COSMIC DUST IN THE ANTARCTIC

By D. W. PARKIN*

IN the tropics, when the Sun is just below the horizon, on clear nights, it is often possible to see a faint cone of light extending along the plane of the ecliptic. This zodiacal light (the "dawn's left hand" as Omar Khayyám put it) is due to the reflection of sunlight from myriads of small dust particles orbiting about the Sun strictly in the same plane and perhaps in the same direction as the planets themselves. Again, on any clear night anywhere in the world we always see the odd brilliant shooting star streaking its way across the sky some 100 km. up. With binoculars and several observers scanning the whole sky, very many fainter meteors are observed; on average some 10 sporadics per hour can be seen. At certain times of the year, for two or three consecutive nights, this rate goes up some three- or four-fold; and when this happens all the streaks are seen to radiate from a particular point in the sky—the radiant of the meteor shower. This latter point is merely a perspective effect (like railway lines apparently coming from a single distant point) and clearly indicates that the Earth is moving, for a few days, through a band of dust particles in orbit about the Sun. These orbits are not necessarily in the ecliptic plane; and because they are similar, in many cases, to the orbits of comets, astronomers believe that the meteor shower particles are indeed derived from comets. Comets are most strange bodies and there exists as yet no agreed opinion as to their physical and chemical make-up. Nevertheless, on approaching to within about two Earth distances from the Sun they begin to break up and give off a good deal of fine dust, which together with a lot of gas swells out to enormous diameters in forming the head and later the tail.

We see then that the spaces of the solar system are by no means empty of fine particulate matter but, because of its organization, we may have to deal with several different modes of origin and each mode may have special features which are impressed on the dust's chemical and physical character. By catching the dust as it drifts down to earth and counting the numbers caught each day, by measuring the size and noting the shape, and by chemical analysis, these different modes of origin will become clear eventually. When this day dawns a great deal of information on the chemistry of outer space will have been secured, and perhaps this will go a long way to elucidating that greatest of all puzzles—the solar system.

With these grand goals in mind, several laboratory groups in recent years have started on systematic dust collections. Professor Hans Pettersson in Sweden first renewed the interest by counting the number of tiny black magnetic spherules that can be found in the deep-sea muds. These so-called cosmic spherules are really quite fascinating; usually they are below 100μ in diameter and when broken they show an inner core of bright metal very rich in nickel. There is no doubt about their extra-terrestrial nature but just how they are formed is still very much an open question. Perhaps they are formed from fragments of nickel–iron alloy, which, on striking the upper air at just the correct angle for their speed and mass, merely become molten momentarily without losing much material by evaporation. Another possibility is that they are droplets swept off the surface of the much larger meteorite as it plunges all the way down through the atmosphere. However, the latter possibility is unlikely for two reasons:

i. Meteorite falls are infrequent and there are rather too many of these metallic centred spherules to be accounted for.

ii. The fusion crust of a meteorite is mainly oxide about 1 mm. thick.

Certainly, following the work of Krinov in Russia, meteorites must shed a considerable amount of their material in the form of spherules but these seem to be only oxide and many of them are simply hollow magnetite spherules, or bubbles of boiling oxide.

Many workers have tried to catch these spherules in the air and in the early days a great deal of confusion was caused by similar black magnetic spherules issuing in profusion from

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nearby factory chimneys! Indeed, this question of contamination is an ever-present problem to the would-be worker in the field of micro-meteorites. However, by sampling in very remote parts of the world and taking extreme care over cleanliness, the hazards of contamination can be pushed into the background.

At our laboratory, over the last three or four years, we have tried to reduce the possibility of contamination even further by not only going to remote parts, but concentrating attention on the metallic fraction of the dust. After all, there is not all that much metallic iron and nickel flying about, particularly on a remote oceanic island; furthermore, one's confidence grows when the analysis shows that the number of iron flakes (about 100μ in size) together with a smaller number of nickel flakes, varies with date, and this variation can be reproduced as an annual event. Mainly around June and early July the air in northern latitudes (we collect airborne dust on the Isles of Scilly) contains many of these metallic flakes. On a greasy nylon mesh of area 0·75 m.^{2} about a dozen can be collected over a two-day period, during which time about 300 miles (480 km.) of wind blows through the mesh. In August the numbers fall to practically zero. A few spherules ranging up to about 70μ in diameter accompany the flakes, but these are always of the hollow magnetite variety. In fact, in the whole of our airborne collecting experience, only one metallic spherule out of hundreds of the hollow kind has been found.

