RARE AND UNIQUE METEORITES FROM ANTARCTICA

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Among the several thousand meteorite specimens recovered from Antarctic ice-fields, there is a certain number of meteorites, that deserve special attention. They either belong to meteorite classes with only few members or they are unique in the sense that they do not fit into any of the existing meteorite groups. The importance of some of these meteorites cannot be overestimated. For example, the detection of Antarctic meteorites of Lunar and perhaps Martian origin, belongs to the most important discoveries in planetology during the last years. The prospect of finding more of these meteorites should be incentive enough to continue the collection of Antarctic meteorites for the next decade.

Lunar Meteorites:

On January 18, 1982 an, by appearance, unusual meteorite was collected in Antarctica (1). The specimen weighed 31.4 grams and was designated ALHA 81005. By the time of the 14th Lunar and Planetary Conference in March 1983 it was unanimously agreed by the scientific community, that this meteorite represents ancient lunar highland crust (2).

In 1985, papers given at the 10th symposium on Antarctic meteorites in Tokyo described a lunar meteorite from the Yamato mountains (3). This meteorite (Y-791197, 52.4 grams) was only recently recognized as a lunar rock, although it was collected in 1979, 2 years before the Allan Hills Lunar meteorite. Still another lunar meteorite Y-82192 (36.7 grams) was identified in the Japanese collection (4). The two lunar meteorites investigated so far, ALHA 81005 and Y-791179, are very similar in texture, mineralogy and chemical composition. Both meteorites are anorthositic regolith-breccias with solar wind implanted rare gases (4, 5). The two lunar meteorites contain abundant lithic and mineral clasts, similar to those from Apollo highland breccias (6, 7). The absence of KREEP, a component rich in incompatible elements in front-side Apollo highland rocks, and the pattern of siderophile elements suggest that both meteorites sample the old lunar crust (older than 4 b.y.) some distance away from the large basins on the front side. They are perhaps samples from the far-side of the Moon. A closer inspection, however, reveals significant differences between ALHA 81005 and Y-791179. The Yamato lunar meteorite has a higher Fe/Mg ratio and a higher content of Sc, than the Allan Hills meteorite and most of the Apollo highland rocks (7, 8). Therefore the composition of the Y-791179 meteorite does not fit into the mixing diagram that has been successfully established for lunar highland samples from the Apollo missions (9). The ALHA 81005 meteorite does marginally lie within compositions of the mixing diagram (10). The major and trace element chemistry of the front-side samples was established by large basin forming impacts 3.9 to 4 b.y. ago. These samples probably contain material from deeper stratigraphic levels. Impacts on the far side did not penetrate the crust (because of its larger thickness). Therefore, meteorites such as Y-791179, which is likely to come from the far side may provide the opportunity to study the composition of the earliest lunar crust. Another important signature of the Y-791179 meteorite is its high content of volatile elements, which is in some cases comparable to the volatile rich rusty rock 66095 (11). Similar high Ga contents, as those found in some fragments of ALHA 791179 have never been observed in other highland samples (7, 11). Since Ga enrichment is accompanied by enrichments of other volatiles (11) there is no doubt that the high Ga is a result of a general enhancement in volatile elements. Redistribution of volatile elements may therefore be a moon-wide phenomena. There is, abundant evidence for these processe to have occurred on the front side 3.9-4.0 b.y. ago. The Yamato lunar meteorite clearly demonstrates the importance of of mobilisation of volatile elements on a more Moon-wide basis. Some preliminary age data suggest that volatilisation and recondensation may have occurred around 3.9 b.y. at the same time as on the front side (12).

With these questions in mind one may well anticipate that additional lunar meteorites will considerably enhance our knowledge of the formation of the lunar highland crust. Some 5 to 10 more lunar meteorites could solve some important questions of lunar geochemistry. We would then presumably know the average far-side composition. With this knowledge better models for the early differentiation of the Moon, including formation of an anorthositic crust, could be set up.

Meteorites from Mars?

An important consequence of the discovery of lunar meteorites (without noticeable shock features) is the increasing readiness of researchers to accept the proposition that the SNC-meteorites (Shergottites, Nakhlites, Chassignites) are impact ejected Mars rocks. Some of the most convincing evidence is obtained from nitrogen isotope determinations and rare gas abundance measurements on samples from the Antarctic meteorite EETA 79001 (13, 14). This meteorite and the Allan Hills A 77005 have increased the number of potential Mars meteorites by some 30 %. There is, of course, the hope to find more SNC-meteorites by future Antarctic expeditions or even identify SNC-meteorites in the present Antarctic meteorite collections. Any new SNC-meteorite may provide the crucial evidence for a Martian origin of the SNC-group. In contrast to the time before the detection of Antarctic meteorites we are now in the position to actively pursue these questions by further searching for those meteorites.

