To Doc "G" from an "olde studente" Dick C.

Institute of Polar Studies
Report No. 23

Glaciology of the Queen Maud Land Traverse, 1964-1965 South Pole–Pole of Relative Inaccessibility

by

R. L. Cameron, E. Picciotto,
H. S. Kane, and J. Gliozzi
Institute of Polar Studies

April, 1968

The Ohio State University
Research Foundation
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GLACIOLOGY ON THE QUEEN MAUD LAND TRAVERSE, 1964-1965

SOUTH POLE-POLE OF RELATIVE INACCESSIBILITY

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FOREWORD

The glaciological program was supported by the National Science Foundation through a grant awarded to The Ohio State University Research Foundation (NSF Grant GA-135). The glaciological work was done by Professor E. Picciotto, of the University of Brussels; Olav Dybvadskog, of the Norwegian Polar Institute; and James Gliozzi, Scott Kane, and Richard L. Cameron, of The Ohio State University Institute of Polar Studies.

The geophysical studies were conducted by personnel of the University of Wisconsin, led by Dr. Charles Bentley, and were supported by the National Science Foundation under a separate grant.

ABSTRACT

An oversnow traverse was made from the South Pole to the Pole of Relative Inaccessibility along a zigzag path of about 800 nautical miles during the period 4 December 1964 to 27 January 1965. The surface varied from very hard with many highly developed sastrugi to very soft and mooth. The average air temperature was -28.8°C, with an absolute maximum of -18.2°C on 5 January and an absolute minimum of -44.7°C on 26 January. The absolute maximum wind speed recorded was 9.0 m/s on 29 December and 17 January; there was 3 percent calm in December and 1 percent calm in January. Solar halos were frequent. Firn temperatures were taken at 29 sites; the most striking anomaly occurred on the last leg of the traverse where there was an abrupt change in slope and as the height increased the temperature anomalously increased before decreasing as expected. The temperature profile at the Pole of Inaccessibility was similar to that obtained by the Soviets in 1964. Temperature gradients were negative at the South Pole but strikingly positive in the vicinity of the Pole of Inaccessibility. Density profiles to depths of 40 m were taken at 12 sites with a neutron-scattering device; most of the density curves showed a break at a density of 0.52 to 0.54 g/cm^3. Snow accumulation studies in pits showed an accumulation generally between 5 and 10 g/cm^2. Snow accumulation measured at the anemometer mast and the instrument shelter at the Pole of Inaccessibility for the period 14 December 1958 to 30 January 1965 was 3.6 g/cm^2/yr.

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ERRATA

Cover, Title — Read Glaciology on

p. iii, line 5 — For mooth read smooth

p. iv, line 4 — Should read Optical phenomena 7

p. iv, line 19 — For Depths of 10 m read Depth of 10 m

p. vii, line 5 (Fig. 4) — For recorder read recorded

p. vii, line 6 (Fig. 5) — For 30 January 1964 read 30 December 1964

p. vii, line 7 (Fig. 6) — For 8 January 1964 read 8 January 1965

p. 9, Fig. 6 — For 8 January 1964 read 8 January 1965

p. 16, 3rd from bottom line — For Soviel read Soviet

p. 52, line 17 — For 3.6 g/cm^3 read 3.6 g/cm^2

p. 90, line 11 — Should read - the position of the samples collected in view of isotopic measurements (fallout, Pb^{210} and oxygen isotopes).

pages 95 and 96 should be transposed

Institute of Polar Studies Report 23

Cameron, Picciotto, Kane, and Gliozzi

INTRODUCTION

The Queen Maud Land Traverse left the South Pole on 4 December 1964 and made a zigzag path of 800 nautical miles, arriving at the Soviet Station Pole of Relative Inaccessibility (Lat. 82°06'47" S, Long. 55° 02'02" E) on 27 January 1965 (Figs. 1 and 2). Along the first leg of the traverse, due north on the 60° E meridian, there was a gradual increase in elevation from 2800 m at the South Pole to 3106 m at the end of this leg, Mile 185 (Fig. 3). The topography was varied with numerous distinct troughs and ridges. The second leg of the traverse remained at a constant elevation for the first 35 miles, decreased 350 m in the next 85 miles, and then decreased very gradually, 100 m in 110 miles, to the low of 2628 m, and the end of the leg (Mile 415). The third leg had a distinctive profile; the elevation increased only 50 m the first 35 miles, it remained constant for the next 70 miles, and then there was an abrupt change in slope. This change in slope could actually be seen and was indeed impressive. During the remaining 260 miles to the Pole of Inaccessibility, the elevation increased over 1000 m.

Along this traverse route, both geophysical and glaciological studies were made. The geophysical measurements consisted of gravity, magnetics, ice thickness from seismic measurements, and bedrock velocity measurements by seismic refraction. The glaciological studies were confined to the top 40 m of the ice sheet, and consisted of density measurement (0-2 m and 0-40 m); firn temperatures to 40 m; snow pit studies to determine snow accumulation; sampling of firn for oxygen-isotope, fission products, and Pb^{210} measurements; surface hardness (0-50 cm); and surface features. In addition, daily meteorological observations were made.

Table I gives the position and elevation of traverse stations and the glaciological studies made at these stations. Appendix VI is a log of the traverse.

METEOROLOGY

General

Four observations were made each day (0000, 0600, 1200, and 1800 hours) of temperature, wind direction and speed, cloud cover, and visibility. Table II gives the results of these observations, and Fig. 4 is a plot of the mean daily temperatures and the mean daily wind. The detailed observations are given in Appendix I.

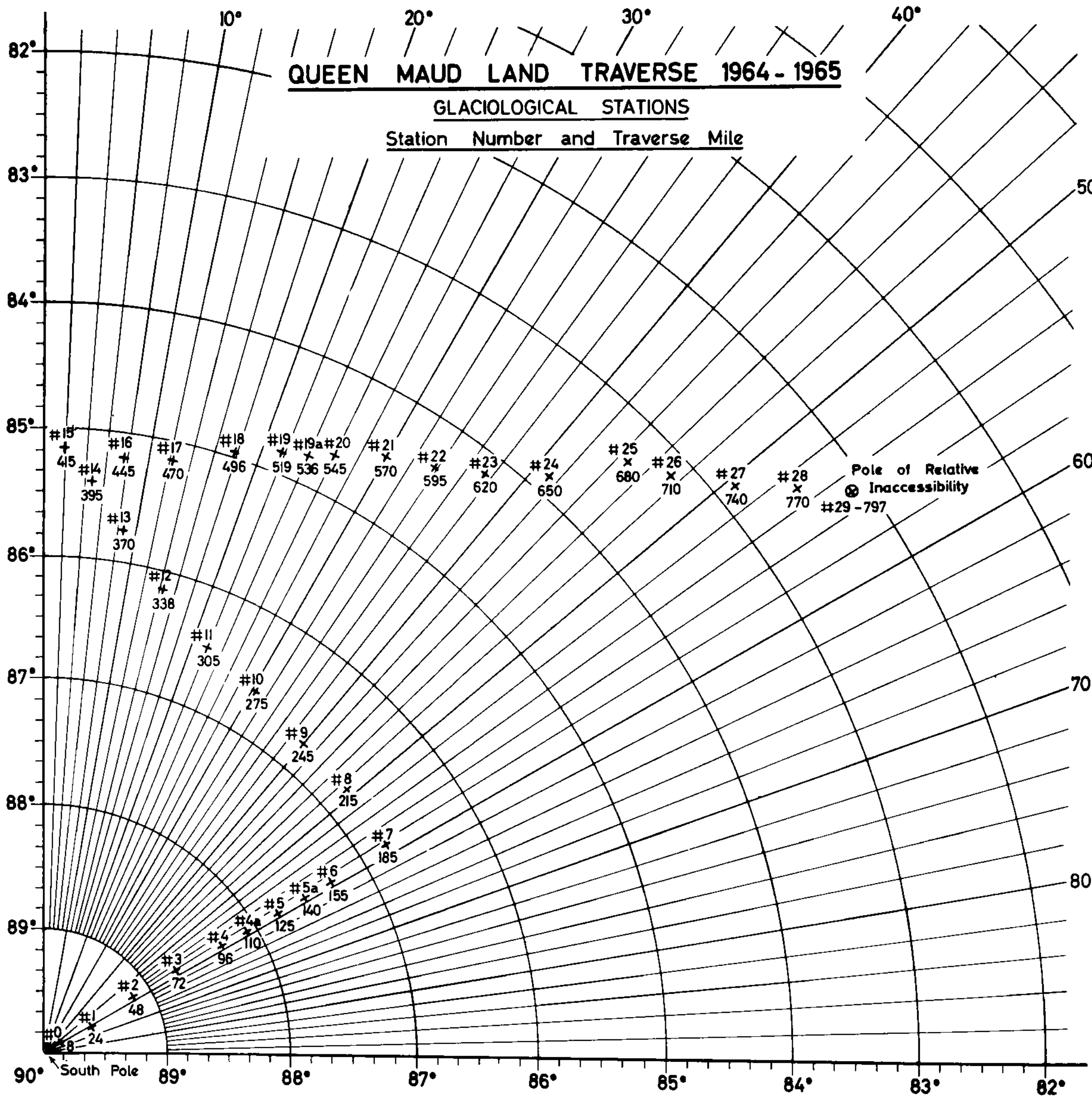


Fig. 1 - Traverse route with glaciological station number and traverse mile

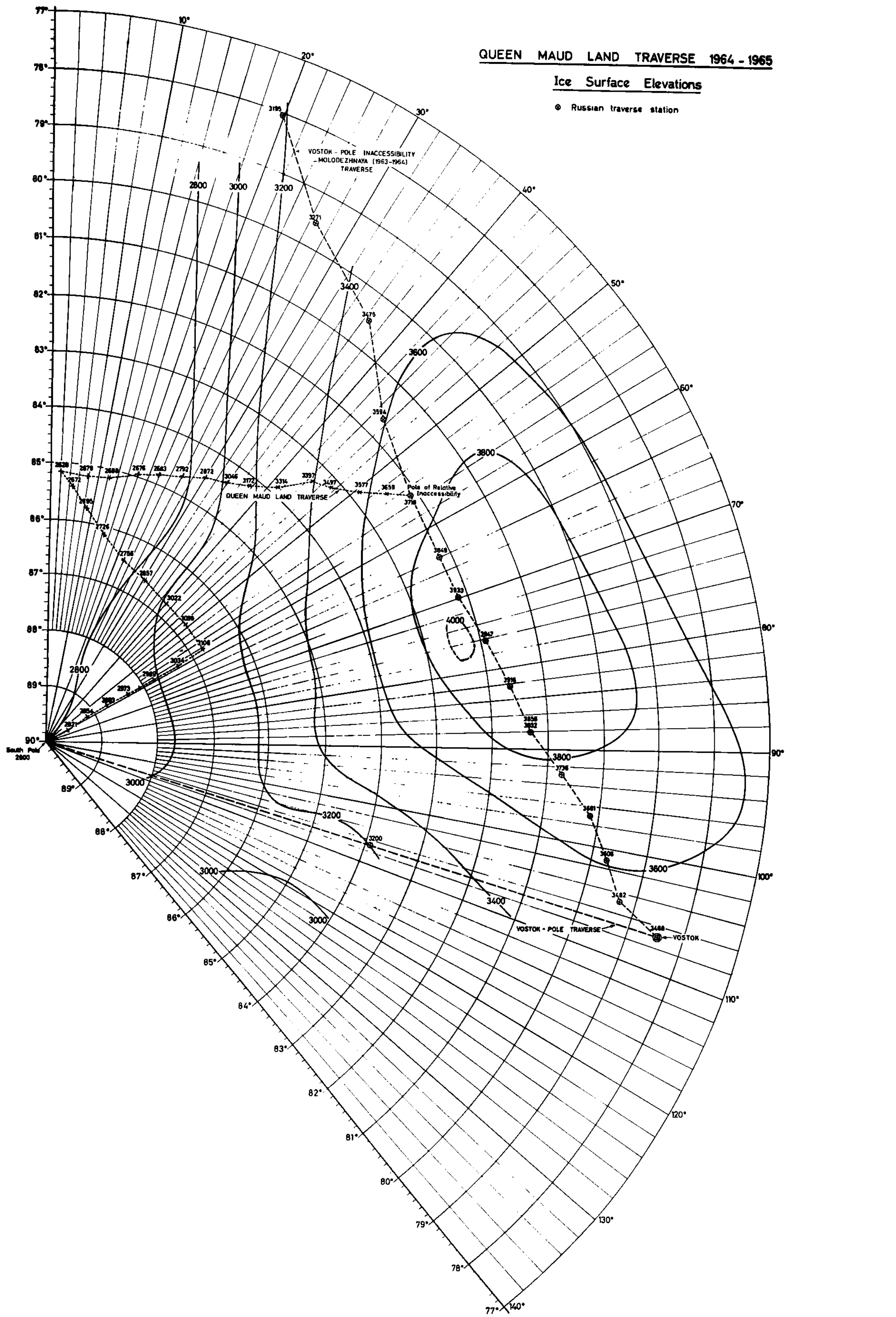


Fig. 2 - Topography of East Antarctica from ice elevation data obtained on QMLT I 1964-1965 and the Soviet Vostok-Pole of Relative Inaccessibility-Molodezhnaya Traverse 1963-1964

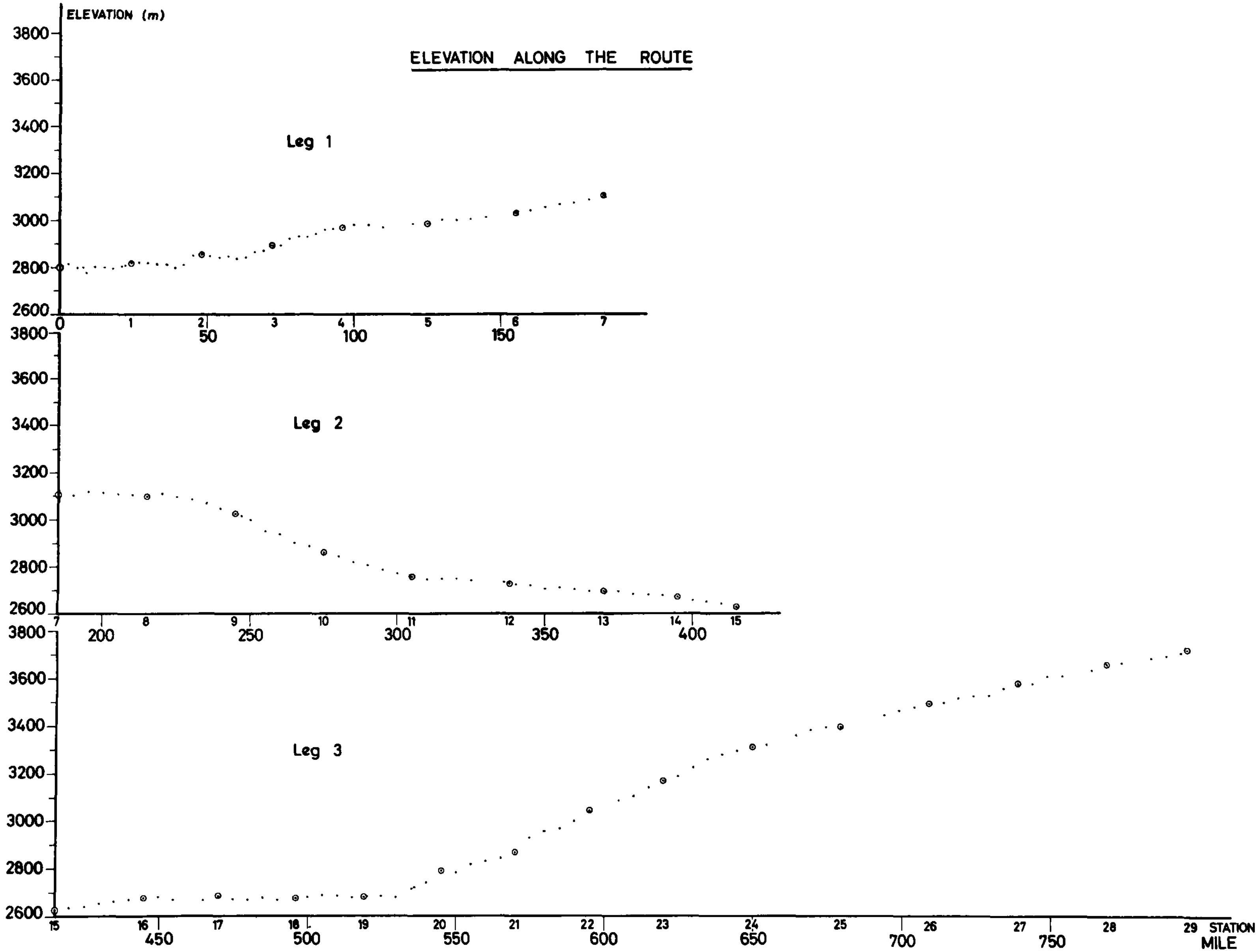


Fig. 3 - Elevation profiles of the three traverse legs of QMLT I

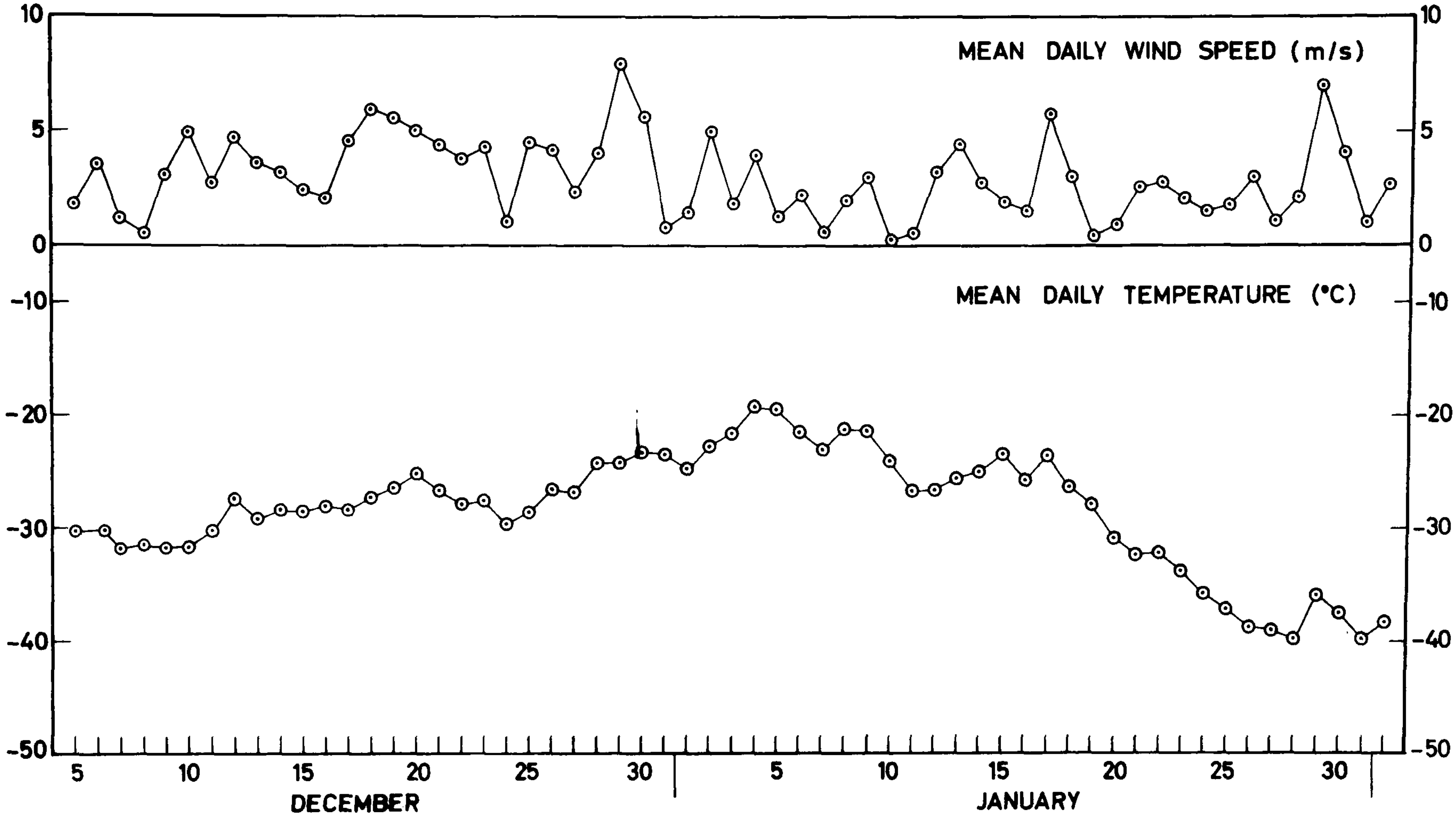


Fig. 4 - Mean daily wind speed (m/s) and mean daily temperature (°C) recorded on the traverse for the period 5 December 1964 to 1 February 1965

Table I - Traverse Positions, Elevations, and Glaciological Programs

Station No.	Traverse Miles	Latitude (South)	Longitude (East)	Elevation Meters	Sampling Program 1	2	3	Measurement Program 4	5	6	7
0	8	89°52'	60°00'	2800	-	-	-	-	+	-	-
1	24	89°35'42"	60°00'	2821	-	+	-	+	+	-	+
2	48	89°10'30"	58°30'	2854	+	+	-	+	+	-	+
3	72	88°44'54"	58°00'	2893	+	+	-	+	+	-	+
4	96	88°19'	58°54'	2973	+	+	-	+	+	-	+
4a	110	88°05'18"	59°00'	2978	-	+	+	-	+	-	-
5	125	87'48'18"	59'12'	2989	+	+	-	+	+	+	-
5a	140			3006	+	+	-	-	+	+	-
6	155	87°16'48"	58°54'	3034	+	+	-	+	+	+	-
7	185	86°45'	58°36'	3106	+	+	+	+	+	+	+
8	215	86°47'48"	49°12'	3099	+	+	-	+	+	-	-
9	245	86°44'30"	40°00'	3022	+	+	-	+	+	+	-
10	275	86°37'42"	30°36'	2857	+	+	+	+	+	-	+
11	305	86°30'	22°12'	2756	+	+	-	+	-	+	-
12	338	86°08'54"	14°48'	2726	+	+	-	+	+	-	-
13	370	85°45'48"	08°42'	2695	+	+	+	+	+	-	+
14	395	85°26'18"	04°42'	2672	+	+	-	+	+	+	-
15	415	85°10'12"	01°48'	2628	+	+	+	+	+	+	+
16	445	85°13'18"	07°42'	2679	+	+	-	+	+	+	-
17	470	85°10'48"	13°12'	2688	+	+	-	+	+	+	+
18	496	84°58'06"	17°54'	2676	+	+	+	+	+	+	-
19	519	84°50'48"	21°48'	2683	-	+	-	+	+	+	-
19a	536				-	+	-	-	-	-	-
20	545	84°41'48"	26°00'	2792	+	+	-	+	+	+	+
21	570	84°31'42"	30°06'	2872	+	+	-	+	+	+	-
22	595	84°22'12"	33°54'	3046	+	+	-	+	+	+	-
23	620	84°10'30"	37°36'	3172	+	+	+	+	+	+	+
24	650	83°52'42"	41°18'	3314	+	+	-	+	-	+	-
25	680	83°20'00"	44°33'	3397	+	+	-	+	+	+	-
26	710	83°10'30"	47°28'	3497	+	+	+	+	+	+	-
27	740	82°50'12"	50°31'	3577	+	+	-	+	+	+	-
28	770	82°27'12"	52°52'	3659	+	+	-	+	+	+	-
29	797	82°06'47"	55°02'02"	3718	+	+	+	+	+	+	+

Sampling Program: 1 = O^{18}/O^{16}
2 = Fission products
3 = Pb^{210}

Measurement Program: 4 = Firn temperature
5 = Snow accumulation from stratigraphy
6 = 0- to 2-m densities
7 = 0- to 40-m depth density profiles

Table II - Temperature and Wind Speed, 5 Dec. 1964-1 Feb. 1965

Temperature	°C	Wind Speed (m/s)
Average for December	-28.0	
Average for January	-29.2	
Average for Dec.-Jan.	-28.6	
Average for Dec.-Feb.	-28.8	
Maximum daily mean	-19.2 on 4 January	7.9 on 29 December
Minimum daily mean	-39.8 on 28 & 31 Jan.	0.2 on 10 January
Absolute maximum	-18.2 on 5 January	9.0 on 29 Dec. & 17 Jan.
Absolute minimum	-44.7 on 26 January	
		Percent of calm 3% in Dec. 1% in Jan.

