PAIRING OF METEORITES FOUND IN VICTORIA LAND, ANTARCTICA

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Abstract: A review of published suggestions for pairing Victoria Land meteorites suggests that the difficulty of correctly identifying specimens from the same fall has been greatly underestimated. In 24 cases where types 4–6 ordinary chondrites have been paired by petrologists and subsequently analyzed for noble gases or cosmogenic nuclides, the later studies argue against pairing in half of the cases. For other meteorites, similar studies confirm pairing in all 19 cases, but disagreements between petrologists suggest that several polymict eucrites, mesosiderites and CM2 chondrites may have been mispaired. The distribution of discovery sites and sample sizes of 33 paired L3 chondrites resembles that of a strewn field from a large meteorite shower, but strong winds produced this distribution, separating specimens according to size by distances of up to 6 km. Aeolian transport may also have spread 29 paired Yamato diogenites over a 20×7 km area. My estimate of the number of meteorites represented by the 299 numbered specimens found at Allan Hills in 1977–78 is between 50 and 150. A list of 303 Victoria Land specimens that have been paired is included together with rough estimates of the confidence levels of pairing.

1. Introduction

"Paired" meteorites are specimens that are probably or possibly part of the same meteorite fall (HEY, 1966). Accurate pairing of Antarctic meteorites is useful because it minimizes unnecessary duplication of research and destruction of meteorite samples. It also conserves curatorial resources and will assist statistical studies of the distribution of Antarctic meteorite falls. In addition, the identification of paired specimens from a large meteorite shower could help in understanding the mechanisms responsible for transporting meteorites in Antarctica.

Meteorites may be fragmented during atmospheric entry, on impact with the earth's surface, and subsequently by processes such as weathering. In Antarctica, frost-fracture and ice movement may be important processes that cause fragmentation. The aims of this paper are to review the pairing of Antarctic meteorite samples and to estimate the number of different meteorites that are represented in Antarctic meteorite collections.

2. Criteria for Pairing Specimens

The following properties and factors should be considered when evaluating the possibility that two specimens are paired (the first four are more useful than the others): 1) Bulk elemental and isotopic concentrations; 2) mineral abundances and compositions; 3) primary textural characteristics and secondary changes due to shock, metamorphism and cosmic alteration; 4) rarity of meteorite type; 5) proximity of discovery locations and the local density of recovered specimens; 6) shape and size of specimens, and effects of ablation and terrestrial weathering; and 7) number of specimens, if any, with which the specimens have already been paired, and their discovery locations.

The utility of a given meteorite property in assessing the possibility of pairing depends on the range found in a single fall of that meteorite type relative to the range found among many meteorites of the same type. The larger the difference between these ranges, the more useful the parameter is. Chemical and isotopic data are useful measures for this purpose, but without estimates for concentration ranges in an individual fall and comparable data for many other meteorites of the same type, they are of little value. For example, bulk chemical data for major and minor elements in chondrites are commonly of minor importance in pairing because the variations to be expected in an individual fall are poorly documented. Cosmogenic isotope data used to derive cosmic-ray exposure and terrestrial ages are of greater value, because variations in large masses have been studied. However, concentrations of several different cosmogenic products are required to unravel effects due to differing shielding depths and to multi-stage irradiation histories (GOSWAMI and NISHIIZUMI, 1983).

There have been many studies of pairings among non-Antarctic iron meteorites using chemical and textural criteria (BUCHWALD, 1975; MALVIN *et al.*, 1984, and papers listed therein). Irons can be paired with some confidence because chemical variations within groups are commonly much larger than those found in individual meteorites, and chemical variations in large falls have been studied (WASSON, 1968; ESBENSEN *et al.*, 1982). Comparable work for chondrites and achondrites is lacking.

In this paper, I review published studies of possible pairings among meteorites recovered from Victoria Land using the criteria discussed above, and assess the confidence with which these specimens can be paired. This study is based very largely on the lists of paired meteorites published in the Antarctic Meteorite Newsletter (**4** (2), 9–10, 1981; 7 (1), 27–29, 1984). These lists, which do not include references, have been compiled by R.A. SCORE, B. MASON and C.M. SCHWARZ largely from their own studies of the mineralogy, texture and exterior surfaces of specimens. To date, maps showing the discovery locations of numbered samples are available only for specimens recovered from the Allan Hills area during the three seasons 1976–79 (YANAI, 1982), and for 18 specimens found near Reckling Peak and Elephant Moraine during the 1979–80 season (CASSIDY and RANCITELLI, 1982).

3. Achondrites

3.1. Polymict eucrites: ALHA76005, 77302, 78040, 78132, 78158, 78165, 79017, 80102, 81006–81010, 81012

MIYAMOTO *et al.* (1979) suggest that ALHA76005 and 77302 are part of the same fall because of their virtually identical pyroxene compositions and textures, while TAKEDA *et al.* (1980) and SCORE *et al.* (1981) argue that 78132 and 78158 are probably paired. According to REID and SCHWARZ (1980) all of the first six specimens listed above might be pieces of a single fall, as they are petrographically similar; they were found within a 3×4 km area (YANAI, 1982). ALHA79017 was added to the list by SCORE *et al.* (1982b) following their petrographic studies. DELANEY *et al.* (1983) have also studied the 76- to 79- specimens (except 78132) and agree that they are paired.

Specimens 80102, 81006, 81007, 81008 and 81010 resemble the other Allan Hills polymict eucrites petrographically, and are probably (or possibly for 81008) paired with them (SCORE *et al.*, 1982a; SCORE, 1983a; MASON, 1983a). MASON (1983a) argues that 81009 and 81012 should be tentatively paired with each other; he finds that both differ from the other polymict eucrites in their pyroxene compositions. However, DELANEY *et al.* (1984) favor a different pairing scheme: they find that 81009, 81010 and 81012 are mineralogically similar to the 76–79 specimens. In addition, they discovered rock fragments in 81006–81008 that are not present in other polymict eucrites, and they conclude that these three specimens may be samples of a different meteorite.

Other studies confirm the pairing of the 76- to 78- specimens. NISHIIZUMI *et al.* (1983) find that 76005, 77302 and 78040 have similar ^{53}Mn concentrations, and WEBER *et al.* (1983) note that concentrations of cosmogenic noble gases in 76005, 78132 and 79017 differ by less than 10%. Thus the evidence for pairing these relatively rare polymict eucrites would seem to be very good. However, more studies are clearly needed on the 80- and 81- specimens to establish which are paired.

3.2. *Eucrites/polymict eucrites/howardites: EETA79004, 79005, 79006, 79011, 82600*

There is no agreement on the classification or pairing of these five brecciated basaltic achondrites from Elephant Moraine, the first four of which were found within 600 m of each other (CASSIDY and RANCITELLI, 1982). SCORE *et al.* (1982a) find that their petrographic data and the geographic propinquity strongly suggest that 79005 and 79011 are pieces of a single fall. However, DELANEY *et al.* (1983) propose different pairings on the basis of their petrographic studies: 79004 and 79011; 79005 and 79006. Subsequently, MASON (1983b) has suggested that 79006 is possibly paired with 82600.

WEBER *et al.* (1983) analyzed 79004, 79005 and 79006 for He, Ne and Ar isotopes; they argue from the spallogenic isotope data that the specimens come from three independent falls. However, it is possible that the small differences that they measured could reflect chemical heterogeneities in a breccia. SCHULTZ and FREUNDEL (1984) measured Ar, Kr and Xe isotopes in 79005, 79006 and 82600 and deduce that they have similar cosmic-ray exposure and terrestrial ages of 25 and 0.20 Ma, respectively. Contrary to WEBER *et al.* (1983), they conclude that these three specimens *are* paired. In view of the numerous disagreements among petrographers and noble-gas analysts, I conclude that these five achondrites cannot be paired with maximum confidence, despite the unusually high concentration of achondrites found at the Elephant Moraine site.

