

ALTITUDES ON
THE INLAND ICE IN NORTH GREENLAND

BY

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Introduction.

The scientific work of the British North Greenland Expedition (1952—1954) included the accurate determination of height above sea level at approximately three hundred points on the inland ice. These points lay between latitudes $76^{\circ}40'$ N. and $78^{\circ}10'$ N. on a line stretching from Dronning Louise Land in the east to the Nunatarssuaq region, at the head of Wolstenholme Fjord, on the west coast.

The purpose of this paper is to put these heights on record, together with a brief description of how they were determined and a statement of their accuracy. The slope of the inland ice in different directions was also measured at a few points. These results are also included.

Altitude measurements.

The primary purpose of the work was to determine the altitudes of a series of gravity stations, the gravity measurements being made in connection with determinations of ice thickness. Also, for meteorological purposes, it was necessary to know the altitude of the Expedition's central station, "Northice", situated in latitude $78^{\circ}04'$ N., $38^{\circ}29'$ W. The requirements of the gravity survey determined the route, which did not follow the shortest distance between the coasts. The work was carried out during the summers of 1953 and 1954. A tripod was left during the winter to mark the end point of the first year's work (station B73).

The method employed has been described in detail elsewhere (1). Briefly, it consisted of levelling by triangulation between stations about 4 kilometres apart. The survey started at the summit of Krebs Bjerg, a mountain on the western margin of Dronning Louise Land. The altitude of this mountain was known from the triangulation of Dronning Louise Land carried out by the Expedition. An isolated nunatak, the most westerly land in this area, was included in the survey. From there,

the route ran to "Northice". The final station on the inland ice was A172. This station was at the edge of the ice, in the Nunatarssuaq region. The accurate position quoted for this point was determined from a map based on the Geodaetisk Institut survey of the area. (The position computed from the survey agreed within 300 metres). From here the survey was carried over land for a distance of 30 kilometres to sea level in Wolstenholme Fjord near the north side of Moltke Gletscher. The results for these fifteen stations on land have not been included because most of the stations were not marked and so cannot be recovered with sufficient accuracy for the altitudes to be of value.

A detailed consideration of the accuracy of the work is given in the paper referred to previously. The standard error of the absolute altitudes is ± 10 metres, though height differences between adjacent stations are correct to the nearest metre. Latitudes are correct to ± 0.1 minute (180 metres), longitudes to ± 0.5 minute (200 metres). This represents the accuracy necessary for the requirements of the gravity measurements.

Slope measurements.

Measurements of the slope of the inland ice were made for the purpose of verifying Nye's hypothesis (2 and 3). This relates the slope of the surface of an ice sheet to its thickness. This aspect will be treated elsewhere; the results are included here merely as additional topographical information.

The slope was measured by sighting the theodolite on the horizon at azimuth intervals of 30 degrees. The azimuths, which are true azimuths, were determined by sun sights and are correct to the nearest degree. The corrections for dip and for refraction, which should be made to the vertical angles, are uncertain. The horizon distance is not known accurately, and the assumption that refraction is the same in all directions is not justifiable. It is considered better not to make corrections for dip and refraction, but to assume that, at any one station, the maximum upward and downward slopes are equal. A correction, stated in each case, has been applied to all the angles at each station, in order to equalise these maximum slopes. In view of these uncertainties, the standard error of each slope is probably about ± 0.5 minute. Ignoring the effect of small local undulations, the assumption of equal slopes over a distance of about 10 kilometres (the range of visibility) is justifiable for the central portion of the inland ice, although at the last three stations where slope measurements were made, it is likely that the correction is too great.

In the results, the last two values for each station are maximum upward and downward slopes. These were obtained by graphical inter-

pulation, and in this case the azimuths are only correct to ± 5 degrees. Upward slopes are taken as positive, downward as negative.

Additional altitudes.

The Expedition's seismic party took aneroid readings at thirteen additional points on the inland ice. From these readings, the altitudes have been computed by HAMILTON using a method described elsewhere (4). The results have been put on record here also. The standard error of each of these altitudes is ± 13 metres, and the latitudes and longitudes of these stations are correct to the nearest minute.

References.

