Glaciological studies in Allan Hills, 1978–79

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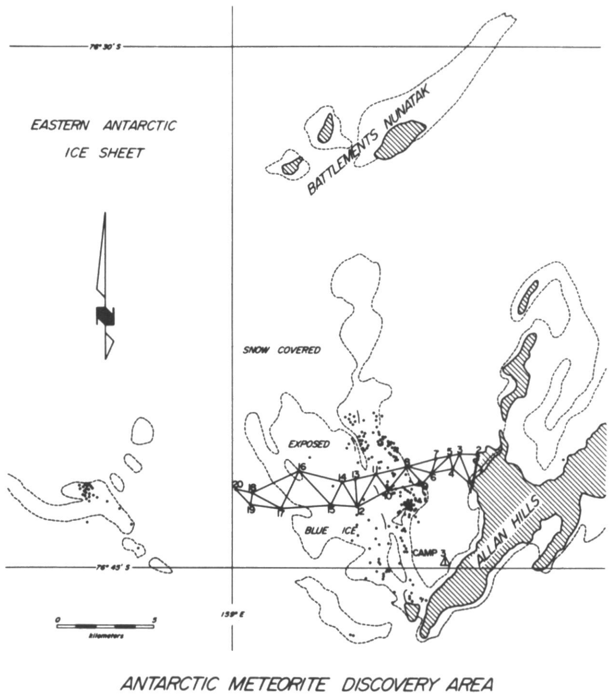
The Allan Hills (76°45′S/159°40′E) blue icefield, located about 230 kilometers northwest of McMurdo station, has been the site of extensive meteorite searches during the past three austral summers. Joint Japanese and United States field parties, led by W. A. Cassidy (University of Pittsburgh) found 9 specimens in the region during the 1976–77 season, 303 during 1977–78, and 262 during 1978–79.

The Japanese, at a blue ice field in the Queen Fabiola (or Yamato) Mountains (71°30′S/35°40′E), have found nearly 1,000 specimens in four summer season searches since 1969. The mechanism of concentration of meteorites in the Queen Fabiola Mountains has been related by Nagata (1978) to the movement of the ice sheet, although the mechanism is not well understood. It does appear, however, that the Antarctic Ice Sheet tends to collect, transport, and concentrate meteorites in the stagnant blue ice areas.

The Allan Hills, as shown in the accompanying figure, are abutted to the west by the East Antarctic Ice Sheet. The bare icefield where the meteorite concentrations are found appears at the edge of the firn about 2.5 kilometers west of the base of the hills and measures about 10 kilometers across. The main portion of this field is about 100 square kilometers with a northward projection of about 20 square kilometers and a small unattached western section approximately 10 kilometers square. The elevation of the firn from the west edge of the Allan Hills remains fairly constant at 1,900 meters until the edge of the blue icefield. The ice surface then dips slightly west for about 1 kilometer, at which point it rises abruptly to over 200 meters in 0.5 kilometer. A gradual increase of another 40 meters of elevation is noted over the next 8 kilometers westward.

The sharp increase in elevation of the bare icefield has been described by Cassidy (1978) as a monocline that may reflect the existence of a near surface ridge across which the ice is flowing. An attempt by A. Kovacs and T. Fenwick of the U. S. Army Cold Regions Research and Engineering Laboratory (Hanover, New Hampshire) to measure the depth of the ice at this spot with an impulse radar profiler was only partially successful during the 1978–79 season.



Allan Hills triangulation chain extending west across the meteorite discovery area.

During December 1978, we established a triangulation chain to measure the movement and the rate of ablation of the blue ice in the Allan Hills area in succeeding seasons. The network consists of a 20-station, 13-kilometer-long line of bamboo poles (see figure). The baseline, consisting of stations 1 and 2, was established on an outcrop of the Mawson Formation, a prominent volcanic unit in the Allan Hills area. Station 1 was placed on the crest of a hill and station 2 was located in a small rubble field about 200 meters below and 1,090 meters to the north of station 1. Both stations consist of holes drilled into outcrop, then filled with lead with a small brass screw as the plumb bob marker. Yellow paint, striped range poles, and red trail flags are suitably placed for ease of recovery in subsequent seasons.

From these points, the survey line was extended westward across the bare icefield where the meteorite finds were concentrated to the upstream side of the monocline. Stations 3 through 9 were established on firn, and stations 10 through 20 were set up on blue ice. As illustrated in figure 1, the snow-covered area is subject to change periodically, depending upon the severity of the katabatic winds. At the time the survey line was established, stations 17–20 were in a relatively snow-free area.

