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The Origin and Early History of the U.S. Antarctic Search for Meteorites Program (ANSMET)

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The information that would first lead U.S. teams to search for meteorites in Antarctica was presented at an evening session of the Meteoritical Society on 27 August 1973 in Davos, Switzerland. On that occasion, Dr. Makoto Shima of the Institute of Physical and Chemical Research of Japan described four meteorite fragments with differing mineralogical and chemical compositions that had been collected in 1969 from a downhill sloping patch of bare ice in the Yamato Mountains of eastern Antarctica.

In the audience sat William A. Cassidy, of the University of Pittsburgh. Bill Cassidy wrote later that, on hearing that report a comic-strip lightbulb appeared in his mind with a message reading: "Meteorites are *concentrated* on the ice!" To him, this was a new and electrifying idea. Cassidy expected the whole room to be excited, but looking around he found the audience looking as comatose and glassy-eyed as audiences sometimes do. I was chairing the session that evening, but I was much too preoccupied with keeping the speakers more or less on schedule to be having any eureka experiences.

After the session, Cassidy talked with Dr. Shima and his wife, Dr. Masako Shima, both of whom are chemists who were then visiting the Max-Planck-Institut für Chemie in Mainz. Dr. Shima explained to Cassidy that the team of glaciologists in the Yamato Mountains had collected five more meteorites from the same patch of ice. Of the nine meteorites, only the four they had reported on had been analyzed for their chemical compositions and rare gas contents. These had been identified as (a) an enstatite chondrite, (b) a Ca-poor achondrite, (c) a probable carbonaceous chondrite, and (d) an olivine-bronzite chondrite. The remaining five also clearly were meteorites of differing types. Earlier that summer the Shimas had coauthored an article about the four analyzed meteorites with Dr. Heinrich Hintenberger of Mainz, in *Earth and Planetary Science Letters* [*Shima et al.*, 1973], and the Shimas also had published a brief summary of their chemical results in the abstract volume of the meeting at Davos [*Shima and Shima*, 1973]. But Cassidy had not seen the article and had skimmed too quickly through the abstracts.

At the meeting, Cassidy was captivated by the evidence that meteorites from different falls sometimes are concentrated by the dynamics of ice motion. Within the hour, he began planning a proposal to the National Science Foundation's Division of Polar Programs to lead an expedition to search for meteorite concentrations on patches of ice in Antarctica. He assumed that the concentration in the Yamato Mountains could not be unique in a huge continent making up 9% of the Earth's land surface, so he would propose to work out of McMurdo Station, the U.S. base that lies near the opposite edge of Antarctica from the Yamato Mountains (Figure 1.1).

1.1. HISTORY OF METEORITE FINDS IN ANTARCTICA

Cassidy was well aware of the historical record of random meteorite finds in Antarctica, in which only four meteorites had been encountered since 1912. In that year, Douglas Mawson led the Australian-Antarctic Expedition on a five-year study of the Adelie Land coast. Mawson's three-man party discovered a stony meteorite lying on hard snow on their fourth day after breaking camp. That stone, Adelie Land, was the only known Antarctic meteorite for the next 50 years. Then, soon after the International Geophysical Year (July 1957–December 1958) had generated a widespread interest in Antarctica,

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Figure 1.1. Meteorite finds in Antarctica: 1911–2012. From *Marvin and MacPherson* [1989].

three more meteorites had been found during geological surveys. In 1961 Russian geologists discovered two fragments of Lazarev, an iron meteorite lying on a rocky spur of the Humboldt Mountains. Later in that same year, geologists of the U.S. Geological Survey picked up two pieces of Thiel Mountains, a pallasite, lying on hard irregularly surfaced glacier ice, where it was associated with debris of a moraine. Three years later, in 1964, another team of U.S. Survey geologists found Neptune Mountains, an iron on a mountainside in the Pensacola Range. Of these three finds, only Thiel Mountains lay on ice. Cassidy realized that this sparse record of four meteorite finds in the past 63 years could not be read as particularly encouraging, but to him it emphasized the importance of the new discovery reported by the Shimas of nine different kinds of meteorites on a patch of ice in the Yamato Mountains. He took it as positive proof that a concentration mechanism, unknown on bare ground, can be effective on ice. And he never doubted that additional concentrations of meteorites would be discovered in Antarctica once serious searches for them began.

1.2. CASSIDY'S FIRST PROPOSAL TO THE NSF FOR METEORITE SEARCHES

Before the deadline of 1 June 1974, Cassidy submitted his first proposal to the National Science Foundation, which supported all projects of U.S. scientists in Antarctica. He even included in it the possibility of finding lunar meteorites there [*Cassidy*, 1998, personal communication]:

> Many scientists agree that lunar material can be transferred to Earth as a result of large impacts on the Moon. Such material has not been recognized yet but would be concentrated in the same manner as, and together with, concentrations of meteorites. Lunar material, therefore, might also be recovered as a result of this proposed work.

He had high hopes that the referees would share his excitement. But in due time, his proposal was rejected. The reasons for proposal denials are always kept secret to protect the referees. However, we can hazard a guess or two. First, most referees would be experienced members of Antarctic teams familiar with the difficulties of living and working, between storms, in the snow and ice. To them, the idea of looking for meteorites there might appear ludicrous; in fact, the word *ludicrous* surfaced at one time, rightly or wrongly, having been leaked out by a referee. Next, the question might be raised as to why we should collect meteorites at all. By training and experience, most geologists are not interested in loose rocks, which cannot yield direct clues to the formations from which they are derived. Meteorites are the ultimate loose rocks which, it then seemed, never could be matched to their original sources. So meteorites might be of interest to collectors and dealers but not to earth scientists. I was made acutely aware of this attitude as late as 1978 when I was preparing for my first trip to Antarctica on Cassidy's team. More than once during visits to universities, I was asked by professors and students: "Why do you want to collect meteorites?" and "What would you want to do a thing like that for?" Faced with questions like these, I wondered how so many people could seem to be so unaware that we were living in the Space Age.

The Space Age had dawned two decades earlier on 4 October 1957, when the Russians launched Sputnik I and sent it beeping around the world. In the following year, President Eisenhower announced the establishment of NASA on 29 July 1958. And on 25 May 1961, President John F. Kennedy declared that Americans would fly to the Moon and return safely back to Earth within that decade. So, by the time Cassidy submitted his proposal to the NSF in 1973, six *Apollo* missions already had returned from the Moon with samples of its crust and soils. There was great public interest in space flight and the Moon but not in meteorites, which may have seemed more than ever like orphaned rocks from space.

Perhaps we may stop here to ask why Bill Cassidy was so interested in meteorites. Cassidy had attended the Institute for Meteoritics in Albuquerque, where he served as a research assistant to the director, Dr. Lincoln LaPaz, who took all his students to see Meteor Crater and its irons. Cassidy won the first Fulbright Fellowship in meteoritics and spent a year investigating tektites, meteorites, and craters in Australia and Thailand. On his way home, he arranged through Theodore Monod, Director of l'Institut Francais d'Afrique Noire in Dakar, to visit the newly discovered Aouelloul crater in Mauritania. Later on, he examined the Campo del Cielo craters in the Argentine chaco and a crater in the deserts of Chile. For a time, in the 1950s, Cassidy must have held a world's record for the number of meteorite impact craters he had seen. His PhD thesis, at the Pennsylvania State University, dealt with the high-temperature chemistry of meteorite and tektite systems.

1.2.1. A Link with Japan

On arriving home to Pittsburgh from Davos in the fall of 1973, Cassidy met with Professor Takesi Nagata, who was paying one of his regular visits to the University of Pittsburgh. He had been a visiting professor there since 1961, and he typically came to the department once or twice a year to collaborate on research with two members of the regular faculty. In his own book, *Cassidy* [2003, p. 19] describes the high honors accorded to Dr. Nagata internationally. He was one of the few non-U.S. members of the National Academy of Sciences, and in Japan the emperor had designated him as a National Living Intellectual Treasure. Furthermore, a few weeks later, on 29 September 1973, the National Institute of Polar Research was opening in Tokyo with Takesi Nagata as director general.

Cassidy assumed Dr. Nagata would know all about the meteorite concentrations reported by Dr. Shima at Davos. But Dr. Nagata pushed his chair away from his desk, seeming to be quite taken aback to learn, in this way, of meteorite concentrations that Japanese scientists had collected four years earlier! A short description of them had been published by the team leader, Dr. Masao Yoshida, in 1971, and as we noted above, the Shimas had published their results with Dr. Heinrich Hintenberger at Mainz early in the summer of 1973. But neither Nagata nor Cassidy had read these papers. Nagata immediately sent telegrams to Japan asking for details, and he encouraged the current field party, the 14th Japanese Antarctic Research Expedition (JARE-14), in the Yamato Mountains, to collect more meteorites. During the remainder of that season, 1973–1974, the Japanese team of glaciologists collected 12 more meteorites from the same patch of ice in the Yamato Mountains. Cassidy added that news to his proposal and resubmitted it to the NSF, which responded with the same negative decision as before.

1.3. JAPANESE INTEREST IN ANTARCTIC METEORITES

In Japan, an interest in Antarctic meteorites had arisen rather casually, almost as a joke. The story begins with a short letter written in 1970 by Professor Masao Gorai, of the Tokyo University of Education, who kept a meteorite collection at the University. His letter appeared under the title “Meteorite Museum” in *Magma,* a small newsletter on petrology. Here he used the term *meteorite museum* to refer to a naturally occurring collection of differing species of meteorites.

Dr. Gorai wrote that Dr. Yoshida of Hokkaido University had greeted him in his laboratory one day in the fall of 1968 just before Yoshida’s departure for the 10th Japanese expedition to Antarctica:

> I sent him off saying that the rock samples around the Syowa base do not continue to interest me because I have plenty of them. This time please get me a meteorite, or some *getemonos* (uncommonly odd rocks) as a souvenir.

Yoshida spent a year and a half in Antarctica (because the trip on an icebreaker from Japan to Syowa was too long for a return after a single summer), and it was May or June of 1970 when he visited Dr. Gorai again. At that time, Gorai was away, so Yoshida left a bagful of samples with Mr. Sugiyama of the laboratory. Several days later, Sugiyama brought the bag to Gorai, who had completely forgotten about his own request for meteorites or *getemonos* as a souvenir. So he decided to open the bag sometime later on.