1. PATERSON, W. S. B. and SLESSER, C. G. M. Trigonometrical levelling across the inland ice in North Greenland. *Empire Survey Review*. Not yet published.
 2. NYE, J. F. A method of calculating the thicknesses of the ice-sheets. *Nature*, 169, p. 529. 1952.
 3. — The flow of glaciers and ice-sheets as a problem in plasticity. *Proceedings of the Royal Society, A*, 207, pp. 554—572. 1952.
 4. HAMILTON, R. A. Determination of altitudes on the inland ice from aneroid readings. Not yet published.
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Station Positions and Altitudes.

Station:	N. Latitude	W. Longitude	Altitude in metres	Station:	N. Latitude	W. Longitude	Altitude in metres
Krebs Bjerg.	77°13.7'	24°23.0'	1633	A 14	27.7'	06.0'	1812
A 82	16.3'	23.5'	927	B 14	27.6'	10.0'	1841
B 81	15.6'	27.0'	940	A 15	27.7'	12.0'	1839
A 81	15.7'	33.0'	977	B 15	28.1'	20.5'	1843
B 80	15.5'	35.0'	1002	A 16	28.3'	27.0'	1859
A 80	15.4'	42.0'	1052	B 16	28.7'	33.0'	1855
B 79	15.3'	44.5'	1053	A 17	29.1'	40.5'	1853
A 79	14.7'	57.0'	1152	B 17	29.4'	48.5'	1853
B 78	14.2'	25°06.5'	1205	A 18	29.6'	53.5'	1862
A 78	14.1'	09.5'	1218	B 18	29.9'	30°05.5'	1863
B 77	13.5'	21.0'	1270	A 19	30.0'	10.5'	1878
A 77	13.4'	23.5'	1281	B 19	29.9'	17.0'	1888
B 76	13.1'	30.0'	1296	A 20	30.0'	38.0'	1931
A 76	12.7'	37.0'	1328	B 20	30.2'	43.0'	1939
B 75	12.5'	41.0'	1342	A 21	30.4'	47.0'	1936
A 75	12.1'	49.0'	1355	B 21	30.9'	53.5'	1926
B 74	11.9'	55.0'	1364	A 22	31.6'	31°03.0'	1921
A 74	11.4'	26°03.0'	1395	B 22	31.9'	08.5'	1921
A 0 (Cairn on Nunatak)	10.8'	11.5'	1484	A 23	32.3'	21.5'	1966
B 0	11.0'	12.5'	1429	B 23	32.4'	24.0'	1972
A 1	11.1'	15.0'	1498	A 24	33.1'	34.0'	1978
B 1	11.1'	15.5'	1503	B 24	34.0'	42.5'	1986
A 2	11.4'	23.0'	1572	A 25	34.9'	54.0'	2014
B 2	11.5'	23.5'	1576	B 25	35.0'	57.5'	2019
A 3	12.1'	27.5'	1573	A 26	35.4'	32°08.0'	2021
B 3	12.5'	29.0'	1573	B 26	35.8'	15.5'	2033
A 4	13.5'	35.0'	1567	A 27	36.1'	18.5'	2036
B 4	13.8'	39.5'	1585	B 27	36.8'	26.0'	2045
A 5	14.0'	46.0'	1601	A 28	37.3'	34.5'	2053
B 5	15.6'	55.5'	1623	B 28	37.7'	42.0'	2062
A 6	16.6'	27°02.0'	1632	A 29	37.9'	45.0'	2072
B 6	16.8'	04.0'	1636	B 29	38.2'	50.5'	2083
A 7	17.4'	11.0'	1637	A 30	38.6'	56.0'	2089
B 7	17.8'	17.0'	1639	B 30	39.4'	33°06.5'	2093
A 8	18.2'	28.0'	1669	A 31	40.0'	14.0'	2096
B 8	18.2'	40.5'	1681	B 31	40.6'	21.0'	2110
A 9	18.4'	41.5'	1686	A 32	41.2'	28.5'	2114
B 9	19.4'	55.5'	1713	B 32	41.5'	32.5'	2120
A 10	21.0'	28°06.5'	1719	A 33	42.2'	42.0'	2126
B 10	21.4'	14.5'	1751	B 33	43.0'	49.5'	2128
A 11	21.8'	21.5'	1771	A 34	43.8'	57.5'	2132
B 11	24.7'	40.0'	1796	B 34	45.0'	34°07.5'	2125
A 12	25.0'	43.5'	1813	A 35	45.6'	12.5'	2137
B 12	25.4'	50.0'	1826	B 35	46.0'	20.0'	2154
A 13	25.6'	53.0'	1834	A 36	46.1'	25.5'	2157
B 13	26.1'	29°00.0'	1838	B 36	46.8'	34.5'	2153
				A 37	47.2'	38.0'	2164

