well as the special education session, were held at nearby Space Center Houston.

Highlights of the conference included Michael H. Carr's Masursky Lecture on the role of water in the evolution of martian geology, and the implications of this history on the search for possible martian life; Matthew P. Golombek's overview of the geology of the Pathfinder site; and the Pathfinder and Discovery special sessions.

Continued on page 19

The *Lunar and Planetary Information Bulletin* is published quarterly by the Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058-1113.

Brian Anderson, Editor

Editorial and production support are provided by the LPI Publications and Program Services Department. Copy deadline for the next issue of the LPIB is July 10, 1998.

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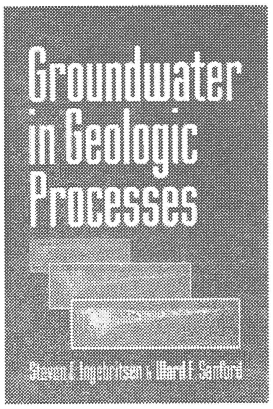

Recently Published

Groundwater in Geologic Processes, by Steven E. Ingebritsen and Ward E. Sanford (Cambridge University Press, 1998, $69.95).

The publisher touts this book as "ideal for graduate-level hydrogeologists and geologists with backgrounds in calculus and introductory chemistry" and as an "invaluable reference for professionals in the field."

RealSky CD — The Southern Sky

This digitized southern sky survey by the Royal Observatory of Edinburgh/Anglo-Australian Observatory complements the original RealSky CD set, released on 9 CD-ROMs in 1996. The Southern sky set includes more than 1000 images compressed by a factor of 100× on 11 CD-ROMs. Sample images may be viewed on the Web at http://www.aspsky.org.

The CD-ROM package includes viewing and manipulation software and is compatible with Windows, Macintosh, UNIX, and VMS systems. The cost of the 11 CD-ROM set is $250, plus shipping and handling. The entire RealSky CD set may be purchased for $450. For more information, call 800-355-2624.

Astronomical Almanac to Be Revised

The publishers of the *Astronomical Almanac* are seeking reader input into possible format and content revisions. Proposed changes for the annual volume, a joint publication of the Astronomical Applications Department of the U.S. Naval Observatory and the H. M. Nautical Almanac Office of the Royal Greenwich Observatory, include adoption of the International Celestial Reference Systems and the addition of a companion CD-ROM. The changes are expected to be incorporated into the 2002 edition of the almanac.

Almanac users wanting to voice their opinions on possible revisions can complete a survey available on the World Wide Web at http://www.ast.cam.ac.uk/nao/survey.html. The survey site will close on August 1, 1998.

NASA History Takes Leopold Prize

The Organization of American Historians recently awarded the 1998 Richard W. Leopold Prize to Andrew J. Butrica's *To See the Unseen: A History of Planetary Astronomy.* The Leopold Prize is awarded every two years to the best book written by a historian associated with a governmental body in the areas of foreign policy, military affairs, federal government history, or biography.

The book, part of the NASA History Series produced by the NASA Headquarters History Division, provides a comprehensive history of planetary radar astronomy, a technology that involves aiming a controlled radar signal at a planet (or some other target) and analyzing information from the signal's echo. The book is available through the Government Printing Office (stock number 033-000-01163-6).

The juxtaposition of textures of basalts is shown in this photomicrograph from Basaltic Volcanism.

PHOTO COURTESY OF G. LOFGREN

Basaltic Volcanism Available On Line

The popular text *Basaltic Volcanisn on the Terrestrial Planets* (Pergamon Press, 1981) is now available on line through the NASA Astrophysics Data System website. The online text, available at http://adsbit.harvard.edu/books, is part of ADS's extensive online holdings. Other recent additions to the ADS archive include back issues of *Meteoritics & Planetary Science Online.*