On his next trip to Tokyo, Yoshida visited Gorai and reminded him that he had brought him the *getemonos* as requested. At last, Gorai remembered that he had asked Yoshida for meteorites or some *getemonos*. He opened the bag, not really expecting anything special, and found something very odd inside. In *Magma*, Gorai wrote:

> The colors are dark gray and gray-green and the shapes are rounded and covered with a thin skin; they looked something like meteorites but it seemed incomprehensible that such various kinds of meteorites are found in the very limited area near the Yamato Mts. I thought they were some sort of ordinary moraine rocks and that they were weathered by the special environment of Antarctica. So, half-believing and half-doubting, I was more or less convinced, at 95% of my confidence level, that they were not meteorites. But, just in case, I took pictures of them and weighed them and had thin sections made of them. I was surprised at the thin sections; they were all meteorites: 8 of them are chondrites and 1 is an achondrite. Literally, I was astonished and sent a wire with this news to Mr. Yoshida. Under the circumstance, the details of the meteorite collection in Antarctica will be presented soon by Yoshida et al. in 1971. I have decided to ask them to investigate from the standpoint of glaciology how the “Museum of Meteorites” had formed. I also want to proceed in mineralogical, petrological, and cosmochemical research of the samples, consulting appropriate people.

It is interesting to note that in Yoshida’s article of 1971 he reports that members of the field party said it seemed easy to recognize the meteorites because they were black rocks on the bare white ice. However, these black rocks were unrecognizable to Gorai when they came out of the bag in which they had been packed and carried for so long. But when he saw the thin sections he sent a telegram to Yoshida, saying: “All were found to be meteorites!” Then he wrote Yoshida a letter listing the differing species of the meteorites. It was Gorai’s list that the Shimas reported on in Davos. Gorai added that his earlier letter requesting meteorites or *getemonos* had been meant as a half joke. But he now was searching for possible explanations of the formation of meteorite concentrations on the ice.

Searches for meteorite concentrations were then formally incorporated into the work schedules of the glaciology group of JARE-14 in the polar summer of 1975–1976. In that season, when the field team was deliberately searching for meteorites rather than just picking them up in the course of other work, the team returned from the same large ice patch in the Yamato Mountains with a spectacular collection of 663 more specimens!

When this news reached Cassidy, he called Mortimer Turner, the program manager in the Division of Polar Programs at the NSF, and reported this figure. Turner reconsidered the situation. He told Cassidy that the panel had just declined his proposal again, but he advised him to add this new information and resubmit his proposal immediately; he thought it might pass this time. And indeed it did. Cassidy was approved to lead a team of two members to search for meteorites out of McMurdo Station in December and January of 1976–1977.

When Dr. Nagata arrived for his next visit to Pittsburgh, Cassidy hastened to inform him that his proposal had been accepted, and he planned to search for meteorites out of McMurdo Station in the polar summer of 1976–1977. Nagata cordially congratulated him, and then he delivered a profound blow: he told Cassidy that he was planning to send a man to McMurdo to search for meteorites in that same season! Bill was thunderstruck. There had been no suggestion of possibly working together, and the very thought of a competitive search out of McMurdo left him speechless. But Bill soon learned that JARE had had a cooperative arrangement with the U.S. program at McMurdo for a number of years. So he realized that Nagata could send a meteorite hunter there whenever he chose. Meanwhile, Bill had so much to do that he soon stopped worrying about how things might turn out with Nagata.

1.4. THE U.S. ANTARCTIC SEARCH FOR METEORITES GETS ORGANIZED

One of Cassidy’s first problems was to decide whom he should invite to accompany him to Antarctica. At just about that time, he received a letter from Edward Olsen, the curator of minerals at the Field Museum in Chicago. Ed had read the abstracts of the meeting at Davos and decided that further searches for meteorite concentrations should be made in Antarctica. He contacted his friend Carleton B. Moore, director of the Center for Meteorite Studies at Arizona State University, and proposed that they submit a joint proposal to search for meteorites in Antarctica. Carleton had been a reviewer of Cassidy’s third proposal, so he told Ed he was too late. Then, after proper hesitancy, Carleton broke the rules and told Ed whose proposal had been accepted. So Olsen wrote to Cassidy and they arranged to work together in Antarctica.

In 1976, the NSF shipped its scientists and other personnel from Port Hueneme in California to Christchurch, New Zealand, in the Military Air Transport System, which consisted of C-141 cargo planes. Bill and Ed climbed aboard the one assigned to them and found much of the floor space filled with chairs bolted to the floor. The plane had virtually no insulation against sounds, so the cabin not only was crowded and noisy, but it could be smoky, whenever the nature of the cargo would allow for smoking. The flight was about 22 hours long, but passengers had opportunities to emerge and walk around a bit at two nighttime refueling stops: Honolulu and Pago Pago. Identical box lunches with hearty slices of steak, French fries, a salad vegetable, and a cookie or an apple, were distributed three times during the trip.

1.4.1. Christchurch, New Zealand

Early one morning in late November, they arrived at Christchurch after losing a day from the calendar by crossing the international date line. Christchurch impressed Cassidy with its elegant British-style homes surrounded by gardens, which were just then bursting into bloom. He and Ed had a few days to rest and relax before leaving for McMurdo. So Cassidy took advantage of this opportunity to visit Oxford Terrace and contemplate the statue of Robert Falcon Scott, standing in a heroic pose gazing southward. Cassidy remarked that Scott occupies a mystical niche in the British psyche, but in no place more so than in Christchurch, which lies close to the harbor at Lyttleton, from which Scott's last expedition set out. Scott's final letter, written as death approached, made him a hero wherever English is spoken. However, in subsequent years, excerpts from Scott's own diary and those of some of his team members have become available, indicating that he made serious mistakes and alienated some members of his expedition. Cassidy concluded that Scott may have overreached his abilities and brought death upon all five members of the team that had arrived at the Pole. Cassidy recommended that interested readers look into the currently available literature before forming opinions on Scott.

The NSF maintains a huge clothing distribution center (CDC) at the Christchurch airport, stocked with Antarctic clothing of all types and sizes. Travelers to McMurdo are expected to try on pieces of inner- and outerwear they feel they will need. More specifically, each person is required to carry at least three types of well-fitted boots and shoes for working on the ice. And each must have a long, hooded Antarctic parka. Although beautiful parkas were available at the CDC, I was among those who bought my own, to keep as a souvenir. When Bill and Ed were scheduled to leave for McMurdo, they dressed in their Antarctic clothing at the CDC and packed their street clothing into suitcases that they checked there for the season. They then were presented with huge, orange waterproofed bags for carrying their spare Antarctic clothing. They boarded a C-141 Starlifter, a wheeled jet with four engines, that could reach McMurdo in 5½ hours, provided it did not have to turn back for bad weather or any other problem.

1.5. ANSMET SEASON I: 1976–1977

At McMurdo, Bill and Ed checked into the NSF headquarters at the administration's chalet and were assigned living quarters for the time they would spend there. They also were informed that Nagata and two other Japanese scientists had already arrived and had gone on a helicopter search for meteorites. They had found none, but in any case, the chief administrator, Duwayne Anderson, was unhappy about the prospect of being asked to support two meteorite-hunting groups when none at all had been scheduled in previous years. He proposed that the two field parties should work together. Nagata agreed to that, so Anderson asked Cassidy to write an agreement for them both to sign. Cassidy consulted with Nagata, thought about it overnight, and then wrote out the following memo with four main provisions:

1.5.1. The U.S-Japan Agreement

December 9, 1976

1. Logistics and base facilities of the USARP program at McMurdo will be used by a joint U.S.-Japan team to search for meteorites in the Dry Valleys and adjacent parts of the ice cap during the 1976–1977 field season.

2. Any meteorite specimens recovered will be distributed in the following way:
   a. Specimens larger than 300 g will be cut in two approximately equal pieces at the Thiel Earth Science Laboratory (in McMurdo). One piece will be utilized by the U.S. group and the other by the Japan group.
   b. Specimens 300 g or smaller will be distributed in equal numbers between the groups on an alternate-choice basis.

3. As observations from helo pilots and other groups come in, we may find it desirable to visit other field areas. The arrangements described above will apply to any meteorites recovered as a result of such change of plans.

4. Even though specimens will be distributed between our two groups, we will remain in contact about our current research programs on them, in order to avoid duplication of effort and in order to plan better how they may be utilized. We feel it would be appropriate to acknowledge the efforts of the joint U.S.-Japan team in any subsequent publication of research results.

Cassidy and Nagata both signed the document and it went into the official records of the Office of Polar Programs of the National Science Foundation. Cassidy then gave the U.S. effort a name: ANSMET, the Antarctic Search for Meteorites.

This project was a radical departure from anything previously done at McMurdo, and it generated considerable hilarity among the old hands. "What program are you with?" asked a young British petrologist who fell into step with Ed Olsen on the way to the galley.

"I'm collecting meteorites."

"Ah, yes, we saw that meteorite project on the list the other night. We had rather a good laugh over that one."

Of the three Japanese men who had taken that first helo ride, only one was planning to search for meteorites. Nagata himself could not spend time on the high ice plateau because of a heart condition, and Katsu Kaminuma was in Antarctica to conduct other research activities. So Keizo Yanai joined Bill and Ed for the 1976–1977 season. (In reviewing this situation, one is tempted to wonder if Nagata had not planned it this way all along. It seems inconceivable that he had brought Yanai there to hunt for meteorites by himself. So, by not sharing his plans with Cassidy, he might well have been playing a bit of a joke on him, since Cassidy had caught him out on the information from the Shimas at Davos.) Keizo, who had led the Japanese search that acquired 663 meteorites in the Yamato Mountains was of much help to Bill and Ed. They soon got used to Keizo's efforts in English, and he adopted a phonetic approach to writing their lingo.

In preparation for this effort, Cassidy had made a detailed study of satellite and aerial photographs in the library of the U.S. Geological Survey at Reston, Virginia. Searching for streams of bare ice, he had found a very promising tongue that descended from the plateau and penetrated about 2 km into one of the Dry Valleys before sublimating or melting and dropping its cargo of meteorites, if any, into its terminal moraine. Cassidy planned to camp on the bare rock below the moraine. For a second camp he chose a small ice patch at an elevation of 1 km on nearby Mt. Baldr. When their helo pilot had deposited them and their camping gear below the moraine, he found he still had time enough for some reconnaissance. So Cassidy asked to be taken to their second camping spot. That required flying 10 km horizontally while the surface below them rose 1 km vertically. Up there, they found a small patch of ice measuring about 3 x 3 km and landed on it. They got out of the helo and Keizo noticed a black rock nearby. It was a meteorite! While Bill and Ed were admiring it and photographing it, Keizo gazed through his binoculars and spotted another black rock. He started running. Bill and Ed followed him. Then the pilot jumped into the helo and followed, 20 meters behind them at an elevation of about 2 meters. Bill glanced back at the helo and thought this must be what an insect feels like being chased by a praying mantis. That stone was another meteorite! Keizo Yanai had found two meteorites in the first 20 minutes of the field season! Bill felt he could declare the season a success regardless of what more might happen.