In general, the climate was ideal for field work. Bad days, with either high winds or poor visibility, were infrequent. Strong winds occasionally increased surface noise to interfere with seismic work, and an overcast sky hindered navigation by sun compass. Only during the last few days, at the Pole of Relative Inaccessibility, did low temperature markedly hinder field work. Near and below -40°C, outdoor work became painfully slow.

Optical Phenomena

Solar Halos. Solar halos were relatively frequent, and the displays consisted mainly of 22° halos and the lower tangential arc of the 22° halo. Occasionally, the 46° halo developed, and twice, brilliant, multi-component, halos were formed. The halos recorded here were marked displays; certainly others went unnoticed because of poor definition or because they were displayed during the short daily sleeping period. There were 14 displays between 1 December and 8 January. The data of the display and the mean temperature for that day are given in Table III.

Table III - Halo Occurrence

Date	Mean Temperature (°C)
1 December 1964	-29.2*
4 December 1964	-30.0*
17 December 1964	-28.4
20 December 1964	-25.3
21 December 1964	-26.7
22 December 1964	-27.8
23 December 1964	-27.6
25 December 1964	-28.6
26 December 1964	-26.6
30 December 1964	-23.2
1 January 1965	-24.8
2 January 1965	-22.6
6 January 1965	-21.5
8 January 1965	-21.3

* Temperature at time of halo

The finest displays were on 30 December 1964 and 8 January 1965. The data for the 30 December display follow, and Fig. 5 is a sketch of the display.

30 December 1964

Mile 338
Elevation 2726 m
Position 86'08'54" South Latitude
14°48' East Longitude
Time 0830 to 0915
Temperature -23°C
Wind 5 m/s

This display was indeed impressive and lasted for 45 minutes. During this time, the light intensity of the various components varied considerably. The display consisted of a 22° halo with brilliant parhelia, and a 46° halo as well. The upper tangential arc of the 22° halo was well developed, and the circumzenithal arc was especially brightly colored. On occasion, the parhelic circle was complete.

The most spectacular display occurred on 8 January. The data for this display follow, and Fig. 6 is a sketch of the display.

8 January 1965

Mile 445
Elevation 2679 m
Position 85°13'18" South Latitude
07°42' East Longitude
Time 0630
Temperature -24.2° C
Wind 1.3 m/s

The optical phenomenon consisted of the 22° and the 46° halos, with an extremely well-developed upper tangential arc of the 22° halo. The infra-lateral tangential arcs of the 46° halo were visible only for a few minutes. The parhelic circle and the circumzenithal arc were both complete for an instant, with the parhelic circle remaining for some tens of minutes later. The paranthelia were developed at 120°, and directly opposite the sun were the anthelic arcs. The circumzenithal, parhelic, and anthelic arcs were white. The most persistent feature was the lower tangential arc of the 22° halo.

Whiteout. Whiteout conditions were infrequent, and were only well developed on two occasions. Figure 7 demonstrates the difficulties of perception without a frame of reference.

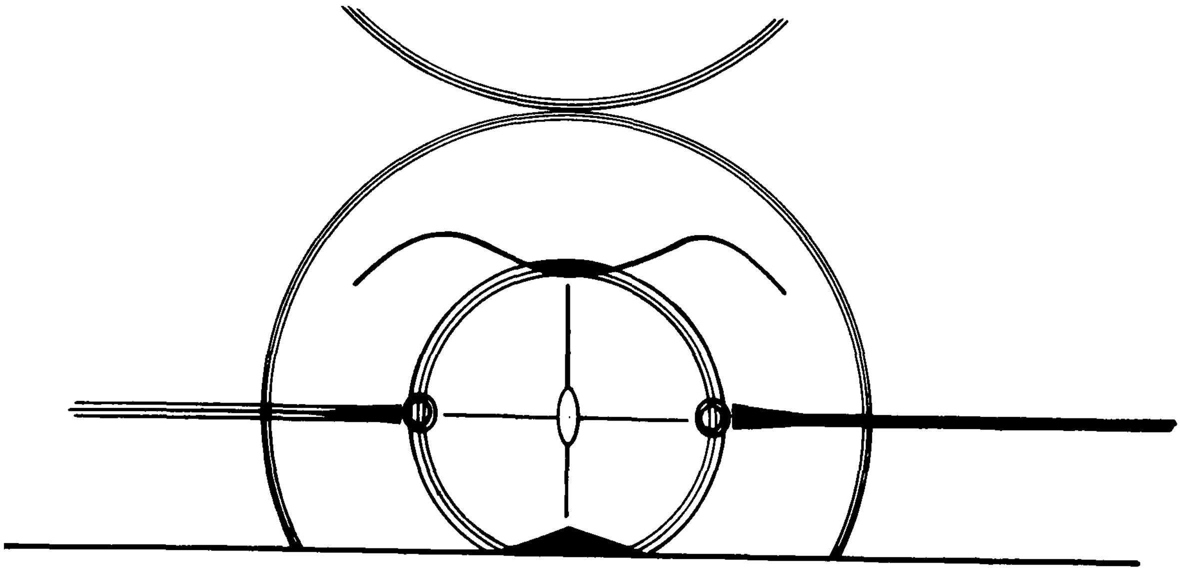


Fig. 5 - Drawing of solar halo seen on 30 December 1964. Details of display are given in text

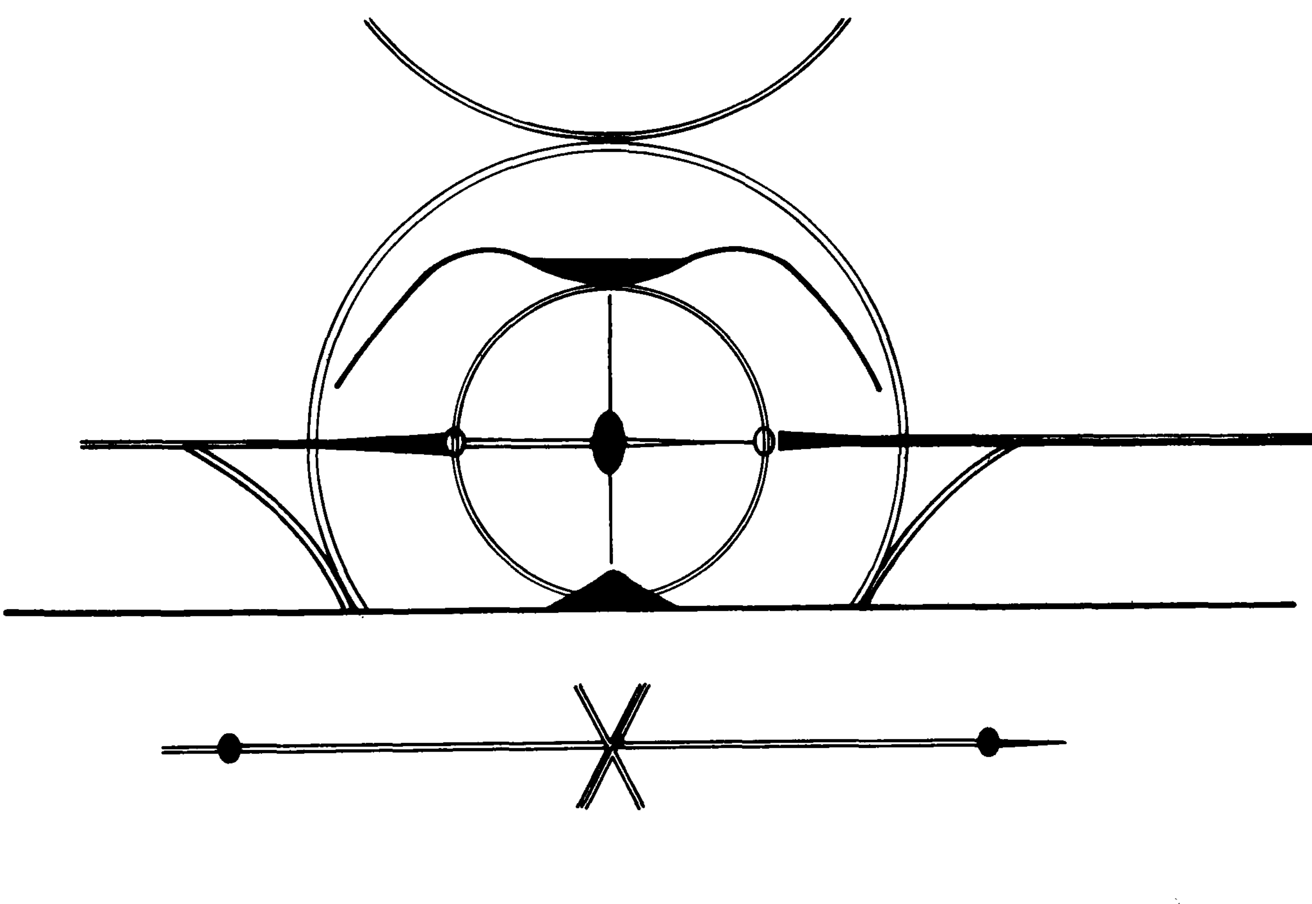


Fig. 6 - Drawing of solar halo seen on 8 January 1964. Details of display are given in text

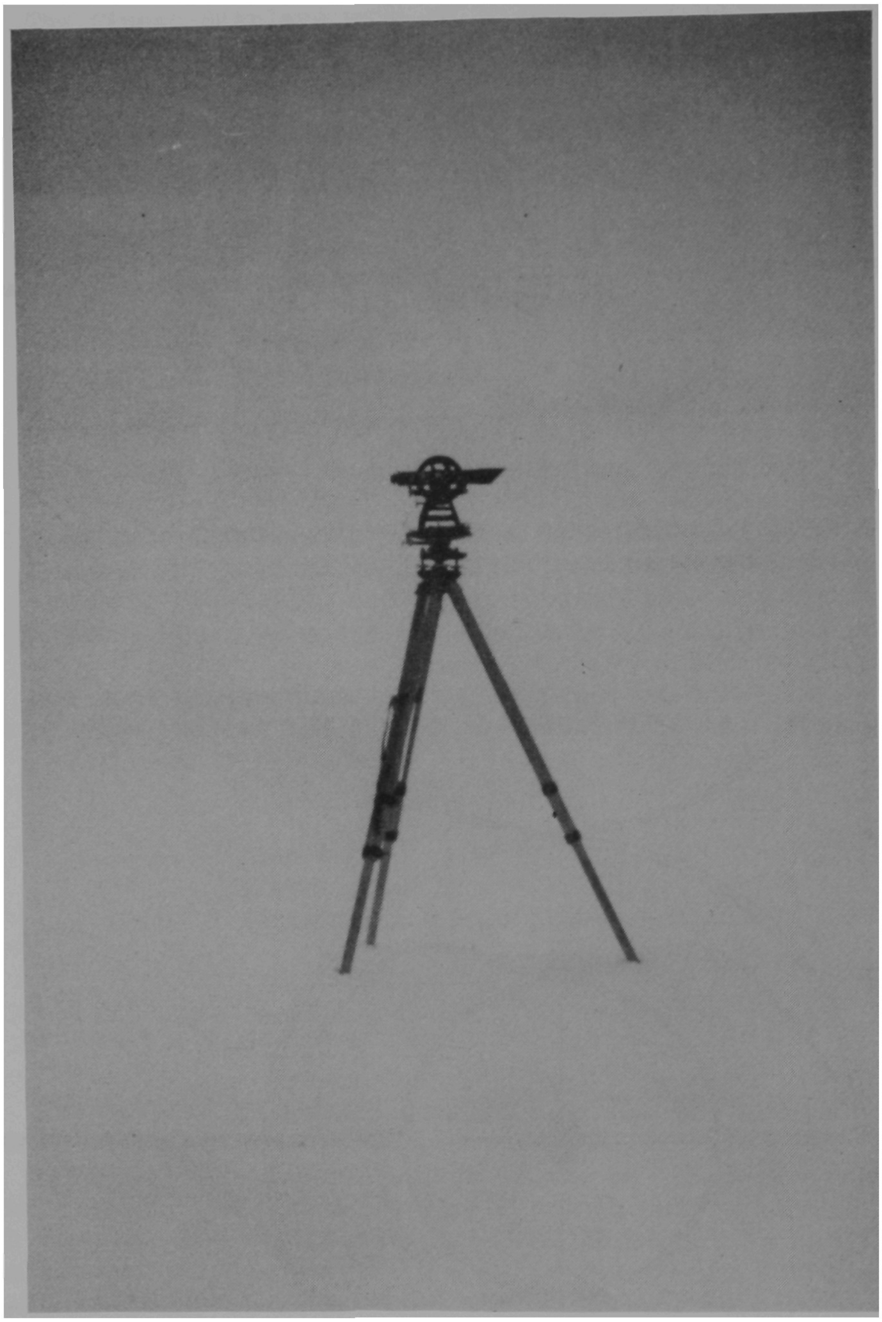


Fig. 7 - Whiteout. Tripod seems suspended in mid-air and no horizon is discernible (Photo by R. L. Cameron)

FIRN TEMPERATURE

General

Temperatures were measured in boreholes at 29 sites; 19 were bottom-of-the-hole temperatures, and 10 were temperature profiles. These temperature data are given in Table IV.

Most bottom-of-the-hole temperatures were measured with a thermohm and a Leeds-Northrup direct-reading Wheatstone bridge. Two thermohm cables were used; one was 16 m long and the other was 51 m long. Usually both thermohms were placed in the hole at night, and the measurements made in the morning. The temperatures were read to the nearest 0.05°C and are considered good to 0.1°C. Temperature profiles were measured with thermistors and a Leeds-Northrup No. 4735 guarded Wheatstone bridge in conjunction with a No. 9834 null detector. Resistances were converted to the nearest 0.01°C and the temperatures were considered good to 0.05°C.

Mean Annual Surface Temperature

Figure 8 shows a plot of temperature versus the elevation profile of the traverse route, and Fig. 9 is a plot of temperature versus elevation for all stations. The temperatures used in both figures are the deepest temperature at each site (their depths varied from 30 to 46 m).

Between the South Pole and Mile 185, there was a rather constant increase in elevation. However, in contrast to the expected inverse relationship between temperature and elevation, the temperatures showed little or no trend. The difference in elevation between the South Pole (2800 m) and Mile 185 (3106 m) is about 300 m. Taking into account the usual decrease in temperature with elevation of 1.1 to 1.4°C per 100 m, as determined by Crary (1963) for U. S. traverses in East Antarctica, the expected temperature would be 3.3 to 4.2°C lower than the South Pole. But, in fact, the South Pole temperature is -50.7°C and at Mile 185 it is -51.6°C, a decrease of only 0.8°C, equivalent to a lapse rate of 0.27°C per 100 m.

On the second leg of the traverse, there was a relatively constant decrease in elevation from Mile 185 (3106 m) to Mile 415 (2628 m), a drop of 478 m. Temperatures here were generally higher, but there is considerable scatter. The highest temperature (-47.8°C) occurred at 2857 m, the lowest (-52.0°C) at 3099 m. The temperature at the end of the traverse leg, which is the lowest elevation as well, was -48.4°C.

The elevation on the third leg of the traverse was fairly constant for the first 100 miles, but there was a slight increase in temperature. At this point, the surface slope increased sharply (this slope could

Table IV - Temperature Measurements (-°C)

Depth (m)	Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Mile	24	48	72	96	125	155	185	215	245	275	305	338	370	395	415	445
	Date	6 Dec	8 Dec	9 Dec	11 Dec	14 Dec	15 Dec	17 Dec	21 Dec	24 Dec	26 Dec	28 Dec	29 Dec	1 Jan	2 Jan	4 Jan	8 Jan
	Hole Depth (m)	32.5	38	40	36	37	38.5	37.5	40	40	40	39.5	16	10	37.9	40	39
	Surface Elev. (m)	2821	2854	2893	2973	2989	3034	3106	3099	3022	2857	2756	2726	2695	2672	2628	2679
1									44.88								
2									51.31	44.16	43.28	44.84				44.90	
3									52.49								
4									52.78								
5		50.66		50.26				52.46	52.82	50.29	48.90	49.15				49.44	
6									52.88								
7									52.58	50.05	48.60	48.84				49.33	
8									52.38								
9									52.25								
10		50.45		49.67	51.40	53.50		51.52	52.04	49.59	48.20	48.42		5150		49.75	
11																	
12																	
13																	
14																	
15		50.53		49.75				51.51	51.92	49.32	47.88	47.96				48.54	
16													48.35				
17																	
18																	
19																	
20		50.61		49.87				51.33	51.98	49.35	47.87	47.98				48.51	
21																	
22																	
23																	
24																	
25		50.67		49.92				51.57	52.01	49.35	47.89	48.01				48.48	
26																	
27		50.68															
28																	
29																	
30		50.66		49.96				51.19	52.01	49.33	47.84	48.03				48.46	
31																	
32		50.69						51.55									
33																	
34												48.02					
35				49.96					52.02	49.32	47.84	48.00				48.41	
36																	
37					52.35												
38			51.54		51.30		51.50								48.90		
39							↑					47.94		49.83	↑		49.40
40							(38.5m)		51.98	49.25	47.77				(37.9m)	48.39	
41																	
42																	

Table IV - Temperature Measurements (-°C) - continued

Depth (m)	Station	17	18	19	20	21	22	23	24	25	26	27	28	29
	Mile	470	496	519	545	570	595	620	650	680	710	740	770	797
	Date	9 Jan	10 Jan	14 Jan	15 Jan	17 Jan	18 Jan	19 Jan	23 Jan	24 Jan	25 Jan	26 Jan	27 Jan	30 Jan
	Hole Depth (m)	41.7	41.8	40.2	41.0	36.3	40.3	42.5	30.1	39.9	39.7	39.3	39.2	45.8
	Surface Elev. (m)	2688	2676	2683	2792	2872	3046	3172	3314	3397	3497	3577	3659	3718
1														51.53 (2.3 m)
2								41.98						
3														57.18 (4.3 m)
4								49.16						
5														58.28 (6.15m)
6								49.41						
7														
8														
9														
10								49.14						58.11
11														
12														
13														
14														57.42 (14.15m)
15						46.15	47.20	48.78	51.45		54.00	55.60	56.65	
16														
17														
18														
19														
20								48.73						
21														
22														
23														
24														57.00 (24.15m)
25														
26														
27														
28														
29														
30								48.70	51.05 (30.3m)					56.41
31														
32														
33														
34														56.84 (34.15m)
35														
36						46.10 (36.3m)								
37														
38														
39														56.79
40		49.80 (41.7m)	48.80 (41.8m)	48.60 (40.2m)	46.70 (41.0m)		47.20 (40.3m)	48.50 (42.5m)		52.70 (39.9m)	53.60 (39.7m)	55.20 (39.3m)	56.30 (39.2m)	56.72 (45.8m)

