The planned crash of Lunar Prospector onto the moon may, or may not, help solve "the puzzle" of detecting water there. The results and implications of clinical studies in Switzerland—in which people addicted to heroin were prescribed that drug as part of their treatment—are debated: one reader says those studies were "distinctly political"; another asks for "a full account of [the] findings in the scientific literature."

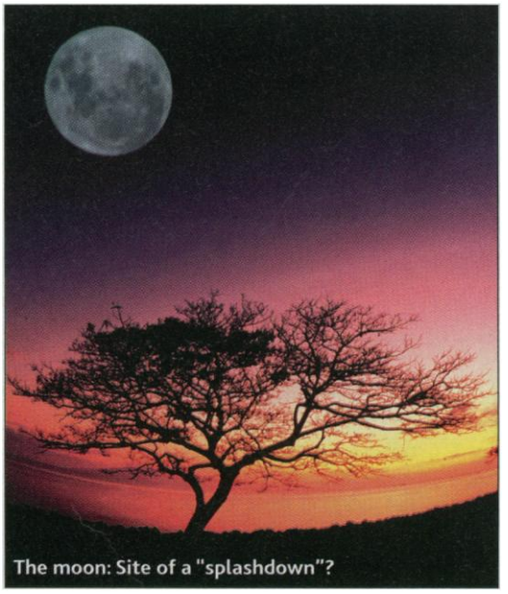
No Ice on the Moon?

Spacecraft measurements have been interpreted in *Science* as suggesting that there is water in the form of ice at polar cold spots on the moon. W. C. Feldman *et al.* (*1*) reported data from neutron spectroscopy (which can detect hydrogen) gathered by Lunar Prospector. Earlier, S. Nozette *et al.* (*2*) reported data from radar (which might detect ice) gathered by Clementine.

Lunar Prospector is now nearing the end of its useful life, so the National Aeronautics and Space Administration (NASA) plans to crash it into a permanently shadowed polar crater on the moon in an attempt to evolve gases for verification on 31 July 1999 (*3*). But the attempt may provide, at best, ambiguous results. That is, it might show the desired signs of water, even if there is no free water on the moon.

Some intensive radar studies, including a report by N. J. S. Stacy *et al.* (*4*) on data from the Arecibo radar system as well as a reanalysis (*5*) of data from the Clementine mission, did not find convincing evidence of ice on the moon. Recall that much-less-sensitive radar studies of Mercury (*6*) did provide compelling evidence for ice at the poles of this similar airless body of the inner solar system, and that this result was a major instigation to the searches for ice on the moon.

We believe that there could be a simple solution to the puzzle. There are two possible kinds of reservoirs for water products on the moon and Mercury. The possibility of ice reservoirs has been the main consideration heretofore, starting decades ago with the seminal papers that identified the special properties of permanently shaded cold traps at the poles (*7*). But thermodynamic data (*8*) suggest that ice in contact with anhydrous minerals like those in Apollo and Luna soil samples (*9*) will eventually react, forming hydrous minerals in which the constituents of water are chemically bound into the mineral crystals. (This anhydrous and hydrous material is somewhat like portland cement and dry concrete paste, respectively.) Reaction may be exceedingly slow, but with up to a few billion years available, hydrous-mineral reservoirs may have formed at the cold traps. If so, the hydrogen detected by Lunar Prospector (*1*) may be bound in the hydrous minerals, and no clear radar indication of ice is observed because the ice reservoir has been emptied. (Why do we detect ice on Mercury? It could be because a major comet has impacted the planet too recently to allow for the complete absorption of its water by anhydrous minerals.)



The moon: Site of a "splashdown"?

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We conclude that water as a lunar resource may not be available in the form of ice, but that it might be obtained from hydrous minerals in polar soil by strong heating. If hydrous minerals are present, then detecting hydrogen, water, or hydroxide ions (products that might be generated by the crash of Lunar Prospector) in soil pyrolysates would not be a definitive test for ice or any other form of free water on the moon.

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Response

The suggestions made by Eshleman and Parks are worthy of a more extended quantitative analysis. Since the publication of our initial determination of enhanced hydrogen abundances at both lunar poles, two new and relevant results have been obtained: (i) regions in permanent shade poleward of ±87.5° have been mapped using the Goldstone Solar-System Radar facility, as described in a report by J. L. Margot *et al.* (*1*), and (ii) analysis of Lunar Prospector neutron data measured at low altitudes (30 ± 15 kilometers) has revealed (*2*) no increase in the epithermal signature of hydrogen near the north pole, but an increase in both the epithermal and fast-flux signatures near the south pole.

The signature in the fast flux is now sufficiently large at the south pole to exceed its detection threshold of 1%. Comparison of neutron- and radar-determined topography maps shows that the strongest hydrogen signal comes from two permanently shaded craters with centers that are within 2.5° of the south pole. A quantitative analysis using the permanently shaded areas within these craters yields a hydrogen abundance, enhanced relative to that at equatorial latitudes, of 1700 ± 900 parts per million [which is equivalent to 1.5 ± 0.8% water by mass (*2*)]. Such a deposit of hydrogen would not be detected with the use of radar because the same-sense polarization signature needed to identify water ice in radar data requires a nearly pure deposit for its detection (*3*).