Nothing more did happen for the next six weeks, in which they camped and searched on numerous patches of ice. Finally, it was time to pack up their camping equipment and return to McMurdo. Back at McMurdo, Cassidy requested a reconnaissance flight to the Allan Hills. He was told that the Allan Hills lay beyond the permitted range for helicopter flights. However, that afternoon, one of the pilots told Cassidy he actually had put a field party into the Allan Hills in the previous season. With that information, Cassidy gained permission for a reconnaissance flight to the Allan Hills on 18 January 1977.

On this reconnaissance flight, the pilot set them down near a rock. It was a meteorite. They then found three more before it was time to leave. In a few days they were allowed one more flight to Allan Hills. This time their helo pilot found four meteorites for them. But his flight time was ending, and he said there was nothing up ahead except a scattered moraine. Bill thought it was an odd place for a moraine, scattered or not, so he asked the pilot to let them check it out. Bill, Ed, and Keizo got out of the helo and each of them quickly found a meteorite. In fact, the "scattered moraine" consisted entirely of yellowish-brown meteorite fragments with no terrestrial rocks mixed in. The pilot moved the helo close to the largest of the meteorite fragments from which all the others had broken off. With great difficulty, Bill, Ed, and Keizo hoisted the large mass onto the floor of the helo cabin. Then they collected the remaining 33 fragments of it. Figure 1.2 shows Bill at the site reaching for one of the final fragments. All together, the pieces added to the main mass would have made up a meteorite weighing about 407 kg.

During that season, they had collected the 2 meteorites at Mt. Baldr, and 6 more of them on two helicopter stops, plus 34 pieces of the same one on the final day. The 2 Mt. Baldr stones have since been paired as 1, and the 34 Allan Hills meteorites count as 1, so that leaves a seasonal take of 42 fragments of up to 5 different meteorites.

Cassidy had proved that meteorite concentrations do occur within reach of McMurdo Station. And after the successes of the first day and the last day of his initial field season, Cassidy's proposal was certain to be renewed. Indeed, ANSMET is still collecting meteorites 38 years later, under the guidance of Dr. Ralph Harvey of Case Western Reserve University, whom Cassidy recommended to the NSF as his replacement beginning in the austral summer of 1994–1995.

Figure 1.2. Bill Cassidy reaching for a fragment of the large meteorite at the Allan Hills.

1.5.2. Processing and Distribution of Samples

At McMurdo, Bill, Ed, and Keizo moved the specimens to the Thiel Earth Science Laboratory and followed the procedures described in the joint memo: first, they cut the large specimen in half using the available rock saw. Then they divided all their smaller specimens into two groups and Keizo packed the Japanese share for shipment to Japan. Bill and Ed Olsen sawed the U.S. portion of the large stone in half and sorted out their shares of the smaller stones. Each of them shipped his samples home, as field geologists generally do in order to carry out their research on them, even though actual ownership of the rocks traditionally remains with their funding agency.

Cassidy was appalled at the sight of meteorites that had been collected from the most sterile environment on the Earth being cut on a rock saw in everyday use for terrestrial rocks. He now was giving serious thought to the expected worldwide interest and demand for samples of Antarctic meteorites. No procedures had been discussed for receiving and curating these meteorites, so he decided to write a proposal for a curation center using clean facilities at the University of Pittsburgh, from which samples for research would be distributed around the world.

For planning purposes, he sent a questionnaire to every member of the Meteoritical Society, and to every other interested person he could think of, asking for opinions on how Antarctic meteorites should be collected, stored for transport, processed, and distributed for research. He received answers from nearly 90 meteoriticists in 15 countries. Cassidy summarized their responses in a 22-page survey with four appendixes and circulated it for discussion at the meeting of the Meteoritical Society in Cambridge, England, on 24–29 July 1977. In it he listed the four major concerns expressed by his correspondents:

1. An oblique and/or stereo photos should be taken of each meteorite *in situ.* Detailed information should be recorded on its field occurrence, its degree of weathering, completeness of fusion crust, and, if possible, its magnetic orientation as found.
2. Meteorites should be altered as little as possible during collection, storage, and transport. A specimen must not be touched by hands or gloves; it must be collected in cleaned containers, such as glass jars, teflon bags, polyethylene bags, or aluminum cans or foil. They must be shipped to the U.S. to avoid having them x-rayed at airport security. For carbonaceous chondrites, exposing them to Pb-bearing helo exhaust must be avoided (assuming that they can be identified in the field.)
3. Meteorites, and subdivided parts of them, must be maintained in a chemically non-reactive, non-contaminated environment at sub-zero temperatures in a dry environment, or in dry nitrogen. Rock saws lubricated by water or organics must be avoided; specimens should be broken by stainless steel implements or cut with dry wire saws.
4. Complete laboratory documentation should be carried out while meteorites are being subdivided. A need was expressed for eventual archival storage of a part of each meteorite, but there was no general agreement on how much of each meteorite should be saved, or where it should be stored.

In summary, the international scientific community clearly favored clean handling of Antarctic meteorites, based on procedures used for the lunar samples, with a few extra-special precautions to minimize terrestrial contamination.

Cassidy wrote his proposal for processing ANSMET meteorites at Pittsburgh, although he could hear what he described as the presence of leviathans lumbering about half-seen at the edge of the clearing. He was referring to the new and competitive interests being shown in the care and handling of Antarctic meteorites by two huge organizations: NASA and the Smithsonian Institution.

NASA had had the unique experience of processing and distributing the lunar samples, and its Building 31 at the Johnson Space Center was well-equipped with clean-room facilities. NASA also had a highly trained and dedicated staff. By 1976, however, NASA was constructing a new building for the curation of lunar samples and was beginning to look into possible uses of Building 31 for meteorite research. Early in 1977, one NASA staff member, John O. Annexstad, suggested that Building 31 might be put into good use for processing meteorites such as those Cassidy had begun collecting in Antarctica. Some NASA managers reportedly resisted that idea at first, but upon learning about it in more detail they lent it their full support. Thus, NASA played an active role in the meeting held at the NSF on 11 November 1977.

The Smithsonian Institution (SI) also took an early interest in the Antarctic program, mainly through the efforts of Brian Mason. Mason saw its importance to meteoritics the moment he heard from Cassidy about his plans for going to Antarctica. Mason volunteered to have thin sections made of each meteorite collected in Antarctica and to publish descriptions of them. He also hoped to join the field team some year soon. Meanwhile, the Smithsonian management pursued its century-old tradition of claiming ownership of specimens or artifacts found on federal lands or collected by projects on federal funds. At the meeting on November 11, it yielded to NASA the processing of Antarctic meteorites and their primary distribution for research. But it successfully pressed its claims to serve as the final, archival curator of samples of each ANSMET meteorite.

1.6. A MEETING OF MINDS AT THE NSF, 11 NOVEMBER 1977

On Armistice Day in 1977, shortly before the start of ANSMET's second field season, the NSF convened an ad hoc group of meteorite specialists from NASA, the Smithsonian, and various universities to formulate procedures for collecting, processing, and distributing Antarctic meteorites. I was invited in a surprise call from Mort Turner. He said he was calling people who were recommended by other people. (Perhaps I was on somebody's list because I had served as president of the Meteoritical Society in 1975 and 1976.) Mort said he would like me to come, but he added: "We have no funds to pay for your travel." I knew the Smithsonian would pay my way, so I agreed to attend the meeting, at which I obtained my first intimate knowledge of the Antarctic meteorite project and of big government bureaucracy.

At the meeting, Cassidy willingly relinquished his proposal to process meteorites at Pittsburgh. And the NSF, NASA, and SI worked out a three-agency agreement that was unique in the U.S. government: the NSF would continue to fund and provide field support for the expeditions from the University of Pittsburgh, but the NSF stipulated its technical ownership of all Antarctic meteorites collected with NSF funding; NASA agreed to serve as the processor and distributor of meteorite samples for research, and the U.S. National Museum (Smithsonian Institution) would become the final archival curator of ANSMET meteorites. The Smithsonian also would publish reports on each season's activities and describe its collection of meteorites.

During the meeting, the NSF set up two advisory groups: the Meteorite Working Group (MWG), and the Meteorite Steering Group (MSG). The MWG consists of about 10 people with a rotating membership from the three agencies and the wider meteoritical commuity. Its main responsibility is to review requests for Antarctic meteorite samples for research and to prepare an allocation plan for approval by the MSG, which consists of three members: one each from the NSF, NASA, and SI. In an effort to inform the worldwide scientific community of the number, character, and availability of each new batch of specimens, the MWG proposed the issuing of what became the *Antarctic Meteorite Newsletter,* which is composed and distributed by the curatorial staff at NASA's Johnson Space Center (JSC). It includes descriptions of each available sample and its thin section, and is accompanied by a sheet for submitting requests for research material to be reviewed by the MWG.

These new procedures were to be put into practice in the upcoming 1977–1978 season. Meanwhile, the field team lost one member and gained two new ones. Ed Olsen did not take part again because he could not add his finds to the collection at the Field Museum. In fact, he would be collecting for the benefit of a competitor: the Smithsonian Institution. Bill found an enthusiastic partner in Billy P. Glass, a professor of geology at the University of Delaware. Billy was well known for having discovered microtektites in deep sea cores and greatly extending the sizes of certain tektite strewnfields. Keizo Yanai and Minoru Funaki made up the Japanese contingent. Incidentally, from the beginning of these searches, there was a clear understanding among participants that this was to be a group effort. No counts would be kept of the numbers of specimens found by each person. Only the final totals would be recorded. Everyone approved of this policy, which served to keep the team members friendly.

1.7. ANSMET SEASON II: 1977–1978

For this season, Cassidy decided to return to the Allan Hills and do some more searching. This proved to be an excellent choice. They soon discovered what we now call the Allan Hills Main Icefield. It is a large exposure of blue ice bearing a rich concentration of meteorites with no terrestrial rocks among them. The team erected its tents at the edge of the ice for an extended stay. During that season, they recovered about 350 specimens, each of which was collected according to the new protocols.

On being discovered, each specimen was described in a short note and photographed in situ beside a measuring device with a 6-cm scale. Figure 1.3a illustrates a chondrite, from a rock formation about 4.5 billion years old, that fell so recently that it broke into two pieces when it struck the ice. Figure 1.3b shows an achondrite, a polymict breccia likely from the surface of asteroid 4 Vesta (Plate 57), that has been carried within the moving ice for perhaps several hundred thousand years before appearing at the surface.

Figure 1.3a. A chondrite, about 4.5 billion years old, that fell so recently that it broke into two pieces when it struck the ice.