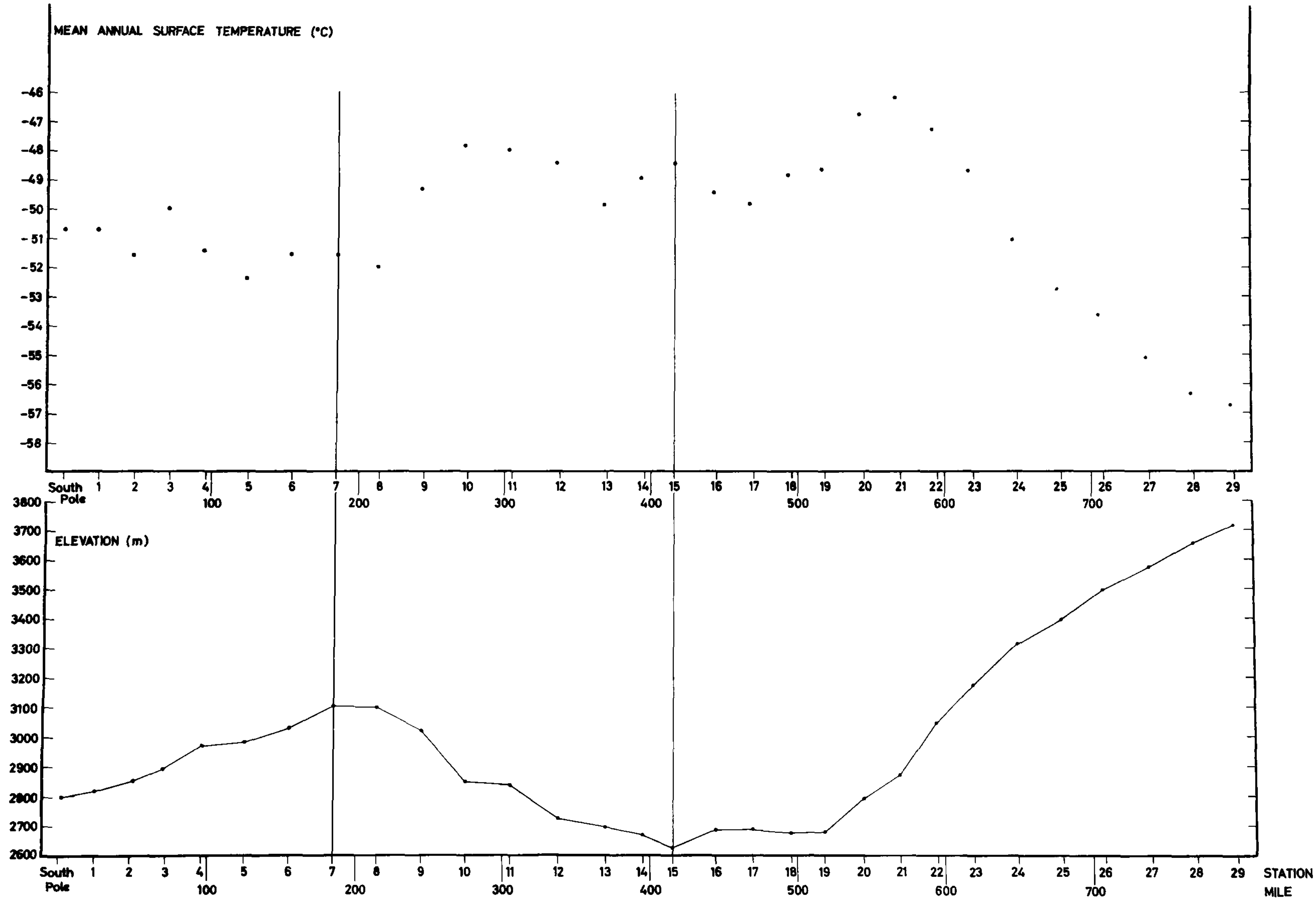
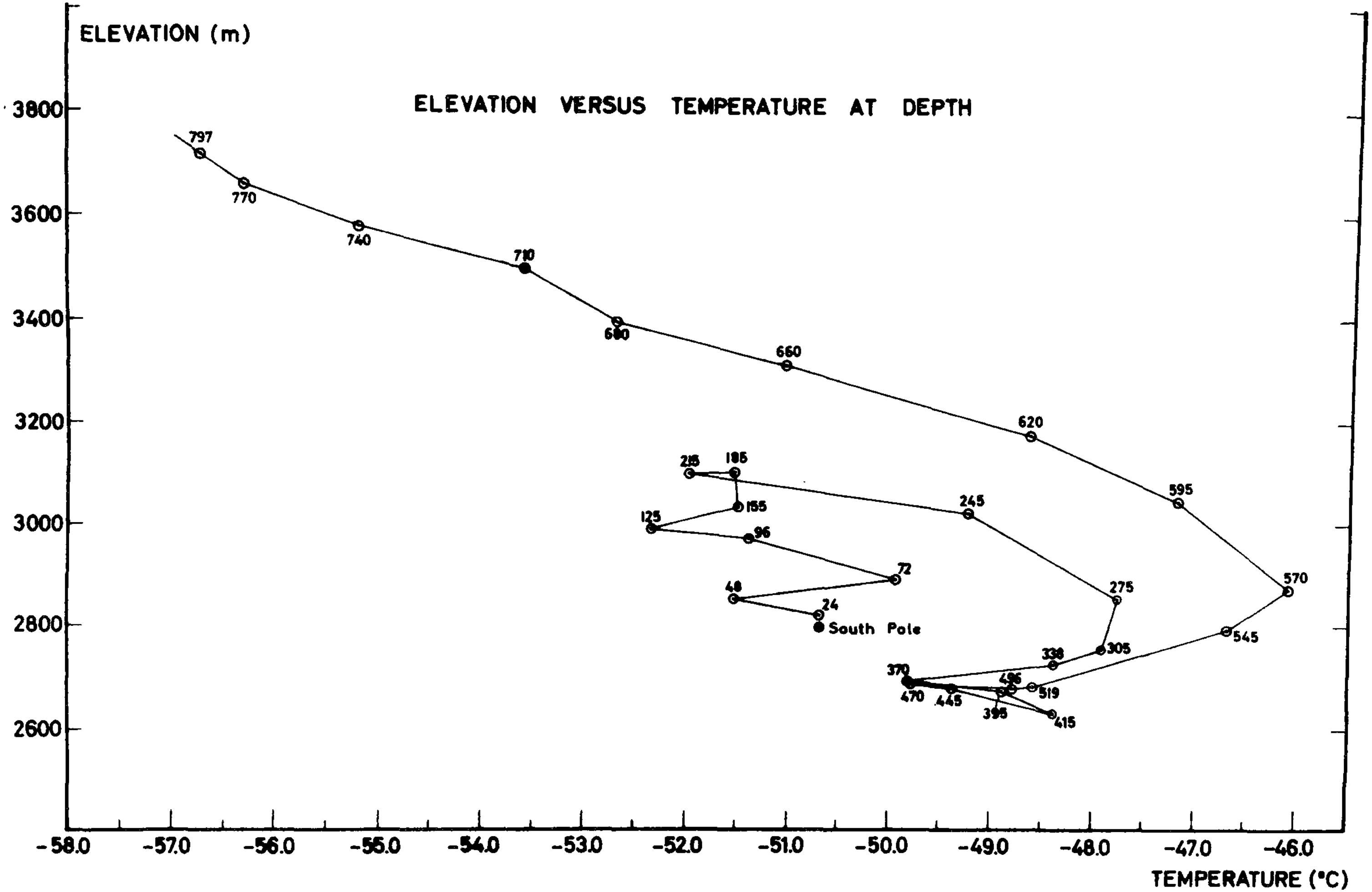


Fig. 8 - Mean annual surface temperature plotted against elevation profile of traverse route. Note striking anomaly on the third leg of the traverse where there is an increase in temperature with an abrupt increase in elevation



15

9

Fig. 9 - Firn temperature (at 30 to 46 m depth) versus surface elevation. It is evident that elevation is not the only factor influencing temperature; latitude and continentality also modify the temperature

actually be seen), and there was a marked increase in temperature for the next 50 miles. The temperature increased from -48.6°C at Mile 519 to a maximum of -46.1°C at Mile 510, an increase of 2.5°C as the elevation increased 189 m. This corresponds to a lapse rate of +1.32°C per 100 m, indeed an anomaly; it probably results from the warming of gravity winds as they descend this slope.

From Mile 595 to the Pole of Relative Inaccessibility (Mile 797), the elevation increased 672 m and the temperature decreased 9.5°C, for a lapse rate of 1.26°C per 100 m.

The lowest mean annual surface temperature recorded (-56.7°C) on the traverse was at the Pole of Relative Inaccessibility.

A map of mean annual surface temperature has been prepared, utilizing the results of this traverse and of the 1963-64 Soviet traverse (Fig. 10). The map shows the positions of the 50° and 55°C isotherms, and the locality of the anomalously warm area at the beginning of the steep slope.

Temperature Profiles

The temperature profiles were measured at 10 sites on the traverse, and the curves were plotted (Fig. 11). Temperature gradients between 15 m and the bottom of the drill hole have been obtained graphically from the thermistor temperature curves and calculated from thermohm measurements.

Table V shows that on the first leg of the traverse the first two profiles had negative gradients and the end profile was only slightly positive. The South Pole has a negative temperature gradient; negative temperature gradients have been reported from near the Pole by Crary (1963) and on the South Pole traverse of 1962-63 (Taylor, 1965).

The steepest gradients were at the end of the last leg of the traverse with a maximum of 2.01°C per 100 m at the Pole of Inaccessibility. The average of all positive gradients measured is 0.61°C per 100 m.

Pole of Relative Inaccessibility

A 47-m borehole was made at the Pole of Relative Inaccessibility in 1958. The temperature profile of this borehole was made by members of the Soviel traverse of 1963-64. Their measurements and those of the present (1964-65) traverse are compared in Table VI and in Fig. 12. The results show good agreement.

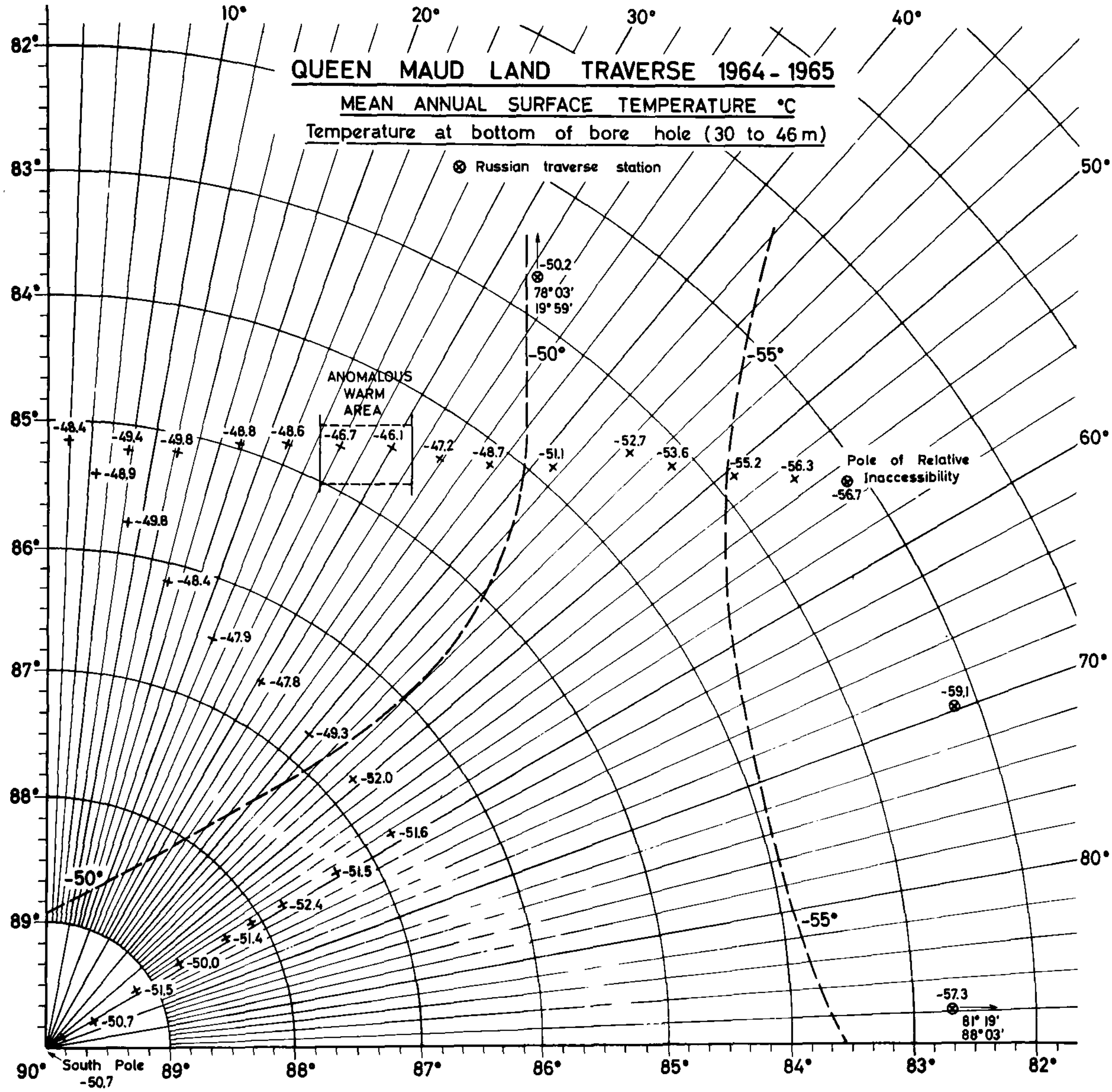


Fig. 10 - Distribution of mean annual surface temperature in East Antarctica

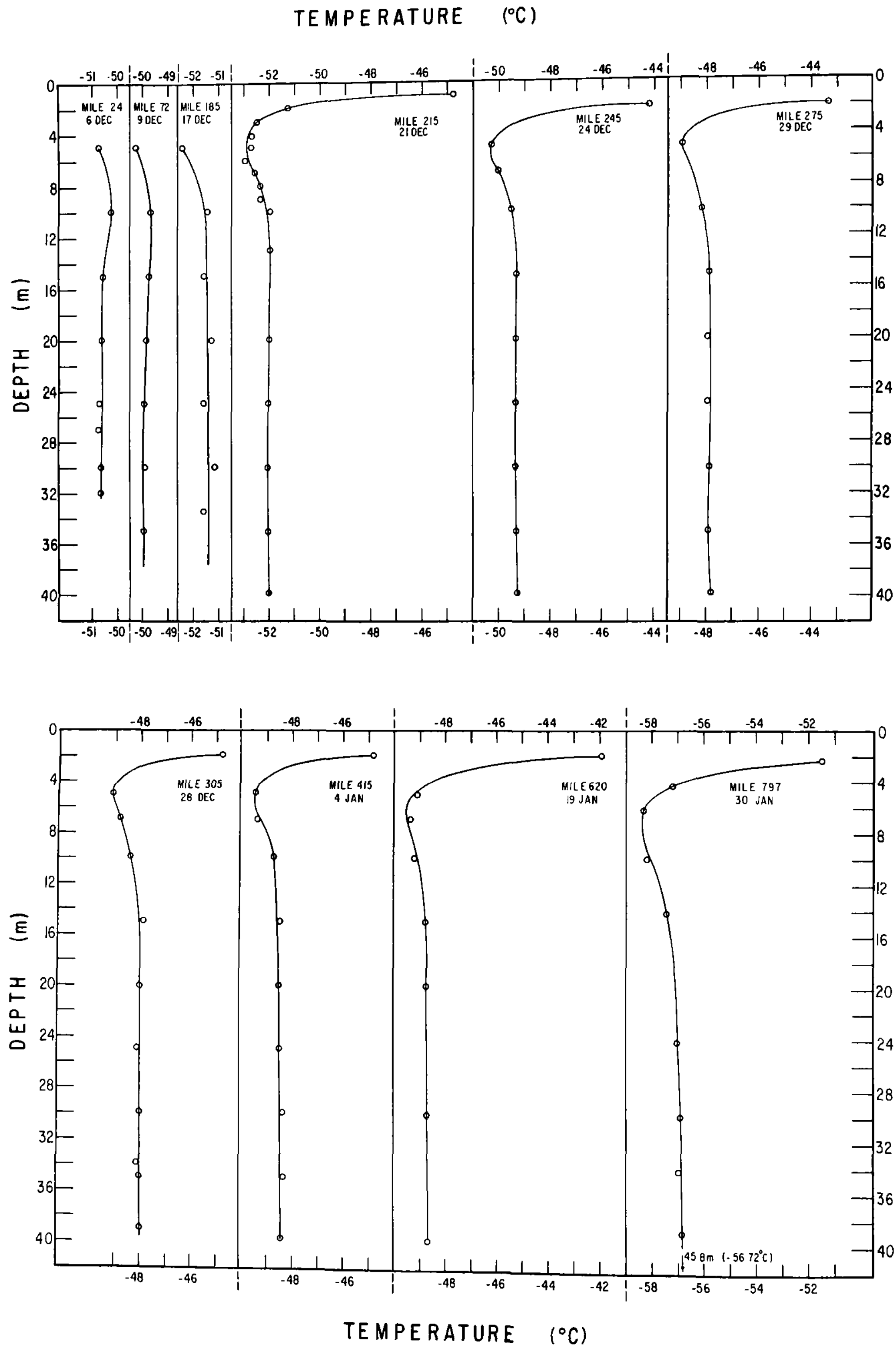


Fig. 11 - Temperature profiles, surface to 40 m, at ten sites on the traverse

Table V - Temperature Gradients from 15 m to Bottom of Borehole

Station	Mile	Thermistor (+) Thermohm (*)	Depth (m)	Interval (m)	Temperature Difference	Gradient (°C per 100 m)
1	24	+	15-32	17	-0.16	-0.94±0.05
3	72	+	15-35	20	-0.25	-1.25±0.05
7	185	+	15-32	17	+0.03	+0.18±0.05
8	215	+	15-40	25	+0.03	+0.12±0.05
9	245	+	15-40	25	+0.05	+0.20±0.05
10	275	+	15-40	25	+0.11	+0.44±0.05
11	305	+	15-39	24	+0.08	+0.33±0.05
15	415	+	15-40	25	+0.15	+0.60±0.05
21	570	*	15-36.3	21.3	+0.05	+0.23±0.20
22	595	*	15-40.3	25.3	0.00	0.00±0.20
23	620	+	15-42.5	27.5	+0.28	+1.02±0.05
24	650	*	15-30.3	15.3	+0.40	+2.61±0.20#
26	710	*	15-39.7	24.7	+0.40	+1.62±0.20
27	740	*	15-39.3	24.3	+0.40	+1.65±0.20
28	770	*	15-39.2	24.2	+0.35	+1.45±0.20
29	797	+	15-45.8	30.8	+0.62	+2.01±0.05

Questionable value

Table VI - Temperature Profiles at Pole of Relative Inaccessibility

Depth (m)	Zotikov, Kapitsa & Sorokhtin (1965) 4 February 1964 Temperature (°C)	Cameron and Kane 30 January 1965 Temperature (°C)
0	34.0	
1		
2	45.4	51.53
3		(2.3m)
4		57.18
5		(4.3m)
6		58.28
7	58.0	(6.15m)
8		
9		
10		58.11
11		
12	57.2	
13		
14		57.42
15		(14.15m)
16		
17	57.2	
18		
19		
20		
21		
22	56.7	
23		
24		57.00
25		(24.15m)
26		
27	56.9	
28		
29		
30		56.91
31		
32	56.8	
33		
34		56.84
35		(34.15m)
36		
37	56.8	
38		
39		
40		56.79
41		
42	56.8	
43		
44		
45		56.72
46		(45.8m)
47	56.8	

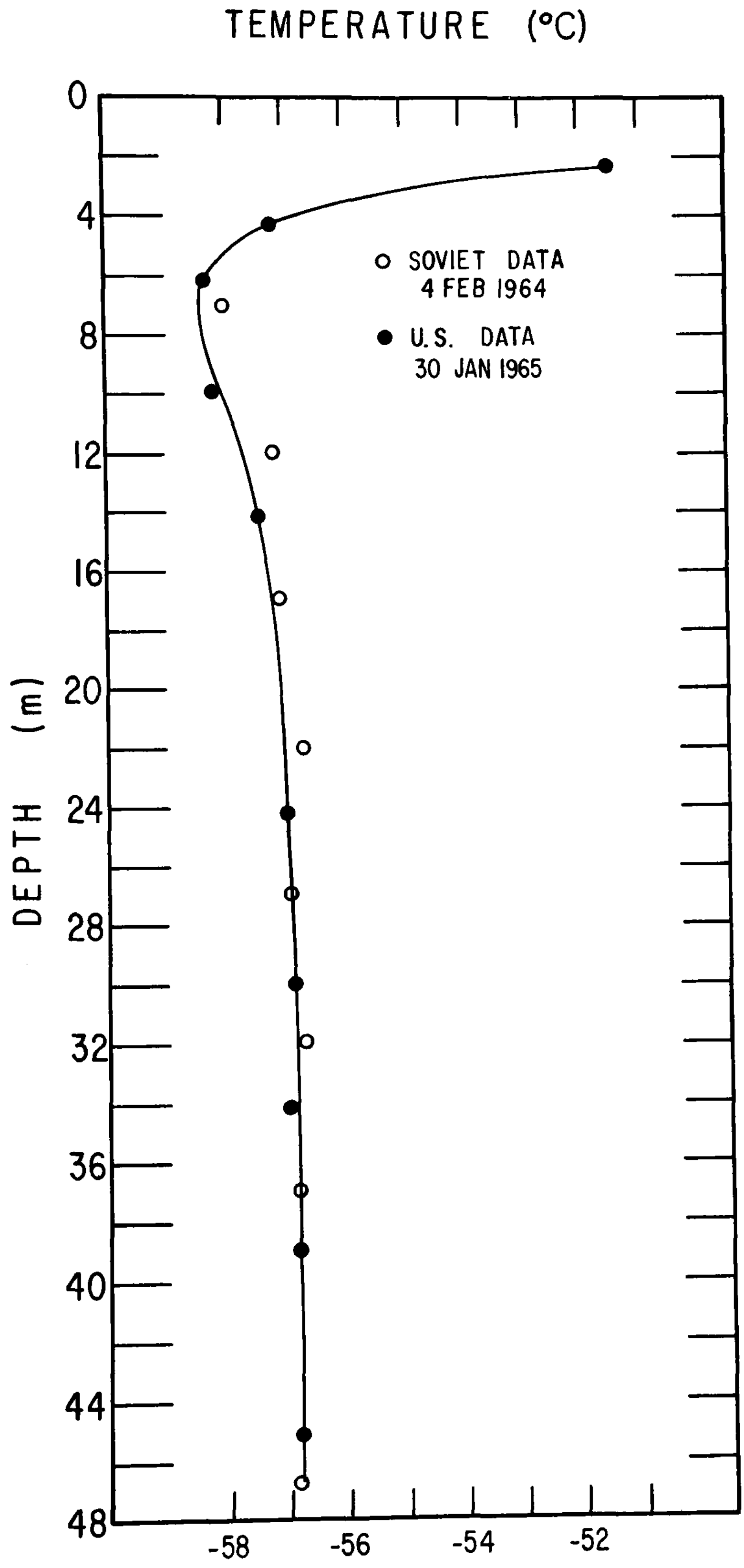


Fig. 12 - Temperature profile at the Pole of Relative Inaccessibility as determined by the Soviets, 4 February 1964 (open circles), and by the U. S. traverse, 30 January 1965 (solid circles). The curve is drawn on the U. S. data

SURFACE CONDITIONS

The variability of the ice sheet surface roughness was great, ranging from smooth (Fig. 13) to sastrugi more than a meter in height (Fig. 14); the hardness (0-50 cm) ranged from a low of 10 kg/cm^2 to a high of 190 kg/cm^2. The surface was so soft at one point that one vehicle and its rolli-trailer got stuck.

Snow Hardness

The hardness of the surface snow, 0-50 cm, was measured with a Rammsonde penetrometer at 171 sites along the traverse route. Five measurements were made at each site. These hardness values and means are tabulated in Appendix II; Fig. 15 is a plot of the means. The maximum mean hardness, 137 kg/cm^2, occurred at Miles 500 and 790. The absolute maximum was 190 kg/cm^2 at Mile 330, and the absolute minimum, 10 kg/cm^2, at Miles 500 and 750. The average snow hardness for the first leg of the traverse was 47 kg/cm^2; for the second leg, 56 kg/cm^2; for the third leg, 38 kg/cm^2; and the average for the entire traverse was 45 kg/cm^2. Figure 15 clearly shows the variability of the surface snow hardness.

Surface Characteristics

The surface characteristics at the snow pit stations are given in Table VII.

