Cambridge University Press
978-1-107-40391-8 - Meteorites, Ice, and Antarctica
William A. Cassidy
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Introduction

The Yamato Mountain Range wraps the ice sheet around its shoulders like an old man with a shawl. Ice coming from high off the ice plateau of East Antarctica, arriving from as far away as a subice ridge 600 km to the south, finds this mountain range is the first barrier to its flow. The ice has piled its substance up against the mountains in a titanic contest that pits billions of tons of advancing ice against immovable rock, whose roots extend at least to a depth of 30 km. The ice is moving because billions of tons of ice are behind it, pushing it off the continent and into the sea. Ultimately it yields, diverging to flow around the mountains. On the upstream side the rocks have been almost completely overwhelmed – only pink granite peaks protrude above the ice, which spills down between and around them in tremendous frozen streams and eddies, lobes, and deeply crevassed icefalls. The change in elevation of some 1100 m between the high plateau upstream of the mountains and the lower ice flowing away from the downstream slopes creates a spectacular view of this giant downward step in the ice surface. Almost constant howling winds from the interior blow streamers of ice crystals off the mountain peaks and "snow snakes" dance down the slopes in sinuous trains, as if somehow connected to each other. The scale of the scene is such that people become mere specks in an awesome, frigid emptiness.

In 1969, a group of Japanese glaciologists were specks in this scene. With all their supplies and equipment, they had traveled inland 400 km from Syowa Base, on the coast, to reach the Yamato Mountains (called the Queen Fabiola Mts. on most maps) and carry out measurements on the velocity of ice flow, rate of ablation and ice crystallography. Their safety depended on the reliable operation of two tracked vehicles in which they ate, slept and waited out the storms. These scientists were physically hardy and highly motivated. Because the Japanese supply ship could reach Syowa base only in the middle of summer, when parties had already left for the field, they had already wintered over at Syowa Base and would spend another winter there before being able to return to their families, just so they could spend the four months of antarctic summer at this desolate place, gathering fundamental data along the margin of a continental ice sheet. One of them, Renji Naruse, picked up a lone rock that was lying on the vast bare ice surface and recognized it as a meteorite.

In the preceding 200 years only about 2000 different meteorites had been recovered over the entire land surface of the earth, and finding a meteorite by chance must be counted as extremely improbable. It's lucky, therefore, that this initial discovery at the Yamato Mountains was made by a glaciologist, who would not be expected to have a quantitative understanding of exactly how rare meteorites really are, and of what a lucky find this should have been; Naruse and his companions proceeded to search for more. By day's end they had found eight more specimens in a 5×10 km area of ice – a tiny, tiny fraction of the earth's land surface.

Until that time, such a concentration always represented a meteorite that had broken apart while falling through the earth's atmosphere, scattering its fragments over a small area called a strewnfield. In such a case, all the fragments are identifiable as being of the same type. In this instance, however, all nine meteorites were identifiably different, and so were from different falls. A meteoriticist would strike his forehead with the palm of his hand, in disbelief.

Naruse and his companions undoubtedly were pleased with this unexpected addition to their field studies but there is no record that they immediately attached great significance to the find. They bundled up the specimens carefully, for return to Japan, and then resumed the ice studies that had drawn them to this spot. The ice at the Yamato Mountains, however, was destined for great fame, not for its glaciology but for the thousands of meteorites that would later be found on its surface. One might say that the Yamato Mountains icefields were *infested* with meteorites.

This book is about what some of us did about that discovery, how we did it, what we thought while we were doing it, and what the effects have been on planetary research.