(continued)

Station:	N. Latitude	W. Longitude	Altitude in metres	Station:	N. Latitude	W. Longitude	Altitude in metres
B 37	47.5'	42.0'	2168	A 62	02.9'	56.5'	2488
A 38	48.2'	52.0'	2162	B 62	02.8'	42°06.5'	2496
B 38	48.8'	59.0'	2171	A 63	02.7'	16.0'	2499
A 39	49.8'	35°11.0'	2198	B 63	02.6'	26.0'	2503
B 39	50.3'	16.0'	2202	A 64	02.5'	35.5'	2508
A 40	51.5'	30.0'	2198	B 64	02.4'	45.0'	2512
B 40	51.8'	34.5'	2203	A 65	02.2'	54.5'	2517
A 41	52.3'	43.5'	2199	B 65	02.1'	43°05.0'	2520
B 41	53.1'	53.0'	2214	A 66	02.2'	16.0'	2522
A 42	53.6'	36°01.0'	2229	B 66	02.4'	28.0'	2525
B 42	54.2'	10.0'	2235	A 67	02.4'	38.0'	2527
A 43	54.8'	18.0'	2248	B 67	02.4'	47.5'	2530
B 43	55.3'	26.0'	2252	A 68	02.4'	57.0'	2531
A 44	56.4'	34.0'	2255	B 68	02.4'	44°06.5'	2532
B 44	57.2'	41.0'	2261	A 69	02.4'	16.5'	2532
A 45	58.1'	48.0'	2267	B 69	02.3'	26.5'	2531
B 45	59.1'	54.5'	2269	A 70	02.3'	36.0'	2529
A 46	59.7'	59.5'	2276	B 70	02.1'	46.5'	2528
B 46	78°00.3'	37°06.0'	2281	A 71	02.1'	56.5'	2527
A 47	01.1'	13.5'	2286	B 71	01.9'	45°06.5'	2524
B 47	01.9'	22.5'	2286	A 72	01.8'	16.0'	2520
A 48	02.8'	31.0'	2290	B 72	01.6'	26.5'	2519
B 48	03.5'	37.5'	2300	A 73	01.4'	36.5'	2516
A 49	04.0'	43.5'	2303	B 73	01.1'	47.0'	2514
B 49	04.2'	54.0'	2312	A 101	77°59.8'	55.5'	2516
A 50	04.4'	38°03.0'	2319	B 101	58.5'	46°06.5'	2517
B 50	04.4'	13.5'	2328	A 102	57.0'	16.0'	2516
"Northice".	04.3'	29.3'	2345	B 102	55.8'	26.5'	2516
B 51	04.4'	36.0'	2349	A 103	54.3'	37.0'	2514
A 52	04.3'	46.5'	2356	B 103	52.7'	46.5'	2513
B 52	04.3'	57.0'	2365	A 104	51.1'	55.5'	2517
A 53	04.2'	39°06.0'	2374	B 104	49.5'	47°05.0'	2517
B 53	04.2'	15.5'	2382	A 105	47.8'	14.0'	2519
A 54	04.1'	24.5'	2391	B 105	46.1'	22.5'	2519
B 54	04.1'	34.5'	2396	A 106	44.4'	32.0'	2521
A 55	04.0'	44.5'	2409	B 106	42.7'	41.0'	2524
B 55	03.9'	54.5'	2414	A 107	41.2'	50.5'	2527
A 56	03.7'	40°04.0'	2420	B 107	40.2'	56.0'	2526
B 56	03.7'	14.0'	2424	A 108	38.6'	48°05.5'	2527
A 57	03.6'	23.0'	2429	B 108	37.0'	14.5'	2528
B 57	03.5'	34.0'	2435	A 109	36.0'	21.5'	2531
A 58	03.4'	43.0'	2442	B 109	34.6'	31.5'	2530
B 58	03.3'	53.0'	2446	A 110	32.8'	41.0'	2523
A 59	03.3'	41°01.0'	2458	B 110	31.2'	51.0'	2533
B 59	03.3'	08.5'	2461	A 111	29.8'	49°02.0'	2524
A 60	03.2'	17.0'	2463	B 111	28.0'	10.5'	2527
B 60	03.2'	26.5'	2470	A 112	26.1'	20.0'	2528
A 61	03.1'	35.5'	2474	B 112	23.8'	26.0'	2530
B 61	03.0'	46.5'	2482	A 113	21.9'	35.5'	2527