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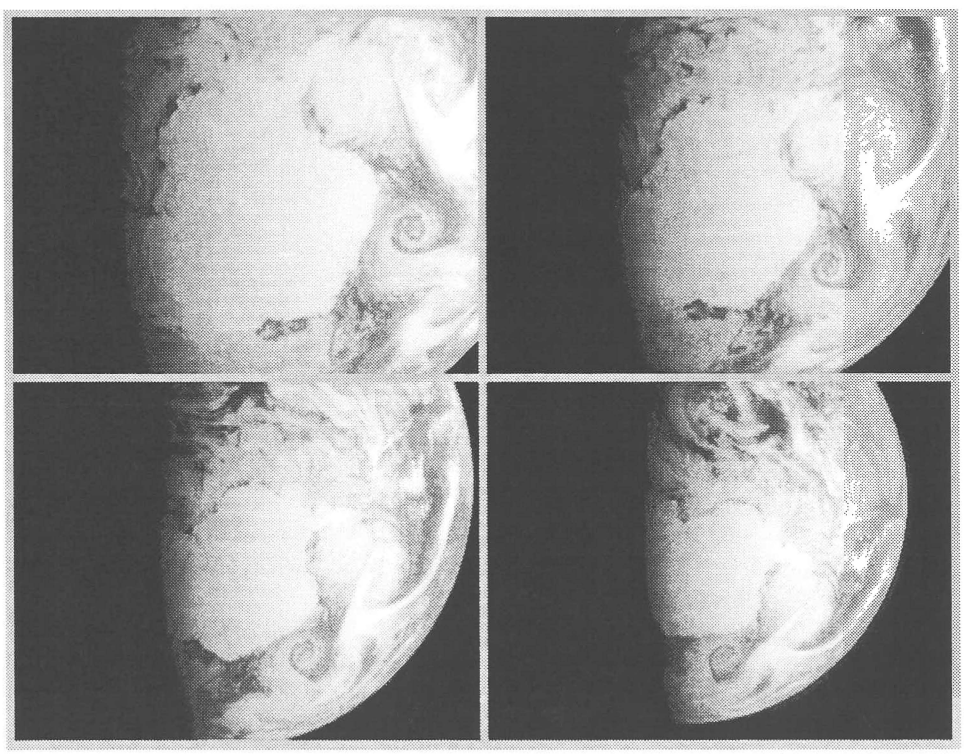
APL REPORTS NEAR ON TARGET AFTER FLAWLESS EARTH FLYBY

The Near Earth Asteroid Rendezvous (NEAR) spacecraft flew by the Earth on January 23, "right on schedule and right on target," says a jubilant Thomas Coughlin, Space Programs Manager at The Johns Hopkins University Applied Physics Laboratory (APL), which manages the NEAR mission. All spacecraft subsystems worked flawlessly as NEAR swooped around the Earth during a two-hour visit for a gravity assist that put it onto the correct trajectory for an encounter with asteroid 433 Eros in January 1999.



These images were taken at 80-minute intervals, as the spacecraft's distance from Earth increased from 92,000 miles (148,000 kilometers) to 160,000 miles (256,000 kilometers). They clearly show Earth's clockwise rotations as viewed from the spacecraft's perspective, starting from the upper left image. The South Pole is at the center of each image, and the continent of Antarctica is surrounded by sea ice and storm fronts.

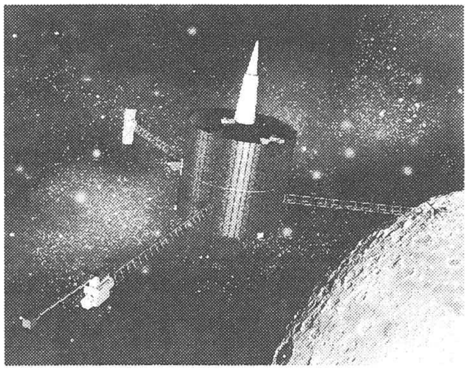
The January 22–23 flyby of the NEAR spacecraft put the U.S. on watch for its first naked-eye glimpse of an interplanetary spacecraft. The southern states from east to west, and especially Hawai'i, got the best view because of clear skies and darkness that made it easier to see sunglints off the spacecraft's four solar panels. Although closest-encounter data is still being processed, early indications were that NEAR passed within 336 miles of southwest Iran, as predicted. (Encounter data is being posted on the NEAR Web page as soon as it is available: http://sd-www.jhuapl.edu/NEAR/.)

The first sighting of NEAR was made at about 1:30 p.m. EST by an astronomer in Caussols, France, using a 0.9- meter telescope, as the spacecraft approached far above the Middle East. When sighted, NEAR was 580,000 miles from Earth and within a half-mile of its expected location.