3.3. *Ureilites: ALHA78019, 78262*

SCORE *et al.* (1981, 1982b) conclude that the olivine and pyroxene compositions, textures and external morphology of these two ureilites are identical in all respects and the two stones are part of the same fall. However, BERKLEY and JONES (1982) discovered small mineralogical differences and conclude that the stones come from different falls. Although both specimens are less shocked than other ureilites, BERKLEY and JONES found diamond in 78262 but not in 78019. In addition, they argue that olivine in 78019 is less magnesian (Fa 23.3, *cf.* 22.0 in 78262) and pigeonite contains less Al_2O_3 (0.48 wt %, *cf.* 0.80% in 78262). Further work by BERKLEY (private communication, 1984) shows that sections of the two stones can be distinguished on the basis of mineral compositions. However, the two stones also share some unusual features.

In view of the mineralogical heterogeneity of individual ureilites (BERKLEY *et al.*, 1980) and the known heterogeneity of shock effects, the balance of evidence seems to favor tentative pairing, but more data are needed. Interestingly, the fourth and fifth known ureilites, North Haig and Dingo Pup Donga, were found only 30 km apart in Western Australia (MASON, 1974). ALHA78019 and 78262 were found 5.5 km apart (YANAI, 1982), and are not paired with either of the other two ureilites found at Allan Hills, 77257 and 81101 (TAKEDA *et al.*, 1980; MASON, 1983b).

4. Stony Irons

4.1. Mesosiderites: ALHA77219, 81059, 81098

MASON (1983a, b) analyzed the silicates in these specimens and concludes that 81059 may be paired with 81098, but that 77219 appears to be different. However, HEWINS (1984) finds mineralogical evidence that all three specimens are probably paired.

4.2. Mesosiderites: RKPA79015, 80229, 80246, 80263; RKPA 80258

CLARKE and MASON (1982) surveyed the mineralogy of metallic Fe,Ni and silicates in these specimens and conclude that all five are paired. 79015 is a large metal-rich sample (10 kg) whereas the others are silicate-rich and weigh 4–17 g. All are heavily weathered and contain relatively homogeneous orthopyroxene, Fs 17–24. However, HEWINS (1984) finds that pyroxene in 80258 is more magnesian than in other Antarctic mesosiderites; this specimen also contains a silicate matrix which he did not observe in the other four specimens. As a result, he concludes that the evidence for pairing 80258 is weaker.

5. Irons

5.1. Group IA: ALHA76002, 77250, 77263, 77289, 77290; ALHA77283

The first five specimens weighing 1.5 to 10 kg were found in a 1.5×4 km area (YANAI, 1982). Because of their similar external appearance, metallography and concentrations of Ni, Ga, Ge and Ir, CLARKE *et al.* (1980) conclude that they are paired. CASSIDY (1980) includes 77283 with these paired specimens as it is another large IA iron which was found within the 1.5×4 km area, but CLARKE *et al.* show that it has a very different composition. MALVIN *et al.* (1984) analyzed all six irons for 9–12 elements and confirm these conclusions. Evidence for pairing the first five specimens listed above is therefore very strong.

5.2. Group IIB: DRPA78001–78016

These 16 specimens are the only recovered meteorites from the Derrick Peak region and all have highly distinctive and strikingly similar external appearances (CLARKE, 1982). Metallographic studies and analyses for Ni, Co and P are consistent with pairing;

cosmogenic nuclide data on two specimens (NISHIIZUMI, 1984) indicate that they are fragments of a very large meteoroid.

6. Carbonaceous Chondrites

6.1. CM2: ALHA77306, 78261, 81002, 81004, 82100, 82131

SCORE *et al.* (1982b) and MASON (1983a) suggest that the first four CM2 chondrites should be tentatively paired on the basis of petrographic similarities. The first two were found 5.5. km apart (YANAI, 1982). From modal analyses and textural studies, MCSWEEN (private communication, 1984) finds that 81002, 81004 and 82100 are probably paired, and that 78261 and 82131 are possibly paired with these three. He considers that 77306 is less likely to be paired because of its extensive alteration, and that 83100 is unique. MCSWEEN concludes that more data would be useful to check these tentative pairings.

6.2. CO3: ALHA77003, 82101

These two specimens were paired in the Antarctic Meteorite Newsletter (**7** (1), 27, 1984). My unpublished data shows that olivines in 82101 are much poorer in FeO than those in 77003 (SCOTT *et al.*, 1981), and their compositional ranges are very different. Mean compositions are Fa 25 in 77003 and Fa 17 in 82101; pairing seems unlikely.

7. Enstatite Chondrites

7.1. EH3 or 4: ALHA77156, 77295

These two specimens, which weigh 18 and 141 g respectively, were found 18 km apart (YANAI, 1982) and have identical mineral compositions and textures (MCKINLEY and KEIL, 1984). Since EH3/4 chondrites are rare and these two are different from other known E chondrites, MCKINLEY and KEIL are confident in pairing them, despite the large distance between their recovery sites.

8. H4 Chondrites

8.1. ALHA77004, 77190–77192, 77208, 77221, 77223–77226, 77232, 77233

These 12 H4 chondrites were found within a 1×2 km area in the Near Western Icefield (YANAI, 1982). YANAI *et al.* (1978) note that all 25 specimens found in 1977–78 in this area appeared to be fragments of a single fall. However, subsequent work has revealed that these specimens include five H5 chondrites, one EH4, one CO3 and a mesosiderite. CASSIDY (1980) proposes that six of the 12 listed above are paired; the others, except 77221, are included in the Antarctic Meteorite Newsletter pairing list (**7** (1), 27–29, 1984). Specimen 77221 is included here because it was found on the edge of the 1×2 km area.

All 12 chondrites listed above have a weathering grade of C and weigh between 0.2 and 15 kg (KING *et al.*, 1980). These specimens lack unusual features which would assist pairing, though 77190 has a higher proportion of fragmented chondrules. KING *et al.* report that some specimens have variable olivine and low-Ca pyroxene compositions, Fa 16–20 and Fs 13–27, but 77208, 77221, 77223–77226 and 77232 have essentially uniform compositions. Concentrations of ^{26}Al have been measured in 9 of the 12 chondrites (EVANS *et al.*, 1982) and their uniform value of 52±3 dpm/kg is consistent with pairing.

Since H4 chondrites are relatively uncommon, only 6.5% of meteorite falls (WASSON, 1974), it would be surprising if most of these 12 H4 chondrites are not paired. However, more data are needed to be sure that all are paired.

8.2. ALHA77009, 81022; ALHA78084

MASON (1983a) and SCORE *et al.* (1984) tentatively paired these three H4 chondrites, which have respective weights of 235 g, 14 kg and 912 g. However, according to MASON's data, low-Ca pyroxenes in 78084 are much more heterogeneous (Fs 8–24) than those in 77009 (Fs 16) and 81022 (Fs 17). Concentrations of ^{36}Cl in 77009 and 78084 are also quite different (NISHIIZUMI, 1984). Specimens 77009 and 81022 may be tentatively paired, but evidence for pairing 78084 seems weaker.

8.3. ALHA78193, 78196, 78223

These small (6–13 g) specimens were first paired by the Antarctic Meteorite Newsletter (**4** (2), 9–10, 1981). YANAI's map (1982) shows that they were all found at one spot along with 95 other specimens. All three have olivine with Fa 18 and low-Ca pyroxene with Fs 16 according to SCORE *et al.* (1982b, Appendix); pairing seems likely.