Figure 1.3b. An achondrite, ALH A81006, a polymict breccia likely from the surface of asteroid 4 Vesta (Plate 57), that has been carried within the moving ice for perhaps several hundred thousand years before appearing at the surface.

NASA's curatorial facility at JSC had supplied the field crews with all the newly cleaned equipment they needed for collecting specimens without touching them. Sometimes nicknamed "*Apollo* surplus," this included teflon bags, stainless steel tongs, and teflon tape designed for use at sub-zero temperatures. Each specimen was placed in a Teflon bag and then that bag was dropped into a second bag carrying a numbered aluminum tag. The second bag was then sealed shut. In order to maintain the specimens at sub-zero temperatures while they were being stored and shipped, NASA provided the teams with burglar-proof padded steel boxes measuring about 60 × 60 × 90 cm. One of these boxes was brought to the camp site at the Allan Hills.

The harvest of meteorites in that season was acquired under especially trying circumstances: the team had no snowmobiles, so they were obliged to take turns trudging to each rock, carrying the camera and collecting equipment, and then carrying each wrapped-up stone back to the camp to be stored in the shipping box.

1.7.1. Early Procedures at Johnson Space Center

Many of the meteorites had ice or snow on them when they were collected, so at JSC each new specimen was put into a glove box in a stream of dry nitrogen to be thawed and dried and then sawed with a clean blade, or chipped apart depending on its size. It was photographed at each step of its processing. Three chips for thin sections were taken from each specimen that weighed more than 100 g. The sections were cut and polished at the Smithsonian in Washington for distribution to Japan, and to libraries at the NASA Johnson Space Center in Houston and the Smithsonian's Natural History Museum in Washington. The mineralogy of each thin section was described by Brian Mason, who, as noted above, had volunteered for the job. At the earliest meeting of the MWG in Houston, Klaus Keil raised the question of who would describe all these thin sections. He didn't want to do it himself, and he didn't want his students to spend time that way, either. But Brian, knowing that this question would arise, had given me a copy of one of his succinct descriptions of a thin section to read out to the members. Keil relaxed, seeming fully satisfied. Brian, during his long career of field and laboratory investigations, and his writing of books on geochemistry and meteorites, had developed a quick and effective technique of identifying meteorites in thin sections. He said later that he had had a wonderful time going through the several thousand new thin sections of Antarctic meteorites. And he was pleased that this was recognized as the essential service it was.

Each specimen unpacked at JSC was assigned a unique label. The labels had been worked out by the MWG in discussions with the Committee for Nomenclature of the Meteoritical Society. Each label would begin with three letters identifying its location, followed by the letter A, followed by two digits indicating the year of its discovery, and three more digits indicating the sequence in which the specimen was opened at JSC (not when it was found in the field). For example, ALH A78362 designated the following: Allan Hills, Expedition A, 1978, the 362nd to be opened at JSC. "Expedition A" was adopted at the insistence of Paul Pellas, the member from France, who insisted that many countries might begin sending collecting expeditions each year and would need different expedition letters. The MWG agreed to assign new letters whenever additional expeditions were fielded in a given year, but this never came to pass, so the letter A, which had been part of every label since 1975, was dropped in 1982.

Figure 1.4a. Iron ALH A77283.

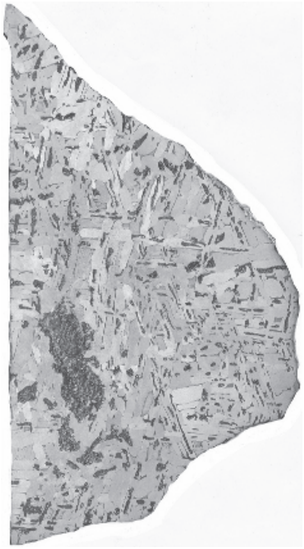

Figure 1.4b. A polished and etched slice of the iron. Minute grains of diamond and lonsdaleite occur within inclusions such as the dark one at lower right.

In this, its second season, ANSMET discovered a unique iron, ALH A77283, which measured about 16 × 16 × 12 cm and weighed 10.5 kg (Figure 1.4a). It proved to be a carbon-rich octahedrite similar in composition to Canyon Diablo. That seemed simple enough until its inclusions of troilite-carbon-schreibersite-cohenite were found to contain carbonado-like material rich in minute diamonds and lonsdaleite (Figure 1.4b)! Had the iron smashed into the ground with enough force to form tiny diamonds? No, because the meteorite had a heat-altered ablation zone along one side of it, indicating that it had had an uninterrupted passage through the atmosphere and a nonexplosive impact on the Earth. This identifies it as the only known iron meteorite showing evidence of a diamond-forming impact in space [*Clarke Jr*., 1982, p. 51].

Unlikely as it seems, this iron gave rise to some second thoughts about Canyon Diablo: Could its diamonds be preterrestrial? Was Meteor Crater volcanic after all? No, it was not. That yawning crater, nearly a mile wide and surrounded by large fragments of an iron meteorite, bears testimony to a powerful diamond-producing impact on the Earth. ALH A77283 shows us that an impact in space also can create diamonds in irons.

1.7.2. Repercussions from Japan

At the end of the 1977–1978 field season, all the meteorites were shipped to NASA/JSC for processing. But nobody had thought to inform Takesi Nagata of this new arrangement. So when Keizo Yanai arrived home without Japan's half of the meteorites, Nagata raised a storm. Although it seemed to others that Nagata surely would approve of this effort to keep the meteorites uncontaminated, nationalism evidently outweighed science when he realized that he had not been consulted. It took a face-to-face meeting in Washington with Edward Todd, the Director of NSF's Division of Polar Programs, to win his agreement, as long as (1) the United States promised not to circulate any preliminary descriptions of meteorites before Japan received its share, and (2) a Japanese member was present when the collection was opened. That promise was easily fulfilled by inviting Keizo Yanai to be present at JSC during the opening and distribution of that season's meteorites.

1.8. BECOMING A MEMBER OF ANSMET

By then, I had developed a yearning to go to Antarctica. At the NSF meeting on 11 November 1977 there had been talk of maybe sending several field parties each season. So I asked Mort Turner about submitting proposals, and he loaded me with maps, forms, and booklets. However, when I checked back with him, he said, “Realistically, we won't be sending more than one team a year; call up Bill Cassidy and ask to join his team.”

I had known Bill for years. In fact, he recently had written a favorable review of a paper I had submitted for publication. However, it certainly did no harm to my cause to call Bill and be able to say, “Mort Turner told me to call you and ask to join your team in Antarctica.” After we talked awhile, Bill agreed to take me the next season: 1978–1979.

At about that time, Cassidy was formulating his policy on choosing team members. First, he always would take a crevasse expert. They are the most essential members of the teams. Next, he would look for senior people actively involved in meteorite research, including Europeans.

Next came graduate students in meteoritics or allied fields, and if there still was any room he would consider specialists who could contribute to the well-being of the field teams: first aid, communications, snowmobile maintenance, and such. When I learned about his list, I was glad to note that I would have fitted into his Category 2, even without a recommendation from Mort Turner.

In 1978, I had been invited to serve as a visiting professor for the fall semester at Arizona State University in Tempe. Both my husband and I were Arizonans by preference, if not by birth, so we found a comfortable motel near the campus and Tom led me through a fitness program for going to Antarctica. It began by running together several times around the university track early each morning and then performing exercises for improving my balance. To our delight, we soon found that I was sharing the office of Dr. Robert S. Dietz, in his absence, with Dr. James F. Hays of Harvard, who often had gone running with Tom and had led both of us on birding expeditions. Hays is a master birder, so we sometimes had late afternoon forays into the desert followed by dinners with Jim and his wife, Diane, at the French cafeteria Le Café Cazino in Phoenix. (I wrote to the manager from Antarctica urging him to open a branch in Harvard Square. He responded with thanks, but without a word about expanding his restaurant chain.)

In Tempe, I took the opportunity to examine meteorites in the new Center for Meteorite Studies. And I searched through the archives of the Meteoritical Society that were stored in file cabinets in the basement. I found interesting old letters discussing the need for a society devoted to meteorite research.

1.9. ANSMET SEASON III: 1978–1979

When the semester ended, Tom and I drove to San Diego and took a birding cruise to San Clemente Island. Then, on to Port Hueneme to catch my cargo plane for the flight to Christchurch. Dean Clauter, one of Cassidy's students, boarded the plane too, as did three graduate students from Tempe, bound for a different project. I found the flight to be much more comfortable than the one Cassidy had described. There was a padded pallet of cargo at center front of the cabin, with seats filling the rest of the floor. The five of us rushed for the middle of the front row of seats where we could rest our feet on the pallet. Shortly before takeoff, it was announced that due to the nature of the cargo there would be no smoking on the flight. That was wonderful news to us! It would be a long trip with the same box lunches and two refueling stops that Cassidy reported: at Honolulu and Pago-Pago. I had been to Honolulu before, and have been there since, but that was the only stroll of my lifetime under the tropical trees at Pago-Pago.

In Christchurch a young marine biologist named Susan Patla and I quickly discovered our common interest in birding, so we explored the incredibly beautiful botanical garden. Then we hired a taxi to take us birding in the countryside and along the shore. The driver, who owned her vehicle, was so pleased by such a mission that she charged us very little.

When the time came to leave, we assembled our Antarctic clothing at the CDC and took off for McMurdo. Shortly after we arrived there, Bill Cassidy came in from the Darwin Camp and arranged for Dean Clauter and me to replace him there while he set off in a helicopter for the Allan Hills. Counting Cassidy, there were seven active participants in three major ANSMET projects during that season. The projects were (1) the design and erection of a geodetic network across the meteorite-rich portion of the Allan Hills Main Icefield, (2) meteorite searches from the Darwin camp near the head of the Darwin Glacier, and (3) searches for more meteorite concentrations in the Allan Hills.

1.9.1. The Geodetic Network at the Allan Hills

John Annexstad of the Johnson Space Center in Houston, who had wintered over in Antarctica during the International Geophysical Year of 1957–1958, took the responsibility for laying out a geodetic network across the meteorite concentration on the Allan Hills Main Icefield. He was joined by Minoru Funaki and Fumihiko Nishio, both of the National Institute for Polar Research in Tokyo. They set up their camp at the Allan Hills on 7 December and stayed there for 26 days, through one 4-day blizzard and several other storms that kept them tent bound. Their net consisted of 20 stations stretching westward across the icefield for 15 kilometers. They anchored Stations 1 and 2 to the bedrock of the Allan Hills. For the rest, they bored auger holes 50 to 100 cm deep into the ice. They filled the holes with bamboo or aluminum flag poles and established the position of each station by means of a Wild-2 theodolite (Figure 1.5). Their plan was to come back in future years and remeasure the station locations to determine the direction and rates of ice motion and ablation. While they were constructing the network, the three of them picked up 103 meteorites, which they added to the season's collections.