On January 23, NEAR took a series of images of Asia, Africa, and Antarctica as it moved away from Earth, and during the following weeks, its Multi-Spectral Imager and Near-Infrared Spectrograph were calibrated using proven measurements of Earth and lunar geological features. Over the next year, as NEAR closes in on Eros, scientists and engineers will be developing and testing flight and ground software for the spacecraft and finalizing procedures for the yearlong encounter with the asteroid.

NEAR's study of Eros will be the first in-depth examination of a near-Earth asteroid and is expected to yield information that will help scientists better understand the evolution of our solar system. NEAR, which is being tracked by NASA's Deep Space Network, is the first mission in the Discovery series.

NEWS FROM SPACE



WATER, WATER, EVERYWHERE . . .

Just one month after announcing that there is a "high probability" that water ice exists at both poles of the Moon, NASA scientists are saying the amount of water present on the Moon may be much more than previously thought.

Initial estimates, announced in March 1998 and based on data returned by the *Lunar Prospector*, placed the amount of lunar water ice in the range of 11 million to 330 million tons. Scientists involved in analyzing the *Prospector* data are now cautiously asserting that the total may be closer to a billion metric tons.

"There's quite a bit more ice than we were thinking," said Lunar Prospector Principal Investigator Alan Binder, of the Lunar Research Institute in Gilroy, California. Early in the investigation, Binder said, "we knew we were seeing water, but we thought the data indicated a low mixing ratio."

Binder cautioned, however, that the new estimates are still based on "theoretical models" about the Moon's atmosphere, the rate of cometary impact, and how these factors affected the regolith mixing ratio over time.

In addition, Binder has been careful to reiterate that the *Prospector's* neutron spectrometer detected only the presence of hydrogen, and did not directly measure the presence of water ice.

"We're inferring that it's water. But I would be very surprised if it's just large hydrogen deposits," Binder said.

The discovery of water on the Moon could be a major catalyst to reviving interest in building a lunar base, Binder said, since the water could be used for fuel and life support. Binder said he believes a lunar base is the first logical step in the colonization of other planets and would also provide invaluable opportunities for lunar science and astronomy.

"Clearly, the post-Apollo plan that we had in the 1970s was to have a base by the end of the decade," he said. "If *Lunar Prospector* were to kindle this spirit again — and we would have to rebuild some of the technology — we might be able to build a base in 10 years. It's really a political question."

Binder said a sampler lander mission could definitively answer the questions surrounding the presence of ice on the Moon.

DISK DISCOVERY STIRS DEBATE

NASA astronomers using the new Keck II telescope have discovered what some are terming the "clearest evidence yet" of a budding solar system around a nearby star.

Scientists released an image of the possible site of planet formation around a star known as HR 4796, about 220 light-years from Earth in the constellation Centaurus. The image, taken with a sensitive infrared camera developed at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, shows what appears to be a swirling disk of dust around the star. Within the disk is an empty region that may have been swept clean when material was pulled into newly formed planetary bodies, the scientists said.

"This may be what our solar system looked like at the end of its main planetary formation phase," said Michael Werner of JPL, who discovered the region along with David Koerner and Michael Ressler, also of JPL, and Dana Backman of Franklin and Marshall College, Lancaster, Pennsylvania. "Comets may be forming right now in the disk's outer portion from remaining debris."

Koerner of JPL said the finding represents a "missing link" in the study of how planetary systems are born and evolve.

"In a sense, we've already peeked into the stellar family album and seen baby pictures and middle-aged photos," Koerner said. "With HR 4796, we're seeing a picture of a young adult star starting its own family of planets. This is the link between disks around very young stars and disks around mature stars, many with planets already orbiting them."

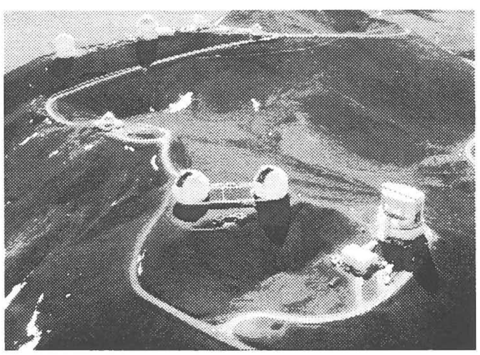
Other scientists, however, remain skeptical of the construction-zone interpretation.