8.4. ALHA80106, 80121, 80128, 80131

MASON and CLARKE (1982) note that these four specimens have similar compositional ranges of olivine (Fa 18–19) and low-Ca pyroxene (Fs 15–22), and suggest they are possible paired.

8.5. ALHA81041, 81043–81052

SCORE (1983b) and MASON (1983b) studied the external morphology and petrography of these 11 H4 specimens, which weigh 8–728 g, and suggest that some or all of them may be paired.

8.6. RKPA80232; RKPA80237, 80267

MASON and CLARKE (1982) conclude that these three H4 chondrites weighing 22–80 g are possibly paired on the basis of similar mineralogy, texture and degree of weathering. ^{26}Al concentrations in 80237 and 80267 (EVANS *et al.*, 1982) are similar, 44 and 46 dpm/kg, but that in 80232 is much higher, 62±4 dpm/kg.

9. H5 Chondrites

9.1. ALHA77014, 77264

CASSIDY (1980) paired these two without comment; they were found 700 m apart in an area where about 20 other specimens were recovered in 1977–78 (YANAI, 1982). MASON (private communication, 1984) finds that these two specimens are similar in petrography and weathering. Since 15% of all meteorite falls are H5 chondrites (WASSON, 1974), some additional data would be useful to confirm this pairing.

9.2. ALHA77021, 77025, 77061, 77062, 77064, 77071, 77074, 77086, 77088, 77102

Cassidy (1980) suggests that eight of these ten chondrites (all but 77025 and 77074) might be paired on the basis of field data; all ten were found in a 1×2 km area where about 100 specimens were collected in 1977–78 (Yanai, 1982). Score *et al.* (1981) suggest that nine of the specimens listed above (not 77102) might possibly be paired on the basis of their petrographic studies, but they note that additional research is needed to confirm their conclusions. Presumably, they omitted 77102 because they found its low-Ca pyroxene had a lower FeO concentration; Fs 15, *cf.* Fs 17 in the others. Concentrations of ^{26}Al in four of the specimens range from 47 ± 5 to 58 ± 6 (Evans *et al.*, 1982), values which are consistent with pairing. Yanai's map (1982) shows that 36 other H5 specimens, which are described by McKinley and Keil (1984), were found in the same 1×2 km area, so it is possible that other specimens are paired with some or all of these nine.

9.3. ALHA77118, 77119, 77124

These three H5 specimens are all small, 4–8 g, and were found within 100 m of each other (Yanai, 1982). Cassidy (1980) and Mason (private communication, 1984) suggest that they are paired. Concentrations of ^{26}Al in 77118 and 77124 (Evans *et al.*, 1982) differ somewhat (53 ± 5 and 70 ± 7 dpm/kg) suggesting that these pairings should be considered tentative.

9.4. ALHA78209, 78221, 78225, 78227, 78233

The Antarctic Meteorite Newsletter (**4** (2), 9–10, 1981) claims that these small H5 specimens, each 1–12 g, are paired. This seems possible as all five were found at the same location (Yanai, 1982).

9.5. ALHA79031, 79032

Score *et al.* (1981) paired these two 3 g specimens on the basis of field notes and studies of their external morphology.

9.6. ALHA80111; ALHA80124, 80127, 80129, 80132

Mason and Clarke (1982) tentatively paired these five H5 specimens weighing 11–152 g because they are similar in texture, mineralogy and degree of weathering. Concentrations of ^{26}Al in 80129 and 80132 (J.C. Evans, unpublished data) are identical, consistent with pairing. However, Sarafin and Herpers (1983) measured different terrestrial ages for 80111 and 80124 and conclude that they may not be paired.

9.7. RKPA80217, 80218; RKPA80220, 80223; RKPA80250, 80251

Score *et al.* (1982a) argue from studies of external morphology and petrography that these six specimens are from three different meteorites. Mason and Clarke (1982), however, note that all 19 H5 chondrites found in 1980–81 at the Reckling Peak area resemble each other in texture, mineralogy and degree of weathering. They suggest that further research will reveal additional pairings.

10. H6 Chondrites

10.1. ALHA77144, 77148

CASSIDY (1980) paired these small specimens weighing 8 and 13 g, respectively; they were found 100 m apart (YANAI, 1982). SCORE *et al.* (1981) found that 77144 has olivine and pyroxene with higher concentrations of FeO, but the differences may not be significant.

10.2. ALHA77271, 77288

CASSIDY (1980) also paired these two H6 chondrites, which weigh 0.6 and 1.9 kg, respectively. They were found 100 m apart at the southern edge of the Allan Hills ice field where few meteorites were recovered, and have rather similar ^{26}Al concentrations of 39 ± 2 and 45 ± 8 dpm/kg (J.C. EVANS, unpublished data). Pairing of these specimens seems probable.

10.3. ALHA78211, 78213, 78215, 78229, 78231

These five small specimens weighing 2–11 g each are listed as paired in the Antarctic Meteorite Newsletter (**4** (2), 10, 1981) without detailed evidence for pairing. However, YANAI's map (1982) shows that all five were found at the same spot.

10.4. ALHA80122, 80126, 80130

MASON and CLARKE (1982) conclude that these H6 specimens are probably pieces of a single meteorite, as they have similar petrographic properties.

10.5. ALHA81035, 81038, 81103, 81112

The first two specimens were paired by MASON (1983a) on the basis of similar texture, mineral compositions and degree of weathering. MASON (1983b) also paired the second pair and the Antarctic Meteorite Newsletter (**7** (1), 28, 1984) combined both pairs.

10.6. MBRA76001, 76002

These two meteorites were found less than 1 km apart near Mt. Baldr in an area where no other meteorites were discovered; they have similar petrologic features (OLSEN *et al.*, 1978). WEBER and SCHULTZ (1980) support NOONAN's conclusion in OLSEN *et al.* (1978) that the specimens are paired, as they have similar concentrations of spallogenic and radiogenic noble gases.

10.7. RKPA80203, 80206, 80208, 80211, 80213, 80214, 80221, 80231, 80254, 80255, 80262, 80265, 80266

MASON and CLARKE (1982) conclude that all the H6 chondrites except 80201 that were found in 1980–81 in the Reckling Peak area are paired, because they have a characteristic granulated and well-weathered texture. MASON's olivine and pyroxene analyses (SCORE *et al.*, 1982a) support this pairing, as he found Fa 19 and Fs 17 in all specimens except 80231, in which he measured Fa 18 and Fs 16. Specimen 80231 is somewhat larger than the other 12; its original weight was 238 g, *cf.* 2–68 g for the remainder. Concentrations of ^{26}Al in 80231 and 80254 (J.C. EVANS, unpublished data) are indistinguishable, but that in 80262 is 30% lower, implying that there may be samples from more than one fall in this group.

11. L3 Chondrites

11.1. ALHA77011, 77015, 77031, 77033, 77034, 77036, 77043, 77047, 77049, 77050, 77052, 77115, 77140, 77160, 77163, 77164, 77165, 77166, 77167, 77170, 77175, 77178, 77185, 77211, 77214, 77241, 77244, 77249, 77260, 77303, 78013, 78015, 78038, 78186, 78188, 78236, 78238, 78243, 79001, 79045, 80133, 81025, 81030, 81031, 81032, 81053, 81060, 81061, 81065, 81066, 81069, 81085, 81087, 81121, 81145, 81156, 81162, 81190, 81191, 81214

All of the 77- to 79- specimens listed above except 78013, 78015, 78186, 78236, 78238 and 78243, which were added during this study, were paired by McKINLEY *et al.* (1981), on the basis of their microscopic studies. CASSIDY (1980) had earlier paired seven specimens on field evidence, and SCORE *et al.* (1981) paired three on petrographic grounds. McKINLEY *et al.* found that all the specimens contain a few vol % of aggregates of graphite and magnetite. Some Antarctic and non-Antarctic L3 and LL3 chondrites contain smaller amounts of graphite-magnetite, but no others were known then with as much. Thus McKINLEY *et al.* argue that these Allan Hills L3 specimens can be paired with some confidence. The remaining 20 specimens were paired during the course of this study on the basis of similar petrographic studies. The discovery locations of these L3 specimens are discussed in a subsequent section.