1.9.2. The Darwin Camp

At the beginning of the season, Cassidy and Kazuyuki Shiraishi of the National Institute of Polar Research in Japan went to a temporary camp the NSF had erected at the head of the Darwin Glacier for use by several projects. The camp consisted of Jamesway huts linked together for sleeping, dining, working space, laundry,

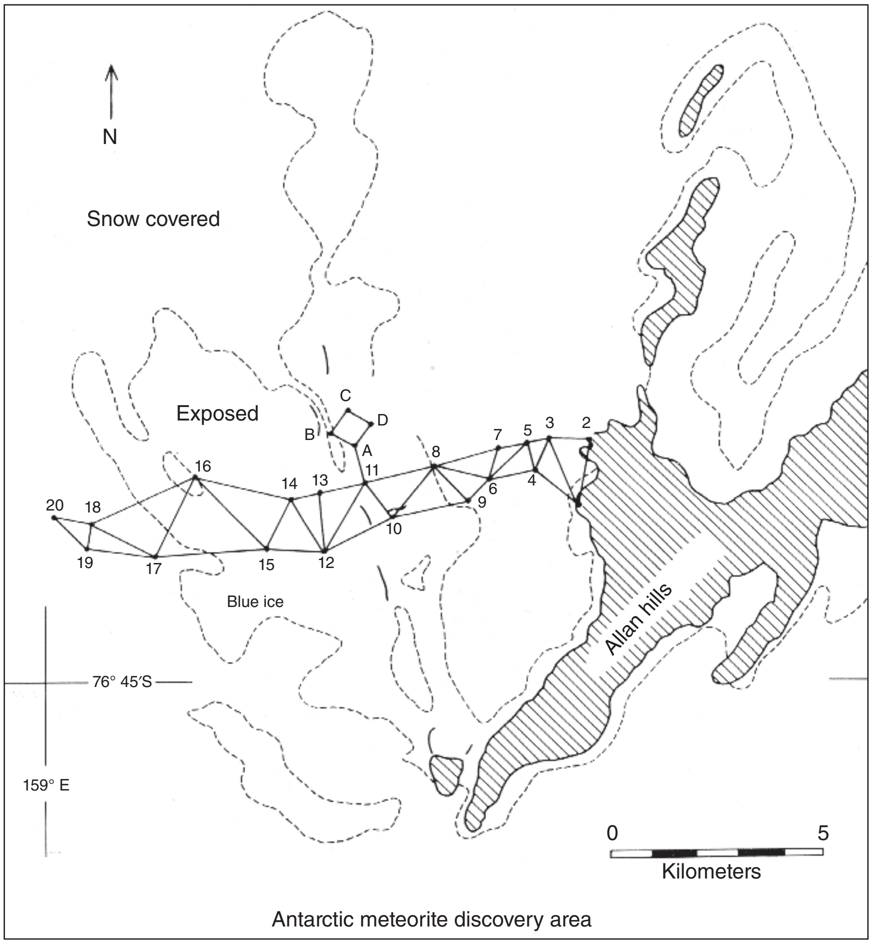

Figure 1.5. The geodetic network across the Main Icefield. Note Stations 1 and 2 on bedrock and the rest in auger holes bored in the ice. The small strain net with Stations A, B, C, and D was added three seasons after the original was completed. The meteorite distribution under the net is not shown.

plumbing, and an electric generator. There was a pad outside with three helos, one of which always was available for emergencies. A cook rustled up three meals a day for everybody.

On the high plateaus within helicopter range of the Darwin camp, Cassidy and Shiraishi found large patches of ice with no meteorite concentrations on them. They collected only eight stones up there. However, a major attraction at that site proved to be the scattered fragments of an iron meteorite that geologists from New Zealand had discovered and from which they had already recovered six fragments on the rocky, ice-free slopes of Derrick Peak. They radioed Bill to come and take a look, so searching jointly with them, Cassidy and Shiraishi found six more irons, which the Kiwis urged them to keep. All of these irons were coarsest octahedrites that appeared to lie in a strewnfield on the mountainside. One of these pieces was the enormous 160-kg iron that Bill found and photograped (Figure 1.6a; see also Plate 78).

After this run of remarkably good luck, Cassidy departed from the Darwin Camp, leaving Shiraishi to act as a guide for Dean and me when we would arrive there. On 20 December after a couple of days of being socked in at McMurdo, we took off from the ice at Williams field, next to Scott Base, in a Hercules LC-130, and flew to the Darwin Camp. There, I was happily surprised to discover that the chief scientist at the Darwin Camp was Dr. George Denton, who had been my best student back in 1960 when I was teaching mineralogy at Tufts College.

On 21 December, Shiraishi led us to a moraine near the head of the Darwin Glacier where there seemed to be nothing in view except a broad, closely packed assemblage of terrestrial boulders. I thought it would be helpful to look closely at a few of the boulders to get an idea of what sort of rocks were there. I reached out with my pick and pulled up a big stone at random, took it in my hands (which I should not have done), and saw that it was a meteorite! My first meteorite from Darwin was already

Figure 1.6a. The enormous 160-kg iron found and photographed by Cassidy on Derrick Peak.

Figure 1.6b. The 139-kg iron found by Shiraishi on Derrick Peak on 24 December. The iron is inside the helo cabin, with Shiraishi at the right of it and Clauter behind it.

contaminated! So I carried it with me when I went to join the others. By then, they had climbed down a steep hillside where Clauter had found a chunk of a fusion crust but no meteorites. When we got back to where we would meet our helo, we searched for more meteorites like the one I had found. Then, at the last minute, as the helo was descending, Shiraishi discovered a big stone similar to mine.

On the next afternoon, we found an ice patch on the Darwin glacier with 23 stones on it (21 of which appeared to be pieces of the same meteorite). We had to spend the next day, December 23, in camp because the helo time was all signed up for. So our next search took place on December 24, on the lower slopes of Derrick Peak. There, Shiraishi found one more rather small but nicely shaped iron. Then, just as the helo was landing, he (as was typical) spotted one more iron, but this one weighed 139 kg and was so heavy that both of the helo pilots helped Shiraishi and Clauter to lift it into the helo cabin (Figure 1.6b; see also Plate 78).

Christmas was upon us and all the field parties had come in and pitched their tents at the camp for the holiday. On Christmas Eve, a gale wind arose, but it subsided before morning, making way for a heat wave. At Darwin, the temperature climbed to −5° C and by December 31 it had broken all records at McMurdo: 9.4° C. Meanwhile, at 5:00 p.m. on Christmas Day, the cook served up a most royal feast: trays of cold oysters, shrimp, and lobster tails, three huge roasted stuffed turkeys with gravy and cranberry sauce, baked ham with fruit sauce, sweet potatoes, white potatoes, succotash, onions, fresh rolls, cornbread, and four kinds of pies. Wines were available if ordered in advance, but for those of us who had not known about putting in orders, there were plenty of wine bottles being passed around, and everyone was encouraged to sample any wines that appealed to them. It was a high-spirited celebration with much laughter and singing.

We spent the next day in camp with high winds and light snow and nothing flying. Bill called us by radio via the South Pole station to wish us happy holidays and ask how we were doing. He soon was leaving for the Allan Hills and hoped we would catch up with him there. We told him we planned to leave for McMurdo, carrying 26 stony meteorites and 8 irons on the earliest Hercules we could catch. He congratulated us and signed off. Then we palletized our samples to carry them off on a moment's notice.

I then learned that George Denton had arranged for me to fly over the huge Byrd Glacier on the 27th. He told me the Byrd is one of the few geological features on the Earth that can be seen from Mars. I think he was serious, but much as I would have liked to see the Byrd glacier, I could not risk being separated from my party when we were so close to leaving for McMurdo.

On December 30, we were awakened at 4:30 a.m. to get ready to leave the Darwin Camp on a Hercules. We had come on a Hercules, so we had no expectations of excitement. We dressed and had some breakfast before the plane landed close by with a great roar. It never shut off its motors while the captain handed over the mail he was carrying (he brought me two letters from Tom) and unloaded the cargo, including a much-needed fuel tank for use at Darwin. As soon as they loaded the new cargo, the three of us climbed aboard and settled into canvas seats held in place by netting. The Herc started forward and then, suddenly, we felt a frightful bumping and thumping and things falling to the floor. We stopped abruptly and the fight master ordered everybody back aft. Four Navy men and three of us USARP members squeezed past the cargo to the tail, where we lay on the tilted flap and were tied down with ribbons. Then we started up again with the same thumping and bumping. On the third try, we gained a little altitude and then kept climbing. Once we were securely aloft, we were directed to return to our seats. Forty minutes later we landed on the ice at Willy Field. Later that day at McMurdo, I described our takeoff to a woman pilot, who told me we had had a jet-assisted takeoff. Even so, it was no fun.

1.9.3. The Allan Hills

The Allan Hills camp was close to the edge of the Main Icefield, which made it easy to find and collect meteorites. I had a yellow Scott tent to myself, Dean and Bill shared one, and Shiraishi had his own tent. I had no stove for cooking because I was expected to have my meals with the others. This was a pleasure, considering Shiraishi's store of frozen foods from Japan. He particularly enjoyed munching on frozen Brussels sprouts as though they were candy. I had my own snowmobile and fully enjoyed it without realizing how lucky I was. This was the first season that the NSF had furnished snowmobiles to ANSMET members. Some people at McMurdo seemed to regard the new meteorite project as rather a bother, taking money and equipment away from more traditional pursuits. So, for the first two seasons, the ANSMET teams had to await helicopters to move long distances, and had to hike between close ones. This made no sense at all to our Japanese companions, who finally arranged for snowmobiles to be shipped directly to them from Japan. Suddenly, the NSF managers saw that they could not send ANSMET members out on foot, or as hitchhikers, alongside snowmobiles bearing the huge letters JARE. Thus we received our own snowmobiles for exploring the scene and carrying meteorites from the field to camp or pulling Nansen sleds for setting up temporary camps.

We made daily searches for meteorites on the Main Icefield, in a moraine on the western edge of it, and sometimes on the polar plateau beyond it. I found that the wind scoops around boulders almost invariably held small, cherry-sized stony meteorites, which, no doubt, had skittered across the ice in the wind and fallen into the scoops. A study of 145 of these cherry-sized stones, weighing less than 150 grams each, was published by *McKinley and Keil* [1984], who showed that although all of these stones were chondrites, they included some new and rare types. They found 19 specimens of a chondrite containing previously unknown intergrowths of graphite and magnetite in their matrixes. They also found one example of a new type of carbonaceous chondrite and two specimens of a rare enstatite chondrite.