(continued)

Station:	N. Latitude	W. Longitude	Altitude in metres	Station:	N. Latitude	W. Longitude	Altitude in metres
B 113	20.1'	44.5'	2522	A 138	58.1'	54.0'	2088
A 114	18.4'	54.0'	2518	B 138	57.4'	58°01.5'	2086
B 114	20.0'	58.5'	2514	A 139	56.6'	10.0'	2084
A 115	21.4'	50°05.5'	2506	B 139	55.5'	21.0'	2080
B 115	23.2'	14.5'	2496	A 140	54.4'	33.5'	2076
A 116	25.3'	23.0'	2486	B 140	52.4'	42.5'	2079
B 116	26.7'	28.5'	2479	A 141	50.5'	52.5'	2080
A 117	29.0'	36.5'	2469	B 141	48.4'	59°01.0'	2080
B 117	31.6'	43.5'	2460	A 142	46.9'	07.5'	2078
A 118	34.1'	49.0'	2451	B 142	45.3'	15.0'	2072
B 118	36.7'	53.5'	2441	A 143	43.1'	24.0'	2063
A 119	38.7'	58.0'	2433	B 143	41.2'	32.0'	2057
B 119	41.2'	51°02.5'	2425	A 144	39.6'	39.5'	2050
A 120	43.2'	08.5'	2414	B 144	37.6'	48.5'	2040
B 120	45.7'	15.0'	2402	A 145	35.5'	59.5'	2027
A 121	47.1'	26.5'	2390	B 145	33.6'	60°10.0'	2008
B 121	48.4'	38.0'	2379	A 146	31.9'	20.5'	1994
A 122	49.7'	50.0'	2367	B 146	30.2'	30.5'	1976
B 122	51.1'	52°01.5'	2353	A 147	28.4'	40.5'	1957
A 123	52.4'	13.0'	2340	B 147	27.3'	49.0	1946
B 123	53.6'	24.5'	2328	A 148	26.3'	58.0'	1929
A 124	54.8'	36.5'	2317	B 148	25.0'	61°09.5'	1900
B 124	56.0'	48.5'	2304	A 149	23.7'	21.0'	1873
A 125	57.0'	57.5'	2296	B 149	22.9'	28.0'	1854
B 125	57.8'	53°10.5'	2283	A 150	21.3'	40.5'	1826
A 126	58.8'	21.5'	2272	B 150	20.4'	47.0'	1812
B 126	59.7'	30.5'	2263	A 151	18.9'	58.0'	1782
A 127	78°00.8'	42.5'	2250	B 151	16.9'	62°06.0'	1768
B 127	01.5'	52.0'	2241	A 152	14.8'	15.0'	1749
A 128	02.1'	54°01.5'	2232	B 152	14.1'	18.5'	1743
B 128	03.4'	18.0'	2214	A 153	12.4'	29.0'	1716
A 129	04.3'	32.0'	2203	B 153	11.1'	37.0'	1698
B 129	05.2'	44.5'	2189	A 154	09.5'	47.5'	1675
A 130	05.9'	53.5'	2179	B 154	07.8'	57.5'	1654
B 130	06.9'	55°06.0'	2167	A 155	06.7'	63°04.5'	1643
A 131	07.4'	13.5'	2159	B 155	05.3'	13.0'	1625
B 131	08.2'	26.0'	2146	A 156	03.0'	27.0'	1602
A 132	09.1'	38.5'	2131	B 156	00.8'	40.0'	1579
B 132	10.4'	51.0'	2122	A 157	76°59.8'	45.5'	1568
A 133	10.0'	56°05.0'	2113	B 157	57.7'	58.0'	1548
B 133	08.6	16.5'	2110	A 158	57.3'	64°00.5'	1544
A 134	07.5'	29.0'	2106	B 158	56.5'	05.5'	1540
B 134	06.3'	39.5'	2105	A 159	55.5'	11.5'	1534
A 135	05.1'	51.0'	2102	B 159	53.3'	24.5'	1513
B 135	03.9'	57°01.5'	2099	A 160	52.7'	28.5'	1506
A 136	02.5'	14.0'	2097	B 160	52.1'	32.5'	1491
B 136	01.2'	26.0'	2094	A 161	51.3'	36.5'	1482
A 137	00.2'	35.0'	2092	B 161	49.5'	47.0'	1455
B 137	77°59.0'	45.5'	2089	A 162	48.3'	54.5'	1445