ALHA81024 is another L3 chondrite that contains abundant graphite-magnetite but it appears different from the other specimens in having smaller, rounder chondrules, and silicates that are less fractured and have a reddish weathering color instead of an orange-brown color. Analyses of its silicates show that this chondrite is more equilibrated than 77011 and paired specimens, and it is unlikely to be paired with them.

With one exception, studies by other authors have confirmed the pairing of these specimens. SEARS *et al.* (1982) measured the thermoluminescence sensitivity of eight specimens and conclude that they represent two distinct falls: a) 77011, 77015 and 77050, and b) 77167, 77214, 77249, 77260 and 78038. However, NISHIIZUMI *et al.* (1983) found very similar ^{53}Mn concentrations in 77015, 77167, 77214, 77249 and 77260. They note that 8 out of 10 of the L3 specimens listed above have very similar ^{26}Al values of 38 ± 3 dpm/kg (EVANS *et al.*, 1982; J.C. EVANS, unpublished data). ALHA77214 has an ^{26}Al concentration of 56 ± 5 dpm/kg, but in view of its very similar ^{53}Mn activity and noble gas concentrations (see below), NISHIIZUMI *et al.* argue that all 10 of these L3 specimens are paired.

TAKAOKA *et al.* (1981) and NAGAO *et al.* (1983) have measured noble gas concentrations in 77015, 77167, 77214 and 77260, and they conclude that all four are paired. In each specimen they found unusually high concentrations of planetary gases: $87–96\times 10^{-8}$ cm^3 STP/g of ^{36}Ar. The compilation of HUSS *et al.* (1981) shows that other type 3 ordinary chondrites contain $6–60\times10^{-8}$ cm^3 STP/g of ^{36}Ar. Thus arguments for pairing all 60 L3 specimens appear to be reasonably strong.

11.2. ALHA77215, 77216, 77217, 77252

These four L3 specimens were paired by SCORE (1980) and SCORE *et al.* (1981) on the basis of their characteristic external appearance, mineral compositions and brecciated texture. All four were found within 300 m of each other (YANAI, 1982). The probability that these specimens are paired is very high, because NAUTIYAL *et al.* (1982) found solar-flare tracks in all four specimens; only 3–4% of L chondrites contain these tracks (GOSWAMI and NISHIIZUMI, 1983). In addition, EVANS *et al.* (1982) found consistently low concentrations of ^{26}Al (36–40 dpm/kg) in 77215–77217.

12. L4 Chondrites

12.1. RKPA80216, 80242

SCORE *et al.* (1982a) suggest that these two specimens are possibly paired because they resemble each other in mineralogy, texture and degree of weathering. They note no unusual features that would assist pairing; however, L4 chondrites are relatively rare, accounting for only 3% of falls (WASSON, 1974).

13. L5 Chondrites

13.1. ALHA81017, 81018, 81023

The possibility that these large specimens weighing 0.4–2.2 kg are paired has been suggested by MASON (1983a), who notes their similar mineralogy.

13.2. PCA 82504, 82505

MASON (1984) notes that these 3 kg specimens from Pecora Escarpment resemble each other in mineralogy, texture and degree of weathering. He states that the possibility of pairing should be considered.

13.3. RKPA80209, 80228, 80268

These three L5 specimens weighing 3–11 g are possibly paired (MASON and CLARKE, 1982) as they are all rather similar in texture, mineralogy and degree of weathering. However, the analyses of SCORE *et al.* (1982a) tend to argue against pairing, as these authors found a rather wide variation in olivine (Fa 23–25) and low-Ca pyroxene compositions (Fs 19–21).

14. L6 Chondrites

14.1. ALHA76003, 76007

NOONAN in OLSEN *et al.* (1978) suggests that these two specimens, which were found 600 m apart (YANAI, 1982), should be paired on the basis of their similar petrography. However, WEBER and SCHULTZ (1980) find that they have different cosmic-ray exposure ages and ^{40}Ar concentrations, and conclude that these specimens are definitely not paired.

14.2. ALHA77001, 77292, 77293, 77296, 77297; ALHA77150, 77180, 77305

The first five specimens weighing 0.1–1 kg were found close together at the north end of the Allan Hills area where most recovered specimens are much smaller; these five appeared to be fragments of a single mass (CASSIDY, 1980; YANAI, 1982). Three specimens, 77001, 77293 and 77297, were found only centimeters apart; while specimens 77292 and 77296 were discovered 40 m away, also a few centimeters apart (CASSIDY, 1980; private communication, 1984). The five are listed as weathering grade A or B and appear to be typical L6 chondrites. FULTON and RHODES (1984) analyzed three of these specimens, 77001, 77296, 77297, and found that 77296 has higher Cr and 77001 has higher Al concentrations than their supposed pairs. These authors conclude that their chemical data argue against pairing, although little is known about chemical variations in multi-kilogram chondrites. Cosmogenic nuclide data support the pairing of 77296 and 77297, as both have similarly high concentrations of ^{26}Al, 67 and 70 dpm/kg (EVANS *et al.*, 1982; J.C. EVANS, unpublished data). However, the ^{26}Al concentration in 77001 is 52 ± 5 dpm/kg suggesting that these five specimens may come from at least two falls. Alternatively, they could all come from different depths in a single, large meteoroid. Specimens, 77001 and 77297 have indistinguishable ^{53}Mn and ^{36}Cl concentrations (NISHIIZUMI, 1984), implying that the latter is more likely.

The other three L6 specimens listed above, 77150, 77180, and 77305 were paired with the first five specimens in the Antarctic Meteorite Newsletter (7 (1), 29, 1984) without additional comment. CASSIDY (1980) paired 77150 and 77305, which were found 700 m apart (YANAI, 1982), but did not suggest that both were paired with the first five specimens, which were found 2.5 km away. ALHA77150 and 77305 weigh 0.06 and 6.4 kg, respectively: both are more weathered than the first five specimens. The third specimen, 77180, is equally weathered and was found over 2.5 km from 77305 and 77150, and 2 km from 77001 and paired specimens.

Since L6 chondrites are the commonest kind of meteorite, accounting for 28% of all meteorite falls (WASSON, 1974), I conclude that 77150, 77180 and 77305 should not be paired with any of the first five specimens until more studies are made. Evidence for pairing all three is also very weak.

14.3. ALHA77231; ALHA77272, 77273; ALHA77280, 77282; ALHA77269, 77270, 77277, 77281, 77284.

CASSIDY (1980) paired the first four L6 specimens which were found within 400 m of each other on the southeast corner of the Allan Hills area (Fig. 1). They are all large specimens with recovered weights of 0.5–9 kg and would seem to be good candidates for pairing but for the work of GOSWAMI and NISHIIZUMI (1983). These authors measured cosmic-ray track densities and ^{53}Mn concentrations in 77273 and 77280. By comparing observed and calculated ^{53}Mn activities as a function of shielding depth and meteoroid size, GOSWAMI and NISHIIZUMI conclude that these two specimens are definitely not paired.