Most meteorites have been found in the vicinity of stations 8, 9, 10, and 11, where the ice appears to be stagnant. The ice is almost completely snow-free in the vicinity of stations 10 and 11, with extensive wind cups over the surface.

Stations 12 and 13 are located at the crest of the monocline where the ice appears to be fairly smooth and dense. Wind cupping is more pronounced just below the crest of the monocline than at the crest.

Stations 17–20 are all located in an area of extensive crevassing, stress cracks, pressure ridges, and 1-2-meterhigh ice hummocks. Although the ice appears to be moving rapidly in this region, the crevassing does not indicate a preferential direction of movement.

Bulk ice samples were collected by chipping at locations near stations 10, 12, and 17. The samples will be melted and the dissolved gases (N_2, O_2, Ar, CO_2) and carbon-14 abundances will be measured for dating by E. L. Fireman (Smithsonian Astrophysical Observatory) (Fireman, 1979).

The Allan Hills will be revisited by the authors during the 1979–80 season for a resurvey of the line and to extend the triangulation chain farther west. Ice samples for gas analysis will be obtained from selected stations.

The discovery of large numbers of meteorites presents a unique opportunity for glaciological studies relating to their transport and concentration. If the mechanism can be deduced, it may be possible, with accurate measurements of meteorite terrestrial ages, to predict where the specimens originally fell. Until that time, we can only speculate that the meteorites recovered have been transported by the Antarctic Ice Sheet over some undetermined distance.

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Byrd Glacier

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Our study of Byrd Glacier investigates the ice-stream dynamics that link the ice-sheet dynamics studied for the International Antarctic Glaciological Project and ice-shelf dynamics studied for the Ross Ice Shelf Project, so that the dynamics of this major ice sheet, ice stream, ice shelf system can be addressed. It was done in conjunction with a separate glacial-geological investigation of the Byrd Glacier-Darwin Glacier region of Antarctica directed by G. H. Denton. The combined study is the first attempt to relate the present glaciology of a major antarctic ice stream to its glacial history, with the larger aim of understanding antarctic glacial history in terms of present glaciological processes.

Glacial geological evidence throughout the Byrd Glacier-Darwin Glacier region indicates that the Byrd Glacier surface was about 1200 m above its present surface at the downstream end of Byrd Glacier fiord, and this additional ice elevation tapered off in the Byrd névé area on the East Antarctic polar plateau immediately inland of the upstream end of the fiord. Fresh striations in the unweathered sandstone crowns of nunataks in the Byrd névé and polished bedrock in Byrd fiord are indications that the thicker ice existed during the last ice age maximum. The thicker ice at the mouth of Byrd Glacier fiord, with decreasing additional thickness up the fiord and onto the East Antarctic polar plateau, is consistent with the contention by Mercer (1968, 1972), Denton and Borns (1974), Denton et al. (1975), and Stuiver, Denton, and Hughes (in press) that the West Antarctic Ice Sheet expanded during the last ice age and that the present Ross Ice Shelf was created during its subsequent collapse in the Ross Sea sector. Some of the glacial geology points toward substantial and recent downdraw of Byrd Glacier. A discussion of all the glacial geological evidence studied by George Denton and his colleagues appears elsewhere in this issue of the *Antarctic Journal of the United States*.

From the viewpoint of ice dynamics, Byrd Glacier begins as a zone of converging flow in the Byrd névé, becomes an ice stream as it passes through a fiord in the Transantarctic Mountains, and ends as a floating tongue imbedded in the Ross Ice Shelf. Ice dynamics of the sheet-flow to stream-flow transition in the Byrd névé is dominated by longitudinal acceleration and transverse convergence. Ice dynamics in the stream-flow regime of Byrd Glacier fiord is dominated by lateral shear along the fiord walls where thermal and strain softening largely uncouple the glacier along its sides, and by basal ungrounding about midway in the fiord where ice buoyancy completely uncouples the glacier from its bed. Ice dynamics in the stream-flow to shelf-flow transition in the floating glacier tongue is dominated by longitudinal deceleration and transverse divergence of the tongue, and rifting in the lateral shear zones between the tongue and the Ross Ice Shelf. Tilted ice blocks and a flat floor of brash ice at sea-level elevation in the rifts are evidence that rifting is through the entire ice thickness.

Field studies on Byrd Glacier were completed during the 1978–1979 antarctic summer. The work consisted of aerial photography and radio-echo sounding from an