Part I Setting the Stage

Antarctica is the best place in the world to find meteorites, but it is also a singular place in many other ways. In Part I, while I outline the manner in which the Antarctic Search for Meteorites (ANSMET) project came into being, I also describe our field experiences as untested beginners, discovering the hardships and dangers of this special place in the world, as well as our slowly growing awareness and appreciation of its alien beauty. Antarctica is a *presence* in any scientific research conducted there, imposing its own rules upon what can and cannot be done, how things can be done, and what the cost is for doing those things. At the same time, it rewards the dedicated field person, not only in yielding scientific results not available anywhere else in the world, but with a headful of wonderful memories, startling in their clarity, of snow plumes swept horizontally off rocky peaks like chimney smoke in a strong wind; of poking a hole through a snowbridge and marveling at the clusters of platy six-sided ice crystals that have grown in the special environment of a crevasse below the fragile protection of a few centimeters of snow; of emerging from one's tent after a six-day storm to find the delicate snow structures randomly sculpted by a wind which, while it was churning furiously through camp, seemed to have no shred of decency about it, much less any hint of an artistic impulse; of returning late one evening after a 12-hour traverse to a campsite occupied earlier in the season, when the sun makes a low angle to the horizon and we camp beneath a tremendous tidal wave of ice with its downsun side in shadow and displaying every imaginable shade of blue, and, having been there before, learning again the pleasant feeling of having come home.

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1 Antarctica and the National Science Foundation

THE CONTINENT

Antarctica occupies about 9% of the earth's total land surface. For this to be true, of course, you must accept snow and ice as "land surface," because this is what mainly constitutes that part of the continent that lies above sea level. Think of the antarctic continent as a vast convex lens of ice with a thin veneer of snow. In contrast to the region around the north pole, which is just floating ice at the surface of the ocean, the antarctic ice lens rests on solid rock. In most places the ice is so thick, and weighs so much, that it has depressed the underlying rock to about sea level. If the ice melted completely, the surface of the continent would rebound over a long period of time until its average elevation would be higher than any other continent. As it is, the ice surface itself gives Antarctica a higher average elevation than any other continent.

It is only in a very few places, where mountains defy the ice cover, that we can directly sample the underlying rocks. Most of these places are near the coast, where the ice sheet thins. At the center of the continent the elevation is about 4000 m. At the south geographic pole, which is not at the center of the continent, the elevation is 3000 m.

This ice ocean is both vast and deep. Except near the coast, total precipitation averages less than 15 cm of water-equivalent per year, so Antarctica is by definition a desert. It has accumulated such a great thickness of ice by virtue of the fact that whatever snow does fall, doesn't melt. Antarctic ice comprises about 80% of all the fresh water on the earth's surface. This great mass of ice is not contained at its margins, so as it presses downward it ponderously moves outward, creeping away from its central heights toward the edges, thinning and

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losing altitude as it spreads out, but partly replenished along its way by sparse precipitation.

We have marked the southernmost point on earth with a pole surmounted by a silvered sphere, of the type sometimes seen on well kept lawns or in formal gardens. But ice is moving past the geographic south pole at a rate of 10 m per year, so every few years we must get the pole and bring it back to its proper location. The problem is less tractable for South Pole Station itself. It slowly drifts away with the ice and at the same time sinks ever deeper as the yearly snowfalls impose their will. As a result, we have a string of several buried former South Pole Stations marking the particular flow line that passes through the south pole. They are accessible for a while, but as they go deeper below the surface they are ultimately crushed flat, or invaded and filled by ice.

Field conditions in Antarctica are extreme; more so the closer one approaches the south pole. The areas where we work are typically at 2000 m elevation. In these areas and at the times of year during which we are in the field we expect temperatures ranging between −10 and −25 °C. In still air, with proper clothing and a high-calorie diet, these temperatures are quite tolerable. In moving air they are less so.

We are in Antarctica during the relatively more balmy months of the austral summer: November, December, and January. This is also a time of continuous daylight: suppose when you emerge from your tent in the morning, the sun is shining directly on the entrance. It will be at an elevation in the sky that I would read as around 10 a.m., if I were home in Pennsylvania. During the following 24 hours, due to the rotation of the earth, the sun will appear to make a complete circle of the tent, but will always give the impression that the time of day is around 10 a.m. Actually, at "night" it will appear to be around 9 a.m., changing its angle of elevation a little because we are not exactly at the south pole. But it never sets during the summer season. Knowing this does not mean that we immediately adjust to this new set of conditions. Many times we leave our camp when the atmosphere is hazy, and I find myself thinking, "Well, this fog will burn off as soon as the sun comes up." And the sun has been up for two months!