Having 24 hours of daylight and a bright yellow-orange tent to live in suited me perfectly. I quickly found that being cold was no real problem, given padded clothing and a cozy sleeping bag. One night, I awoke about midnight and heard tremendous winds coursing down northward past my tent. This was something unusual so I snatched up my camera and burst out of the tent. There, I saw lines of snow and ice crystals sweeping over the low-lying end of the range and all along the ice sheet. The midnight Sun was shining over the highest peak of the Allan Hills so brightly that my light meter indicated I could not get a picture. I closed down the meter as far as it would go and snapped, expecting the worst. But in

Figure 1.7. The midnight sun on the Allan Hills at 12:15 a.m. 6 January 1979. A corner of my yellow tent is in the wind scoop at lower right. South is at the top of the picture.

Figure 1.7 we have the midnight Sun in full glory shining on the driven snow.

As noted above, Annexstad, Nishio, and Funaki, who had already left for home, collected 103 meteorites while setting up their geodetic network across the Allan Hills Main Icefield. At the head of the Darwin Glacier, including Derrick Peak, our party of four, Cassidy, Shiraishi, Clauter, and Marvin collected 8 irons from a single shower and 32 stones. At the Allan Hills camp, we collected 67 stones, making our total for the season of 204 stones and 8 fragments of a single iron.

1.10. CATALOGING THE HISTORY OF ANSMET

As was agreed at the November 11th meeting at the NSF, the Smithsonian members would report on each season's fieldwork and its harvest of meteorites. Brian Mason volunteered to write these reports, and then he persuaded me to join him. We styled them to be published in the well-established series *Smithsonian Contributions to the Earth Sciences.* However, from the first, we departed from the format of a standard catalog by including descriptive articles on field occurrences, collection and curation procedures, measurements of ice motion, terrestrial ages, and overviews of selected meteorite species. We dropped the name *catalog* altogether from issue Number 26 that described the 1981–1982 season.

In summary, Brian and I published the following issues of the *Contributions:* Number 23, on season 1977–1978; Number 24, on seasons 1978–1979 and 1979–1980; and Number 26, on seasons 1980–1981 and 1981–1982. Then Brian retired from this effort and was succeeded by Glenn MacPherson of the Smithsonian Natural History Museum, who contributed to Number 28, which reported on seasons 1982–1983 and 1983–1984. By then, we both found this to be an overwhelming assignment on top of our other responsibilities. We also realized that the *Antarctic Meteorite Newsletter*, which was issued and distributed by the curatorial staff at the Johnson Space Center, was fulfilling the needs of scientists in a much more timely fashion than we ever could. Thus ended the ANSMET series of *Smithsonian Contributions to the Earth Sciences.*

1.11. ANSMET: WELL ESTABLISHED BY 1980

By the end of its third season, ANSMET had become highly successful at carrying out this new mode of scientific inquiry. It would continue to do so for going on four decades, adding to the list of meteorite concentrations in Antarctica and, needless to say, adding thousands of meteorites, some of which were new to the science but would now become available to the international community.

Several changes to the procedure lay directly ahead: 1978–1979 was the final season in which Japanese members would take part in the fieldwork and share meteorites with ANSMET. The NSF soon would abandon the use of military cargo planes and negotiate government discounts to send its scientists to New Zealand via scheduled airlines. Cassidy remarked that the main advantage to this change was that passengers would arrive in Christchurch with smiles on their faces. In 1980–1981, Cassidy added to the team Ludolf Schultz of the Max-Planck-Institut für Chemie at Mainz, the first of numerous team members from Europe. He also acquired a highly skilled crevasse expert, John Schutt, who quickly became adept at recognizing meteorites and sometimes authored or coauthored seasonal reports for the *Catalog*s. Schutt remained with ANSMET for more than three decades, and his services were recognized in 2008 by the awarding of a well-deserved honorary Doctor of Science degree by Case Western Reserve University.

But the most exciting and significant event in the early history of ANSMET would occur on 18 January 1982, when John Schutt guided a visiting glaciologist, Ian Whillans, to the Middle Western Icefield and they found a lunar meteorite! Inasmuch as we have seen that Cassidy had included the possibility of finding lunar meteorites in his original proposal of 1974, we will extend this early history long enough to include that event.

1.12. ANSMET SEASON IV: 1979–1980

In that season, Bill Cassidy; John Annexstad; Lou Rancitelli of Batelle Memorial Institute at Columbus, Ohio; and Lee Benda, a crevasse expert from the University of Washington, conducted an expedition northward from the Allan Hills to Reckling Peak to check out a stretch of bare ice 100 km long by 3–5 km wide that extends westward from Reckling Peak. A year earlier, Philip Kyle of Ohio State University had visited this area and found five meteorites near Reckling Peak. The Allan Hills lie at the limit of helicopter range from McMurdo, so Cassidy's party had to make this trip by towing Nansen sledges, packed with camping equipment, behind their snowmobiles. They left the Allan Hills on 5 January and drove 24 km northward, carefully skirting crevasses before setting up Windy Camp, where they spent two days due to high winds and low visibility. On 8 June they broke camp and drove 32 km farther north and up a rather steep slope to the vicinity of Reckling Peak. There, crevasses became so large and numerous that the party stopped and erected Crevasse Camp for rest and relaxation. The next day they turned westward and carefully made their way downslope until they reached bare ice. There, they used snowmobiles in tandem to lower each Nansen sledge: one snowmobile in front, pulling and steadying, and one in the rear, braking. At the bottom they were on a part of the 80-km strip of bare ice where they found traces of Kyle's trail markers. Nearby, they found a clear, snow-covered spot adjacent to a moraine and set up Moraine Camp, about 12 km west of Reckling Peak. During a day and a half at Moraine Camp they recovered 13 meteorites.

Traveling westward along the northern edge of the ice patch, they soon were off the bare ice and thus learned nothing about whether the entire ice strip has meteorites on it. However, at a point about 65 km west of Reckling Peak they found a second large moraine, which they called Elephant Moraine, for its rounded form and long protuberance reminiscent, from the air, of an elephant's trunk. There, they built a camp and found 12 more meteorites. In the future, Elephant Moraine would prove to harbor a rich concentration of meteorites, but on that first visit, they turned southeastward toward a site they called Carapace Camp. They found no meteorites there, but it was not far from the Allan Hills, so they were picked up by a helicopter and flown back to the Allan Hills camp.

On their Reckling Peak traverse they collected a total of 26 specimens representing no more than 15 falls. These included two rare types: one iron meteorite and three achondrites, one of which was a shergottite (EET A79001; Plate 70), which we now classify as a rock from Mars. They found no large concentrations but concluded that the Reckling Peak and Elephant Moraine areas would be well worth another visit in the future.

1.13. ANSMET SEASON V: 1980–1981

Cassidy began his report of this season by pointing out that the team already knew of the major concentration of meteorites on the Allan Hills Main Icefield, and of lesser concentrations on the Near Western Icefield, Reckling Moraine, and Elephant Moraine. Now they were eager to investigate new sites in hopes of locating additional concentrations to be exploited in future seasons. Accordingly, in 1980–1981 they emphasized reconnaissance while devoting as little time as possible to collecting enough meteorites to assure a successful season.

That season, the participants were Bill Cassidy, John Annexstad, John Schutt, Lou Rancitelli, and Ludolf Schultz, plus two new members: Harry "Hap" McSween, a professor of geology at the University of Tennessee, and Joanne Danielson, a student at the University of Pittsburgh.

They collected 32 specimens at the Allan Hills Main Icefield (which had begun to serve as a reliable bank account), and then traversed back to Reckling Moraine, where they had to repeat the tandem lowering of their supply-laden Nansen sledges down over the steep slope to the 80-km strip of ice. Cassidy concluded that this ice strip is associated with a bedrock barrier, parallel to its long dimension, over which ice spills down the east-facing slope, just as it does down the "monocline" that bounds the Allan Hills meteorite concentration on the west. This return to Reckling Peak yielded 32 more fragments: 30 chondrites, one iron, and one achondrite, making a seasonal total of 62 specimens.

At Reckling Moraine they received an air-drop of eight drums of snowmobile fuel, which enabled them to travel further northward to new sites that were seen from the air to include ice patches. These were Outpost Nunatak, Griffin Nunatak, Brimstone Peak, Tent Rock, and Sheppard Rocks. To their disappointment, none of these sites had any meteorite concentrations, and the party collected only one isolated meteorite specimen near Outpost Nunatak. Cassidy wrote that the net result of this exploration was to give them a greater understanding of conditions under which concentrations do and do not form.

1.14. ANSMET SEASON VI: 1981–1982

This season is remembered as being, by any measure, a highly successful one. The activities were planned by Cassidy, but after he got things well started, he left to spend Christmas at home for the first time in five years. The team included Annexstad, Schultz, Schutt, myself, and two new members: Ghislaine Crozaz of Washington University at St. Louis, and Robert Fudali of the Smithsonian's National Museum of Natural History in Washington. For three of us, Crozaz, Fudali, and me, the season began on 29 November 1981 at the airport in Los Angeles, where we found a gate serving travelers associated with the U.S. Antarctic Program (USARP) and boarded a scheduled flight to Auckland, New Zealand. From there we flew to Christchurch (Figure 1.8) and visited the botanical garden, among other places. As the time approached to leave for McMurdo, we selected our Antarctic clothing (although Ghislaine and I already had our own parkas) and packed it all into the huge orange waterproof cloth bags that had proven to be very useful when camping on the ice (Figure 1.8). At McMurdo, we moved into the small dormitory and dined at the mess hall until it was time to leave for our assignments.