The first four specimens and the other six listed above were all paired in the Antarctic Meteorite Newsletter (7 (1), 29, 1984). However, they do not appear to have any unusual petrographic features that would assist pairing. All 10 specimens are fairly large with recovered weights of 140 g to 9 kg and were found in a 2×4 km area (Fig. 1). However, most specimens recovered in this region of the icefield are similarly large (YANAI, 1982). CASSIDY (1980) paired 77270 and 77277 with 77284; 77270 and 77284 were found 100 m apart, but 77277 was found 2 km away (Fig. 1). No other evidence for pairing of these specimens has been discussed. GOSWAMI and NISHIIZUMI (1983) show that 77273 could not be paired with 77282 by similar arguments to those listed above. FULTON and RHODES (1984) argue that 77284 could not be paired with 77231 and 77270 because it has significantly higher Cr concentrations. However, as dis-

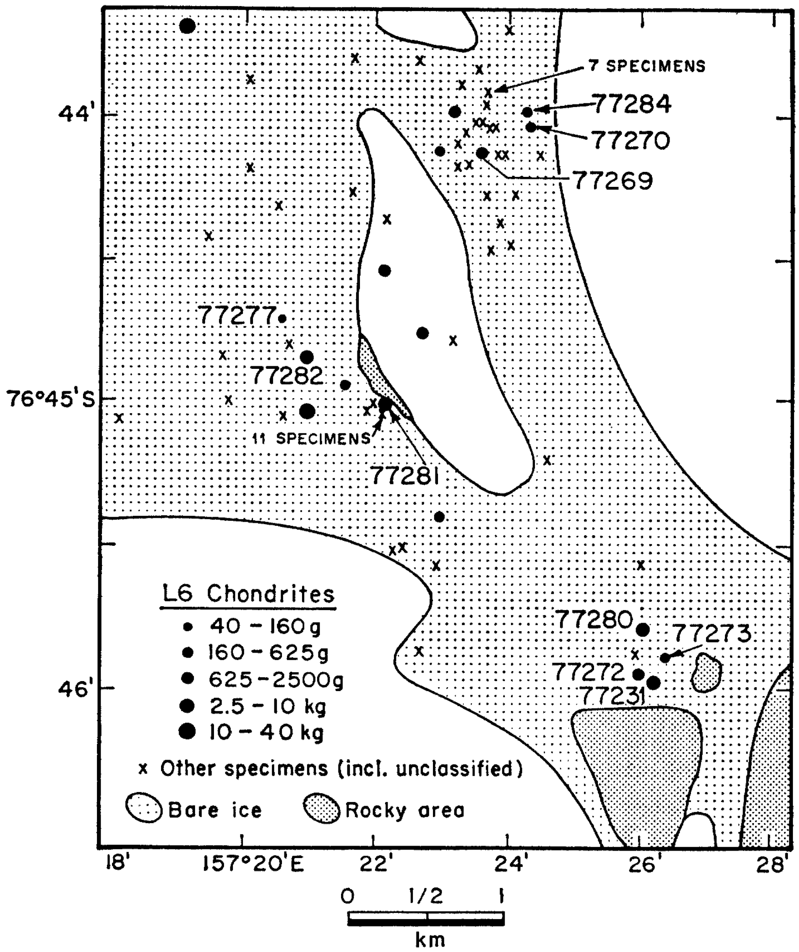

*Fig. 1. Map of the southeast corner of the Allan Hills ice field (*Yanai*, 1982) showing the discovery locations of ten L6 chondrite specimens that have been paired by various authors (Section 14.3) and other 76- to 78- specimens. Field evidence suggested that 77231, 77272, 77273 and 77280 were most likely to be pieces of a single meteorite (*Cassidy*, 1980), but cosmogenic nuclide and track data indicate that 77273 and 77280 cannot be paired (*Goswami *and* Nishiizumi*, 1983). Some other labeled and unlabeled L6 chondrites could be paired with each other or with these four chondrites, but such pairings are most uncertain at present.*

cussed above, the range of chemical variations within large chondrites is poorly known.

Concentrations of the cosmogenic nuclides ^{53}Mn, ^{26}Al and ^{36}Cl in five of these L6 specimens (Nishiizumi, 1984) suggest that 77272 and 77273 are probably paired and that 77280 and 77282, which were found 3 km apart, might be paired with each other (L. Rancitelli, private communication). However, 77270 is less likely to be paired with any of the other four specimens. Evidence for other pairings among the 10 L6 chondrites seems too weak at present.

14.4. ALHA78043, 78045

Score *et al.* (1981) note that these two specimens weighing 680 and 396 g are petrographically very similar. They were found about 300 m apart (Yanai, 1982) and have similar low concentrations of ^{26}Al, 34–38 dpm/kg (Evans *et al.*, 1982). Thus pairing seems possible.

14.5. ALHA78103, 78105; ALHA78104, 78251

These four L6 specimens weighing 0.6–1.3 kg were paired in the Antarctic Meteorite Newsletter (**4** (2), 9, 1981; **7** (1), 29, 1984). The first two were found within 150 m of each other, over a km from any other specimen, in the southwest corner of the Main Icefield (Yanai, 1982); pairing seems possible. However, 78104 and 78251 were found 4 and 7 km away. Apart from similarities in the exterior morphology of 78105 and 78251 (Score *et al.*, 1981), no other evidence for pairing has been presented. Concentrations of ^{26}Al in 78103 and 78105 are similar, 58 ± 3 and 61 ± 7 dpm/kg (Evans *et al.*, 1982), consistent with their pairing; concentrations in 78104 and 76251 are slightly lower, 53 ± 3 and 56 ± 6 dpm/kg.

14.6. ALHA78112, 78114

Score *et al.* (1981) note that these two L6 specimens are petrographically similar in all respects; they were paired in the Antarctic Meteorite Newsletter (**4** (2), 9, 1981). These two specimens have very similar concentrations of ^{53}Mn and ^{26}Al but very large differences in their concentrations of ^{36}Cl and ^{10}Be (Nishiizumi *et al.*, 1983; Evans *et al.*, 1982; Nishiizumi, 1984). Nishiizumi *et al.* note that the specimens were found 8 km apart, and conclude that they are not paired.

14.7. ALHA78126, 78130, 78131

Score *et al.* (1981) note that these specimens which weigh 0.3 to 2.7 kg, are petrographically similar in all respects but mention no characteristic features which would confirm the pairing. Since 78130 and 78131 were found 5.5 km apart and they have very different concentrations of ^{36}Cl and ^{26}Al but similar concentrations of ^{53}Mn (Nishiizumi, 1984), they are unlikely to be paired (L.A. Rancitelli, private communication). There appears to be insufficient data for pairing 78126 with either 78130 or 78131.

14.8. ALHA80101, 80103, 80105, 80107, 80108, 80110, 80112–80117, 80119, 80120, 80125

All 15 L6 specimens collected at Allan Hills in the 1980–81 season are reported to be identical in texture, mineral compositions (Fa 24 in olivine and Fs 20 in low-Ca pyroxene) and degree of weathering and may be paired (Score *et al.*, 1982a; Mason and Clarke, 1982). Their weights vary from 34 g to 8.7 kg, and some are reported to contain maskelynite. Uniform concentrations of 59 ± 3 dpm/kg ^{26}Al (J.C. Evans, unpublished data) in nine specimens lend credence to this pairing.

14.9. ALHA81027–81029

Mason (1983a, b) suggests that these three shocked L6 specimens weighing 80–3800 g each are paired because of petrographic similarities including the presence of maskelynite.