Surface Cracks

Surface cracks were noted at a number of sites along the traverse route (Fig. 16). They generally occurred in glazed areas having little slope. These cracks were especially pronounced at Miles 100, 195, 250, 280-285, and 680. The cracks are a few centimeters wide and tens of meters long; the depth of one crack was 250 cm. Surface cracks have previously been reported from East Antarctica by Stuart and Heine (1961), and by Giovinetto (1963), who reported a 6-m-deep crack.

The cracks occur as polygonal or parallel systems. The widest surface crack, 7 cm, was at Mile 285 (Fig. 17). The cracks widen with depth. A peculiarity of the cracks when viewed in the wall of a pit is the horizontal displacement (Fig. 18).

The most extensively "cracked" area was at Mile 185. Here, a system of parallel cracks was developed perpendicular to the slope. These cracks were especially persistent, and some could be followed for 100 m. The distance between adjacent cracks was measured for a group of the cracks (Table VIII), and the spacing averaged 17.2 m.

Fig. 13 - Smooth surface of ice sheet (Photo by E. Picciotto)

Fig. 14 - Sastrugi over 1 m high on first leg of traverse
(Photo by E. Picciotto)

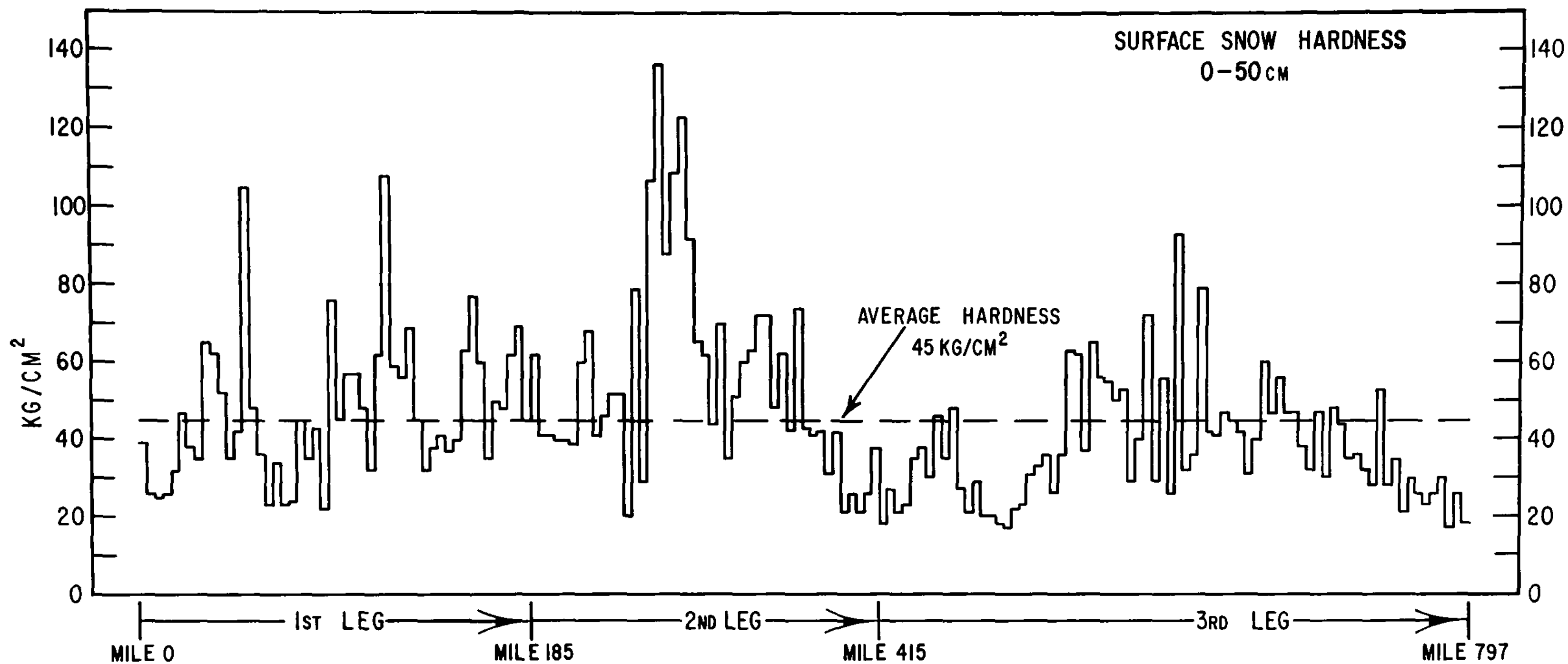


Fig. 15 - Snow surface hardness, 0-50 cm, along the traverse route

Table VII - Surface Characteristics at Pit Stations

Station	Mile	Surface Characteristics
0	8	High sastrugi
1	24	High sastrugi
2	48	Low sastrugi (15-20 cm)
3	72	Flat glazed surface
4	96	Dense, medium high sastrugi
4a	110	Low sastrugi
5	125	Very few sastrugi. Flat glazed surface, without sastrugi, icy crust above soft snow layer
5a	140	Low sastrugi
6	155	Low sastrugi
7	185	Very low sastrugi, cracks
8	215	No sastrugi, hard crusts alternating with loose surfaces
9	245	No sastrugi, flat surface
10	275	Wavy topography, medium high sastrugi
11	305	1- to 3-km-wide very flat strips alternating with medium high sastrugi strips. One of the flat strips is composed of an icy crust lying on a 10- to 20-cm loose layer formed by large (5-7 mm) cup-shaped (sublimation) crystals
12	338	Medium high sastrugi
13	370	Medium high sastrugi
14	395	Low sastrugi, soft snow
15	415	Very low sastrugi
16	445	Low sastrugi, soft snow
17	470	No sastrugi, soft snow
18	496	Flat surface, soft snow
19	519	Medium high sastrugi
20	545	Flat surface without sastrugi, fine medium-hard snow
21	570	Flat surface, very low sastrugi, loose snow
22	595	Flat surface, very low sastrugi, loose snow
23	620	Medium high sastrugi
24	650	Flat surface, sastrugi absent or low
25	680	
26	710	Flat surface, no sastrugi
27	740	Flat surface, no sastrugi
28	770	Flat surface, no sastrugi, soft snow
29	797	Flat surface, very low sastrugi, soft snow

Fig. 16 - Cracks developed in glazed snow surface
(Photo by R. L. Cameron)

Fig. 17 - Crack 7 cm wide on the surface at Mile 285.
Mitten to right of crack (Photo by R. L. Cameron)

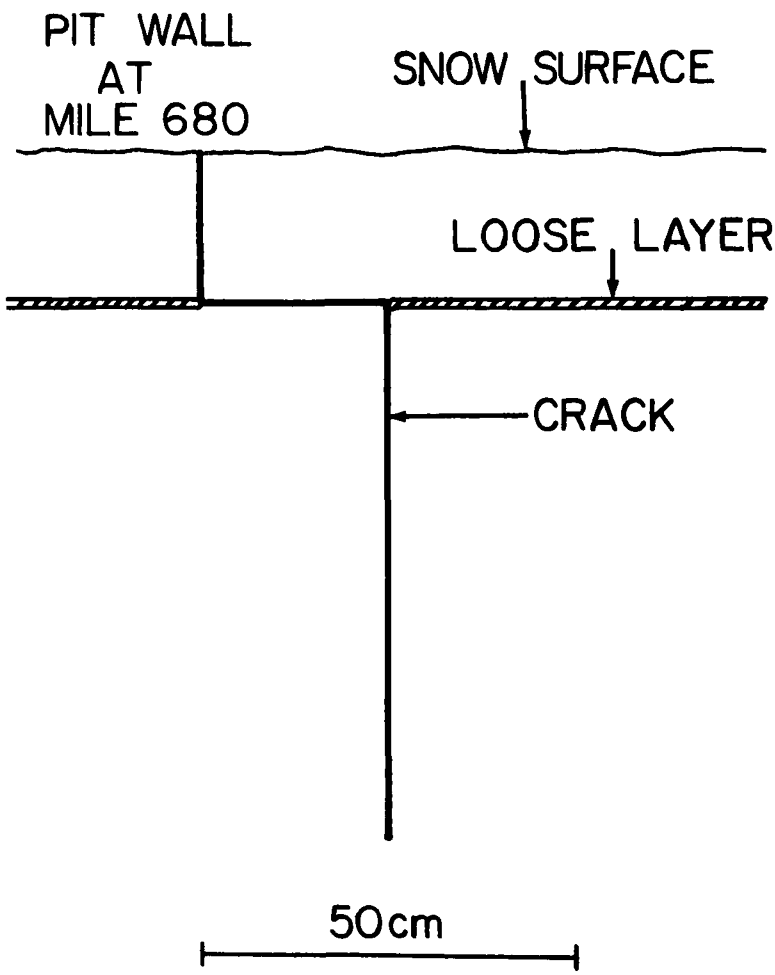


Fig. 18 - Sketch of 1-cm-wide crack in wall of pit at Mile 680

Table VIII - Spacing of Surface Cracks at Mile 185

(m)	(m)	(m)
16.0	17.1	25.8
19.3	17.5	26.8
43.0	23.1	15.3
12.5	10.0	11.3
9.2	14.1	7.2
16.0	13.9	21.3
12.8	9.0	25.4
29.4	14.6	18.8
8.8	14.6	14.6
32.0	15.0	14.9
12.4	26.0	16.2
7.3	12.3	26.9
15.5		

These cracks often bifurcate at angles of 120° (Fig. 19); they terminate in a slight curve and another crack begins (Fig. 20); some cracks cut through sastrugi (Fig. 21).

The cracks are generally associated with relatively flat, glazed surfaces where snow accumulation is low. The polygonal crack systems may be the result of seasonal temperature differences, and the parallel crack systems (perpendicular to the slope) may be incipient minor crevasses, or they too may be thermally produced but affected by the slope.

FIRN DENSITY

Depths of 0-2 m

Snow density from the surface to a depth of 2 m was measured at 23 stations.* These data are presented in Appendix III. The average densities are given in Table IX and are plotted on the map in Fig. 22.

The densities range from 0.363 g/cm^3 at Station No. 28 (at Station 29, the Pole of Inaccessibility, the density was 0.364 g/cm^3), to 0.411 g/cm^3 at Station No. 26. The average 0- to 2-m density was 0.385 g/cm^3.

* Snow samples were obtained with SIPRE density tubes, volume 500 cc, and weighed on a triple beam balance. Two density profiles were determined using horizontal sampling and the remaining using vertical sampling.

Fig. 19 - Bifurcation of surface crack at Mile 185
(Photo by E. Picciotto)

Fig. 20 - Relation of two cracks at Mile 185
(Photo by E. Picciotto)

Fig. 21 - Surface crack at Mile 185 developed in a sastruga
(Photo by E. Picciotto)

Table IX - Average Firn Density, 0-200 cm

Station	Mile	Density (g/cm^3)
5	125	0.396
5a	140	0.387
6	155	0.411
7	185	0.374
9	254	0.393
10	275	0.405
13	370	0.394
14	395	0.394
15	415	0.393
16	445	0.369
17	470	0.365
18	496	0.385
19	519	0.375
20	545	0.397
21	570	0.385
22	595	0.392
23	620	0.397
24	640	0.392
25	680	0.375
26	710	0.382
27	740	0.371
28	770	0.363
29	797	0.364
	Average	0.385

Crary (1963), in his analysis of the United States traverses in East Antarctica, computed average densities for 1-m intervals, and from these data the average density from 0 to 2 m for 40 stations is 0.397 g/cm^3. For the 13 stations on the McMurdo-South Pole traverse, the average density is 0.388 g/cm^3.

The areal distribution of 0- to 2-m densities shows no particular trend. The only significant points are the anomaly at Mile 470, where the density is low, 0.365 g/cm^3, and at the end of the traverse, where the densities are again low, 0.363 and 0.364 g/cm^3.

Depths of 0-40 m

Because 40-m holes were to be drilled at each traverse station for seismic investigations, it was decided to utilize these holes for depth-density measurements. The boreholes were drilled with a 9-cm-diameter auger driven by a hydraulic motor mounted on the bed of the 742 Sno-Cat; in the loose firn in Queen Maud Land, this produced a hole between 9 and 12 cm in diameter.

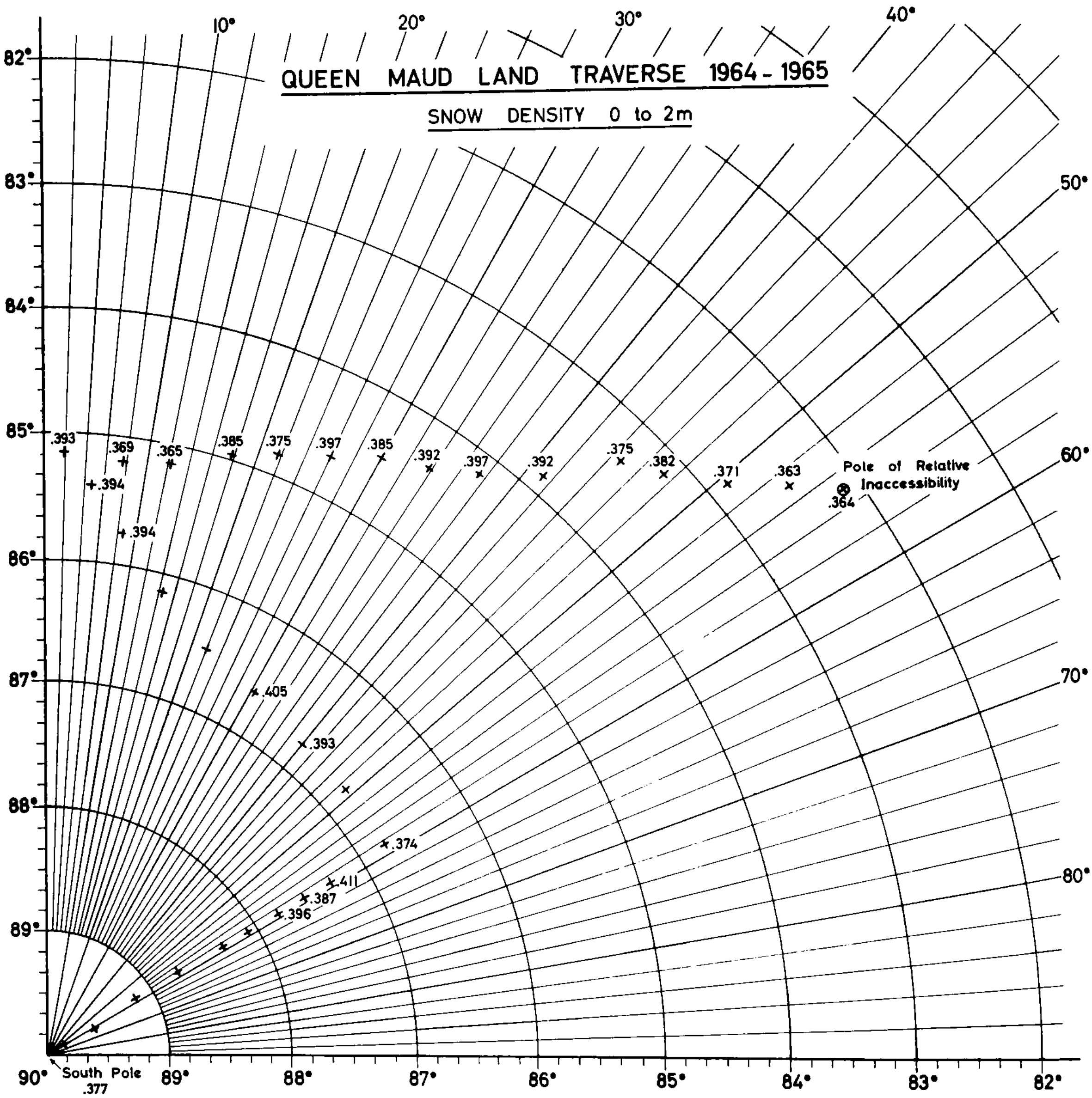


Fig. 22 - Average snow density, 0-2m, along traverse route

The only technique readily adaptable to measuring snow density at depth in a single hole of varying diameters is the neutron-neutron, or neutron scattering, method.

A probe, containing a neutron source ($Ra^{226}Be^{9}$), and a detector (BF_3 gas-filled proportional counter), suitable for registering the passage of low energy neutrons, are lowered down the hole. High-energy neutrons emitted by the source are moderated in the snow and returned as low-energy neutrons to the detector.

The RaBe source emits neutrons whose average energy is 5 MeV. In an elastic (billiard ball) collision, a neutron will lose the maximum amount of energy if the colliding particle is of the same mass as the neutron. The mass of a neutron is 1.00898 amu, and the mass of hydrogen is 1.00814 amu. On the average, it will take less than 30 collisions with hydrogen to reduce the neutron energy from 5 MeV to the thermal equilibrium value $\simeq 1 \times 10^{-8}$ MeV. These 30 collisions will occur close to the source for a high density of hydrogen (in this case, snow), and result in a large concentration of thermal neutrons. For a lower snow density, this thermalization will occur at greater distances, resulting in a reduced concentration of thermal neutrons (Halliday, 1955, p. 215).

The probability for detection of a neutron in a BF_3 detector is very great for low-energy (thermal) neutrons and very small for high-energy neutrons. Thus, the output of the BF_3 detector (in counts/unit time) will be proportional to snow density.

Because of relative availability, the equipment consisted of a commercial off-the-shelf soil-moisture probe, Nuclear Chicago Model P-19, and a Nuclear Chicago portable scaler, Model 2800A. There were several difficulties with this arrangement: (1) the probe is small, since it is designed for a 4-cm hole, and thus the count rate is low compared to what it might be for a probe designed for a 9-cm hole--this low counting rate limits the statistical accuracy of the density determinations; and (2) the transistorized preamplifier was not designed for low temperatures, and a small heating element had to be built into the probe. Because of space limitations, this heater was not thermostatically controlled, and thus did not prove entirely satisfactory. New equipment has been designed for subsequent field work which has eliminated these difficulties.

In operation, the probe was held at one depth while two one-minute counts were taken, and then lowered to the next level. Readings were usually taken at 50-cm intervals. A "standard" count was taken in the probe shield, both before and after a hole-logging operation. In this way, corrections could be made for any drifting of the equipment, either during logging or from hole to hole.

The neutron technique does not uniquely determine the snow density at the sampling depth. Several factors contribute to this effect:

(1) Neutrons are emitted in all directions from a point source, and therefore occupy a volume around the source. The information about the density which the count rate yields is thus the result of "integration" over this volumetric sphere of influence. The density this technique will report is a weighted average rather than the exact density at the sampling point. The correlation with the actual point density may be seen in the comparison shown in Fig. 23. As pointed out earlier, the volume of thermal neutrons (and therefore, the sampling volume) varies with density. The diameter of the "sphere of influence" is given by $d_s \simeq 30.5/\sqrt[3]{\rho}$ (cm), where ρ is the snow density.

(2) The quantity measured (counts/unit time) is random in time, and as such is governed by the statistics of random events (Halliday, 1955, p. 209). It is generally held that the standard deviation (σ) of such a count (N) is equal to $\sqrt{N}$. For count N = 100: σ = 10, and $\sigma/N = 0.1 = 10\%$. For a count N = 10,000: σ = 100, and $\sigma/N = 0.01 = 1\%$. Thus, it is readily seen that the larger the number of counts (N) for a given situation the more accurately we know the actual value of N, on a percentage basis. N can be increased by counting for longer periods of time.

(3) The thermal neutron flux measured by the probe is not a simple function of snow density. It depends on many factors attributable to the density and layering of the snow. Additionally, there are effects resulting from the presence of the probe and of the hole itself. It is best to adopt an operational point of view to determine the relationship between count rate and density for a given configuration.

