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Highlights

Meteorites

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Last year began with optimism at the launch of NASA's *Stardust* spacecraft to collect interplanetary dust and dust from comet Wild 2. A month later, as if to underscore that missions are not the only way to recover extraterrestrial material, the 14th martian meteorite was found in the Libyan Sahara, not far from the site of a similar find of a year before. These two fragments of a weathered, 2-kilogram basaltic rock have been dubbed Dar al Gani 489. It is likely that these fragments are pieces of the same Mars rock that disintegrated in the atmosphere or in the desert.

The deserts of North Africa and Australia, the prairies of North America, and the ice fields of Antarctica yielded their usual large crop of meteorites in 1999, including many from the small and rare groups.

At the same time, meteorite researchers still enjoyed returns from serendipitous falls. The first such fall was a shower of 54 pieces of an H6 chondrite that fell on June 13, 1998, near the small New Mexico town of Portales. The 105 kilograms of meteorites were found over the familiar elliptical strewn field, 8 kilometers long.

The class is fairly common, but what makes the Portales Valley meteorites unique is the their abundance of centimeter-sized veins of metal and the presence in these veins of a Widmanstätten structure — a well-known structure normally found in iron meteorites and indicating very slow cooling. Dave Kring and his colleagues at the University of Arizona published their description of Portales Valley in *Meteoritics and Planetary Science* (v. 31, p. 663-669). They conclude that the meteorite originated from the metal-veined floor of a 20-kilometer impact crater on its parent body.

A second serendipitous event occurred when an H chondrite fell on the small Texas town of Monahans (M.E. Zolensky et al., *Science*, v. 285, p. 1377-1379). Researchers were excited because H chondrites are normally bone dry, but this one contains halite and sylverite, minerals produced by the evaporation of brine. Furthermore, these minerals contain inclusions of trapped water. Unlike the abundant water found in carbonaceous meteorites, this water is unreacted primordial water, dating from the meteorite's origins. In principle it should be possible to obtain pressures and temperatures of water entrapment, and chemical and isotopic compositions for the fluid. The Monahans fall could offer a unique window into the parent body and its formation.

Oxygen isotopes

Many researchers think water played a part in determining the curious patterns of oxygen isotopes in meteorites. For three decades, these oxygen isotope fingerprints have been defined and refined and used to establish genetic links between the meteorite classes. However, there has been little understanding of what caused these patterns. In 1999, Ed Young and his colleagues in the United Kingdom showed that fluids flowing down temperature gradients could explain most of the oxygen isotope patterns observed in meteorites and their inclusions, assuming that they started with the ^{16}O fractionation trend for ordinary chondrites (*Science*, v. 286, p. 1331-1335).

Another United Kingdom group, led by Grenville Turner of Manchester University, showed that the ordinary chondrite trend exists across a chondrule that had clearly been a chemically open system during its formation. Chondrules are glass beads almost unique to chondrites (hence their name), formed by flash heating of dust. The new data could indicate that the ordinary trend in oxygen isotope abundances was produced during chondrule formation. Data from NASA's upcoming Genesis project, which should launch a spacecraft in 2001 that will orbit at the first Lagrangian point to capture solar particles, will help define the solar oxygen isotopic composition (R.C. Weins et al., *Meteoritics and Planetary Science*, v. 34, p. 99-107).

Oxygen isotope analysis also played an important part in defining another major new direction for meteorite research: the realization that presolar grains might be present in primitive meteorites. Normally these grains are found to be carbon-rich phases, but in recent years oxygen-bearing phases have been found. To date these have been Al_2O_3, but last year Larry R. Nittler and Conel Alexander, using an automated ion microprobe at the Carnegie Institution in Washington, found presolar TiO_2 grains in ordinary chondrites.

Perplexing chondrites

The enstatite chondrites form a relatively small group and have perplexed meteorite researchers because they are much more reduced than the other classes. Until recently, their study was hampered by a lack of unaltered meteorites, but the Antarctic meteorite collection has remedied that. Yubin Guan and colleagues found evidence for ^{26}Al in the refractory inclusions of enstatite chondrites, showing that this isotope was present in all the major chondrite classes as they formed. The importance of ^{26}Al, of course, is that it is a short-lived isotope of a relatively abundant element. It can thus help determine time scales and heat sources of the early solar system.

Eros, as seen by the *NEAR Shoemaker* camera during the spacecraft's orbit of the asteroid earlier this year. For a complete view of the asteroid, digital images returned by the spacecract are draped over a computer model of the asteriod's shape. NASA.

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The debate over where these meteorites originate continues, and last year some asteroid astronomers claimed they could associate every major asteroid type with a class of meteorites, albeit a rare class. By this reckoning, the H chondrites come from asteroid 6 Hebe. The spectral match is not exact, but requires the addition of considerable amounts of metal to the asteroid's surface. For this reason, the Portales Valley meteorite mentioned above is important.

Other asteroid astronomers argue that the space environment alters the surfaces of asteroids and that most of the S asteroids are ordinary chondrites in disguise. Fuel was added to this idea by papers presented at the International Conference on Asteroids, Comets and Meteors, held July 26-30 at Cornell University. Michael Hicks of NASA's Jet Propulsion Laboratory, and colleagues argued that the smaller asteroids most closely matched the spectra of ordinary chondrites. They believe that small asteroids were more recently produced by fragmentation and therefore have fresher surfaces. This idea does not explain why S asteroids have much lower densities than ordinary chondrites.

The question of the meteorite-asteroid connection will only be resolved by spacecraft missions to multiple asteroids along with studies of the samples returned.

At the end of last year, meteorite researchers applauded the successful completion of the *Deep Space 1* mission, with all it promises for future research of the planetary system. And we looked forward to the adventures of *NEAR* (now *NEAR Shoemaker*) which took orbit around the asteroid 433 Eros on Feb. 14, 2000.

Never before have meteorite researchers been so close to resolving many questions fundamental to their science. Never before has their presence been felt in mission design nor have they felt the impact of missions. We have left the era when meteorite research was a fringe activity for those fascinated with tales of rocks from the sky. It is now emerging as a central part of small-body planetary research.

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