1.14.1. A Second Remeasurement of the Geodetic Net at the Allan Hills

Two members of this season's party, Ludolf Schultz and John Annexstad, had arrived at the Allan Hills on 15 November and set up their camp in the triangular space between stations 6, 7, and 8 of the network. They began remeasuring, for the second time, the horizontal displacement and degree of ablation at each of the 18 stations on the ice of the network. They planned to extend the network

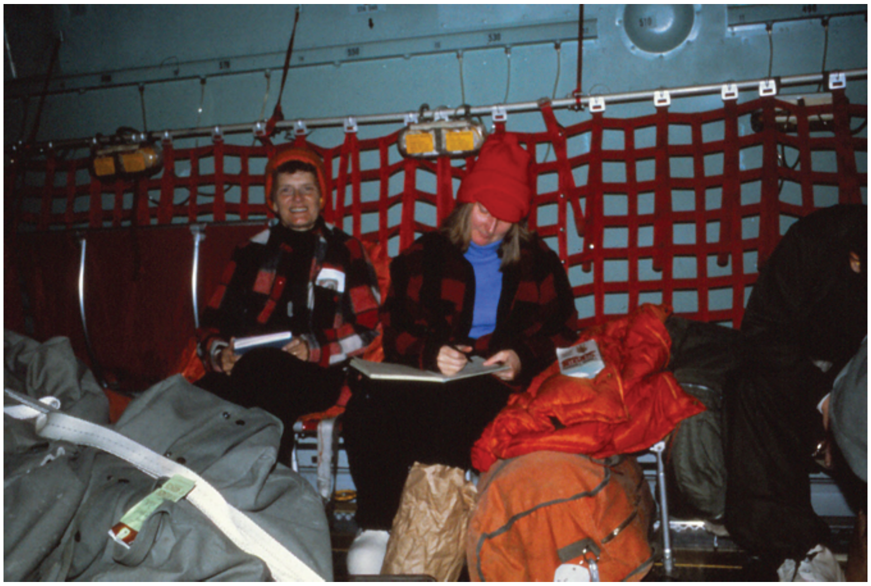

Figure 1.8. Marvin (left) and Crozaz (right) in the C-141 Starlifter en route from Christchurch to McMurdo.

Figure 1.9. Measuring the 5-cm ablation of ice at a flagpole of the geodetic net.

a short distance westward. However, a succession of storms that barely allowed them to complete their measurements prevented them from making an addition at that time. They left the field on 13 December.

Schultz and Annexstad reported the following results: the ablation rate of the ice at the Allan Hills Main Icefield averages about 5 cm per year (Figure 1.9). This serves well to expose new meteorites that have been frozen within the ice. Their measurements of horizontal ice displacement since 1978 indicated that ice moves rather rapidly eastward from the western plateau toward the Allan Hills, but it slows down and becomes stagnant at the foot of a steep slope that leads to a narrow flat-bottomed valley about 4 km wide. On its icy surface, it holds the meteorite concentration. Concentrations like this one develop most readily on ice that has no outlet but loses volume due to ablation of its exposed surface.

1.14.2. The North Victoria Land Camp

In 1978–1979, the NSF had built a season-long field camp, similar to the Darwin Camp, to serve several projects in North Victoria Land (NVL), 600 km north of McMurdo Station. John Schutt and Bob Fudali arrived at the NVL Camp on 24 November to carry out reconnaissance of ice patches that were visible on air photos. They also planned to visit a small circular feature at Littel Rocks to determine whether it could be an impact crater. They made numerous helo flights over ice patches that were strewn with rocks, but frequent stops revealed that the rocks were terrestrial, with no noticeable meteorites among them. When they left the area, they reported that they could not declare there were *no* meteorites in the rocky debris at NVL, but using their best efforts they did not find any.

The crater at Littel Rocks proved to be a former lake that had been overridden by ice more than once. They found no sign of impact features associated with it. So Schutt and Fudali returned to McMurdo.

1.14.3. A Visit to Granite House

Before the season began, I had persuaded Bill Cassidy by telephone to request a helicopter flight to Granite House, a historic edifice that was built in 1911 by four members of Scott's expedition, led by Griffith Taylor, who were mapping the coast of Victoria Land. When they exhausted their kerosene, they fashioned this structure out of natural ledges and boulders to spare a tent from being used for cooking with an oily, smelly, frequently boiling over blubber stove. Finally, they mounted one of their sledges across the top as a roof-tree and covered it with seal skins. They named it Granite House after the edifice in Jules Verne's book, *The Secret of the Island*, which they were carrying with them. Granite House never was a comfortable place for relaxing, but it served its purpose as a kitchen well enough.

Taylor and his group were expecting to be picked up by the ship *Terra Nova* about 15 January 1912, but the sea ice never broke out that season, so by mid-January they decided they must abandon their camp and make their way back at least as far as Cape Roberts, 14.5 km away at the entrance to Granite Harbor. They reclaimed the roof-tree sledge and stacked it with about 260 kg of specimens, including some unique Gondwana fossils, plus extra clothing, books, and tins of food to be recovered later. They then used their better sledge for carrying their needs with them. At Cape Roberts, they found the sea ice stretching toward the horizon, so they lightened their load once again by building a cache with their remaining possessions and tins of food they thought they could do without. Fortunately, their food cache saved the life of Frank Browning, a member of a five-man group that had been forced to winter over for two successive years on short rations. Taylor's group then proceeded southward along the shoreline toward their headquarters at Cape Evans, 160 km away. They were in luck: eight days later, on 14 February 1912, they were sighted from the *Terra Nova,* which sent a boat to their rescue. Within the following year, two colleagues revisited Granite House and brought back their specimens and books and other personal possessions [*Marvin*, 1983].

Granite House had no known visitors for the next 46 years. Then, in November of 1946, Professor Robert L. Nichols of Tufts College and three of his students stopped there in their man-hauling expedition from McMurdo. They took numerous photographs and made an inventory of all the items they found at Granite House. The pictures proved to be of special interest to me because one of them showed a stone that looked remarkably like a meteorite on the ledge behind Granite House. It was about 25 cm across, subangular, and mostly black except along the edges where its light interior was exposed. I had an enlargement made of the meteorite picture and mounted it among the posters at the March 1981 Lunar and Planetary Science Conference in Houston. Beside it, I posted a blank sheet asking for comments. The picture elicited much interest. A few viewers wrote that it surely was a meteorite, or probably was a meteorite. A few words of caution also were expressed, but a strong majority wrote that it must be examined in the field. (Unfortunately, my picture, which I carried to McMurdo, was irretrievably lost in transit.)

At about the same time that Cassidy requested a helicopter trip to Granite House, two young historians from New Zealand's Scott Base also requested one. So on 19 December 1981, a helicopter carried me, Ghislaine Crozaz, Bob Fudali, and two Antarctic historians, Jack Fry and Jerry Turner, on a brief afternoon visit to Granite House. As we circled over Granite House, the stone still looked like a meteorite, but on the ground, that vision faded quickly. We found a light-colored granite boulder with a dark surface over most of it. This was, of course, a disappointment to me. But Granite House with or without a meteorite was well worth a visit, and since I recently had been told it had become a tourist attraction subject to vandalism, I was pleased to learn that it was being properly documented by New Zealand historians who were devoted to the preservation of historic Antarctic huts.

1.14.4. The Allan Hills, Continued

On 13 December after remeasuring the location of each station of the geodetic network across the Allan Hills Main Icefield, Schultz and Annexstad left for home. About one week later, on 22 December, Schutt and Crozaz moved into the camp. Fudali and I joined them in the next available helicopter, which arrived late in the morning of 24 December when we all changed partners in the tents. That afternoon, John Schutt guided us to nearby Man Haul Bay, where exposures of Permian coal and shale beds contain petrified wood and *Glossopteris* seeds and leaves. Man Haul Bay is the open space formed by the Y-shaped arms of the Allan Hills. It is icy enough to allow easy access to the fossils. Afterward, with the Sun still shining, we all celebrated Christmas Eve with nips of Scotch whiskey, an excellent dinner, much singing, and Fudali on the harmonica.

On Christmas Day, we started measuring the force of gravity at each marker in the geodetic network, which by then consisted of 24 stations. This procedure required readings, at each station, of a gravimeter, an altimeter, and a thermometer. We completed these three measurements at 19 stations, leaving 5 more for the next day. When we finished the stations on the net, we measured 8 more stations on bedrock along the Allan Hills, including one on the top of Peak 2330, which stands like a beacon at the southern end of the range. The whole party climbed the peak. We then moved on to nearby Carapace Nunatak, which has its own small icefield. Carapace is a stunning sight with vertical crenulated cliffs of pillow lavas and paragonite lenses. Geodes are plentiful at its base, but we found no meteorites there.

The results of the gravity survey, reported by *Fudali and Schutt* [1984, p. 26], show the bedrock just above ice level at Stations 1 and 2 sloping gently down westward under the ice for about 110 km from both stations. But the two profiles are not identical. The profile beginning at Station 2 shows a slight dip in the bedrock under the valley holding the meteorite concentration. It loses 500 meters in its first 3.5 km, then the bedrock rises 250 m in the next 2.5 kilometers, and finally it slopes steadily downward to a depth of 750 meters under Station 20. The dip is not repeated in the second profile, from Stations 1 to 19, where the bedrock slopes gently westward with only a slight flattening after the first 2.5 km.

1.14.5. Systematic Sweeping of the Allan Hills Icefields

A major advance in field surveys, begun in this season, was the systematic sweeping of icefields. In a systematic sweep, three or more steel-cleated snowmobiles line up abreast, several meters apart, and drive straight ahead in a given direction, with each driver examining the ice on both sides. At the end of the first traverse, all snowmobiles reverse their direction. The driver who occupied one edge of the group (often the right-hand edge) simply pivots in place and follows his or her own track back to the starting line. The others line up at appropriate distances beyond that one and drive to the starting line. Sweeps continue to be made until the area of interest has been completely searched. This technique is a very efficient way to spot meteorites down to a few millimeters in size.

In the area to the west and southwest of the Allan Hills Main Icefield lie three icefields called the Near Western, Middle Western, and Far Western Icefields. In addition, there is the Battlements Nunatak Icefield, which lies north of the Main Icefield (See Figure 1.10).