"While the enthusiasm is understandable, and the scientific value of the observations is only just beginning to be appreciated, care should be taken to not overinterpret them," said David C. Black, director of the Lunar and Planetary Institute in Houston. "Observations have shown that most, if not all, stars younger than HR 4796 have disks associated with them. What is not known is the evolutionary fate of those disks, in particular which of them are likely to evolve to form planetary systems."

Black noted that there are three possible evolutionary tracks for circumstellar disks. Such a disk may form a binary system, evolve into a planetary system, or disperse into nothing of consequence. Black said that, at the present time, no clear evidence rules out any of these possibilities for HR 4796, which he terms "a modest disk at best."

"As more systems are discovered and analyzed, we may gain sufficient insight to know whether the disk associated with HR 4796 is a missing link, and if so, to what endpoint, or whether it is simply a snapshot of an infertile system, to continue the human analogy that seems to be so freely used in discussing these objects."

The discovery of the disk was made on March 16 from the 33-foot (10-meter) Keck II telescope atop Mauna Kea, Hawai'i. Keck II and its twin, Keck I, are the world's largest optical and infrared telescopes. Attached to the Keck II for this observation was the mid-infrared camera, developed by Ressler at JPL and designed to measure heat radiation.



This aerial view of the W. M. Keck Observatory shows the twin Keck telescopes, along with most of the other telescopes situated atop the summit of Mauna Kea. Keck I and Keck II are the world's largest optical and infrared telescopes, each measuring 10 meters (33 feet) in diameter.

The four scientists reported their discovery in a submission to *The Astrophysical Journal Letters*. The disk was discovered independently at the Cerro Tololo Observatory in Chile by another team of scientists, led by Ray Jayawardhana of the Harvard-Smithsonian Center for Astrophysics (CfA), Cambridge, Massachusetts, and Charles Telesco of the University of Florida, Gainesville.

The apparent diameter of the dust disk around HR 4796 is about 200 astronomical units (one astronomical unit is the distance from Earth to the Sun). The diameter of the cleared inner region is about 100 astronomical units, slightly larger than our own solar system.

HR 4796 is about 10 million years old and is difficult to see in the continental U.S., but is visible to telescopes in Hawai'i and the southern hemisphere.

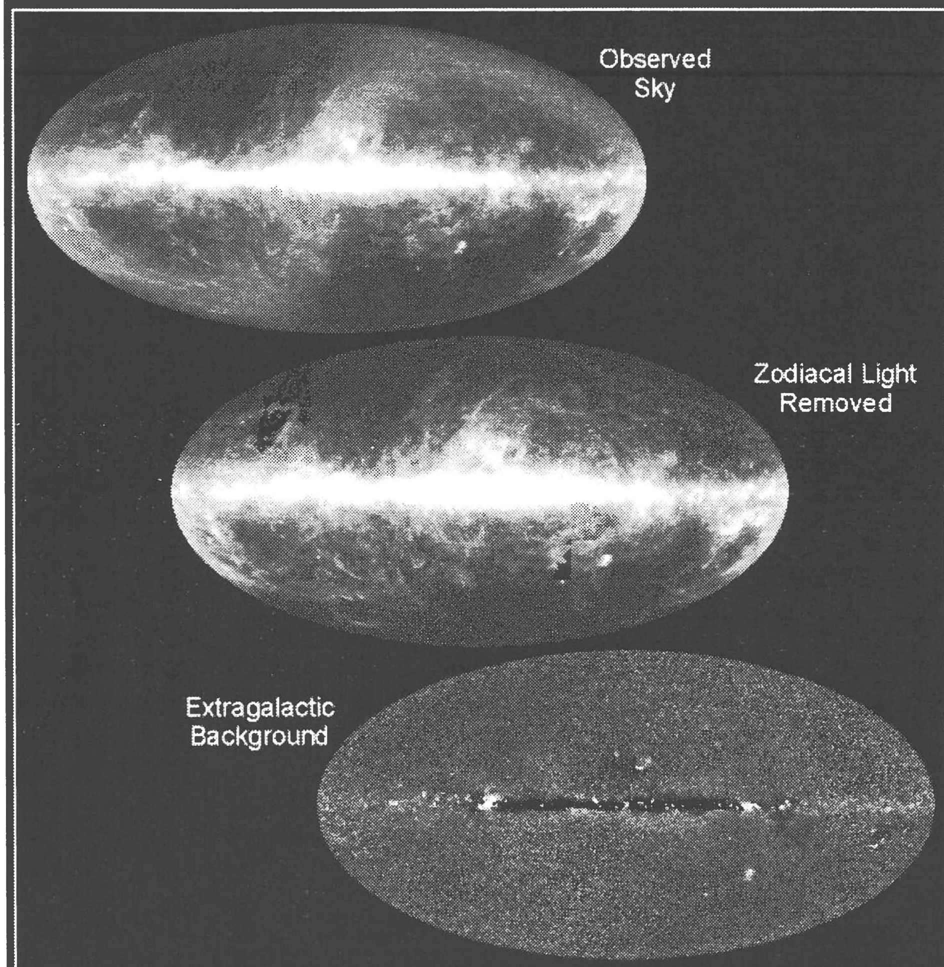
The discovery of the HR 4796 disk was made in one hour of observing time at Keck, but the JPL team plans to return to Hawai'i in June for further studies. They hope to learn more about the structure, composition, and size of this disk, and to determine how disks around stars in our galaxy produce planets. They plan to study several other stars as well, including Vega, which was featured prominently in the movie *Contact.*