In 1962 we were able to carry out two collections simultaneously at the Isles of Scilly and Barbados and, although the same iron and nickel flakes were found at both sites, their concentration with date was slightly different. The mid-summer enhancement, always found at the Isles of Scilly, was not so strongly represented at Barbados, where the flakes were much more uniformly scattered with respect to date. Because of this, we must be very cautious in ascribing the origin of the flakes to meteor showers. Certainly, there are intense daylight (radar detected) showers in June and July; the ζ-Perseids, Arietids and β-Taurids are the most dominant showers in the whole year. As a result of gathering rocket and satellite data, there seems to exist a shell of dust orbiting around the Earth a few hundred miles up. No doubt this shell is replenished from the zodiacal dust, and drag, due to the upper atmosphere, causes the flakes to spiral in on very grazing orbits. If this is so, then expansions in the upper

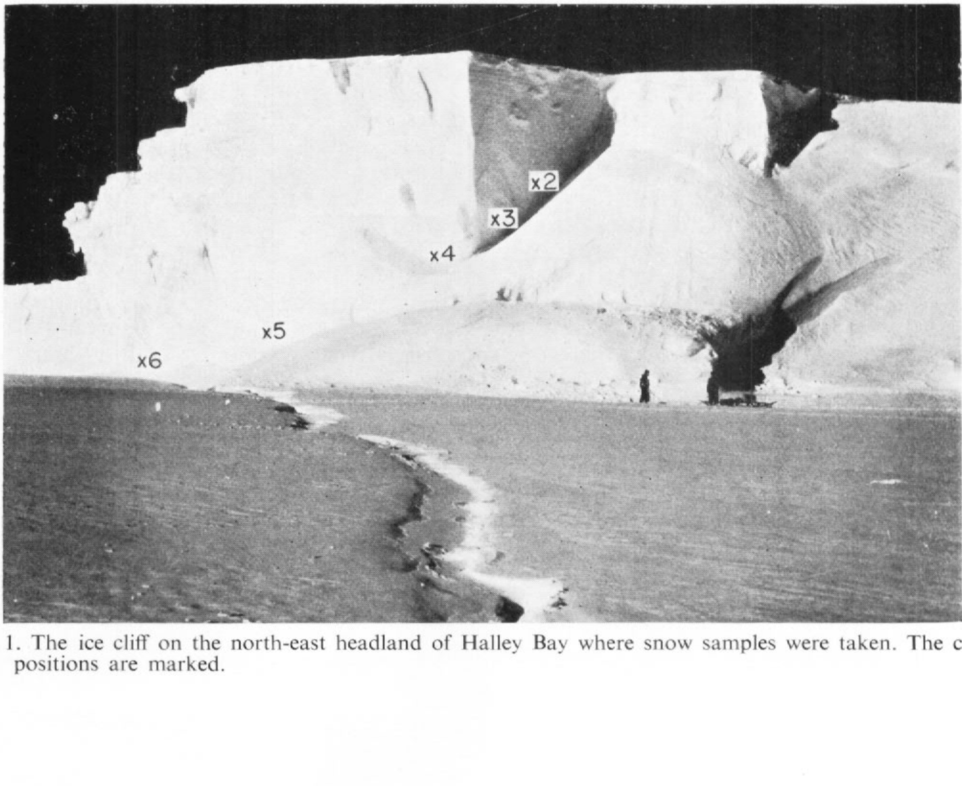

Fig. 1. The ice cliff on the north-east headland of Halley Bay where snow samples were taken. The cavity positions are marked.

air would have to occur in order to account for the mid-summer enhancement at the Isles of Scilly.

During our airborne work we have on occasions found metal flakes with strange translucent attachments. These are either red, white or green in colour. The red material is a mystery and partial analysis indicates that it is merely rust, but the fact of its blood-red colour and its frequent association with pure nickel argues against this. The white and green material is without doubt carbonaceous because it chars on gentle heating. Carbonaceous extra-terrestrial material would not be surprising in view of the abundance of carbon and hydrogen in outer space and also the known existence of CH_4, CO_2, H_2O and NH_3-type molecules in the band spectra of comets.