(continued)

Station:	N.Lati- tude	W.Longi- tude	Altitude in metres	Station:	N.Lati- tude	W.Longi- tude	Altitude in metres
B 162	46.9'	65°02.5'	1445	B 167	45.9'	66°12.5'	1243
A 163	45.9'	08.5'	1429	A 168	46.0'	20.0'	1219
B 163	44.6'	16.0'	1387	B 168	45.7'	39.0'	1163
A 164	43.6'	21.5'	1354	A 169	45.7'	41.0'	1153
B 164	43.2'	24.2'	1335	B 169	45.8'	47.0'	1088
A 165	44.2'	37.5'	1361	A 170	45.9'	50.0'	1039
B 165	44.8'	45.5'	1410	B 170	46.2'	52.5'	993
A 166	44.9'	47.5'	1420	A 171	46.3'	53.5'	967
B 166	45.0'	48.5'	1415	B 171	46.6'	59.0'	816
A 167	45.6'	59.5'	1330	A 172	76°47.4'	67°09.6'	567

Slopes.

B. 52		B. 55		A. 67	
Correction	0	Correction	+ 0.8'	Correction	+ 0.4'
Azimuth (degrees)	Slope (minutes)	Azimuth (degrees)	Slope (minutes)	Azimuth (degrees)	Slope (minutes)
000	- 4.1	022	- 2.2	017	- 6.2
030	- 8.0	052	- 7.1	047	- 5.3
060	- 8.5	082	- 5.8	077	- 3.4
090	- 8.5	112	- 4.5	107	- 0.4
120	- 4.3	142	- 1.2	137	+ 3.2
150	- 0.5	172	+ 2.7	167	+ 5.3
180	+ 3.6	202	+ 6.6	197	+ 5.9
210	+ 8.0	232	+ 7.0	227	+ 4.1
240	+ 9.1	262	+ 5.2	257	+ 1.0
270	+ 7.8	292	+ 3.4	287	- 0.7
300	..	322	+ 1.9	317	- 3.5
330	- 0.4	352	- 1.8	347	- 5.0
	Maximum slopes		Maximum slopes		Maximum slopes
240	+ 9.1	230	+ 7.2	190	+ 6.2
060	- 9.1	050	- 7.2	015	- 6.2

Slopes.

B. 102		A. 106		A. 108	
Correction	+ 1.0'	Correction	+ 0.2'	Correction	+ 2.9'
Azimuth (degrees)	Slope (minutes)	Azimuth (degrees)	Slope (minutes)	Azimuth (degrees)	Slope (minutes)
005	- 5.1	015	- 2.5	011	- 2.0
035	- 2.4	045	- 1.2	041	+ 0.4
065	+ 0.4	075	+ 2.6	071	+ 2.5
095	+ 3.6	105	+ 5.2	101	+ 6.5
125	+ 6.0	135	+ 6.5	131	+ 8.7
155	+ 6.0	165	+ 5.3	161	+ 7.3
185	+ 4.2	195	+ 4.3	191	+ 6.4
215	+ 1.7	225	+ 0.4	221	+ 4.3
245	- 1.3	255	- 3.0	251	- 2.8
275	- 3.9	285	- 5.9	281	- 6.3
305	- 5.2	315	- 6.6	311	- 7.5
335	- 6.3	345	- 5.3	341	- 8.7
	Maximum slopes		Maximum slopes		Maximum slopes
145	+ 6.3	140	+ 6.6	145	+ 8.9
325	- 6.3	315	- 6.6	325	- 8.9