The Main Icefield is about 22 km long and encompasses some 75 km^2 of blue ice. The Near Western Icefield consists of five separate ovoid patches lying about 18 km NNW of Peak 2330 and includes more than 14 km^2 of bare ice. The Middle Western Icefield lies 31 km WSW of the Peak and consists of 30 km^2 of ice. The Far Western Icefield is larger than the Main Icefield, being more than 40 km long and 2 to 8 km wide with an area of more than 100 km^2. A planned reconnaissance of that large field was cancelled for this season because of poor weather and insufficient time. It seems very possible that all of these icefields are the currently exposed portions of one gigantic field separated by variable zones of snow cover. Changes in wind patterns and drifting snow, together

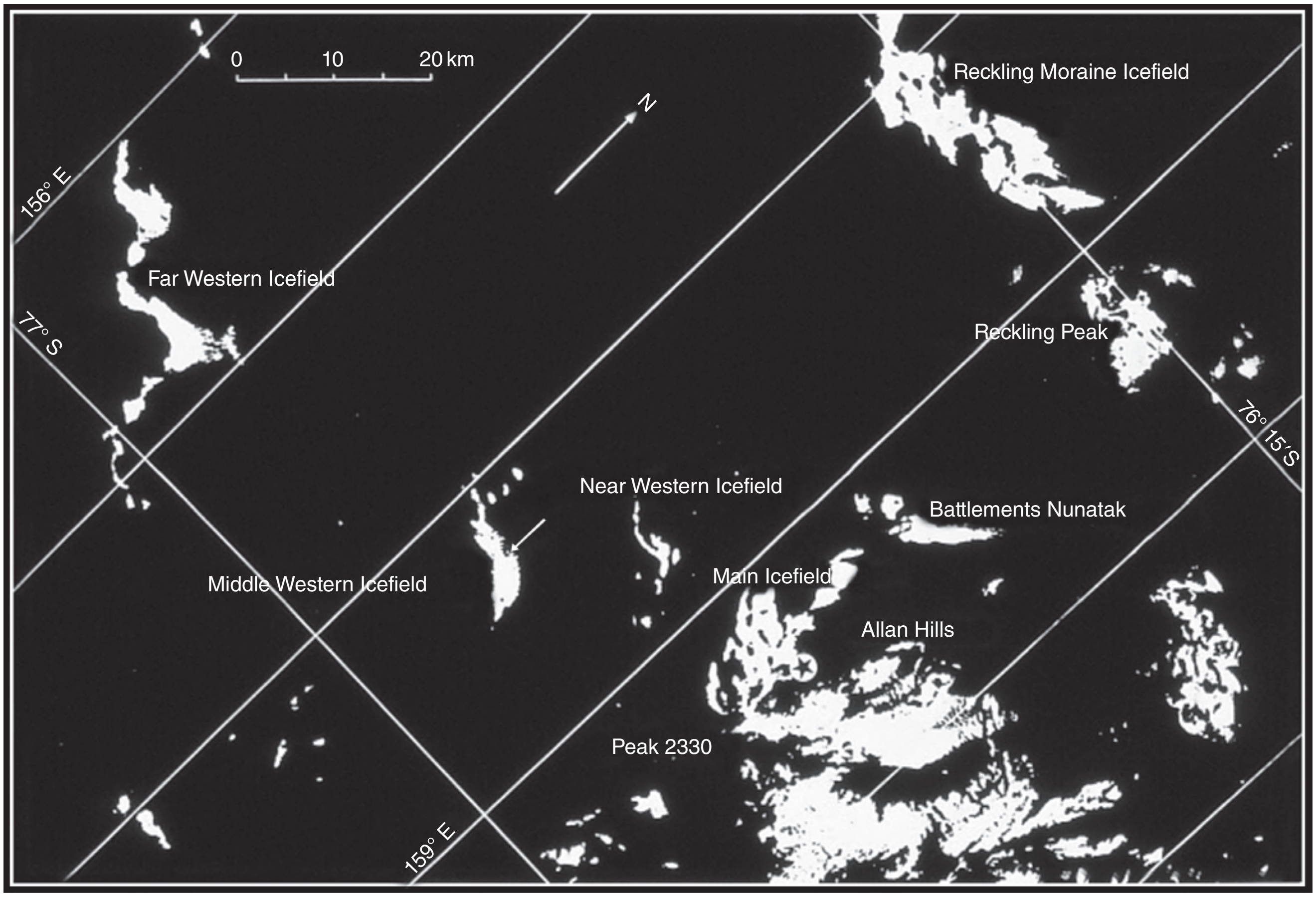

Figure 1.10. The icefields to the west and north of the Allan Hills.

with ablation, may ultimately reveal fresh exposures of ice dotted with meteorites covering this entire area.

The Battlements Nunatak Icefield lies about 10 km north of the Main Icefield. It is composed of two small ice patches a short distance west of the Nunatak and one long, narrow ice patch that extends northeastward for 12 km. The terrain south of the Nunatak is so badly crevassed that no visit to it had been made until this season, when team members Schutt and Fudali found a way through Battlements Nunatak and discovered the ice sheet beyond it to be strewn with terrestrial rocks with no readily visible meteorites mixed in with them. It resembled the patches they had seen in North Victoria Land. Although they found no sign of a meteorite concentration, they recommended that it should be visited again and studied with more care.

During this season, the flagging and mapping of meteorite finds was applied for the first time to create location maps that have since proven to be invaluable in solving pairing problems. In addition, oriented blocks of ice were collected for petrographic studies by Ian Whillans at Ohio State University. Ian spent the last 10 days of the season at the camp.

Schutt, Fudali, Crozaz, and I spent two and a half days sweeping the Near Western Icefield, where we collected 78 specimens (Figure 1.11). When paired, these represented at most 24 meteorites. Fifty-two of the specimens were weathered and appeared to come from one individual. These strongly resembled 30 fragments collected at the same site in previous years. Schutt and Fudali spent one day searching the Middle Western Icefield, where they collected 14 specimens, 11 of which were paired. They found and flagged several more.

On 5 January, Bill Cassidy arrived back at McMurdo after enjoying Christmas at home. He came to the Allan Hills camp on 7 January, when we had about two more weeks to go. The first of these weeks was a very busy one spent collecting, flagging, and searching new areas. 14 January was an exceptionally fine day when we were looking forward to the arrival on the next day of Ian Whillans, hoping he would tell us all about the ice regime governing our icefields. At the end of the day when we arrived back at camp, I got off my snowmobile and started to toss its cover over it. The wind caught the cover and I lunged for it, not knowing that my left foot was wedged into the strut of the ski on my snowmobile. As I was twisted and thrown to the ground, I heard a crack and immediately was in pain. That ended my second sojourn at the Allan Hills. The following day, the helo that brought Ian Whillans to camp carried me to the infirmary at McMurdo, where x-rays showed that I had a spiral fracture of my left leg bone (fibula). Such a fracture is not serious, and the pain had ended long since, so with a proper walking cast and a cane for balance, I was told I could walk around McMurdo. I was walking around home via Los Angeles within 12 days.

1.14.6. "ANSMET Finds a Lunar Sample"

This is the heading that *Bill Cassidy* uses in his book [2003, p. 147] to introduce this topic. Bill led Ian Whillans through the Main Icefield, where they did some coring

Figure 1.11. Schutt takes notes while Marvin examines a small meteorite on the Near Western Icefield. Crozaz snapped the picture.

and mapping of find sites. Then, on 18 January, Ian wanted to see the Near and Middle Western Icefields, so the whole group rode to the Near Western and proceeded to search systematically and collect meteorites. Snow began coming down about noon so Cassidy, Crozaz, and Fudali rode back to camp while John Schutt guided Ian Whillans to the Middle Western Icefield. There, at the edge of the ice, they noted a small stone about the size of a golf ball (See the arrow pointing to the edge of the Middle Western Icefield in Figure 1.10). Schutt, who was keeping the notes, described the stone:

> #1422—Strange meteorite. Thin, tan-green fusion crust, ~50%, with possible ablation features. Interior is dark grey with numerous white to grey breccia (?) fragments. Somewhat equidimensional at ~3 cm.

They went on to collect 10 more meteorites, but that first one made history. It would prove to be the world's first recognized meteorite from the Moon. Some reports honor John Schutt as the finder and some pass the baton to Ian Whillans. In fact, they discovered it together. When the stone arrived in Houston, months later, it was seen by some of the world's leading experts on lunar rocks. They assigned to it the number ALH A81005 (Figure 1.12; see also Plate 64). When Brian Mason saw the thin section, he put in writing what many had been thinking: "Some of the clasts resemble the anorthositic clasts described from lunar rocks." There it was, all 31.4 g of it, almost certainly a meteorite from the Moon, but specific measurements would be required to prove it.

Cassidy, who was chairing the Meteorite Working Group, realized that numerous members of that committee would submit requests for a research sample, which meant there would be a series of absences while their requests were discussed. So he decided to form an ad hoc committee of scientists who were familiar with meteorites and lunar rocks but did not intend to submit sample requests. On 4 December 1982, Cassidy held a special meeting in Houston to assess which lines of research would be the most definitive of lunar origin. Of the requests for samples submitted to the committee, those that were granted proposed to investigate one of the following six lines of research: oxygen isotope ratios, noble gas measurements, cosmogenic nuclides, nuclear particle tracks in feldspar grains, neutron activation analysis, and rare-earth element analyses. The committee itself solicited two more studies: measurement of the magnetic properties of several small chips, and passive counting of a major piece of the specimen for aluminum-26, which indicates how long a meteorite has been lying on the Earth's surface. It sounds like a lot of material, but the total weight of the eight samples allocated summed up to 2.6 g.

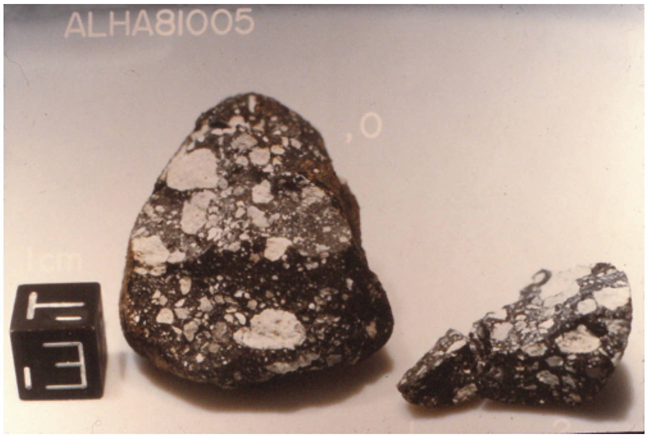

Figure 1.12. The lunar meteorite ALH A81005 after one chip has been taken off at Houston. (NASA photo)

At the annual Lunar and Planetary Science Conference, held in Houston in March of 1983, 16 scientists presented evidence that this was a lunar meteorite. In his book [2003] on page 158, *Cassidy* reports that at the end of a long session of papers supporting a lunar origin, Randy Korotev of Washington University at St. Louis announced that he would like to present some evidence for why we believe ALH A81005 is *not* from the Moon. A hush fell over the room. Then Randy added: "Unfortunately, we were unable to find any such evidence, so I will have to talk about something else."

The very existence of even one meteorite from the Moon forced new lines of thought in planetary science. No longer could it be argued that lunar craters could not be due to meteorite impacts. Nor could it be argued that inasmuch as we have no meteorites from the nearby Moon, we certainly cannot have any from Mars. And it weakened the argument that the force of an impact required to send a martian meteorite into an earth-crossing orbit would totally destroy the rock. In fact, rather quickly after the verification of ALH A81005, studies redoubled of the strangely youthful, 180 million to 1.3 billion (instead of 4.5 billion) -year-old meteorites called shergottites, nakhlites, and chassignites until it was demonstrated that bubbles in the glass of EET A79001 (Plate 70) contain the martian atmosphere.

Some meteoriticists saw this Antarctic expedition as being of equal importance to an *Apollo* Mission, two of which had been cancelled within the previous year.

With the *Apollo* 18 mission cancelled,
the ANSMET expedition of 1981–1982
to the Allan Hills of Antarctica
collected lunar meteorite
ALH A81005
and changed the history
of planetary science.

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