PLANETARY SCIENCE

Where Do Meteorites Come From? A NEAR Miss May Tell

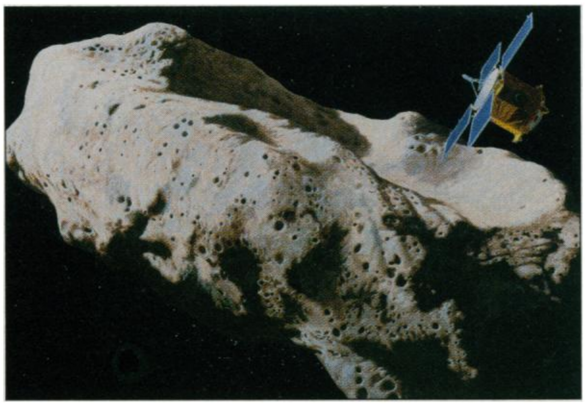
Meteorites have pelted Earth from space for billions of years, but the identity of their source has long stumped planetary scientists. To pin it down, scientists now intend to throw something back.

Later this month, the United States will launch the Near-Earth Asteroid Rendezvous (NEAR) spacecraft on a 3-year journey to Eros, a member of the S-class of asteroids; researchers have long debated whether the bulk of meteorites are chips off these asteroid blocks. The craft will orbit for a year as close as 30 kilometers from Eros—taking an unprecedented close look at the suspect—and use remote sensors, such as a multispectral imaging system, to probe the asteroid's composition. Scientists will compare these data with meteorite samples. "I just cannot conceive that with the added firepower of [an orbiting spacecraft] we won't answer these kinds of questions" about meteorite origins, says asteroid specialist Clark Chapman of the Planetary Science Institute in Tucson, Arizona, a NEAR science team member.

Not everybody shares Chapman's optimism, however. "I don't think the mission is going to discover anything fundamental about asteroids," says Jeffrey Bell of the University of Hawaii, an asteroid specialist. "It's certainly not going to resolve the great S-class asteroid controversy." Bell's skepticism comes from his belief that remote sensing can't provide rich enough data; direct, but more expensive, surface sampling missions are the way to go, he says. And he's not alone in his doubts, although overall enthusiasm for NEAR is high in the planetary science community, as the craft will pin down such physical properties of Eros as its density and its history of impact cratering. The mission is therefore shaping up as a major test of remote sensing: the mainstay of the National Aeronautics and Space Administration's (NASA's) smaller-is-better planetary missions, of which the $150 million NEAR will be the first to launch.

It was very remote sensing, from Earth-bound telescopes, that posed the meteorite puzzle in the first place. About 80% of meteorites are rocky lumps of primordial solar system material, known as ordinary chondrites. Astronomers studying the S-class asteroids 25 years ago found a rough match with chondrite spectra: signatures of the silicate minerals olivine and pyroxene and a subtle reddening that suggested nickel-iron metal. The more S-class asteroids that astronomers inspected, however, the less chondritic they looked. Most of these asteroids seemed to have the wrong mix of silicate minerals. Their composition suggests that the chondritic starting material had undergone early heating and melting, a process called differentiation. Chondrites, in comparison, have never been melted and differentiated.

There are now seven S subclasses, and all but one appear to have the wrong silicate mineral composition to create chondritic meteorites. Asteroids such as Eros, members of the subclass S(IV), come closest to the chondritic ideal. Some researchers, including Chapman, suspect these asteroids actually are the ideal, and some as yet unidentified process—micrometeorite impacts or radiation damage, perhaps—weathered their surfaces, making them appear less chondritic than they are.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Plain and primordial? By orbiting 40-kilometer-long Eros, the NEAR spacecraft may locate the meteorite source.

NEAR planners hope to find out by combining spectral studies with the most detailed geologic mapping of an asteroid ever. The spacecraft carries a multispectral imaging system and a near-infrared spectrograph to map details of mineral variations as small as 5 or 10 meters across. In comparison, the spacecraft Galileo could only pick out details 100 meters across on its fly-bys of the asteroids Gaspra and Ida 4 years ago. So the NEAR sensors could, in theory, find a chunk of unweathered chondritic rock sticking out from the soillike rubble that covers an asteroid or exposed at the bottom of an impact crater. If they do, S(IV)s could be a source of ordinary chondrites. But if the satellite spies strong spectral differences between various sides of the asteroid, that evidence would knock S(IV)s out of the running because a chondrite, having the same mix of minerals throughout, must look much the same on one side as it does on the other.

NEAR will also be carrying an x-ray/gamma-ray spectrometer to determine the abundance of eight or more of the crucial mineral-forming elements, including magnesium, silicon, and iron. Although space weathering may alter the spectral appearance of chondrites, it can't alter their elemental composition. Once the craft starts to orbit the asteroid, the instrument should pick up the distinctive x-ray and gamma-ray emissions of each element and reveal "within a month or so" whether Eros has what it takes to yield chondritic debris, says the spectrometer's builder, Jacob Trombka of NASA's Goddard Space Flight Center in Greenbelt, Maryland.

Bell is hardly so sanguine. "I think it will be a scientifically valuable mission," he says, "but it's not as straightforward as people think to work these things out from either the [spectral images] or the elemental abundances. It's just not true that there's some sharp distinction between differentiated meteorites and ordinary chondrites; there's a gradation." Unless NEAR observers get very lucky, he says, "the spectra [of Eros] will look like the spectra of many asteroids, the elemental abundances will look something like chondritic, and everybody will argue about them."

The surest way to settle such disputes, he continues, is to look directly at the rock: A moment's inspection will reveal whether or not it has been melted. "But you can't measure that from an orbiting spacecraft; you have to bring back a sample," he says. One group of planetary scientists recently proposed sending off a sample-return mission to the asteroid Nereus, but it lost out to a lunar orbital mission (*Science*, 10 March 1995, p. 1425).

"I share some of Jeff's concerns," says asteroid specialist Michael Gaffey of Rensselaer Polytechnic Institute in Troy, New York. He agrees that some luck may be required to show whether Eros is differentiated, and, if NEAR proves unlucky and finds a more or less uniform surface on Eros, the debate could drag on still.

Scientists planning remote-sensing missions to Mars and the other asteroids will be eager to see if NEAR can indeed come up with an answer. These missions, like NEAR, will rely on remote sensing to make fine compositional distinctions without the ground truth of returned samples. The NEAR results may fall "somewhere in the middle and we'll be scratching our heads," says Carlé Pieters of Brown University, but "we just won't know until we get there."

–**Richard A. Kerr**