14.10. BTNA78001, 78002

Both these L6 shocked specimens contain maskelynite (Score *et al.*, 1981); pairing is certain as the two specimens fit together (R.A. Score, private communication, 1984). Marvin (1982) notes that all six specimens collected from Bates Nunatak in 1978–79 look suspiciously like fragments of a single fall, but at least one is not; 78004 is an LL6.

14.11. EET82605, 82606

MASON (1984) finds that these two L6 specimens closely resemble each other in mineralogy, texture and degree of weathering. He concludes that they could be pieces of a single meteorite.

14.12. RKPA78001, 78003; RKPA79001, 79002, 80202, 80219, 80225, 80252, 80261, 80264

SCORE *et al.* (1981) propose that the first four specimens, which weigh 0.2-3 kg, may be pieces of a single meteorite, as they are all heavily shocked and contain maskelynite. MASON and CLARKE (1982) find that six of the seven L6 chondrites collected from Reckling Peak in 1980–81 (excluding 80215) are also identical in texture and mineralogy and most have shock veins. MASON and CLARKE suggest that the six samples are probably paired with each other and that they may be paired with the other four specimens listed above. However, olivine compositions of Fa 23–25 and ^{26}Al concentrations of 48-60 dpm/kg (EVANS *et al.*, 1982; J.C. EVANS, unpublished data) in the ten specimens are more heterogeneous than those of the 15 L6 specimens listed in Section 14.8. The ^{26}Al data are consistent with the pairing of 78001 with 78003, and 79001 with 79002, but suggest that all four may not be paired.

15. LL Chondrites

15.1. LL3: ALHA76004, 81251

These two specimens were paired in the Antarctic Meteorite Newsletter (7 (1), 29, 1984) because I have found several petrographic similarities. However, more data are needed to check this pairing, as 81251 is much more weathered than 76004. Such large differences in the weathering of paired specimens have not been reported previously.

15.2. LL6: RKPA80222, 80238, 80248

Three of the four LL6 specimens collected from the Reckling Peak area in 1980–81 have been paired on the basis of macroscopic and microscopic studies (SCORE *et al.*, 1982a; MASON and CLARKE, 1982); they weigh 7–18 g each. The pairing of 80238 and 80248 is confirmed by measurements of their concentrations of noble gases and ^{53}Mn and ^{26}Al nuclides (SARAFIN and HERPERS, 1983; SIGNER *et al.*, 1983).

16. Geographic Distribution of Paired Specimens

Large meteorite showers typically cover an elliptical area of about 5–20 by 1–5 km in size (HEIDE, 1964), but up to 50×10 km for the Allende shower (CLARKE *et al.*, 1970) and 400×100 km for the iron meteorite, Gibeon (BUCHWALD, 1975). Specimen sizes vary systematically along the major axis of the ellipse. The Allan Hills A77011 paired specimens were also found in an elliptical region about 6×1.5 km in size with sample weights increasing systematically along the ellipse (Fig. 2). However, there are two reasons why this elliptical region is unlikely to represent the original size and shape of a strewn field. Firstly, the boundaries of the region are close to the edges of the northern part of the main icefield where most of the meteorites have been found (YANAI, 1982). Secondly, all meteorites recovered in this region show the same tendency for sample

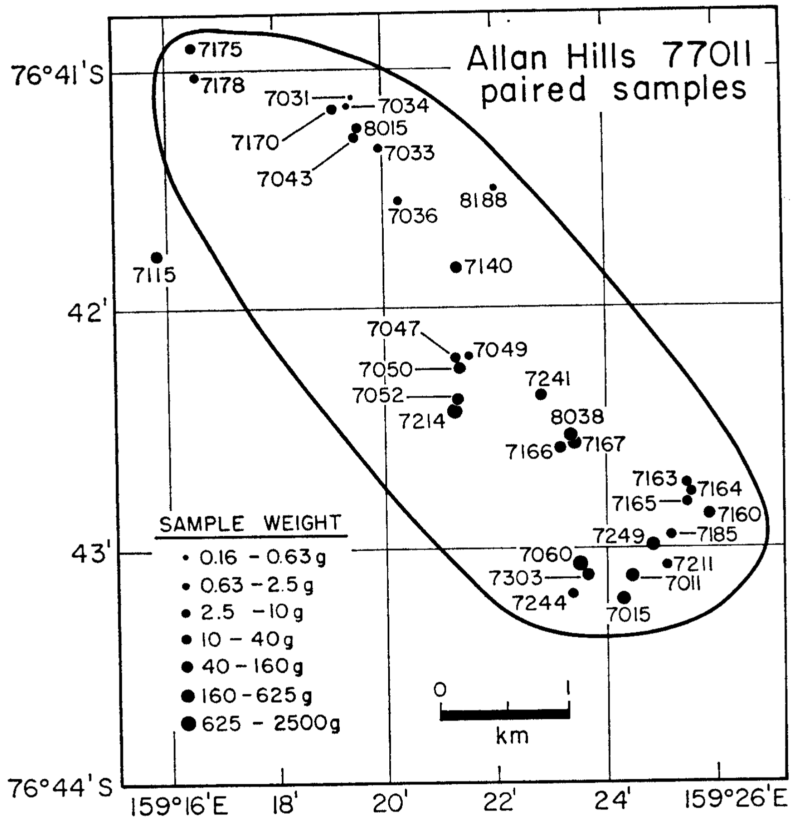

Fig. 2. Map of the Allan Hills ice field (Yanai, 1982) showing where 33 paired L3 chondrites were found (Section 11.1). (The first digit (7) of each specimen number is omitted.) The distribution resembles the elliptical strewn field of a large meteorite fall, in which small and large specimens are found at opposite ends of the strewn field. However, all the meteorites recovered in this region show the same distribution pattern suggesting that it is the prevailing southerly winds which concentrate small specimens at the northern end of the ice field.

size to increase towards the south. Figure 3 shows that the mean size of 77011 paired specimens increases from 9 to 140 g while the mean size of all stony meteorites in the same area increases from 9 to 77 g. This distribution was produced by strong southerly winds, which concentrate smaller specimens weighing less than 100 g at the northern end of the icefield (Yanai *et al.*, 1978).

Takeda *et al.* (1981) have identified 29 paired diogenites from the Yamato Mountains area that have a unique granoblastic texture. These were found in a 20×7 km elliptical region, and Takeda *et al.* note that this region is aligned along the direction of ice flow. There are systematic variations in specimen size along the ellipse like those described above; eight out of nine specimens that weigh greater than 100 g and only one of 13 weighing less than 10 g are concentrated in the southeast 3 km tip of the ellipse (Yanai, 1983). As in Fig. 2, the boundaries of the ellipse are close to those of the region where most meteorite specimens have been recovered, and it is certain that the 20×7 km region does not represent a strewn field. In this area, the direction of ice movement, which is from the southeast (Naruse, 1979), is close to that of the prevailing winds, which are easterly (Kobayashi, 1979). However, in view of the size