In several locations, densities were calculated by the standard technique of weighing known volumes of snow. These results were then compared with the neutron count rate (Fig. 24). A linear regression of the points from four locations yielded the equation:

$$\rho = 0.735 \times 10^{-4} k + 0.1593 \text{ g/cm}^3$$

where ρ = density in g/cm^3, and k = the count rate in counts/minute. The correlation coefficient for this regression is 0.958, and the standard deviation (σ_ρ) is 0.022 g/cm^3. This large standard deviation is to be expected since the weighing technique is a "point" sample, whereas the neutron technique represents a volume average sample, as discussed above. In the surface snow layers, a weighed density has the possibility of a large deviation from the average value. A high correlation coefficient is obtained, since the variation due to point and volume sampling balances out when many values are considered. Thus, a given weighed density can vary quite a bit from the nuclear determined density, while the overall results of the regression equation are really quite valid. This equation has been used in converting all count rates to densities, and can also be used to give the standard deviation of the density (σ_ρ) from the standard deviation of the count (σ_N):

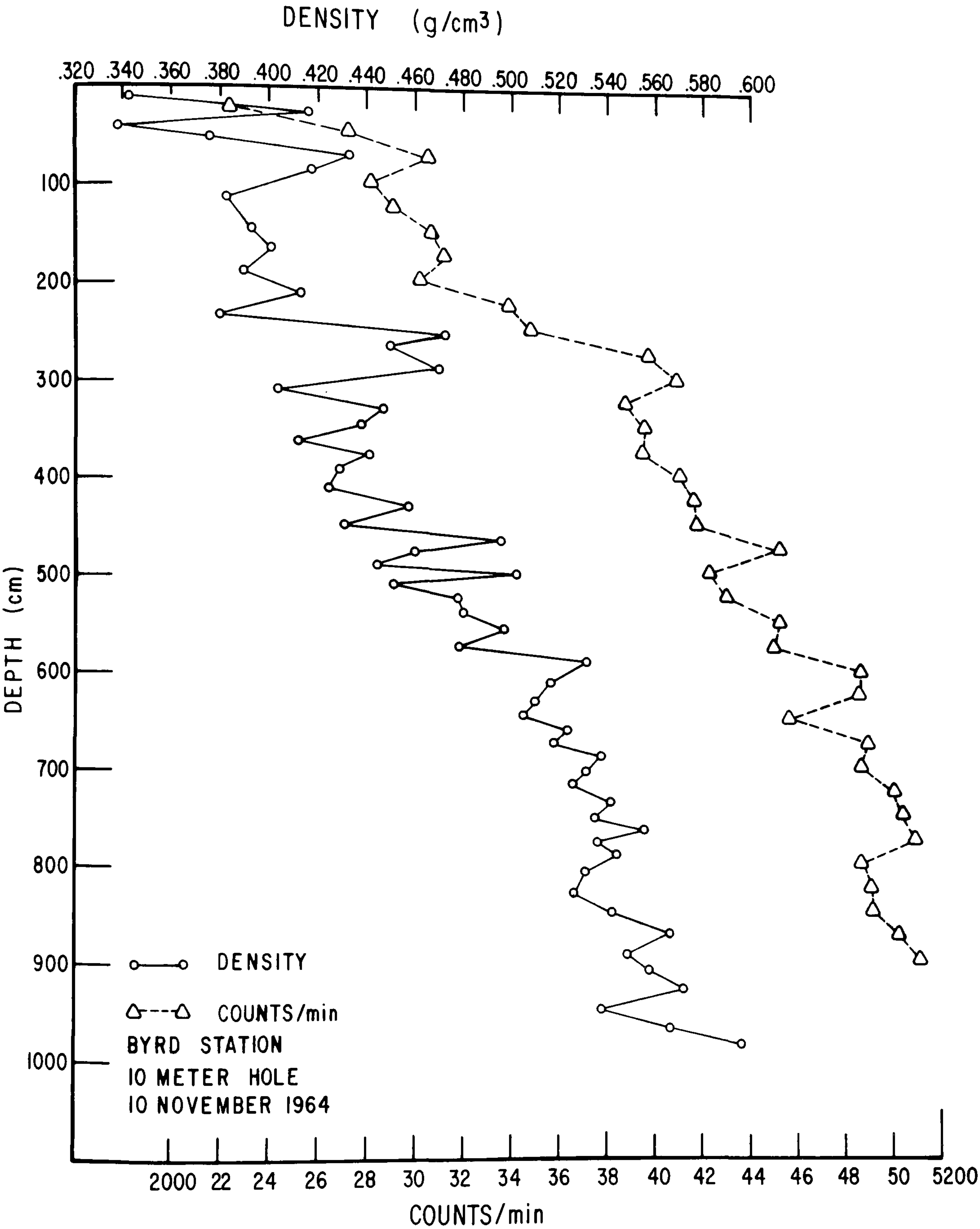


Fig. 23 - Comparison of measured density and raw neutron count rate in 10-m drill hole at Byrd Station, 10 November 1964

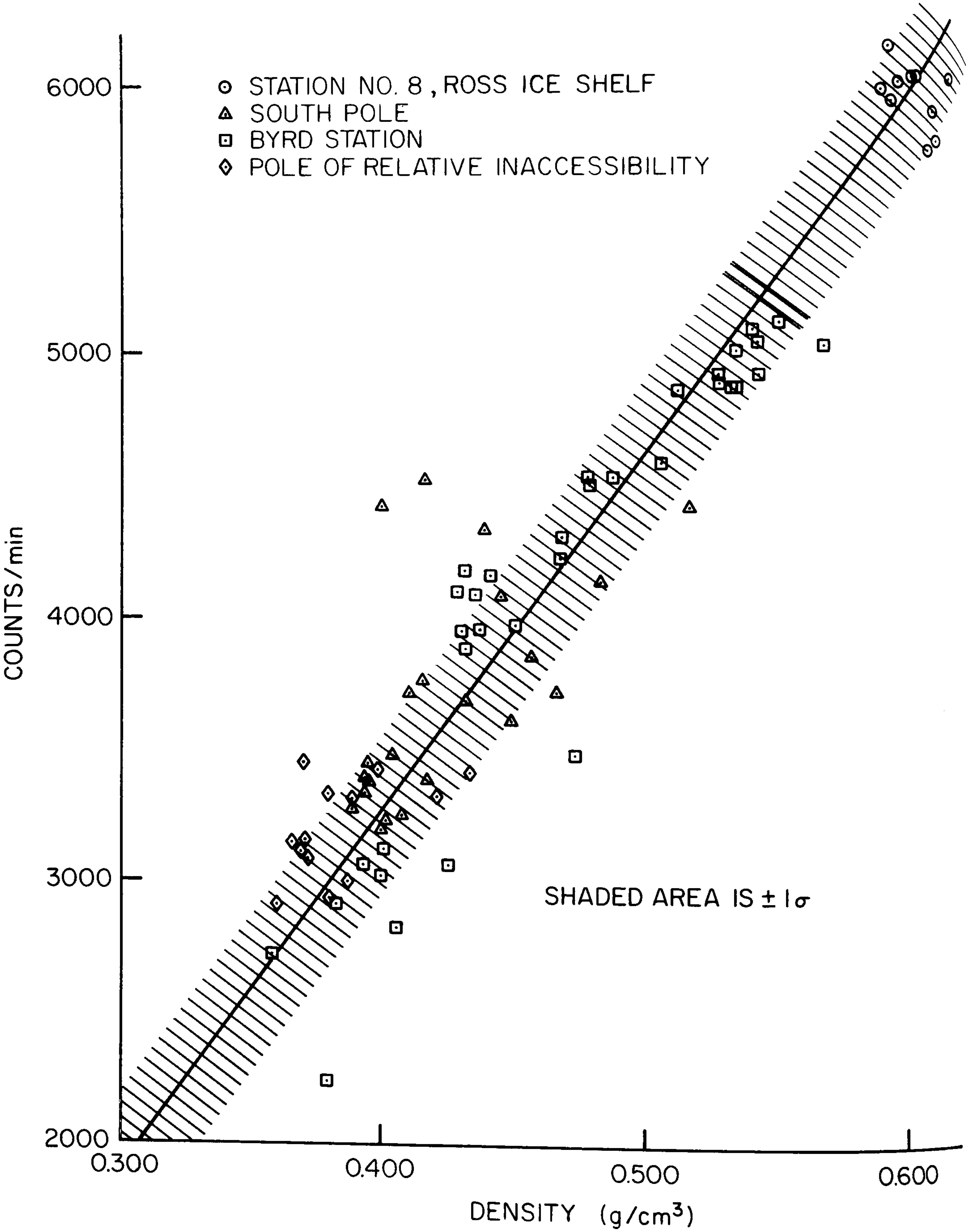


Fig. 24 - Linear regression. Density probe calibration of counts per minute versus density

$$\rho = mk = m\frac{N}{T} ,$$

where $k = N/T$ = counts/unit time. Now with $\sigma_N = \sqrt{N}$, $\sigma_\rho = m\frac{\sqrt{N}}{T} = m\frac{\sigma_N}{T} = m\sqrt{\frac{k}{T}}$. For a two-minute count, with $m = 0.735 \times 10^{-4}$ (from the regression formula), and taking an average count rate, $k = 4000$ counts/minute,

$$\sigma_\rho = 0.735 \times 10^{-4}\sqrt{2000} = 0.0033 \text{ g/cm}^3 .$$

From a statistical point of view, it is 95 percent probable that the true value is within $\pm 2\sigma$ of the measured value ($\pm 2\sigma = 0.013$ g/cm^3). This then is the statistical uncertainty of the density values resulting from the counting technique employed. An error bar ($\pm 2\sigma$) is plotted with the first density curve in Fig. 25.

Twenty depth-density curves were measured on the traverse. The count rates were recorded, and then the depth-density curves were produced by converting these rates to density according to the regression formula. Figure 26 shows the raw count rates for Miles 48 and 797; the higher counts for Mile 48 are indicative of the higher snow density.

The resultant depth-density curves are plotted in Fig. 25, and the count rate-density data are given in Appendix IV. At a number of stations where the 0- to 2-m densities were measured directly in pits, the average is plotted at a depth of 1 m to show the relationship to the indirect profile measurements; in most cases, the correlation is very good. Most depth-density curves show a definite break at a density of about 0.52 to 0.54 g/cm^3, but there are others, at Miles 470 and 710, that are relatively smooth. The scatter of points near the surface at the Pole of Relative Inaccessibility indicates an increase in density near the surface which is most likely caused by compaction of snow by vehicles and personnel movements during the installation and subsequent history of this station. The 0- to 2-m pit was excavated some distance from the station, and the average falls at a point consistent with the rest of the depth-density curve.

Depth of 10 m

The densities at 10 m have been obtained graphically from the depth-density curves in Fig. 25 and are given in Table X. These values are also plotted on the map in Fig. 27. The densities range from 0.440 g/cm^3, at Mile 797, to 0.486 g/cm^3, at Mile 620, and average 0.460 g/cm^3. This is quite a bit lower than the average of about 0.495-0.500 g/cm^3 determined on the McMurdo-South Pole traverse (extrapolation of data presented by Crary, 1963).

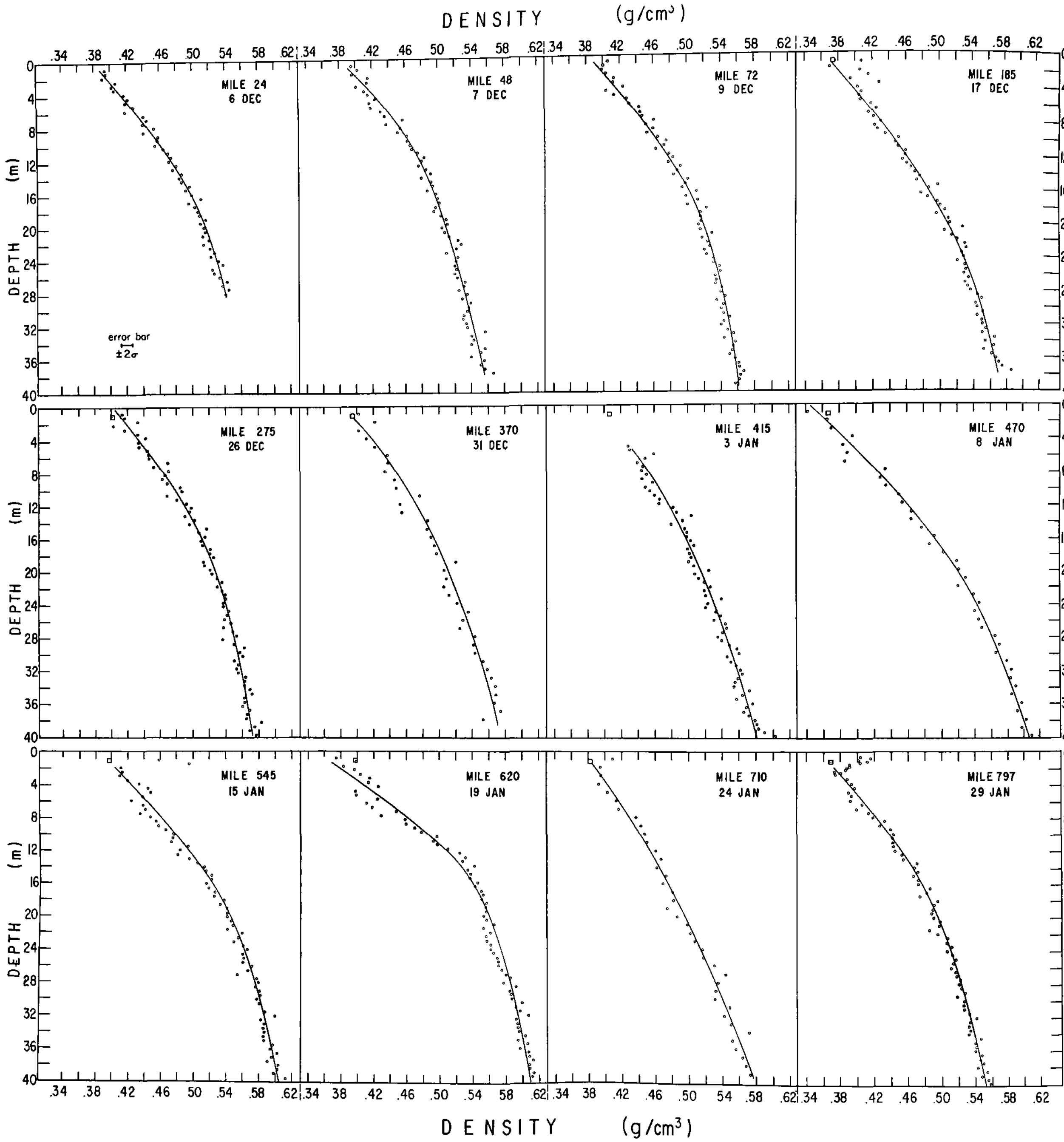


Fig. 25 - Depth-density curves at 12 sites along the traverse. Curves constructed from data obtained from neutron probe

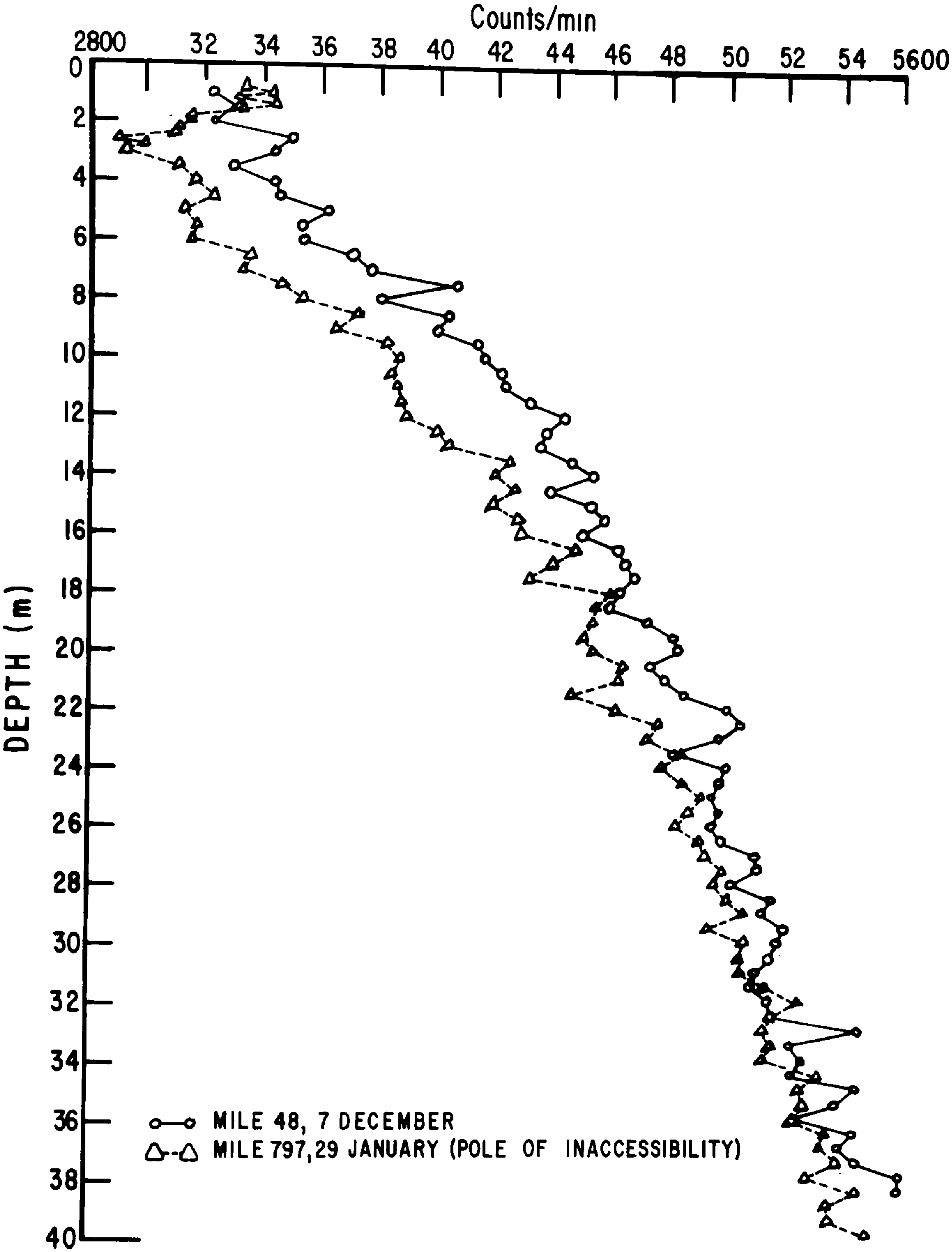


Fig. 26 - Raw neutron count rates at Mile 48 and Mile 797 reflecting the higher firn density at Mile 48

Table X - Density at 10 meters

Station	Mile	Density (g/cm^3)
1	24	0.462
2	48	0.467
3	72	0.464
7	185	0.442
10	275	0.477
13	370	0.462
14	395	0.454
15	415	0.465
17	470	0.442
20	545	0.477
23	620	0.486
26	710	0.442
29	797	0.440

The areal distribution of 10-m densities shows no well-defined trends. The low densities occur at Mile 185 and near the end of the traverse at Miles 710 and 797. In addition, a low value, 0.442 g/cm^3, occurs at Mile 470 where the 0- to 2-m density is also low.

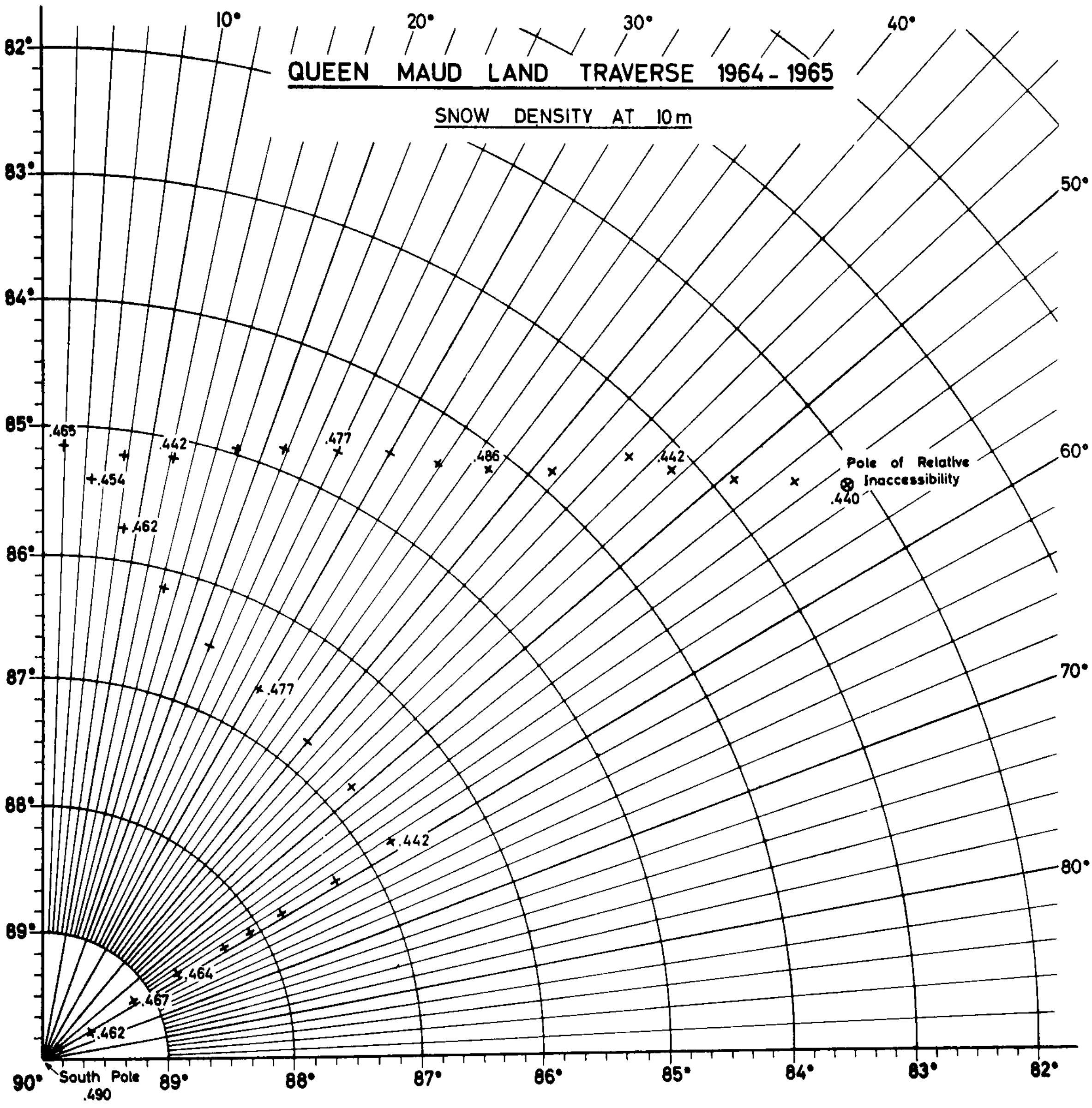


Fig. 27 - Snow density at 10-m depth along traverse route

PIT STUDIES

Twenty-nine 2-m pits were excavated on the traverse for purposes of (1) recording the snow stratigraphy and from this, when possible, estimating the average snow accumulation; (2) measuring the snow density to obtain the average 0- to 2-m density, and using these data to determine water equivalents of the snow accumulation; (3) collecting snow samples from the pit wall and from an 8- to 10-m drill hole at the bottom of the pit for determination of snow accumulation from radioactive fallout and the decay of Pb^{210}; (4) collecting snow samples for determining O^{18}/O^{16} ratio, and thus the average temperature of formation of the snowflake or snow crystal; and (5) collecting snow samples for the analysis of included microparticle contents.

In addition, pits were excavated adjacent to the U. S. Weather Bureau accumulation stakes, B and F, at the South Pole. Snow accumulation has been measured at these stakes since 14 January 1958, and the snow accumulation at stake B seemed to be quite regular, whereas snow did not accumulate at stake F during 1961. The comparison of known horizons (stake measurements) with the snow stratigraphy was an aid in understanding the stratigraphy seen on the traverse.

Stratigraphic studies consisted of measuring the vertical section, noting whether the crusts and layers were continuous or discontinuous, noting relative hardness of layers, measuring grain size in some pits, and photographing the wall of selected pits. The stratification in the pits was remarkably uniform with only slightly undulating but continuous layers, quite in contrast to the frequent rough surface (Fig. 28). Occasionally, however, the stratification was poorly defined, with layers varying greatly in thickness across the wall and sometimes pinching out altogether.

The snow layers were separated by (1) crusts, which were once the snow surface, that are generally thin (1-2 mm) but well defined; (2) thin layers of bonded grains; and (3) the most striking pit feature -- layers of depth hoar. The development of these depth hoar layers is considered to be an annual event. In an extreme case, at Mile 470, the entire snow column was transformed to hoar which essentially erased the stratigraphy. At this site, the 0- to 2-m and the 10-m densities were both anomalously low. The depositional environment here was different from anywhere else on the traverse.

An especially interesting stratigraphic feature was the occurrence of extremely hard, fine-grained layers. They were 3-15 cm thick and were encountered in numerous pits. The origin of these features is unknown.

Fig. 28 - Typically rough surface along first leg of traverse. Surface relief 30-40 cm (Photo by E. Picciotto)

The pit diagrams, given in Appendix V, are not accompanied by detailed written descriptions. Rather, a summary of densities and grain size for the various layers is given in Table XI.