ASTEROID 1997 XF_{11} — A NEAR MISS?

In March, asteroid 1997 XF_{11} came and went. A week after astronomers announced that the asteroid, discovered in December, would pass within 30,000 miles of the Earth in 2028, new calculations showed the passing distance to be a more comfortable 600,000 miles.

Continued on page 17

ASTRONOMERS DETECT INFRARED BACKGROUND FROM COBE DATA



Diffuse Infrared Background COBE • DIRBE
PRC98-01 • ST ScI OPO • January 9, 1998
M. Hauser (ST ScI) and NASA

Astronomers have succeeded in detecting an infrared background glow across the sky produced by dust warmed by all the stars that have existed since the beginning of time. For scientists, the discovery of this "fossil radiation" is akin to turning out all the lights in a room only to find the walls, floor and ceiling aglow with an eerie luminescence.

The telltale infrared radiation puts a limit on the total amount of energy released by all the stars in the universe, which should greatly improve models to explain how stars and galaxies were born and evolved after the Big Bang. It also reveals that a surprisingly large amount of starlight in the universe cannot be seen directly by today's optical telescopes, perhaps because stars are hidden by dust, or are too faint or far away to be seen.

The discovery is the result of several years of meticulous data analysis from the Diffuse Infrared Background Experiment onboard NASA's Cosmic Background Explorer (COBE), which was launched in 1989. The difficulty in making the discovery is analogous to listening for a faint background hum in a shopping mall full of people talking, music playing, and other noises.

"This is another big step in bringing cosmology to a science based on observation as well as theory," said Michael Hauser of the Space Telescope Science Institute, principal investigator on the Diffuse Infrared Background Experiment. "We set out to do this 23 years ago, and these results show it was worth it. Our discovery fulfills the third and final cosmology objective of the Cosmic Background Explorer mission."

LOST STARLIGHT

The unexpected preponderance of far infrared light implies that many stars have been missed in ultrasensitive visible light probes of distant reaches of the universe, such as the Hubble Deep Field survey. Some stars may be hidden in blankets of dust and others may have been born in a flurry of activity in the very early universe but faded away before large telescopes began to survey the sky. In either scenario, the existence of hidden stars is revealed by telltale dust that absorbs and re-radiates their light at infrared wavelengths, and so a permanent record of their existence is encoded in the infrared background.

UNCOVERING THE INFRARED BACKGROUND

Data from two other instruments on COBE have already famously given the precise spectrum and a detailed map of temperature variations in the microwave background radiation from the Big Bang. Finding the infrared background was also an impressive feat, because it is masked by infrared light from nearby dust in our solar system, stars and interstellar dust in the Milky Way galaxy, and, for groundbased instruments, emission from the Earth's atmosphere and from the instrument itself. COBE mission overcame the last two problems by observing from space using a small telescope and instruments cooled to within a few degrees of absolute zero.