As correctly stated by Eshleman and Parks, the chemical form of these deposits cannot be uniquely inferred from neutron data alone. However, the total amount of hydrogen poleward of ±75° inferred from these data is at least an order of magnitude less than that predicted to have been delivered to the moon by comets, meteoroids, and interplanetary dust particles over the

past 2 billion years (*4*). Hydrogen loss rates from the lunar surface must therefore be comparable to its delivery rates. "Weathering" effects of the dominant loss rates (micrometoroid bombardment and solar wind sputtering) are thus likely to affect the chemical form of this enhanced hydrogen abundance. In particular, the amorphous coatings of soil grains (*5*) may figure importantly in the retentivity of hydrogen by the lunar surface. Laboratory simulations of space weathering effects at temperatures ranging between 60 and 120 Kelvin will be needed to guide a quantitative understanding of the problem.

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Prescribing Heroin

In their Policy Forum "The heroin prescribing debate: Integrating science and politics," Gabriele Bammer *et al.* (*Science's* Compass, 21 May, p. 1277) present incomplete information about the Swiss National Cohort Study (*1*). This study was actually a series of studies, conducted between 1994 and 1996 at 18 sites, in which 1146 long-term and treatment-refractory heroin addicts received injections of heroin several times daily at supervised clinics and at a prison. The cohort study (*1*) experienced 350 dropouts (a rate of 30%), which included 36 deaths from various causes (*2*).

Bammer *et al.* state that addicts showed remarkable gains, including "substantial improvements in health and well-being and very pronounced reductions in crime." A similar commentary published the same week (*3*) says Swiss heroin addicts experienced "substantial declines both in drug use outside the program and in criminal activity, as well as improved social reintegration." Both commentaries say that these results merit further investigation and call for more research, "through peer-reviewed publication" and "more advanced design features" (*3*). Yet both gloss over, as having "similar results," the one Swiss study (*4*) that met these criteria.

That study, conducted in Geneva (*4*), was the only one to randomly assign heroin addicts to heroin maintenance or to a 6-month waiting list (individuals serving as controls were encouraged, but not required, to enter traditional treatments, such as detoxification, oral methadone, or drug-free programs; length of stay in treatment was not reported). Some of the results from the Geneva study (*4*) were similar to those of the larger cohort studies (*1*), but some were not. Similarities: The heroin treatment group used illicit heroin less than the control group, engaged in illegal activity less, and enjoyed improved mental health and social functioning. Differences: The heroin treatment group in the Geneva study did not show improvements in work, housing, physical health, or avoiding abuse of other drugs.

Moreover, because conditions varied widely among control treatment programs, the Geneva researchers concluded that they could not say whether the improvements that were seen in their heroin-treatment group were caused by that treatment itself or by the intensive medical and psychosocial services that group also received.

Also, the Geneva researchers found that 62% of their controls declined to switch to heroin maintenance when it became available to them after 6 months. "Most were successfully treated in methadone maintenance programs" and wanted to stop injecting drugs (*4*). This is a surprising finding in light of the presumed ability of heroin maintenance programs to attract and retain addicts who would otherwise not enter treatment.

Bammer *et al.* in their Policy Forum do not mention these findings from the Geneva study, yet one of the authors, A. Uchtenhagen, had overall responsibility for the cohort and Geneva studies. A. Dobler-Mikola, co-edited the final report about the cohort study with Uchtenhagen and F. Gutzwiller (*1*). And while the cohort study has not yet presented its data and results in the peer-reviewed literature, the Geneva researchers have. Bammer *et al.* also do not discuss the external evaluation of the cohort study, which the World Health Organization (WHO) commissioned, yet Bammer was one of the evaluators (*5*). The WHO report noted that (*5*)

> [T]he Swiss studies were not able to examine whether improvements in health status or social functioning in the individuals treated were causally related to heroin prescription per se or a result of the impact of the overall treatment programme. Thus, from a rigorous methodological viewpoint, it was not possible to obtain internally valid results with respect to the research question of heroin prescription being causally responsible for improvements in health status or social functioning in the individuals treated.

The evaluators are critical of several other aspects of the cohort study, including unsubstantiated claims of cost-effectiveness, reliance on self-reports of illicit heroin use, questions as to whether self-reports of other drug use were corroborated with urine screens, inadequate data about death rates, no measures of patient satisfaction at any but two study sites, and addicts' continued drug use: "one-third of the study population continued daily illicit heroin use, 5% had daily cocaine use, and 9% had daily benzodiazepine use" (*5*).

Those responsible for the Swiss heroin studies owe us all a full account of their findings in the scientific literature. Those who comment on the studies have the same obligation. Selecting portions of the data that support particular points of view will not get us to what must be everyone's goal, finding the most effective ways to treat heroin addiction.

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References and Notes

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I read the Policy Forum by Bammer *et al.* with alarm. I have observed how clinics within this program operate at several locations in Switzerland. The program represents a stunning and unsupported reversal of 40 years of laboratory and clinical research. Bammer *et al.* and your readers should turn to the conclusions of responsible international bodies who have looked at the results of this program, which is at its heart distinctly political, rather than scientific. WHO's evaluation of this endeavor concluded (*1*, p. 11), "the