Table XI - Typical Density and Grain Size of Firn Layers

	Density (g/cm^3)	Grain Size (mm)
New snow	0.34	0.2 - 0.4
Soft, medium	0.35 - 0.37	0.4 - 0.6
Very hard layer	0.51 - 0.52	0.3
Depth hoar layer	0.22 - 0.30	1.0 - 10.0

ACCUMULATION

Measurement of Accumulation

In this region of the polar plateau, it is difficult to determine annual accumulation from the stratigraphy. The most distinct evidence of the annual variation of climatic conditions are layers of sublimation crystals, accompanied by thin ice crusts. The interpretation of the stratigraphy and the counting of annual layers would be simple if it were certain that a sublimation layer was formed each year, and that there was only one formed for each year. Unfortunately, this does not seem to be so. The difficulties in determining annual accumulation from the stratigraphy are:

1. The sublimation layers are often discontinuous; they bifurcate or pinch out.

2. The processes forming sublimation layers sometimes affect much of the firn which represents several years of accumulation. An extreme case was Station 17, where the first 2 m of the pit consisted wholly of sublimation crystals.

3. Several thin sublimation layers are fairly close to one another, and it is impossible to decide whether they were formed in one year or represent several years of very small accumulation, or even absent accumulation. Gow (1965) has shown that a double sublimation layer might be formed if there is no deposition.

4. The sublimation layers can be missing. In certain sections, the interval between two sublimation layers is too large to represent one year of accumulation.

5. The uniformity of the firn can be interrupted by features other than sublimation layers, such as continuous ice crusts, very hard layers (frequently of considerable thickness), and discontinuities in hardness or grain size. The significance of these features and their relationship to annual climatic cycles is unknown.

6. In this region of very low accumulation, it is always possible that at some site for at least one year there was no deposition at all, either because the snow accumulation was negligible or because the deposited snow was eroded and removed by the wind.

Definite statements concerning the accumulation at each traverse station can be made only after the field samples have been subjected to geochemical analysis, especially the distribution of fission products and Pb^{210}. It now appears evident that the variations of the stable isotopes of oxygen and hydrogen cannot furnish much more information than that gained by ordinary stratigraphic techniques (Epstein and Sharp, 1965).

The snow accumulation along the traverse route, as determined by pit stratigraphy, is given in Table XII and Fig. 29. Considering the difficulties in interpreting the stratigraphy, maximum and minimum accumulation values for each pit have been given. In general, there is a tendency to underestimate the number of years, and consequently to overestimate the accumulation values. Therefore, these values should be regarded as the upper limit of annual accumulation.

Accumulation at the Pole of Relative Inaccessibility

The Pole of Relative Inaccessibility was established on 14 December 1958, and was occupied until 26 December 1958. The station was next visited in February, 1963, by a Soviet traverse led by Dr. A. Kapitsa. The first Queen Maud Land Traverse arrived at the station on 27 January 1965, and remained until 2 February 1965.

At the station, a meteorological study area was laid out on 14 December 1958 and the anemometer mast and the instrument shelter remain from this installation (Fig. 30). To determine the snow accumulation since December 1958, small snow pits were excavated at the anemometer mast and at the instrument shelter. The base plate of the anemometer mast was covered by 63 cm of snow, and the instrument shelter was covered by 60 cm of snow at the left rear leg (Fig. 31), and by 66 cm of snow at the bottom of the steps. Snow density was measured at the anemometer mast.

Table XII - Accumulation along route of Queen Maud Land Traverse, 1964-1965

Station	Mile	Accumulation (g/cm^2) Maximum	Minimum
0	8	8.8	8.0
1	24	8.0	8.0
2	48	9.8	9.8
3	72	6.6	6.6
4	96	7.2	5.6
4a	110	11.2	11.2
5	125	7.2	4.8
5a	140	5.5	5.5
6	155	8.2	6.1
7	185	6.8	2.8
8	215	6.0	2.8
9	245	6.4	5.6
10	275	7.4	7.4
11	305		
12	338	8.0	6.4
13	370	8.9	8.1
14	395	7.2	6.0
15	415	11.4	7.1
16	445	5.4	4.3
17	470	5.3	?
18	496	8.8	6.7
19	519	7.5	5.3
20	545	7.9	7.1
21	570	7.6	4.4
22	595	7.0	5.4
23	620	13.3	?
24	650	?	?
25	680	7.6	5.7
26	710	?	5.7
27	740	7.8	5.3
28	770	6.5	?
29	797	7.3	4.8

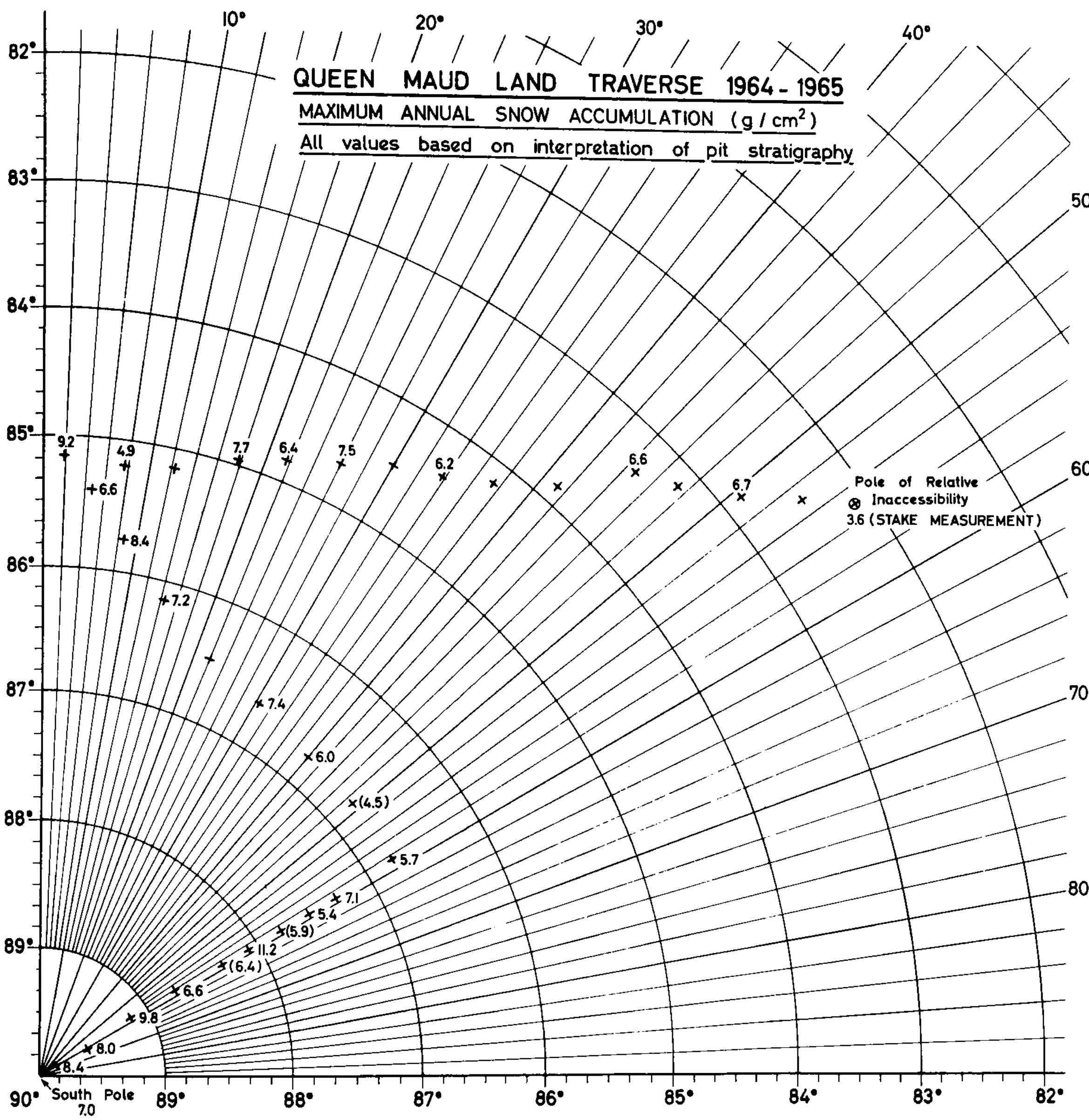


Fig. 29 - Maximum annual snow accumulation (g/cm^2), along traverse route

Fig. 30 - Pole of Relative Inaccessibility. Station building (at right) and meteorological instrument screen and anemometer mast (center) (Photo by E. Picciotto)

Fig. 31 - Snow accumulation at Pole of Relative Inaccessibility. Measured at meteorological instrument screen; for period 14 December 1958 to 30 January 1965 60 cm of snow (3.4 g/cm^2) (Photo by E. Picciotto)

Depth (cm)	Density (g/cm^3)
0-19	0.333
21-40	0.343
41-60	0.348

The average density from the surface to a depth of 60 cm was 0.341 g/cm^3. Using 0.341 g/cm^3 as the average snow density and 14 December 1958 to 30 January 1965 as the time interval ($73\frac{1}{2}$ months, or just over 6 years), the accumulation recorded here is as follows:

	Snow (cm)	Water (cm)	Annual Accumulation for 6 years (cm water)
Anemometer mast	63	21.5	3.6
Instrument shelter (left rear leg)	60	20.5	3.4
Instrument shelter (bottom of steps)	66	22.5	3.8
Average	63	21.5	3.6

Thus, for the period just over six years, the average annual accumulation was 3.6 g/cm^3.

An attempt was made to find accumulation stakes set out by the Soviets in 1958. Although two or three stakes were found, it was impossible to tell if they had been used for accumulation studies. Those that were found seemed to be set too close to the building for accumulation stakes.

A network of accumulation stakes was set out on 30 January 1965. The network consisted of 19 bamboo poles topped with red flags and marked with a saw cut at 150 cm above the snow surface. A map of the network is shown in Fig. 32.

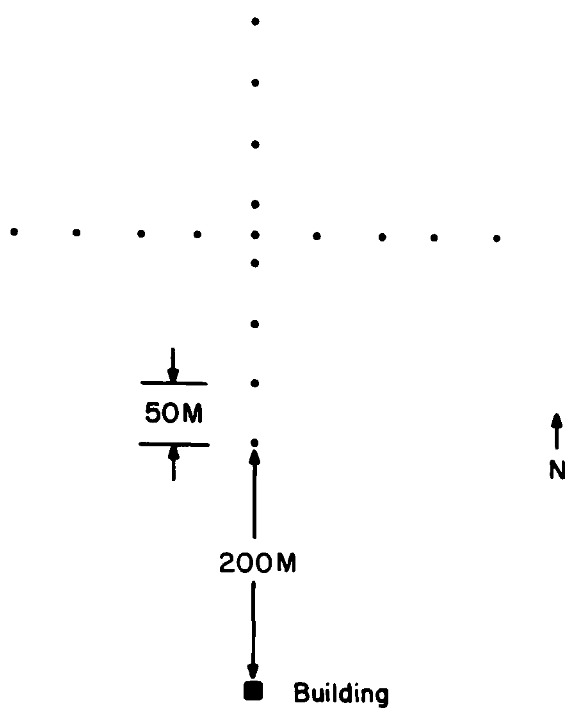


Fig. 32 - Sketch map of snow accumulation stake net established on 30 January 1965 at Pole of Relative Inaccessibility

REFERENCES

Crary, A. P. (1963), Results of United States traverses in East Antarctica, 1958-1961: IGY Glaciological Report No. 7, World Data Center A, Glaciology, American Geographical Society, 144 p.

Epstein, S., R. P. Sharp, and A. J. Gow (1965), Six-year record of oxygen and hydrogen isotope variations in South Pole firn: Jour. Geophys. Res., vol. 70, No. 8, p. 1809-1814.

Giovinetto, M. B. (1963), Glaciological studies on the McMurdo-South Pole Traverse, 1960-1961: The Ohio State University Research Foundation, Institute of Polar Studies Report No. 7, 38 p.

Gow, A. J. (1965), Snow studies in Antarctica: U. S. Army CRREL Research Report 177, 20 p.

Halliday, D. (1955), Introductory nuclear physics: John Wiley and Sons, Inc., New York, 493 p.

Stuart, A. W., and A. J. Heine (1961), Glaciology, Victoria Land Traverse, 1959-1960: The Ohio State University Research Foundation, Report 968-1, 106 p.

Taylor, L. D. (1965), Glaciological studies on the South Pole Traverse, 1962-1963: The Ohio State University Research Foundation, Institute of Polar Studies Report No. 17, 24 p.

Zotikov, I. A., A. P. Kapitsa, and O. G. Sorokhtin (1965), Thermal regime of the ice cover of central East Antarctica: Soviet Antarctic Expedition Information Bulletin, No. 5, Vol. 5, Bulletin No. 51, p. 304-308.

APPENDIX I - METEOROLOGICAL DATA

Date	Hour	TEMPERATURE (°C) Current	TEMPERATURE (°C) Mean Daily	WIND Speed (m/s)	WIND Mean Daily (m/s)	CLOUD COVER (8=complete overcast)	VISIBILITY (km)
4 Dec	00						
	06						
	12						
	18	31.4		0.5		1	inf.
5 Dec	00	30.7	30.3	1.1	1.8	0	inf.
	06	29.7		2.3		0	inf.
	12	30.6		1.3		0	inf.
	18	30.0		2.5		1	inf.
6 Dec	00	29.4	30.2	3.5	3.6	6	inf.
	06	29.6		2.7		7	inf.
	12	30.4		3.5		7	inf.
	18	31.2		4.5		5	inf.
7 Dec	00		31.9		1.2		
	06	31.5		2.5		1	8.0
	12	31.0		0.0		0	inf.
	18	33.1		1.0		1	inf.
8 Dec	00	30.9	31.5	1.0	0.4	1	15.0
	06	32.6		0.5		1	inf.
	12	31.7		0.0		1	inf.
	18	30.9		0.0		3	inf.
9 Dec	00	31.5	31.8	1.6	3.1	3	5.0
	06	32.3		2.6		1	15.0
	12	31.9		4.0		0	8.0
	18	31.6		4.3		0	5.0
10 Dec	00	31.9	31.7	5.1	4.9	0	6.0
	06	31.1		5.4		0	8.0
	12	31.4		4.4		0	inf.
	18	32.4		4.7		0	inf.
11 Dec	00	32.8	30.3	3.5	2.7	0	inf.
	06	29.8		2.6		0	15.0
	12	29.3		3.0		0	inf.
	18	29.3		1.6		0	inf.

APPENDIX I - METEOROLOGICAL DATA (cont'd)

Date	Hour	TEMPERATURE (°C)		WIND		CLOUD COVER	VISIBILITY (km)
		Current	Mean Daily	Speed (m/s)	Mean Daily (m/s)	(8=complete overcast)	
12 Dec	00	30.3	27.5	3.8	4.7	3	inf.
	06	26.7		5.4		1	15.0
	12	25.7		5.7		1	15.0
	18	27.4		4.0		0	15.0
13 Dec	00	28.1	29.1	4.0	3.6	7	3
	06	29.3		4.7		1	8
	12	28.1		4.7		2	5
	18	30.9		1.0		0	inf.
14 Dec	00	30.1	28.5	1.1	3.2	1	inf.
	06	28.0		4.6		1	inf.
	12	27.6		3.7		0	inf.
	18	28.4		3.5		0	inf.
15 Dec	00	29.7	28.5	2.5	2.4	1	inf.
	06	28.9		4.0		4	inf.
	12	26.3		1.2		1	inf.
	18	28.9		1.8		7	inf.
16 Dec	00	27.8	28.0	2.4	2.1	1	inf.
	06	27.1		2.8		1	inf.
	12	27.8		1.3		0	inf.
	18	29.2		1.9		0	inf.
17 Dec	00	30.3	28.4	2.9	4.6	0	inf.
	06	27.2		5.0		0	inf.
	12	27.3		4.5		0	inf.
	18	28.7		5.8		0	inf.
18 Dec	00	29.1	27.3	6.8	5.9	1	inf.
	06	26.3		6.7		2	15
	12	26.2		5.7		1	8
	18	27.4		4.2		1	12
19 Dec	00	27.1	26.5	3.7	5.6	1	12
	06	26.4		6.1		1	12
	12	25.9		6.9		1	12
	18	26.6		5.5		0	inf.

APPENDIX I - METEOROLOGICAL DATA (cont'd)

Date	Hour	TEMPERATURE (°C) Current	TEMPERATURE (°C) Mean Daily	WIND Speed (m/s)	WIND Mean Daily (m/s)	CLOUD COVER (8=complete overcast)	VISIBILITY (km)
20 Dec	00	26.9	25.3	4.7	5.0	0	6
	06	25.5		5.6		1	inf.
	12	24.1		5.2		5	15
	18	24.6		4.3		2	6
21 Dec	00	25.6	26.7	3.6	4.4	7	12
	06	24.7		6.6		8	2.5
	12	27.3		5.0		8	2.5
	18	29.3		2.4		1	inf.
22 Dec	00	30.2	27.8	2.0	2.5	0	inf.
	06	27.4		3.4		0	inf.
	12	26.1		2.6		1	15
	18	27.3		2.1		3	10
23 Dec	00	27.4	27.6	5.0	3.1	7	2.5
	06	27.9		3.2		7	6
	12	28.1		3.5		7	6
	18	27.1		0.5		1	inf.
24 Dec	00	29.1	29.7	0.3	1.0	7	6
	06						
	12	29.4		6.1		5	10
	18	30.5		1.1		7	8
25 Dec	00	30.3	28.6	212	4.6	6	15
	06	29.5		3.7		2	10
	12	28.1		4.0		6	8
	18	26.3		5.4		8	1.5
26 Dec	00	26.1	26.6	4.7	4.2	8	3
	06	27.8		4.7		3	8
	12	25.5		5.2		6	15
	18	26.9		2.0		1	inf.
27 Dec	00	29.1	26.8	1.8	2.3	1	inf.
	06	26.5		2.9		1	inf.
	12	25.3		2.3		2	inf.
	18	26.3		2.0		2	inf.

APPENDIX I - METEOROLOGICAL DATA (cont'd)

Date	Hour	TEMPERATURE (°C) Current	TEMPERATURE (°C) Mean Daily	WIND Speed (m/s)	WIND Mean Daily (m/s)	CLOUD COVER (8=complete overcast)	VISIBILITY (km)
28 Dec	00	27.2	24.3	2.5	4.0	1	inf.
	06	22.1		1.0		1	inf.
	12	23.6		7.0		0	inf.
	18	24.4		5.5		0	inf.
29 Dec	00	25.0	24.3	7.5	7.9	7	3
	06	24.9		9.0		7	3
	12	23.9		7.5		0	12
	18	23.2		7.5		7	15
30 Dec	00	24.2	23.2	9.0	5.7	1	6
	06	23.9		7.8		3	8
	12	22.5		4.5		7	15
	18	22.0		1.5		8	15
31 Dec	00	22.7	23.5	0.5	0.8	3	15
	06	23.8		0.3		7	15
	12	23.8		1.0		7	inf.
	18	23.6		1.5		8	5
1 Jan	00	25.2	24.8	0.5	1.5	8	1.5
	06	25.2		1.5		8	1
	12	23.6		2.0		7	10
	18	25.2		2.0		5	15
2 Jan	00	23.9	22.6	6.0	5.0	7	1
	06	22.6		4.0		6	5
	12	22.0		4.0		7	4
	18	21.9		5.8		8	5
3 Jan	00	22.9	21.6	1.0	1.8	7	8
	06	20.2		1.0		8	3
	12	21.2		3.0		7	inf.
	18	22.0		2.3		7	15
4 Jan	00	18.7	19.2	1.0	3.9	8	0.5
	06						
	12	18.7		6.3		8	1.5
	18	20.2		4.3		6	5

APPENDIX I - METEOROLOGICAL DATA (cont'd)

Date	Hour	TEMPERATURE (°C)		WIND		CLOUD COVER	VISIBILITY (km)
		Current	Mean Daily	Speed (m/s)	Mean Daily (m/s)	(8=complete overcast)	
5 Jan	00	18.4	19.4	3.5	1.3	7	10
	06	22.0		0.3		3	10
	12	18.2		0.5		8	10
	18	18.9		1.0		8	10
6 Jan	00	22.7	21.5	1.5	2.2	7	10
	06	22.8		6.3		4	6
	12	22.8		0.5		5	inf.
	18	19.7		0.3		6	inf.
7 Jan	00	25.0	23.2	0.5	0.6	3	inf.
	06	22.4		0.5		3	inf.
	12	21.8		0.5		2	10
	18	23.4		1.0		3	inf.
8 Jan	00		21.3		2.0		
	06	24.2		1.3		3	15
	12	20.0		3.0		8	1.5
	18	19.6		3.8		8	5
9 Jan	00	23.4	21.4	10.	3.0	2	inf.
	06	21.3		3.3		8	1
	12	20.5		3.5		7	8
	18	20.5		4.0		7	15
10 Jan	00	28.2	24.2	0.3	0.2	7	inf.
	06	24.1		0.3		8	15
	12	21.7		0.0		8	0.5
	18	22.7		0.3		8	3
11 Jan	00	25.9	26.7	0.5	0.6	7	10
	06	25.1		0.5		2	15
	12	26.8		0.5		0	inf.
	18	29.1		0.8		1	inf.
12 Jan	00	29.6	26.6	1.0	3.2	2	inf.
	06	27.7		3.0		3	inf.
	12	24.1		5.5		7	15
	18	24.8		3.3		1	inf.

APPENDIX I - METEOROLOGICAL DATA (cont'd)

Date	Hour	TEMPERATURE (°C) Current	TEMPERATURE (°C) Mean Daily	WIND Speed (m/s)	WIND Mean Daily (m/s)	CLOUD COVER (8=complete overcast)	VISIBILITY (km)
13 Jan	00	27.8	25.6	2.8	4.4	0	inf.
	06	25.7		5.5		0	inf.
	12	24.2		5.5		0	15
	18	24.4		3.8		1	inf.
14 Jan	00	25.5	25.0	3.5	2.7	1	inf.
	06	25.1		3.3		1	inf.
	12	24.1		3.3		0	inf.
	18	25.2		0.5		1	inf.
15 Jan	00	26.4	23.4	0.5	1.9	1	inf.
	06	24.1		2.5		5	inf.
	12	21.1		4.0		6	15
	18	21.8		0.7		7	10
16 Jan	00	26.8	25.7	0.3	1.5	2	15
	06	27.2		1.8		6	15
	12	23.7		1.5		3	inf.
	18	25.0		2.3		0	inf.
17 Jan	00	27.3	23.5	9.0		1	15
	06	23.9		5.5		6	8
	12	20.9		3.0		2	inf.
	18	21.8		5.5		8	0.5
18 Jan	00	26.7	26.5	4.3	3.1	4	5
	06	27.1		4.5		7	5
	12	25.3		3.2		4	6
	18	26.8		0.5		3	inf.
19 Jan	00	31.2	27.9	0.3	0.4	6	inf.
	06	28.8		0.8		6	inf.
	12	24.1		0.3		3	inf.
	18	27.4		0.1		8	1
20 Jan	00	28.9	30.8	0.1	0.9	7	1
	06	31.3		0.3		8	3
	12	30.4		2.2		0	inf.
	18	32.4		0.8		0	inf.