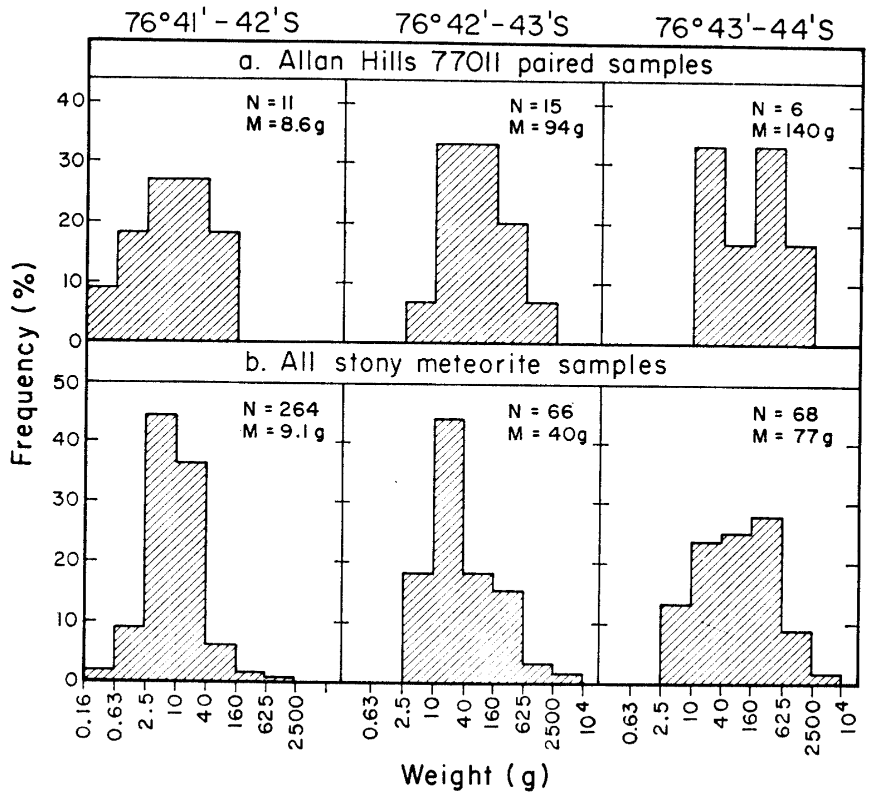

Fig. 3. Histograms showing the variation of sample weights with latitude for a) 32 samples paired with Allan Hills A77011, and b) all stony meteorite samples that are plotted on Yanai's *map (1982); N is the number of specimens and M is the geometric mean. In a) and b) mean sample weights increase with increasing latitude because southerly winds transport lighter specimens more easily than heavier ones.*

sorting of paired specimens which resembles that at Allan Hills, it seems likely that it is an aeolian effect. Thus the wind can probably separate paired specimens according to their masses by distances of at least 10–20 km. Experiments to measure the rate of movement of various sizes of rocks could help to limit the period for which these paired specimens have been exposed on the ice surface.

Most Victoria Land specimens that have been paired were found within 1–2 km of each other. An obvious exception is ALHA77295, which was found 18 km west of 77156 (Section 7.1). If these are paired, either they were part of a shower of which we have no other specimens, or there are other mechanisms such as ice flow that separate paired specimens. Most of the named localities in Victoria Land where meteorites have been recovered are even farther apart, 50 km or more (Marvin, 1982). Thus pairing of specimens from different localities seems unlikely, but cannot be excluded without more study.

17. Uncertainties in Pairing

The level of confidence with which Antarctic meteorite specimens can be paired has been assessed from the criteria used by individual workers, and from cases where a pairing has been studied by different workers. In Table 1 the specimens discussed above have been listed in order with a symbol giving an estimate of the level of confidence with which each specimen may be paired. For example, in Section 14.5, ALHA78103 and 78105 are possibly paired, while pairings of 78104 and 78251 are highly uncertain.

The degree of confidence for most pairings is very uncertain and the estimates in Table 1 are only intended to be approximate guides. In many cases, there is not enough information available to assess accurately the significance of arguments for and against pairing. For example, Berkley and Jones (1982) argue that two Allan Hills ureilites (Section 3.3) are not paired because of differences between their mean compositions of olivine and pyroxene. However, without a knowledge of the uncertainty in these means and the compositional range expected in a large ureilite, the significance of this difference cannot be assessed. For all stony meteorites, especially brecciated types, it would be worthwhile for this and other reasons to study compositional and textural variations in large slices.

Unless two specimens fit together like interlocking pieces of a jigsaw puzzle, it is

Table 1. Specimens from Victoria Land that have been paired, the section in which they are discussed, and the confidence level of pairing.

Specimen number	Section	Confidence* level	Specimen number	Section	Confidence* level
Allan Hills			77064	9.2	c
76002	5.1	a	77071	9.2	c
76003	14.1	x	77074	9.2	c
76004	15.1	c	77086	9.2	c
76005	3.1	a	77088	9.2	c
76007	14.1	x	77102	9.2	x
			77115	11.1	a
77001	14.2	b	77118	9.3	c
77003	6.2	x	77119	9.3	c
77004	8.1	b	77124	9.3	c
77009	8.2	c	77140	11.1	a
77011	11.1	a	77144	10.1	c
77014	9.1	c	77148	10.1	c
77015	11.1	a	77150	14.2	x
77021	9.2	c	77156	7.1	b
77025	9.2	c	77160	11.1	a
77031	11.1	a	77163–77167	11.1	a
77033	11.1	a			
77034	11.1	a	77170	11.1	a
77036	11.1	a	77175	11.1	a
77043	11.1	a	77178	11.1	a
77047	11.1	a	77180	14.2	x
77049	11.1	a	77185	11.1	a
77050	11.1	a	77190–77192	8.1	b
77052	11.1	a			
77061	9.2	c	77208	8.1	b
77062	9.2	c	77211	11.1	a

Table 1 (continued).

Specimen number	Section	Confidence* level	Specimen number	Section	Confidence* level
77214	11.1	a	78105	14.5	b
77215–77217	11.2	a	78112	14.6	x
			78114	14.6	x
77219	4.1	b	78126	14.7	x
77221	8.1	c	78130	14.7	x
77223–77226	8.1	b	78131	14.7	x
			78132	3.1	a
77231	14.3	x	78158	3.1	a
77232	8.1	b	78165	3.1	a
77233	8.1	b	78186	11.1	a
77241	11.1	a	78188	11.1	a
77244	11.1	a	78193	8.3	b
77249	11.1	a	78196	8.3	b
77250	5.1	a	78209	9.4	b
77252	11.2	a	78211	10.3	b
77260	11.1	a	78213	10.3	b
77263	5.1	a	78215	10.3	b
77264	9.1	c	78221	9.4	b
77269	14.3	x	78223	8.3	b
77270	14.3	x	78225	9.4	b
77271	10.2	a	78227	9.4	b
77272	14.3	a	78229	10.3	b
77273	14.3	a	78231	10.3	b
77277	14.3	x	78233	9.4	b
77280	14.3	b	78236	11.1	a
77281	14.3	x	78238	11.1	a
77282	14.3	b	78243	11.1	a
77283	5.1	x	78261	6.1	c
77284	14.3	x	78262	3.3	c
77288	10.2	a	79001	11.1	a
77289	5.1	a	79017	3.1	a
77290	5.1	a	79031	9.5	b
77292	14.2	b	79032	9.5	b
77293	14.2	b	79045	11.1	a
77295	7.1	b			
77296	14.2	b	80101	14.8	b
77297	14.2	b	80102	3.1	b
77302	3.1	a	80103	14.8	b
77303	11.1	a	80105	14.8	b
77305	14.2	x	80106	8.4	c
77306	6.1	c	80107	14.8	b
			80108	14.8	b
78013	11.1	a	80110	14.8	b
78015	11.1	a	80111	9.6	x
78019	3.3	c	80112–80117	14.8	b
78038	11.1	a			
78040	3.1	a	80119	14.8	b
78043	14.4	b	80120	14.8	b
78045	14.4	b	80121	8.4	c
78084	8.2	x	80122	10.4	c
78103	14.5	b	80124	9.6	x
78104	14.5	x	80125	14.8	b

Table 1 (continued).