Material other than metal is likely to be as plentiful if not more so than the metal itself, but our airborne work, as yet, has not allowed this other side to be investigated. With respect to this, collections made from the ice in the Antarctic are likely to be extremely valuable in locating new types of extra-terrestrial material, and once this has been achieved the search for similar fragments in the airborne collections will give added information concerning the chemical species that make up possible meteor showers. Indeed, if we could be sure that the dust is coming from meteor showers and not from a homogeneous dust shell, then the future terms of reference for our programme would be "to determine the amounts and hence the ratio of all the various chemical species arriving at a particular meteor shower period and to see if the various meteor showers were in any way different from one another".

To this end D. Wild, who is joining the team at Halley Bay in 1964, will attempt (in the few days while M/V *Kista Dan* is alongside the ice cliff) the collection of perhaps 0·1 g. of dust on a fine sieve. The method is to shovel snow into one end of a sloping "Pyrex" tube heated with "Primus" stoves; the melt water running out from a spout at the lower end passes

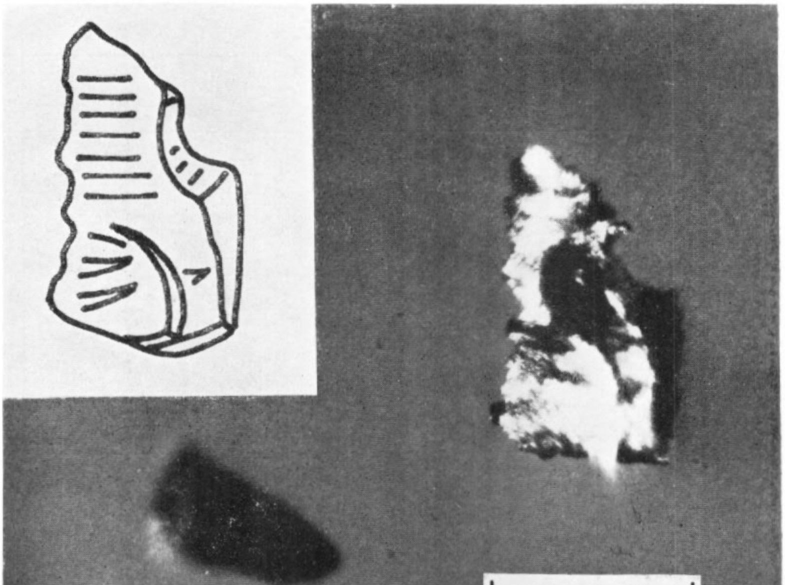

Fig. 2. A NiFe fragment from cavity 4. The sketch shows the striations on the surface of the fragment.

TABLE I

Cavity	*Age* (yr.)	*Snow Accumulation Rate* (m./yr.)	*Volume of Snow* (cm.^{3})	*Iron Flake Sizes* (μ)	*Concentration of Iron in Snow* (μg./m.^{3})	*Accretion Rate* (μg./m.^{2}/day)
1	Surface (1959)	0·82	9,300	50×10×10 80×30×10 70×40×30 90×25×20 90×10×10	143	0·39
2	14 (1945)	0·45	4,500	80×20×20 60×50×10 40×20×3 90×10×10 40×15×10 100×50×10 60×35×20 90×20×15	391	0·48
3	24 (1935)	0·47	17,800	100×25×8 80×20×8 80×30×5 30×30×20	36	0·047
4	29 (1930)	0·42	540	170×90×30	681	0·78
5	38 (1921)	0·40	7,750	80×40×5 60×30×3 50×20×5 50×40×20 80×20×5	89	0·098
6	46 (1913)	0·38	5,810	120×25×20	83	0·087