In the past, territorial claims have been made in Antarctica by Argentina, Australia, Chile, France, New Zealand, Norway and the United Kingdom. Because of sometimes overlapping claims, about 110% of Antarctica was divided up, in pie-shaped areas that converged to points at the south pole. The exception to this was Norway, whose claim stopped at 85° S and looked like a piece of pie that someone had begun to eat. Of the seven countries claiming territory, only Norway stopped short of the south pole, and she seemingly had more right than anyone else to claim it because the Norwegian explorer Roald Amundsen had been the first to reach the south pole.

In an effort to reduce tensions over the expressions of nationalism represented by territorial claims, the claiming nations were persuaded to set aside their aspirations temporarily and, with six other nations, to sign an international accord: the Antarctic Treaty. This treaty has by now been acceded to by 45 nations, and 27 of these are conducting active research programs there. The treaty provides for unhindered access to any part of Antarctica by any signatory nation for scientific purposes. The United States (US) is a signatory nation but makes no territorial claim. We have a large and continuing scientific effort in Antarctica that is supervised by the National Science Foundation (NSF).

MCMURDO STATION

The US has permanent year-round research bases on Ross Island (*McMurdo Station*), at the South Pole (*Amundsen–Scott South Pole Station*), and on the Antarctic Peninsula (*Palmer Station*) (see map, Fig. 1.1). By far the largest of these is McMurdo. At 77° 30′ S, it is admirably sited for scientific work, being as far south as is practical for late-summer access by small ocean-going vessels aided by an ice-breaker, so that yearly resupply missions can be relied upon. It is at the land–sea interface, where the specialized fauna of Antarctica are concentrated and are most accessible for study. It is on a volcanic

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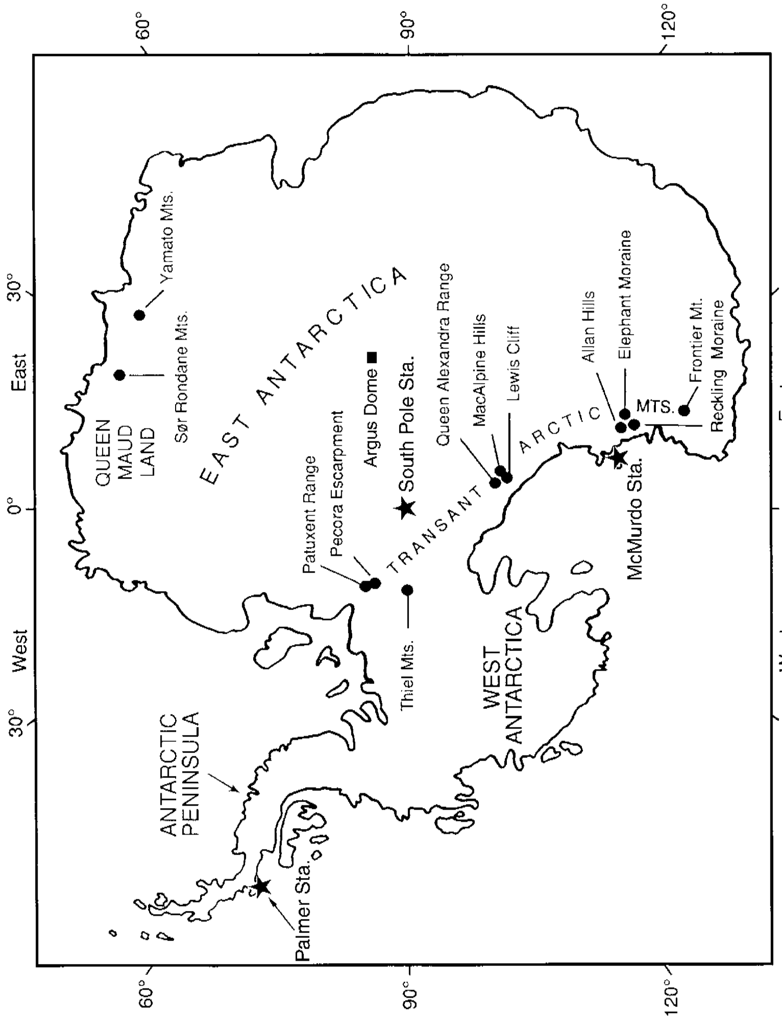

FIGURE 1.1 Map of Antarctica, showing the United States research stations (indicated by stars), the Transantarctic Mountains and some of the major meteorite concentration sites (indicated by filled circles).