Meteorites from the parent body of basaltic achondrites:

A comparatively large number of eucrites, howardites, and diogenites were recovered from the Antarctic. These samples from the third differentiated planet, aside from the Earth, provide important evidence for accretion and differentiation of a small planet under reducing conditions. For unknown reasons eucritic samples from the Antarctic are dominated by polymict eucrites, sampling a variety of compositionally different basaltic clasts (15). We have in our laboratory, for example, analysed clasts from a polymict eucrite (Y-790266). One of these clasts contains abundant sulfides with high contents of Ni, Co, Ir and other siderophile elements (16). This kind of evidence may have some bearing on the evolution of a metal-sulfide core of the eucrite parent body. The Antarctic samples from the eucrite parent body will certainly help deciphering the still controversial story of the evolution of this small planet.

Chondritic meteorites:

The relatively large number of C2 and C3 meteorites from Antarctica may contain a wealth of information on early solar system processes. Detailed investigation of these meteorites is just beginning. We are still expecting the first C1 chondrite.

An unusual chondritic meteorite ALHA 77081 was recovered in 1977 (17). It has chondritic composition and achondritic texture. With its high content of volatile elements and its reduced mineral chemistry, this meteorite belongs to the same group as Acapulco, Winona, silicate inclusions in IAB etc. (18). Such a small meteorite (8.56 g) can only be spotted on a white ice-field. There may probably be more unusual meteorites among the not yet fully investigated small meteorites.

There are also rare unequilibrated enstatite chondrites among Antarctic meteorites (19). In one of the Antarctic enstatite chondrites solar type rare gases were detected, indicating for the first time the existence of regolith on an enstatite chondrite parent body (20).

In the 10th symposium of Antarctic meteorites a lodranite was described (21). Texture and chemistry of this meteorite (Y-79149) suggest that it is a cumulate rock. Although probably because of a parent body with a small gravity field, there was no separation of metal, sulfide, and silicate. Evidence such as this provides important information on the initial differentiation of small planets. It may in addition be possible to extract from these assemblages data on metal- silicate and sulfide-silicate partitioning of trace elements, such as Ni, Co etc. These data are essential in modelling the early differentiation of the Earth.

In summary, there is such a wealth of new information on differentiated and undifferentiated planetary bodies deduced from Antarctic meteorites that it is at present not possible to even qualitatively foresee the impact that these meteorites will have on our understanding of the formation and differentiation of large and small planets in our solar system.

In the past years considerable efforts have been devoted to search for presolar material. Inclusion of Antartic meteorites into these programs has not even started. There is no doubt, in my opinion, that it will not take very long, when new existing evidence will be provided by these meteorites. And if it is for no other reason than the large number of unequilibrated carbonaceous and ordinary chondrites among the Antarctic meteorite collections.

Lit.:
(1) U.B. Marvin (1983) Geophys. Res. Lett. 10, p. 775-778; (2) Results on ALHA 81005 were published by various research groups in 1983 in Geophys. Res. Lett. 10, p. 773-840; (3) Abstracts, 10th Symposium on Antarctic Meteorites, 25-27 March 1985, National Institute of Polar Research, Tokyo, 39-54; (4) K. Yanai and K. Hideyasu ibid. 39 (1-3); (5) N. Takaoka, ibid. 51 (1-3); (6) M. Lindstrom et al. ibid. 53 (1-3); (7) R. Ostertag et al. ibid. 42 (1-2); (8) T. Fukuoka et al. ibid. 41 (1-2); (9) H. Wänke et al. (1976) Proc. Lunar Sci. Conf. 7th, p. 3479-3499; (10) H. Palme et al. (1983) Geophys. Res. Lett. 10, p. 817-820; (11) P.W. Kaczaral et al. (1985) Abstract, 10th Symposium on Antarctic Meteorites, 25-27 March 1985, National Institute for Polar Research Tokyo, 44 (1-2); (12) Nakamura et al. ibid. 45 (1-3); (13) R.H. Becker and R.O. Pepin (1984) EPSL 69, p. 225-242; (14) D.D. Bogard and P. Johnson (1983) Science 221, p. 651-654; (15) J.S.Delaney et al. (1984) Proc. Lunar and Planet. Sci. 15th, 89, C251-C288; (16) unpublished data, this laboratory; (16) L. Schultz et al. (1982) EPSL 61, p. 23-31; (18) H. Palme et al. (1981) GCA 45, p. 727-752; (19) H. Nagahara (1985) Abstract, 10th Symposium on Antarctic Meteorites, 25-27 March 1985, National Institute of Polar Research, Tokyo, 7 (1-3); (20) P. Signer et al. (1983) Meteoritics 18, p. 399; (21) H. Nagahara (1985) Abstract, 10th Symposium on Antarctica Meteorites, 25-27 March 1985, National Institute of Polar Research, Tokyo, 83 (1-4).