A. 111		A. 118		A. 125	
Correction	- 0.5'	Correction	+ 1.7'	Correction	+ 1.8'
Azimuth (degrees)	Slope (minutes)	Azimuth (degrees)	Slope (minutes)	Azimuth (degrees)	Slope (minutes)
023	- 3.3	002	- 3.8	013	- 4.3
053	- 0.5	032	- 0.5	043	0.0
083	+ 3.5	062	+ 2.4	073	+ 3.7
113	+ 6.1	092	+ 5.7	103	+ 7.2
143	+ 6.9	122	+ 7.3	133	+ 9.0
173	+ 5.9	152	+ 6.1	163	..
203	+ 5.2	182	+ 3.7	193	+ 4.5
233	+ 0.1	212	- 0.3	223	+ 1.9
263	- 2.0	242	- 3.2	253	- 3.4
293	- 5.5	272	- 5.6	283	- 7.2
323	- 5.8	302	- 7.4	313	- 8.8
353	- 6.2	332	- 6.4	343	- 8.4
	Maximum slopes		Maximum slopes		Maximum slopes
145	+ 7.2	130	+ 7.6	145	+ 9.1
325	- 7.2	310	- 7.6	325	- 9.1

Slopes.

A. 132		A. 140		A. 149	
Correction	+ 0.4'	Correction	+ 1.3'	Correction	+ 2.6'
Azimuth (degrees)	Slope minutes)	Azimuth (degrees)	Slope (minutes)	Azimuth (degrees)	Slope (minutes)
029	- 4.9	010	- 5.0	005	+ 4.2
059	+ 2.0	040	- 1.5	035	+ 13.2
089	+ 5.6	070	+ 4.6	065	+ 18.5
119	+ 10.0	100	+ 8.6	075	+ 19.3
177	+ 7.9	130	+ 10.5	144	+ 12.8
209	+ 3.0	152	+ 10.0	155	+ 9.7
239	- 1.9	213	+ 2.4	185	+ 1.0
269	- 4.6	250	- 4.3	215	- 10.4
299	- 8.0	280	- 8.1	245	- 18.2
329	- 10.5	310	- 10.3	275	- 19.9
359	- 9.9	340	- 8.7	305	- 16.1
				335	- 7.7
	Maximum slopes		Maximum slopes		Maximum slopes
150	+ 10.7	130	+ 10.5	090	+ 20.3
340	- 10.7	315	- 10.5	270	- 20.3

A. 151		A. 159	
Correction	+ 2.1'	Correction	+ 3.0'
Azimuth (degrees)	Slope (minutes)	Azimuth (degrees)	Slope (minutes)
000	- 2.0	025	- 4.1
030	+ 9.6	055	+ 10.0
060	+ 19.0	085	+ 26.1
077	+ 21.1	115	+ 27.0
138	+ 13.0	145	+ 18.5
150	+ 10.0	175	+ 13.0
180	+ 1.7	205	+ 3.6
210	- 7.6	235	- 9.3
240	- 16.2	265	- 13.6
270	- 20.0	295	- 26.2
300	- 20.1	325	- 28.6
330	- 12.8	355	- 19.5
	Maximum slopes		Maximum slopes
090	+ 21.4	110	+ 29.2
275	- 21.4	300	- 29.2

Seismic Station Positions and Altitudes.

Station:	N. Latitude	W. Long.	Altitude in metres
A	77°10'	48°51'	2547
B	76°56'	48°05'	2603
C	43'	47°20'	2671
D	27'	46°31'	2689
E	12'	45°46'	2742
F	75°59'	45°00'	2774
G	76°13'	44°22'	2778
H	26'	43°36'	2771
DE	33'	45°19'	2733
C1	53'	46°12'	2695
C2	77°02'	45°08'	2664
C3	12'	44°02'	2652
C4	23'	43°01'	2616