The COBE science team began by using the Diffuse Infrared Background Experiment to scan half the entire sky once a week between December 1989 and September 1990. Astronomers then modeled and subtracted the infrared glow from foreground objects in our solar system, our galaxy's stars, and vast clouds of cold dust between the stars of the Milky Way. Solar system dust was relatively easy to identify because its brightness changes from week to week as Earth orbits the Sun. Interstellar dust in our galaxy was identified in the data because it has structure, and so looks different across the sky. Light from stars was removed using a detailed model based on counts of the many types of stars in the various parts of the galaxy.

When infrared light from these sources was subtracted from the all-sky maps, the astronomers found a smooth background of residual infrared light in the 240- and 140-micrometer wavelength bands in "windows" near the north and south poles of the Milky Way, which provided a relatively clear view across billions of light years.

Astronomers next plan to probe the early formation of stars and galaxies using infrared telescopes on new space missions such as the Space Telescope Infrared Facility, Wide Field Infrared Explorer, Next Generation Space Telescope, and the Far Infrared Space Telescope, and hope some day to make more infrared background measurements using instruments launched deep into the solar system to escape the interplanetary dust.

EDITOR'S NOTE: Images accompanying this release can be obtained at the following Web sites: http://oposite.stsci.edu/pubinfo/pr/1998/01.html, http://oposite.stsci.edu/pubinfo/gif/dirbe.gif, and http://oposite.stsci.edu/pubinfo/jpg/dirbe.jpg.

NEWS FROM SPACE

(Continued from page 15)

"We are saying now that the possibility of an impact is zero," Donald K. Yeomans, senior research scientist at NASA's Jet Propulsion Laboratory, told the Associated Press in March.

The flurry of media attention and doomsday speculations brought on by the original announcement prompted a panel of scientists, who were meeting during the LPSC conference to discuss near-Earth object discovery programs, to establish interim guidelines for releasing information to the public and press.

"The goal was to come up with guidelines for what will happen — what should happen — should another event like this happen in the future," said Yeomans. "The problem was that much of the analysis took place after the press releases and we would like to reverse that order."

During the meeting, scientists agreed to set up a committee, consisting of a half-dozen astronomers, that would work to verify and analyze information on potentially dangerous asteroids as quickly as possible.

"There would be a short period for more analysis, and a time to discuss the possibilities of what could be done should a real danger exist," Yeomans said.

Yeomans said such guidelines will help prevent gaps in credibility and will allow scientists to reach a concensus before releasing information to the public.

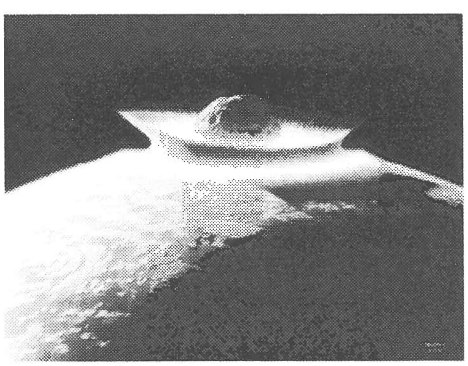
"This is the way science works — you make mistakes and you put a process in place to make sure it doesn't happen again," he said. "If we lose our credibility we've lost everything."

Yeomans also noted that the distraction of the media attention surrounding 1997 XF_{11} hindered the scientific process.

"I was astonished by the media attention. It's very difficult to do analysis in that kind of climate," he said.

In addition, Yeomans and other scientists would like to see more funding and effort dedicated to searching for asteroids and comets, including those that might be on a collision course with Earth.

"There are some modest efforts being funded by NASA — at JPL, in Tucson, and at Lowell — to discover these objects," Yeomans said. "At the moment we're not searching the entire sky on a monthly basis and we should be. Eventually, we'll find them all, but it may take a while."



Artist's conception of a catastrophic asteroid impact with the Earth.

