Planetary science

When is a meteorite not a meteorite?

from I.P. Wright and C.T. Pillinger

IT now seems certain that long before the inception of the Apollo and Viking missions, samples of our nearest neighbours, the Moon and Mars, were already on Earth awaiting discovery. The martian origin for SNC meteorites (named after the 'type' specimens Shergotty, Nahkla and Chassigny and rather unfortunately referred to by the acronym pronounced 'snick' by many in the field) remains somewhat controversial, but for a 32 g meteorite from Antarctica (ALHA 81005), identified during preliminary examinations as an anorthositic breccia, the overwhelming consensus is that it has a lunar origin. Even more surprising than this conclusion, however, is the fact that so many scientists, many of whom met recently in Texas* to discuss the question, have managed to reach agreement on an aspect of extraterrestrial research in such a short space of time. (The meteorite classification number ALHA 81005 implies that it was collected in 1981; it was only made available for study at the end of 1982.)

The evidence that ALHA 81005 has a lunar origin is manifold. U. Marvin (Harvard University) revealed that members of the field collection party themselves recognized the meteorite as being unusual. At the conference D. Bogard and P. Johnson (NASA, Houston) reported that the trapped noble gases in the meteorite were 'obviously' implanted solar-wind species. The inference is that the matrix was resident at the lunar surface before breccia formation. High concentrations of radiogenic ^{40}Ar and old cosmic-ray exposure ages are taken as evidence that the sample is lunar rather than asteroidal in origin. Further isotopic constraints were provided by T. Mayeda and R. Clayton (University of Chicago) who demonstrated that the $\delta^{17}O$ and $\delta^{18}O$ data are quite consistent with a lunar origin. Unfortunately no radiometric dating techniques have yet been applied to the sample.

Many authors have made detailed petrographical observations which together with the major- and trace-element data for ALHA 81005 substantiate a lunar origin for the meteorite. The meteorite sample is broadly similar to Apollo 16 lunar breccias, being not particularly rich in titanium, potassium, rare earth elements or phosphorus (P. Warren, G. Taylor and K. Keil, University of New Mexico, Alburqurque; R. Verkouteren, J. Dennison and M. Lipschutz, Purdue University, West Lafayette). However on the basis of subtle differences in some chemical parameters the consensus was that ALHA 81005 originated from a previously unsampled part of the Moon, perhaps the far side.

From the dynamical point of view it is entirely possible for lunar ejecta to reach the Earth. H. Melosh (University of Arizona) demonstrated that unshocked or slightly shocked material can be ejected at velocities which exceed that necessary to escape from the Moon's gravitational field (2.4 km s^{-1}). This is consistent with observations that ALHA 81005 has not been shocked to any greater or lesser extent than some of the samples which were returned to the Earth by the manned Apollo missions. If it could be demonstrated that ALHA 81005 did not originate from the Moon, this would have profound implications, because it would mean there must be another parent body similar in many respects to the Moon. However this is not thought likely.

By contrast with meteorites from the Moon, the SNC meteorites offer the chance to study rocks from a parent body which has never been visited by man. Direct supporting evidence for a martian origin is available from two observations. First, B. Clark (Denver, Colorado) has demonstrated the similarity in chemical composition between martian fines (as measured by the Viking landers) and Shergotty. Second, D. Bogard and P. Johnson (NASA, Houston) have shown that the noble gases trapped in the glass and feldspar fraction of EETA 79001 (an Antarctic meteorite collected at Elephant Moraine and classified as a shergottite) have relative abundances of Ne, Ar, Kr and Xe similar to the martian atmosphere; also some of the noble gas isotope ratios are consistent with this source. However similar data for Chassigny obtained by U. Ott, F. Begemann and P. Lohr (Max-Planck-Institut, Mainz) show a noble gas distribution pattern which is distinctly different from that observed in the martian atmosphere, so in terms of SNC meteorites, perhaps EETA 79001 is the exception to the rule.

Following the lead of the noble gas investigations, results from two independent studies of light-element isotope ratios were presented at the conference. A. Fallick and colleagues (University of Cambridge) have measured $\delta^{13}C$, $\delta^{15}N$ and δ D in the three type meteorites and have found them to be indistinguishable from typical terrestrial values. These data imply that the processes in operation on the parent body were very similar to those taking place on Earth and therefore suggest a planetary origin for the SNC meteorites. In contrast, the other study by R. Becker, U. Frick and R. Pepin (University of Minnesota) uncovered small amounts of isotopically anomalous nitrogen from the feldspar and glass fraction of EETA 79001. Using the data from the Cambridge investigation, Becker *et al.* have been able to contrive a $\delta^{15}N$ value of about +600 per mill for the shocked fraction which is consistent with isotopic measurements of the martian atmosphere made by the Viking Landers. Thus SNC meteorites preserve a record in the light-element isotopic compositions of both the lithospheric and atmospheric conditions.

Several indirect lines of evidence that the SNC meteorites had an origin on Mars are of course well established. For example, they have young crystallization ages of about 1.3 Gyr, which requires igneous activity on a large planetary object (not an asteroid) and oxygen isotopic compositions which show that they were formed on a different parent body from the Earth, Moon or the eucrites. The original objection to a martian origin was the belief that it was dynamically impossible to eject rocks from the surface of Mars (which has an escape velocity of 5 km s^{-1}). Ironically it is the discovery of a lunar meteorite that in part undermines previous reservations as it demonstrates that planetary surface ejection events do not require special conditions such as the generation of vapour clouds from indigenous permafrost layers. Indeed A. Singer (SUNY) has shown that even the impact-generated gas cloud mechanism is not sufficient to explain the martian origin for Shergotty. However normal impacts into a dense volatile-rich surface (J. O'Keefe and T. Ahrens, Caltech) or impacts at an oblique angle (L. Nyquist, NASA, Houston) both seem to be capable of explaining the Mars origin for the SNC meteorites.

Recently the SNC meteorite group has gained one member, ALHA 77005, previously classified as a unique achondrite but now identified as a shergottite (J. Smith and I. Steele, University of Chicago) and lost another, Brachina, originally thought to be a chassignite but now considered to be a new type of meteorite (G. Crozaz and P. Pellas, St Louis/Paris; and a consortium of workers based in New York/Mainz). Brachina has been shown to have a different oxygen isotopic composition from all the other SNC meteorites and it also has an early crystallization age (4.5 Gyr) demonstrating that it formed early in the history of the Solar System. There were also fears from some investigators that Chassigny itself may not be an authentic SNC meteorite and so perhaps we should not get into the habit of using the 'snick' colloquialism when referring to this fascinating group of extraterrestrial objects. □

*The 14th Lunar and Planetary Science Conference took place on 14–18 March in Houston, Texas.

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