Specimen number	Section	Confidence* level
80126	10.4	c
80127	9.6	c
80128	8.4	c
80129	9.6	c
80130	10.4	c
80131	8.4	c
80132	9.6	c
80133	11.1	a
81002	6.1	c
81004	6.1	c
81006–81010	3.1	b
81012	3.1	b
81017	13.1	c
81018	13.1	c
81022	8.2	c
81023	13.1	c
81025	11.1	a
81027	14.9	b
81028	14.9	b
81029	14.9	b
81030–81032	11.1	a
81035	10.5	c
81038	10.5	c
81041	8.5	c
81043–81052	8.5	c
81053	11.1	a
81059	4.1	b
81060	11.1	a
81061	11.1	a
81065	11.1	a
81066	11.1	a
81069	11.1	a
81085	11.1	a
81087	11.1	a
81098	4.1	b
81103	10.5	c
81112	10.5	c
81121	11.1	a
81145	11.1	a
81156	11.1	a
81162	11.1	a
81190	11.1	a
81191	11.1	a
81214	11.1	a
81251	15.1	c
82100	6.1	c
82101	6.2	x
82131	6.1	c
Bates Nunatak		
78001	14.10	a
78002	14.10	a
Derrick Peak		
78001–78016	5.2	a
Elephant Moraine		
79004	3.2	c
79005	3.2	b
79006	3.2	b
79011	3.2	c
82600	3.2	b
82605	14.11	c
82606	14.11	c
Mt. Baldr		
76001	10.6	a
76002	10.6	a
Pecora Escarpment		
82504	13.2	c
82505	13.2	c
Reckling Peak		
78001	14.12	b
78003	14.12	b
79001	14.12	c
79002	14.12	c
79015	4.2	b
80202	14.12	c
80203	10.7	b
80206	10.7	b
80208	10.7	b
80209	13.3	c
80211	10.7	b
80213	10.7	b
80214	10.7	b
80216	12.1	b
80217	9.7	c
80218	9.7	c
80219	14.12	c
80220	9.7	c
80221	10.7	b
80222	15.2	b
80223	9.7	c

Table 1 (continued).

Specimen number	Section	Confidence* level	Specimen number	Section	Confidence* level
80225	14.12	c	80252	14.12	c
80228	13.3	c	80254	10.7	b
80229	4.2	b	80255	10.7	b
80231	10.7	c	80258	4.2	x
80232	8.6	x	80261	14.11	c
80237	8.6	b	80262	10.7	c
80238	15.2	a	80263	4.2	b
80242	12.1	b	80264	14.12	c
80246	4.2	b	80265	10.7	b
80248	15.2	a	80266	10.7	b
80250	9.7	c	80267	8.6	b
80251	9.7	c	80268	13.3	c

*Confidence levels: a, probably paired; b, possibly paired; c, tentatively paired; x, unpaired or highly uncertain pairing.

difficult to pair them with greater than 99% confidence, as all the available evidence is only circumstantial. For the majority of the Antarctic specimens, which are equilibrated ordinary chondrites, it is unusual to be able to pair specimens with greater than 90% confidence purely on the basis of petrographic studies. In 24 cases where specimens of types 4–6 ordinary chondrites have been paired by petrologists and subsequently analyzed for cosmogenic nuclides or noble gases, the later studies argue against pairing in half of the cases! If these cases are typical and the cosmogenic nuclide and noble gas data have been correctly interpreted, the confidence level for tentatively paired specimens could be as low as 50%.

For type 3 ordinary chondrites and iron meteorites, there is general agreement over pairing and confidence levels are much higher, but for achondrites and mesosiderites, there are appreciable disagreements. In 19 cases where meteorites other than types 4–6 ordinary chondrites have been paired by petrologists and subsequently analyzed for cosmogenic nuclides or tracks, the later studies confirm the pairing in all cases. As a result, I estimate that for those specimens listed in Table 1 as probably paired the confidence level is 95% or higher, for possibly paired specimens it is 80–90%, and for tentatively paired specimens it is 50–75%.

YANAI *et al.* (1978) estimate that the 299 numbered specimens which they collected from the Allan Hills area in the 1977–78 season come from 20–50 different meteorite falls. SCORE *et al.* (1982b) list classifications for 102 of these specimens, and another 145 have been classified by MCKINLEY and KEIL (1984); the remaining 52 are unclassified at present. MCKINLEY and KEIL do not identify any paired specimens except for eleven L3 and two EH4 chondrites (Sections 7.1 and 11.1). Of the 102 specimens classified by SCORE *et al.* (1982b), 82 are listed in Table 1. If the 70 specimens that are listed as tentatively, possibly or probably paired are all paired, and no other specimens are paired, then these 102 specimens would come from 48 different meteorites. As discussed above, many of the proposed pairings of types 4–6 ordinary chondrites are probably incorrect. On the other hand, a systematic search for all pairings among the 102 specimens has not been made (and would not be worthwhile). On balance, it seems possible that the number of meteorites represented by the 299 specimens is somewhat higher than the figure of 20–50 estimated by Yanai *et al.* (1978); I estimate 50–150 different meteorites.

The known specimens of type 3 ordinary and carbonaceous chondrites that were collected in Victoria Land during the 1976 to 1980 seasons have been studied in some detail for possible pairings (Scott, 1984; this work). It is probable that these 61 specimens come from 18 distinct meteorite falls. From all these studies, the number of specimens in the 1976 to 1980 collections of Victoria Land meteorites is probably around 2–6 times the number of different meteorite falls represented. For the 1975 collection of Yamato meteorites, field workers estimate a comparable specimen-to-fall ratio of 3 (Nagata, 1978). However, Olsen (1981) claims that the overall ratio for recoverable Antarctic specimens is 70 times larger. By comparing the mode of the weights of Victoria Land meteorite samples (15 g) with the mode of recovered masses from observed falls (3 kg), Olsen estimates an average specimen-to-fall ratio of 200 for Antarctic specimens. However, this analysis neglects the greater probability of recognizing 10–100 g meteorites on the blue ice surface than on ground that may be covered with soil, rocks, bushes, or other vegetation. Nevertheless, it is probable that the specimen-to-fall ratio for the Allan Hills samples will increase as more exhaustive searches are made each year.

A precise mean fragmentation factor for observed meteorite falls cannot be calculated as this figure is dominated by the few rare events, like the Pultusk shower, which produce 10^{3-5} specimens. Hence, the larger the sample, the larger the calculated mean fragmentation factor becomes. However, in a sample of 130 stony meteorite falls described in Hey (1966), a single specimen was recovered from 56% of the falls. Another 30% produced about 225 specimens, and the remaining 14% produced 'many', 'several' or 'a shower' of specimens. Thus the specimen-to-fall ratio for recovered specimens from these falls is likely to be around 4–10. This figure is comparable to the ratio of 2–6 estimated above for the Antarctic samples, despite the large difference in their sizes, and the different ways in which they were recovered. The abundance of fusion crust on most Allan Hills samples (Yanai, 1979; Score *et al.*, 1981) and on most specimens from observed showers (*e.g.*, Clarke *et al.*, 1970) suggests that the large size difference between Antarctic and non-Antarctic meteorites is not due to fragmentation on and in the ice. The high visibility of 1–10 g specimens on blue ice surfaces may account for much of this size difference, but the size variations at Allan Hills (Fig. 3) show that size-sorting mechanisms, chiefly aeolian, operate in blue-ice areas.

Acknowledgments

I thank R. Score, B. Mason, H.Y. McSween, L.A. Rancitelli and J.C. Evans for their very helpful assistance, members of the Meteorite Working Group who suggested this study, G.J. Taylor for valuable discussions, and the National Institute of Polar Research for generous hospitality. This work was partly supported by NASA grant NAG-9-30 to K. Keil.

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(Received July 9, 1984; Revised manuscript received December 11, 1984)