APPENDIX I - METEOROLOGICAL DATA (cont'd)

Date	Hour	TEMPERATURE (°C) Current	TEMPERATURE (°C) Mean Daily	WIND Speed (m/s)	WIND Mean Daily (m/s)	CLOUD COVER (8=complete overcast)	VISIBILITY (km)
21 Jan	00	35.1	32.5	3.0	2.6	0	inf.
	06	32.6		3.3		0	inf.
	12	30.0		3.0		0	inf.
	18	32.2		1.0		0	inf.
22 Jan	00	34.3	32.2	1.1	2.8	0	inf.
	06	32.3		3.8		0	inf.
	12	3.0		4.3		1	inf.
	18	32.2		1.8		1	inf.
23 Jan	00	35.7	33.8	0.9	2.1	1	inf.
	06	33.8		4.3		1	inf.
	12	31.1		2.5		0	inf.
	18	34.5		0.5		1	inf.
24 Jan	00	38.1	35.8	0.8	1.5	0	inf.
	06	35.5		2.8		0	inf.
	12	32.7		2.0		0	inf.
	18	36.8		0.5		1	inf.
25 Jan	00	39.2	37.3	0.8	1.8	1	inf.
	06	36.9		1.5		1	inf.
	12	34.3		2.5		0	inf.
	18	38.7		2.2		0	inf.
26 Jan	00	44.7	38.9	2.5	3.1	0	inf.
	06	37.9		4.0		0	inf.
	12	34.2		5.3		6	inf.
	18	38.6		0.7		1	inf.
27 Jan	00	42.9	39.1	1.0	1.1	1	inf.
	06	38.4		2.0		1	inf.
	12	35.1		0.5		2	inf.
	18	40.1		0.7		1	inf.
28 Jan	00	44.3	39.8	0.8	2.2	1	inf.
	06	36.7		3.3		3	inf.
	12						
	18	38.4		2.5		3	3

APPENDIX I - METEOROLOGICAL DATA (cont'd)

Date	Hour	TEMPERATURE (°C) Current	TEMPERATURE (°C) Mean Daily	WIND Speed (m/s)	WIND Mean Daily (m/s)	CLOUD COVER (8=complete overcast)	VISIBILITY (km)
29 Jan	00	37.9	35.9	5.0	7.1	1	1.5
	06	35.4		6.8		0	1.5
	12	33.9		8.5		0	1
	18	36.5		8.0		7	1
30 Jan	00	39.1	37.5	6.0	4.1	7	3
	06	37.2		4.5		7	5
	12	34.4		4.5		6	15
	18	39.3		1.3		4	15
31 Jan	00	43.8	39.8	0.9	1.1	5	15
	06	38.8		1.0		1	15
	12	36.7		1.5		1	inf.
	18						
1 Feb	00	43.3	38.2	1.8	2.7	1	8
	06	36.7		4.0		3	5
	12	34.7		2.5		2	5
	18	38.2		2.5		2	6

APPENDIX II - SNOW HARDNESS DATA

0-50 cm

Station	Mile	Ram Hardness					Mean Ram Hardness
	3	63	41	34	29	30	39
	6	26	27	28	29	18	26
0	8						
	9	21	22	21	31	28	25
	12	34	29	24	22	21	26
	15	34	39	25	27	35	32
	18	41	46	42	51	53	47
	21	34	35	52	31	36	38
1	24	39	36	39	26	33	35
	27	80	61	87	42	57	65
	30	56	44	78	66	65	62
	33	51	52	55	48	56	52
	36	45	36	36	30	28	35
	39	35	49	38	39	48	42
	42	78	72	52	187	134	105
	45	32	88	49	45	25	48
2	48	41	32	35	39	33	36
	51	27	31	18	16	24	23
	54	31	36	37	33	32	34
	57	19	23	24	29	18	23
	60	20	24	22	25	28	24
	63	44	46	44	49	43	45
	66	29	18	36	37	56	35
	69	57	26	70	21	39	43
3	72	29	19	21	20	19	22
	75	19	61	117	162	22	76
	78	57	36	22	52	58	45
	81	69	75	64	45	33	57
	84	57	62	52	51	61	57
	87	71	32	39	69	30	48
	90	30	34	43	25	26	32
	93	32	66	56	72	83	62
4	96	151	106	184	46	55	108
	100	187	31	31	19	25	59
	105	40	64	85	43	46	56
4a	110	61	58	52	118	55	69
	115	46	49	31	55	43	45
	120	34	40	28	28	31	32
5	125	25	28	31	34	73	38
	130	46	52	22	37	46	41
	135	88	31	22	19	25	37
5a	140	43	25	61	28	43	40
	145	76	79	43	64	52	63
	150	49	115	121	52	46	77

APPENDIX II - continued

Station	Mile	Ram Hardness					Mean Ram Hardness
6	155	67	37	58	55	81	60
	160	55	25	25	40	31	35
	165	37	40	94	25	52	50
	170	52	76	64	40	58	48
	175	40	46	52	61	109	62
	180	67	97	64	79	40	69
7	185	46	49	52	37	40	45
	190	52	121	43	34	61	62
	195	37	40	43	46	40	41
	200	52	46	34	49	22	41
	205	37	34	37	40	49	40
	210	43	28	43	46	37	40
8	215	34	40	40	37	43	39
	220	61	46	64	64	67	60
	225	79	76	73	49	64	68
	230	22	25	28	49	79	41
	235	25	64	49	55	55	46
	240	59	52	43	46	58	52
9	245	61	61	52	46	40	52
	250	37	49	28	22	13	20
	260	34	37	31	22	19	29
	265	79	187	40	118	109	107
	270	151	136	124	166	109	137
10	275	100	76	139	79	46	88
	280	127	115	109	136	58	109
	285	103	154	91	151	118	123
	290	175	76	55	67	88	92
	295	43	61	61	94	67	65
	300	40	31	82	70	85	62
11	305	19	34	34	43	88	44
	310	37	82	55	106	70	70
	315	43	43	28	28	34	35
	320	37	37	58	49	73	51
	325	49	52	55	58	88	60
	330	19	25	34	46	190	63
12	338	49	49	64	127	70	72
	345	79	58	64	46	115	72
	350	22	40	49	55	73	48
	355	64	73	46	46	82	62
	360	31	34	34	46	64	42
	365	34	76	43	127	91	74
13	370	25	43	28	28	91	43
	375	73	22	28	40	43	41
	380	34	34	40	43	61	42
	385	25	25	37	28	40	31
	390	31	40	40	43	55	42

APPENDIX II - continued

Station	Mile	Ram Hardness					Mean Ram Hardness
14	395	16	19	19	22	31	21
	400	46	13	22	28	19	26
	405	28	13	25	22	19	21
	410	19	19	19	31	40	26
15	415	28	37	28	46	52	38
	420	10	16	16	19	25	18
	425	34	28	28	25	22	27
	430	22	22	19	22	22	21
	435	28	16	28	25	19	23
16	445	16	40	31	31	58	35
	450	19	19	37	79	37	38
	455	13	46	40	31	22	30
	460	16	28	28	52	106	46
	465	40	34	28	28	46	35
17	470	10	16	178	19	16	48
	475	19	22	25	31	37	27
	480	13	19	19	22	34	21
	485	22	28	28	31	34	29
	490	13	16	19	22	28	20
	495	13	16	19	27	23	20
18	496	10	13	22	22	25	18
	500	16	16	19	25	10	17
	505	22	16	25	22	25	22
	510	16	19	25	25	31	23
	515	19	40	28	40	28	31
19	519	25	19	64	25	34	33
	520	28	25	19	46	64	36
	525	19	37	31	19	25	26
	530	22	40	46	49	25	36
19a	536	43	52	127	31	64	63
	540	49	31	55	124	49	62
20	545	16	19	115	13	22	37
	550	37	85	55	76	73	65
	555	52	55	58	61	55	56
	560	91	31	25	85	43	55
	565	25	28	49	70	76	50
21	570	46	25	46	61	85	53
	575	19	22	28	37	40	29
	580	25	34	46	34	61	40
	585	52	58	55	76	121	72
	590	28	25	28	31	34	29
22	595						
	600	55	43	55	61	64	56
	605	19	28	19	31	34	26
	610	58	70	58	232	46	93
	615	22	28	31	37	43	32

Station	Mile	Ram Hardness					Mean Ram Hardness
23	620	34	46	16	37	49	36
	625						
	630	46	52	61	67	169	79
	635	13	19	31	43	103	42
	640	22	31	43	46	64	41
	645	28	34	43	61	70	47
24	650	31	55	64	49	25	45
	655	28	49	40	55	40	42
	660	19	34	22	34	46	31
	665	34	43	40	43	40	40
	670	19	28	82	85	88	60
	675	31	37	43	55	67	47
25	680	52	52	52	61	61	56
	685	34	37	40	49	73	47
	690	34	37	46	37	82	47
	695	31	34	37	43	46	38
	700	25	31	28	37	40	32
	705	28	34	31	40	100	47
26	710	22	28	40	28	34	30
	715	28	31	46	64	70	48
	720	37	28	43	67	46	44
	725	28	37	28	46	34	35
	730	34	31	31	31	55	36
	735	25	28	31	46	28	32
27	740	25	22	34	31	28	28
	745	55	31	55	46	76	53
	750	28	34	40	28	10	28
	755	34	34	31	25	49	35
	760	16	16	31	22	22	21
	765	19	22	37	22	52	30
28	770	16	19	25	19	49	26
	775	28	19	19	25	25	23
	780	19	22	28	46	13	26
	785	19	19	46	28	40	30
	790	16	16	16	16	22	17
	795	16	13	28	31	43	26
29	797	22	22	16	19	13	18

APPENDIX III - FIRN DENSITY, 0-2 METERS

Depth in cm, Density in g/cm^3

South Pole

Depth	Density	Depth	Density	Depth	Density
3	0.374	65	0.364	137.5	0.337
7	0.385	68	0.361	139.5	0.337
9	0.390	72	0.400	143.5	0.363
13.5	0.380	76	0.370	147.5	0.377
15	0.377	78.5	0.350	151	0.408
19	0.348	82	0.335	155	0.399
19	0.358	86	0.361	158	0.398
22	0.331	89	0.397	161.5	0.406
27	0.369	92	0.395	165	0.388
28	0.373	96	0.361 ?	168.5	0.362
33	0.373	99.5	0.391	172	0.361
34.5	0.363	102.5	0.401	176	0.334
37	0.365	108	0.382	179.5	0.334
41	0.341	109	0.387	183	0.370
42	0.302	114	0.371	186	0.379
46.5	0.400	115	0.387	190	0.399
51	0.404	121	0.407	191.5	0.426
54	0.402	125	0.411	194	0.466
58	0.387	130	0.364	199	0.442
61.5	0.385	132	0.372		

Station 5

Depth	Density
0-20	0.338
20-40	0.350
40-60	0.378
60-80	0.398
80-100	0.438
100-120	0.422
120-140	0.416
140-160	0.366
160-180	0.390
180-200	0.468

Station 5a

Depth	Density
0-20	0.386
20-40	0.360
40-60	0.340
60-80	0.400
80-99	0.382
100-120	0.398
120-139	0.386
140-159	0.448
160-180	0.390
180-200	0.384

Station 6

Depth	Density
0-20	0.384
20-40	0.398
40-60	0.428
60-80	0.424
80-100	0.406
102-122	0.430
120-140	0.428
140-160	0.410
160-180	0.416
180-200	0.384

Station 9

Depth	Density
0-18	0.396
20-39	0.350
37-57	0.356
57-77	0.432
77-97	0.388
98-118	0.416
120-140	0.368
142-162	0.418
162-181	0.426
181-201	0.382

Station 10

Depth	Density
7-27	0.400
27-47	0.364
47-67	0.398
67-87	0.428
87-106	0.426
106-125	0.406
125-144	0.440
147-166	0.398
166-185	0.406
185-204	0.388

Station 14

Depth	Density
0-19	0.388
19-38	0.368
38-57	0.382
58-78	0.408
78-97	0.390
88-107	0.378
108-118	0.506*
121-140	0.388
140-159	0.410
159-178	0.392
180-199	0.376

*Very hard layer.

Station 7

Depth	Density	Depth	Density
3	0.370	103	0.388
9	0.360	108	0.342
11	0.360	112	0.370
17.5	0.394	117	0.342
22	0.430	120	0.360
26	0.410	125	0.342
31	0.356	130	0.394
37	0.406	134	0.336
40	0.376	140	0.368
44	0.346	143	0.368
50	0.350	148	0.350
55	0.394	152	0.414
58	0.404	155	0.446
62	0.400	160	0.400
65	0.432	164	0.354
70	0.412	169	0.334
74	0.404	173	0.342
78	0.378	178	0.350
83	0.336	182	0.380
87	0.374	187	0.320
92	0.354	193	0.328
95	0.374	199	0.356
100	0.392	202	0.400

Station 13

Depth	Density	Depth	Density
7	0.448	110	0.360
13	0.398	114	0.372
18	0.392	122	0.452
20	0.374	122	0.456
25	0.372	128	0.502
30	0.372	134	0.396
34	0.362	139	0.408
39	0.338	145	0.434
43	0.376	150	0.370
44	0.388	154	0.380
47-57	0.521*	160	0.380
59	0.410	163	0.406
63	0.400	167	0.386
67	0.382	170	0.368
72	0.420	174	0.374
76	0.428	180	0.322
80	0.382	186	0.422
84	0.362	191	0.420
88	0.356	198	0.414
92	0.368	204	0.400
96	0.358	211	0.362
102	0.368	218	0.350
106	0.306	224	0.360

*Very hard layer.

Station 15

Depth	Density	Depth	Density
6	0.328	102	0.418
8	0.366	105.5	0.412
15	0.396	110	0.406
18.5	0.394	114.5	0.426
24	0.384	119	0.388
27.5	0.402	124	0.350
30	0.398	128	0.368
37	0.274	131	0.396
38	0.380	136	0.414
42	0.374	141	0.398
45	0.322	146	0.404
50	0.446	150	0.370
53.5	0.416	156	0.356
56	0.378	160	0.402
60	0.390	166.5	0.414
64	0.394	171	0.386
67	0.396	176	0.362
71	0.408	182	0.384
75.5	0.432	185	0.430
79	0.420	192	0.436
82	0.426	196	0.388
86	0.464	202	0.368
90	0.496	207	0.354
97	0.390	212	0.348

Station 16

Depth	Density
?-21	0.340
22-41	0.370
41-60	0.390
60-78	0.380
78-97	0.358
97-117	0.368
118-137	0.372
137-156	0.390
156-175	0.362
176-195	0.362
195-214	0.368

Station 17

Depth	Density
0-23	0.258
20-40	0.352
38-46	0.476
42-61	0.440
60-79	0.352
79-98	0.330
99-118	0.408
118-137	0.318
138-157	0.326
160-179	0.352
179-198	0.408

Station 18

Depth	Density
0-25	0.368
25-45	0.370
45-64	0.388
64-83	0.376
85-104	0.356
104-125	0.320
125-144	0.442
144-163	0.448
163-182	0.376
182-201	0.404

Station 19

Depth	Density
0-20	0.336
21-40	0.356
40-60	0.354
60-80	0.416
80-100	0.424
102-121	0.398
120-140	0.412
140-160	0.308
160-180	0.378
180-200	0.372

Station 20

Depth	Density
0-20	0.400
23-42	0.346
42-61	0.324
61-80	0.408
81-99	0.396
100-120	0.448
120-140	0.372
140-160	0.494
160-180	0.414
180-200	0.372

Station 21

Depth	Density
0-19	0.354
20-40	0.356
40-60	0.342
60-79	0.406
80-100	0.398
100-119	0.390
120-139	0.384
140-160	0.416
160-180	0.374
182-201	0.426

Station 22

Depth	Density
0-19	0.312
20-38	0.394
38-58	0.388
59-79	0.388
80-100	0.434
102-122	0.388
122-142	0.372
143-162	0.456
163-183	0.390
184-204	0.402

Station 23

Depth	Density
0-20	0.332
20-40	0.486
42-62	0.372
62-81	0.346
83-102	0.402
102-121	0.378
121-140	0.366
143-162	0.374
165-185	0.516
185-205	0.402

Station 24

Depth	Density
0-19	0.414
20-39	0.360
41-60	0.372
61-90	0.386
90-99	0.422
99-118	0.428
119-138	0.374
139-155	0.378
156-175	0.400
176-195	0.406
196-215	0.378

Station 25

Depth	Density
0-25	0.336
25-44	0.396
44-63	0.378
63-82	0.402
82-101	0.400
101-122	0.392
124-138	0.366
138-158	0.344
158-178	0.392
178-198	0.350

Station 26

Depth	Density
0-24	0.352
24-43	0.380
43-61	0.366
61-80	0.364
80-100	0.378
100-119	0.450
119-138	0.388
138-157	0.396
158-177	0.356
177-197	0.392

Station 27

Depth	Density
0-19	0.326
19-38	0.388
38-57	0.364
57-77	0.360
77-96	0.390
96-115	0.364
116-135	0.360
136-155	0.386
157-176	0.372
176-195	0.402

APPENDIX III - continued

Station 28

Depth	Density
0-19	0.360
19-38	0.374
38-57	0.370
57-76	0.338
76-96	0.346
96-115	0.384
115-134	0.360
134-153	0.380
153-173	0.370
173-193	0.352
193-212	0.366

Station 29

Depth	Density
0-20	0.356
23-33	0.362
33-53	0.370
54-74	0.332
75-94	0.364
95-114	0.382
114-134	0.392
134-154	0.362
154-174	0.358
174-194	0.366
194-214	0.358

APPENDIX IV - FIRN DENSITY FROM NEUTRON SCATTERING DATA, 0-40 METERS

Mile 24, 6 December

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)	Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
100	3181	.393	1700	4570	.495
150	3190	.394	1750	4668	.502
200	3140	.390	1800	4744	.507
250	3351	.406	1850	4773	.509
300	3294	.401	1900	4856	.516
350	3332	.404	1950	4771	.509
400	3490	.416	2000	4832	.514
450	3558	.421	2050	4868	.516
500	3522	.418	2100	4897	.512
550	3542	.427	2150	4915	.520
600	3505	.417	2200	4830	.513
650	3808	.439	2250	4928	.521
700	3870	.443	2300	5014	.527
750	3816	.439	2350	4948	.522
800	3984	.452	2400	5068	.531
850	3813	.439	2450	5154	.537
900	4050	.457	2500	4976	.524
950	4038	.456	2550	5057	.526
1000	4002	.453	2600	5106	.533
1050	4142	.463	2650	5218	.542
1100	4280	.473	2700	5150	.537
1150	4280	.473	2750	5244	.544
1200	4228	.470	2800	5206	.541
1250	4364	.479			
1300	4306	.475			
1350	4453	.486			
1400	4411	.483			
1450	4450	.486			
1500	4589	.496			
1550	4532	.491			
1600	4629	.499			
1650	4777	.510			

Mile 48, 7 December

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)	Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
100	3222	.396	2000	4818	.512
150	3308	.403	2050	4724	.506
200	3232	.397	2100	4777	.509
250	3494	.416	2150	4846	.514
300	3434	.415	2200	4992	.525
350	3296	.402	2250	5040	.529
400	3437	.412	2300	4962	.523
450	3450	.416	2350	4804	.511
500	3617	.425	2400	4993	.525
550	3523	.418	2450	4964	.523
600	3532	.419	2500	4938	.521
650	3700	.431	2550	4964	.523
700	3764	.436	2600	4936	.521
750	4061	.458	2650	4971	.524
800	3790	.438	2700	5094	.533
850	4030	.455	2750	5092	.532
900	3988	.452	2800	5003	.526
950	4128	.463	2850	5142	.536
1000	4149	.464	2900	5066	.530
1050	4208	.468	2950	5192	.540
1100	4218	.469	3000	5163	.538
1150	4310	.476	3050	5137	.536
1200	4430	.484	3100	5087	.532
1250	4382	.481	3150	5070	.531
1300	4344	.478	3200	5132	.535
1350	4448	.486	3250	5141	.536
1400	4528	.492	3300	5441	.558
1450	4380	.481	3350	5204	.541
1500	4518	.492	3400	5244	.544
1550	4568	.494	3450	5210	.541
1600	4486	.488	3500	5435	.558
1650	4612	.498	3550	5362	.552
1700	4640	.500	3600	5206	.541
1750	4668	.502	3650	5424	.557
1800	4616	.498	3700	5374	.553
1850	4592	.496	3750	5434	.558
1900	4718	.505	3800	5583	.568
1950	4804	.511	3850	5578	.568

Mile 72, 9 December

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)	Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
100	3350	.406	2050	4844	.514
150	3268	.400	2100	4874	.516
200	3248	.398	2150	5062	.530
250	3312	.403	2200	4892	.518
300	3454	.413	2250	4990	.525
350	3438	.412	2300	5026	.528
400	3606	.424	2350	4938	.521
450	3323	.404	2400	4980	.524
500	3444	.413	2450	5082	.532
550	3662	.428	2500	5092	.532
600	3701	.431	2550	5184	.539
650	3864	.443	2600	5199	.540
700	3876	.444	2650	5118	.534
750	3905	.446	2700	5125	.535
800	4088	.460	2750	5108	.534
850	3957	.450	2800	5218	.542
900	4074	.459	2850	5196	.540
950	3982	.452	2900	5259	.545
1000	4154	.465	2950	5136	.536
1050	4299	.475	3000	5246	.544
1100	4276	.473	3050	5209	.541
1150	4135	.463	3100	5248	.544
1200	4351	.479	3150	5347	.551
1250	4410	.483	3200	5213	.544
1300	4335	.478	3250	5213	.541
1350	4531	.492	3300	5324	.549
1400	4488	.489	3350	5410	.556
1450	4424	.484	3400	5268	.545
1500	4656	.501	3450	5440	.558
1550	4620	.498	3500	5400	.555
1600	4572	.495	3550	5398	.555
1650	4802	.511	3600	5351	.551
1700	4629	.499	3650	5452	.558
1750	4829	.513	3700	5490	.562
1800	4663	.501	3750	5508	.563
1850	4960	.523	3800	5580	.568
1900	4866	.516	3850	5522	.564
1950	4862	.516	3900	5490	.562
2000	4876	.517	3950	5456	.558