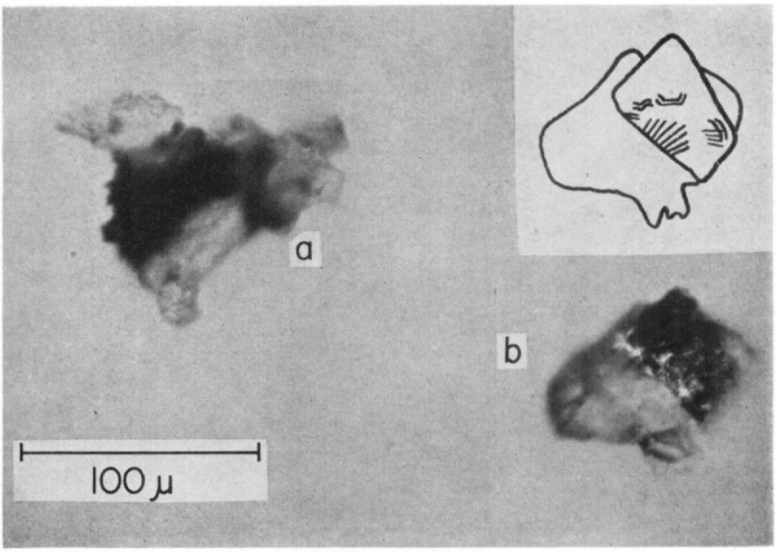

Fig. 3. Carbonaceous composites. The sketch shows striations on the nickel flake.

through a 53μ copper wire mesh. If all goes well perhaps one ton of snow will be melted before the ship has to leave.

Previous Antarctic collections have led us to hope for considerable success in the method outlined above. Indeed, through the kindness of D. A. Ardus, we have been supplied in recent years with samples of melt water taken from various levels in the ice cliff at Halley Bay, and Fig. 1 shows the position of the cavities. In these early days we were mainly interested in finding the metallic fragments, and in Table I the results of the collection are given. From measurements on the cliff, such as the annual rate of accumulation of snow (or the distance apart of the ice bands), the all-important accretion rate can be estimated. Clearly, an average value has to be taken as the fluctuations with age are probably only statistical variations. This average is in remarkably good agreement with our airborne work at Barbados and the Isles of Scilly. The especially large flake found in cavity 4 is shown in Fig. 2. This has been analysed by an electron probe technique. With a composition of 1 per cent Co and 6–8 per cent NiFe alloy, it is without doubt an extra-terrestrial particle; this would be a typical composition for an iron meteorite.

The search for non-magnetic material in the snow was frustrated by a biological growth in the melt water; however, we did manage to find some very important evidence, which is shown in Fig. 3. These are carbonaceous particles with the green material firmly attached to flakes of metal which are practically pure nickel.

Using another later collection, also made by D. A. Ardus, we have been able to make further progress. As far as can be made out at the moment, most of the non-magnetic fragments are carbonaceous. There are great quantities of this material, easily ten or a hundred times more plentiful than the iron. Some of the waxy-type particles, which are nearly 600μ in size, are vividly coloured green and red and appear to be a mass of tiny balls. Shapeless, vivid green jelly-like masses are also present. There are some hundreds of 30μ diameter colourless ovoids that are crystalline organic material, and also some dozens of opaque black slabs, ranging down from 400μ, that appear to be like "coal" or other pitch-type substance. And this is not all; around the sides of the polythene storage bottles, at the level of the melt water, there is a tide-mark of myriads of tiny sticky globules. When these are accumulated a blackish tar-like mass about the size of a small pea results. Our biological colleagues have examined these particles but they cannot recognize them as anything to do with the living world. However, it would be too venturesome on our part to ascribe them, as yet, to an extra-terrestrial origin. It is really quite striking to view the magnetic fraction—nearly all of it is either glittering metal or black spherules (of the hollow kind). Most of this fraction must be extra-terrestrial, so why not most of the non-magnetic fraction also? Clearly, a thorough-going chemical analysis is needed on material collected under much better conditions. The sieve method ought to give us the necessary quantity and since all the apparatus is either glass or copper there can be no chance of introducing organic substances as contaminants.

In view of the recent finds of thin polymer sheets and other more "organized elements" in the very rare carbonaceous meteorites, it is urgent to follow up this work on the carbonaceous dust. There is no doubt that the Antarctic is going to be a very important hunting ground for this material. Currently there is much talk of the "building bricks" of living processes having been formed in outer space. It would be fascinating to think that this organic dust could give helpful clues towards this end.

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