Artwork by Don Davis

CALENDAR 1998

JUNE

13–18
Gordon Research Conference on Origins of Solar Systems, Henniker, New Hampshire. Contact: Alan Boss, DTM-CIW, 5241 Broad Branch Road, NW, Washington DC 20015-1305.
E-mail: boss@dtm.ciw.edu
http://www.grc.uri.edu/

25–26
The Universe in the Classroom — A Workshop on Teaching Astronomy in Grades 3–12, Albuquerque, New Mexico. Contact: Astronomical Society of the Pacific.
http://www.aspsky.org

27–July 2
International Conference on 90th Anniversary of the Tunguska Problem, Krasnoyarsk, Russia. Contact: Orgcommittee Tunguska-98, ul. Lenina 111, Krasnoyarsk 660017, Russia.
Phone: 7+3912-296-998; 7+3912-296-113; fax: 7+3912-296-995
E-mail: root@n-angara.krasnoyarsk.su; andrei@olkhov.msk.ru
http://www.tm.ru/tunguska

29–30
A Symposium on Teaching Astronomy to Non-Science Majors, Albuquerque, New Mexico. Contact: Astronomical Society of the Pacific.
http://www.aspsky.org

28–July 1
Catching The Perfect Wave — Adaptive Optics and Interferometry in the 21st Century, Albuquerque, New Mexico. Contact: Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco CA 94112.
Phone: 415-337-1100, ext. 109
http://www.aspsky.org/u98/u98.html

JULY

5–12
Protostars and Planets IV, University of California, Santa Barbara.
http://astro.caltech.edu/~ugm/ppiv

23–24
Paul Pellas Symposium, Paris, France. Contact: Claude Perron (Phone: 33-1-40-79-35-34; fax: 33-1-40-79-35-24), or Brigitte Zanda (Phone: 732-445-3232; fax: 732-445-3374), or write to Laboratoire de Minéralogie, Muséum national d'Histoire naturelle, 61 rue Buffon 75005, Paris, France.

JULY (CONTINUED)

27–31
61st Meteoritical Society Meeting, Trinity College, Dublin, Ireland. Contact: Publications and Program Services Department, Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058.
Phone: 281-486-2166; fax: 281-486-2160
http://www2.tcd.ie/Geology/metsoc98.html

AUGUST

10–14
Mars Exploration and the Search for Life (10th Planetary Science Summer School), California Institute of Technology. Contact: California Institute of Technology, Division of Geological and Planetary Sciences, 1200 E. California Boulevard, Mail Code 170-25, Pasadena CA 91125.
Phone: 626-395-6123
Fax: 626-568-0935

13–16
Founding Convention of the Mars Society, University of Colorado in Boulder. Contact: Maggie Zubrin, Mars Society, Box 273, Indian Hills CO 80454.
E-mail: mzubrin@aol.com
http://www.nw.net/mars

30–September 3
Eighth Annual V. M. Goldschmidt Conference of the Geochemical Society, Toulouse, France.
E-mail: goldconf@lucid.ups-tsle.fr
http://www.obs-mip.fr/omp/umr5563/goldconf98.html

SEPTEMBER

9–11
Remote Sensing (Annual Conference, Natural Resource Institute and University of Greenwich), Kent, UK. Contact: RSS98, School of Earth and Environmental Sciences, University of Greenwich, Medway Towns Campus, Chatham Maritime, Kent ME4 4AW, UK.
Phone: 44-0181-3319803; fax: 44-0181-3319805
E-mail: rss98@gre.ac.uk

18–20
New Views of the Moon: Integrated Remotely Sensed, Geophysical, and Sample Datasets, Lunar and Planetary Institute, Houston. Contact: Publications and Program Services Department, Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058.
E-mail: simmons@lpi.jsc.nasa.gov
Phone: 281-486-2158; fax: 281-486-2160
http://cass.jsc.nasa.gov/meetings/moon98/

CALENDAR 1998

OCTOBER

19–22

The First International Conference on Mars Polar Science and Exploration, Publications and Program Services Department, Lunar and Planetary Institute, Houston. Contact: Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058.
Phone: 281-486-2166; fax: 281-486-2160
http://cass.jsc.nasa.gov/meetings/polar98/

26–29

Annual Meeting of the Geological Society of America, Toronto. Contact: Geological Society of America.
Phone: 303-447-2020 or 800-472-1988; fax 303-447-0648
E-mail: meetings@geosociety.org
http://www.geosociety.org/meetings/98

NOVEMBER

2–4

Martian Meteorites: Where Do We Stand and Where Are We Going? Lunar and Planetary Institute, Houston, Texas. Contact: Publications and Program Services Department, Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058.
Phone: 281-486-2166; fax: 281-486-2160
http://cass.jsc.nasa.gov/meetings/marsmet98/

NOVEMBER (CONTINUED)

9–12

ESO Workshop on Minor Bodies in the Outer Solar System, Garching, Germany. Contact: Richard M. West
E-mail: rwest@eso.org
http://www.eso.org/mboss98

DECEMBER

1–3

Origin of the Earth and Moon, Monterey, California. Contact: Publications and Program Services Department, Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058-1113.
Phone: 281-486-2158; fax: 281-486-2160
E-mail: simmons@lpi.jsc.nasa.gov
http://cass.jsc.nasa.gov/meetings/origin98

JANUARY 1999

31–Feb. 4

Space Technology and Applications International Forum (STAIF-99), Albuquerque, New Mexico. Contact: Institute for Space and Nuclear Power Studies (ISNPS), University of New Mexico (UNM).
Phone: 505-277-0446
http://www.chne.unm.edu/isnps/isnps.htm

Calendar listings may be submitted via e-mail to anderson@lpi.jsc.nasa.gov

LPSC *(continued from page 9)*

The conference was dedicated to the memory of Gene Shoemaker, and Carolyn Shoemaker made a special appearance at the start of the Discovery session on Wednesday afternoon to respond to the dedication. She said she did not think Dr. Shoemaker "ever missed the LPSC" and lamented that he did not live to see the success of a manned mission to Mars.

"He wanted to see men go back into space," Shoemaker said. "It's not that he thought you couldn't learn a lot from unmanned space missions, but as a hands-on geologist, he thought it was important to send men to other worlds."

The media attention surrounding asteroid 1997 XF_{11} in March gave rise to an impromptu discussion during the conference, as a small panel of scientists worked to establish interim guidelines for releasing information to the public and the media on asteroids and other objects that might pass close to Earth.

The Stephen E. Dwornik Award Committee met after the conference and announced the winners for this year's student awards. Nancy Chabot of the University of Arizona captured the award for oral presentation for her paper "The effect of S on the solubility of K in metal," with honorable mentions going to C. van der Bogert of Brown University and A. Yen of the California Institute of Technology.

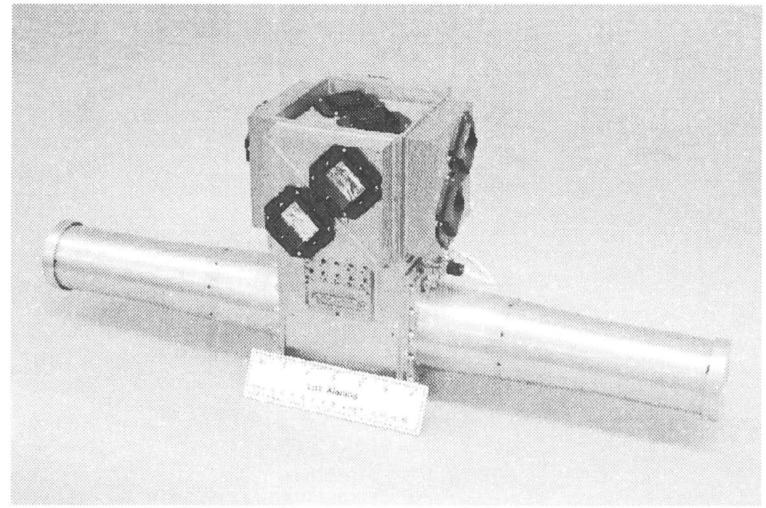
The Dwornik award for poster presentation went to Michelle Minitti of Brown University for her poster "Assessment of shock effects of hornblende water contents and isotopic compositions." Honorable mentions were given to N. Spaun of Brown University and L. Kirkland of the Lunar and Planetary Institute.

Call for Papers

Space Energy and Transportation, a scholarly journal published by High Frontier and SUNSAT Energy Council, is currently seeking articles from policy analysts, students, scientists, lawyers, anthropologists, and other professionals on the technical, economic, societal, or military aspects of space and space exploration.

Both original and previously presented papers are welcome. Articles should be at least 2500 words and may be either in hard copy or on disk, preferably in Microsoft Word format. For more information, or to submit an article, contact the editor, Douglas W. Frye, at Space Energy and Transportation, 2800 Shirlington Road, Suite 405, Arlington VA 22206.

INSIDE



LUNAR PROSPECTOR'S NEUTRON SPECTROMETER

See News From Space, page 14

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