APPENDIX IV - continued

Mile 185, 17 December

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
100	4049	.457
150	3358	.406
200	2854	.369
250	3330	.404
300	3464	.414
350	3183	.393
400	3650	.427
450	3300	.402
500	3344	.406
550	3322	.404
600	3338	.405
650	3519	.418
700	3595	.424
750	3462	.414
800	3552	.420
850	3666	.429
900	3578	.422
950	3622	.425
1000	3732	.434
1050	3958	.450
1100	3914	.447
1150	3951	.450
1200	4076	.459
1250	4065	.458
1300	4023	.455
1350	4092	.460
1400	4166	.465
1450	4232	.470
1500	4312	.476
1550	4252	.472
1600	4603	.497
1650	4484	.486
1700	4325	.477
1750	4440	.485
1800	4605	.497
1850	4640	.500
1900	4733	.506
1950	4594	.496
2000	4786	.510
2050	4804	.511
2100	5020	.527
2150	4712	.505
2200	4838	.514
2250	4916	.520
2300	5060	.530
2350	5078	.531
2400	5006	.526
2450	5028	.528
2500	4941	.521
2550	5062	.530
2600	5079	.531
2650	5050	.529
2700	5108	.534
2750	5057	.530
2800	5102	.533
2850	5154	.537
2900	5266	.545
2950	5332	.550
3000	5230	.543
3050	5264	.545
3100	5347	.551
3150	5265	.545
3200	5338	.550
3250	5352	.551
3300	5406	.555
3350	5342	.551
3400	5542	.566
3450	5399	.555
3500	5536	.565
3550	5374	.553
3600	5506	.563
3650	5580	.568
3700	5631	.572
3750	5680	.576
3800	5831	.587

APPENDIX IV - continued

Mile 275, 26 December

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)	Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
100	3447	.413	2000	4938	.521
150	3484	.416	2050	4968	.523
200	3714	.432	2100	5065	.530
250	3301	.402	2150	5136	.536
300	3488	.416	2200	5064	.530
350	3707	.432	2250	5138	.536
400	3844	.442	2300	5193	.540
450	3723	.433	2350	5193	.540
500	3734	.434	2400	5169	.538
550	3880	.444	2450	5168	.538
600	3904	.446	2500	5250	.544
650	3903	.446	2550	5240	.543
700	4209	.469	2600	5185	.539
750	3983	.452	2650	5290	.547
800	4216	.470	2700	5166	.538
850	4163	.465	2750	5317	.549
900	4115	.462	2800	5382	.554
950	4426	.484	2850	5150	.537
1000	4206	.468	2900	5344	.551
1050	4455	.486	2950	5504	.563
1100	4204	.468	3000	5446	.558
1150	4366	.480	3050	5482	.561
1200	4542	.492	3100	5346	.551
1250	4622	.498	3150	5412	.556
1300	4588	.496	3200	5390	.554
1350	4506	.490	3250	5421	.556
1400	4670	.502	3300	5536	.565
1450	4592	.496	3350	5526	.564
1500	4880	.517	3400	5516	.564
1550	4743	.507	3450	5599	.570
1600	4857	.515	3500	5641	.573
1650	4782	.510	3550	5522	.564
1700	4808	.512	3600	5519	.564
1750	4936	.521	3650	5484	.561
1800	4923	.520	3700	5606	.570
1850	4985	.525	3750	5558	.567
1900	4824	.513	3800	5552	.566
1950	4834	.514	3850	5788	.584
			3900	5604	.570
			3950	5714	.578

Mile 370, 31 December

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)	Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
100	3302	.402	2000	4734	.506
200	3572	.422	2100	4756	.508
300	3298	.402	2200	4712	.505
400	3426	.411	2300	4802	.511
500	3562	.421	2400	4940	.521
600	3786	.437	2500	5130	.535
700	3790	.438	2600	5048	.529
800	3732	.434	2700	4997	.525
900	3894	.445	2800	5234	.543
1000	3914	.447	2900	5204	.541
1100	4318	.476	3000	5233	.543
1200	3991	.452	3100	5375	.553
1300	4009	.454	3200	5441	.558
1400	4458	.486	3300	5510	.563
1500	4441	.485	3400	5576	.568
1600	4514	.490	3500	5574	.568
1700	4566	.494	3600	5548	.566
1800	4597	.496	3700	5652	.574
1900	4918	.520	3800	5378	.553

Mile 395, 1 January

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
100	3360	.406
200	3486	.416
300	3270	.400
400	3618	.425
500	3700	.431
600	3748	.435
700	3812	.439
800	3617	.425
900	4080	.459
1000	4014	.455
1100	4011	.454
1200	4154	.465
1300	4301	.475

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
1400	4222	.470
1500	4816	.512
1600	4544	.493
1700	4618	.498
1800	4655	.501
1900	4543	.493
2000	4735	.506
2100	5010	.526
2200	4918	.520
2300	4942	.521
2400	5265	.545
2500	5340	.550

APPENDIX IV - continued

Mile 415, 3 January

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm³)	Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm³)
100	4085	.460	2000	4975	.524
150	4496	.489	2050	4739	.507
200	3946	.449	2100	4819	.512
250	3778	.437	2150	4910	.519
300	4045	.456	2200	5003	.526
350	4166	.465	2250	4912	.519
400	3954	.450	2300	4920	.520
450	3896	.446	2350	5183	.539
500	3660	.428	2400	4961	.523
550	3680	.430	2450	4926	.520
600	4082	.459	2500	5098	.533
650	3935	.448	2550	5174	.538
700	3812	.439	2600	5064	.530
750	3901	.446	2650	5248	.544
800	3880	.444	2700	5269	.545
850	3948	.449	2750	5192	.540
900	3877	.444	2800	5131	.535
950	4048	.457	2850	5176	.539
1000	3932	.448	2900	5307	.548
1050	4001	.453	2950	5442	.558
1100	4082	.459	3000	5474	.560
1150	4158	.465	3050	5284	.546
1200	4154	.464	3100	5333	.550
1250	4384	.481	3150	5428	.557
1300	4435	.485	3200	5496	.562
1350	4688	.503	3250	5518	.564
1400	4550	.493	3300	5460	.559
1450	4350	.479	3350	5402	.555
1500	4579	.495	3400	5384	.554
1550	4623	.498	3450	5630	.572
1600	4610	.497	3500	5523	.564
1650	4678	.502	3550	5424	.557
1700	4736	.506	3600	5686	.576
1750	4636	.499	3650	5588	.569
1800	4666	.501	3700	5552	.566
1850	4682	.503	3750	5638	.572
1900	4652	.500	3800	5723	.579
1950	4724	.506	3850	5756	.581
			3900	5772	.583
			3950	5884	.590
			4000	6044	.602

Mile 470, 8 January

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)	Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
100	2462	.341	2100	5045	.529
200	2792	.365	2200	4922	.520
300	2860	.370	2300	5182	.539
400	3208	.395	2400	5258	.545
500	3062	.384	2500	5198	.540
600	3130	.389	2600	5268	.545
700	3076	.386	2700	5312	.549
800	3744	.434	2800	5538	.565
900	3652	.428	2900	5601	.570
1000	3734	.434	3000	5548	.566
1100	3950	.450	3100	5723	.579
1200	4010	.454	3200	5808	.525
1300	4157	.465	3300	5802	.584
1400	4150	.464	3400	5874	.590
1500	4322	.477	3500	5806	.585
1600	4534	.492	3600	5970	.597
1700	4456	.486	3700	5906	.592
1800	4689	.503	3800	6058	.603
1900	4913	.519	3900	5984	.598
2000	4938	.521	4000	6150	.610

Mile 545, 15 January

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)	Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
100	4082	.459	2100	5332	.550
150	4584	.496	2150	5220	.542
200	3440	.412	2200	5468	.560
250	3447	.413	2250	5406	.555
300	3407	.410	2300	5334	.550
350	3547	.420	2350	5478	.561
400	3734	.434	2400	5548	.566
450	3890	.445	2450	5478	.561
500	3936	.448	2500	5496	.562
550	3808	.438	2550	5486	.561
600	3608	.424	2600	5629	.572
650	3803	.439	2650	5560	.567
700	3832	.441	2700	5654	.554
750	3757	.435	2750	5708	.578
800	3924	.448	2800	5738	.580
850	4027	.455	2850	5704	.577
900	4060	.458	2900	5748	.581
950	4188	.467	2950	5746	.581
1000	4324	.477	3000	5708	.578
1050	4304	.475	3050	5754	.581
1100	4274	.473	3100	3740	.434
1150	4561	.494	3150	5830	.587
1200	4420	.484	3200	6008	.600
1250	4388	.481	3250	5783	.583
1300	4514	.495	3300	5855	.588
1350	4726	.506	3350	5828	.586
1400	4834	.514	3400	5832	.587
1450	4868	.516	3450	5816	.586
1500	4961	.523	3500	5831	.587
1550	4922	.520	3550	5974	.597
1600	4875	.516	3600	5944	.595
1650	4912	.519	3650	6061	.603
1700	5022	.527	3700	5966	.597
1750	4998	.526	3750	5885	.591
1800	5168	.538	3800	6070	.604
1850	5100	.533	3850	6056	.603
1900	5216	.542	3900	6004	.599
1950	5218	.542	3950	6182	.613
2000	5226	.542	4000	6043	.601
2050	5286	.547			

Mile 620, 19 January

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)	Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
100	2912	.373	2100	5554	.566
150	3240	.398	2150	5376	.553
200	3022	.382	2200	5486	.561
250	3224	.396	2250	5415	.556
300	3307	.403	2300	5427	.557
350	3479	.415	2350	5500	.562
400	3453	.413	2400	5488	.562
450	3618	.425	2450	5536	.565
500	3231	.397	2500	5608	.570
550	3258	.398	2550	5617	.571
600	3598	.424	2600	5618	.571
650	3421	.411	2650	5674	.575
700	3522	.418	2700	5743	.580
750	3912	.447	2750	5803	.585
800	3664	.429	2800	5694	.577
850	4070	.458	2850	5908	.592
900	4080	.459	2900	5804	.585
950	4230	.470	2950	5820	.586
1000	4341	.478	3000	5838	.587
1050	4585	.496	3050	6004	.599
1100	4541	.492	3100	5904	.592
1150	4604	.497	3150	5970	.597
1200	4788	.510	3200	6112	.607
1250	4982	.524	3250	5898	.592
1300	5068	.531	3300	5928	.594
1350	5034	.528	3350	5928	.594
1400	5220	.542	3400	5947	.595
1450	5113	.534	3450	6054	.603
1500	5173	.538	3500	5925	.594
1550	5151	.537	3550	6094	.606
1600	5282	.546	3600	5962	.596
1650	5230	.543	3650	6108	.607
1700	5342	.551	3700	6124	.608
1750	5370	.553	3750	6176	.612
1800	5344	.551	3800	6124	.608
1850	5425	.557	3850	6127	.608
1900	5414	.556	3900	6198	.613
1950	5427	.557	3950	6167	.611
2000	5380	.553	4000	6136	.609
2050	5426	.557			

APPENDIX IV - continued

Mile 710, 24 January

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
100	3375	.408
200	3176	.393
300	3178	.393
400	3145	.391
500	3292	.401
600	3438	.412
700	3473	.415
800	3766	.436
900	3846	.442
1000	3908	.446
1100	3934	.448
1200	4072	.459
1300	4153	.465
1400	4090	.460
1500	4240	.471
1600	4204	.468
1700	4362	.480
1800	4369	.480
1900	4270	.473
2000	4433	.485
2100	4612	.498
2200	4667	.501
2300	4746	.507
2400	4868	.516
2500	4884	.517
2600	5062	.530
2700	5232	.543
2800	5112	.534
2900	5088	.532
3000	5076	.531
3100	5308	.548
3200	5227	.542
3300	5337	.550
3400	5618	.571
3500	5366	.552
3600	5413	.556
3700	5524	.564
3800	5578	.568
3900	5647	.573

Mile 797, 29 January

Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)	Depth (cm)	Mean Count-Rate (Counts/Min.)	Density (g/cm^3)
300	2930	.375	2150	4450	.486
350	3111	.388	2200	4604	.497
400	3182	.397	2250	4754	.508
450	3230	.397	2300	4760	.508
500	3130	.390	2350	4830	.513
550	3174	.393	2400	4764	.508
600	3157	.393	2450	4840	.514
650	3358	.406	2500	4901	.518
700	3278	.399	2550	4860	.515
750	3460	.414	2600	4812	.512
800	3528	.419	2650	4894	.518
850	3720	.433	2700	4914	.519
900	3642	.427	2750	4980	.524
950	3814	.440	2800	4952	.522
1000	3861	.443	2850	4991	.525
1050	3835	.441	2900	5050	.529
1100	3852	.442	2950	4919	.520
1150	3866	.443	3000	5050	.529
1200	3883	.445	3050	5035	.578
1250	3992	.453	3100	5035	.528
1300	4030	.455	3150	5124	.535
1350	4245	.471	3200	5237	.543
1400	4195	.468	3250	5139	.536
1450	4260	.472	3300	5112	.534
1500	4182	.467	3350	5140	.536
1550	4269	.473	3400	5108	.534
1600	4277	.473	3450	5301	.548
1650	4470	.487	3500	5234	.593
1700	4393	.482	3550	5250	.544
1750	4306	.475	3600	5220	.542
1800	4588	.496	3650	5329	.550
1850	4538	.492	3700	5308	.548
1900	4524	.491	3750	5366	.552
1950	4497	.489	3800	5260	.545
2000	4523	.491	3850	5431	.557
2050	4630	.499	3900	5332	.550
2100	4616	.498	3950	5438	.558
			4000	5466	.560

APPENDIX V - PIT DIAGRAMS

The stratigraphy of the pit is represented in the usual way in the following diagrams. From left to right, the following information is indicated for most of the pits:

- the main stratigraphic features;

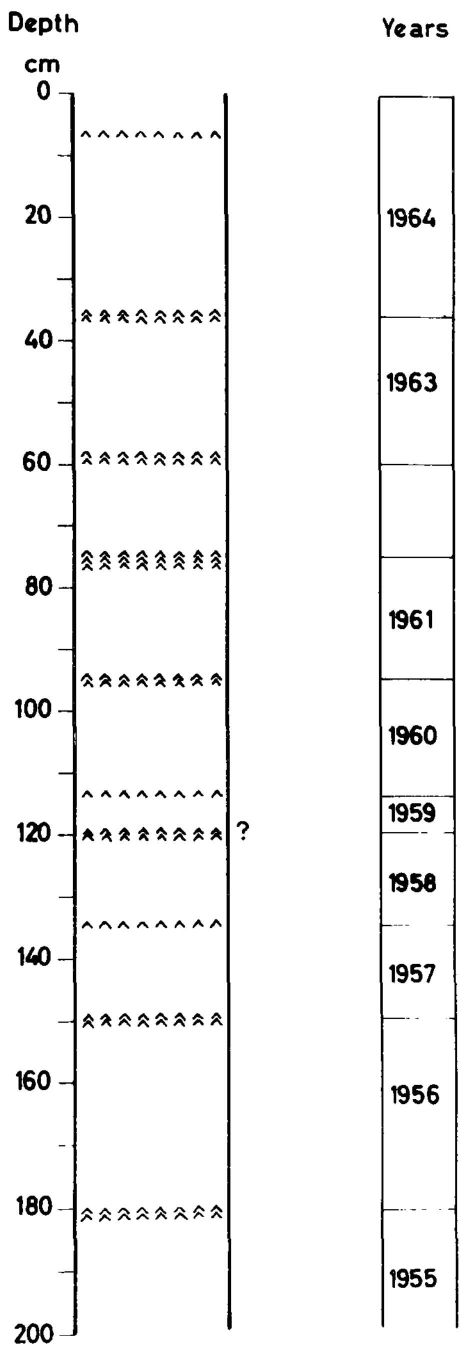
- the density (g/cm^3);

- a tentative identification of the annual layers based on the interpretation of the stratigraphy. Since this interpretation is often ambiguous, the results of the extreme interpretations (maximum and minimum number of annual layers) are generally given;
- The position of the smaples collected in view of isotopic measurements (fallout, Pb^{210} and oxygen).

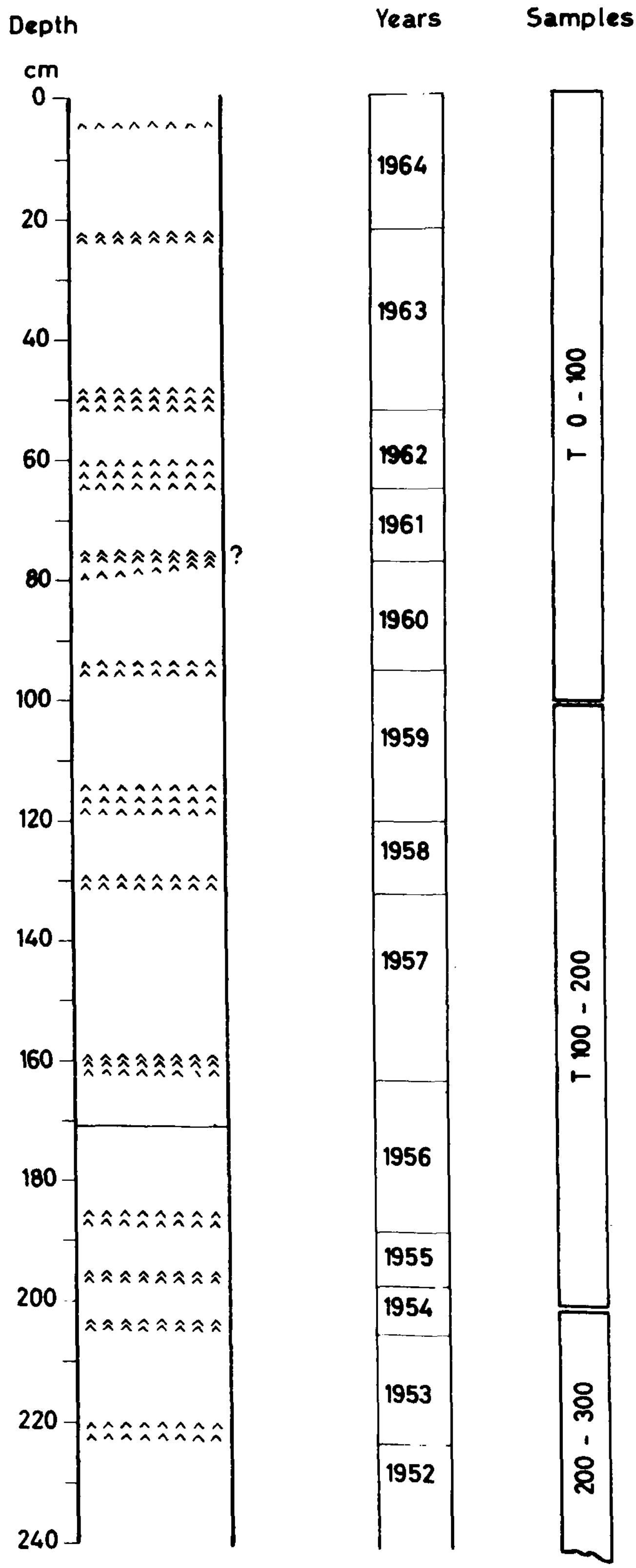
The following symbols and abbreviations are used in the pit diagram:

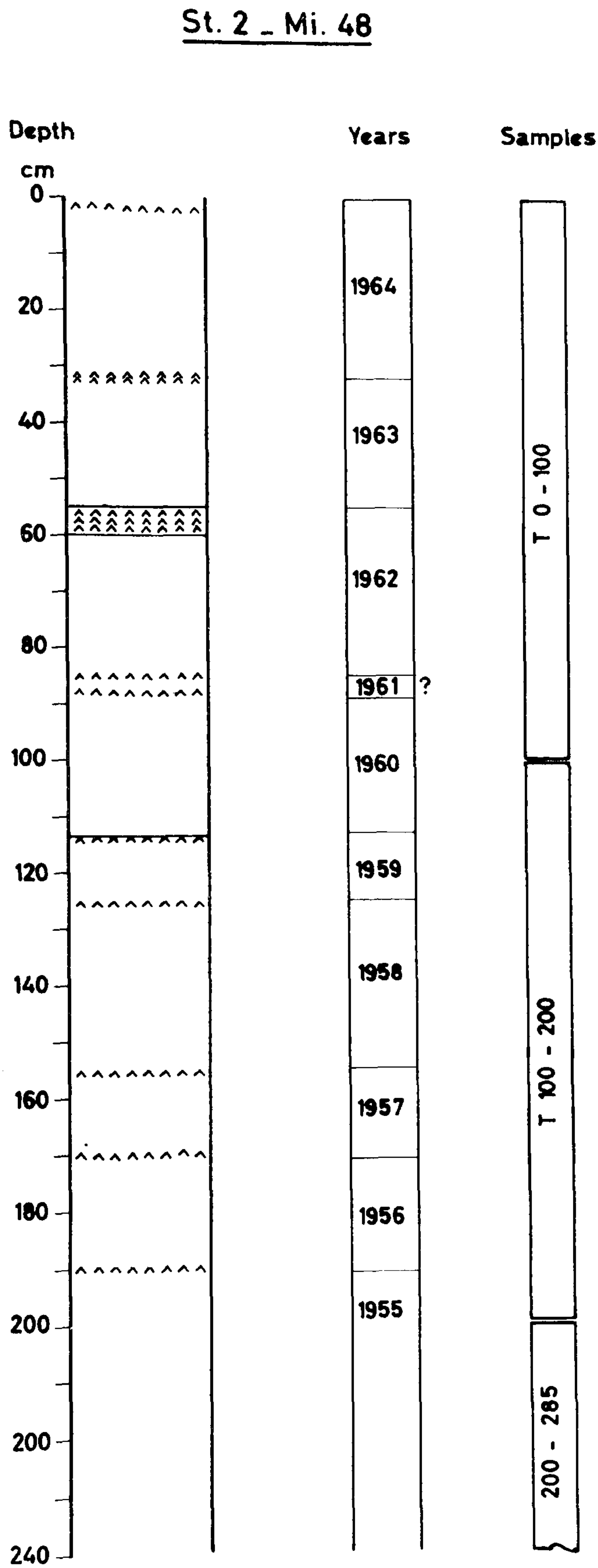
ΛΛΛΛΛ	depth hoar layer
_____	iced crust
IIIII	hard layer
-----	bonded grain layer
?	discontinuous or uncertain feature
vs	very soft
s	soft
m	medium
mh	medium hard
h	hard
vh	very hard
T	tube
C	core
bis	two parallel cores or tubes from same level
tris	three parallel cores or tubes from same level

St. 0 _ Mi. 8


Depth
cm
0
20
40
60
80
100
120
140
160
180
200
?
Years
1964
1963
1961
1960
1959
1958
1957
1956
1955

St. 1 - Mi. 24


Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
Years
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
Samples
T 0 - 100
T 100 - 200
200 - 300


St. 2 _ Mi. 48
Depth
cm
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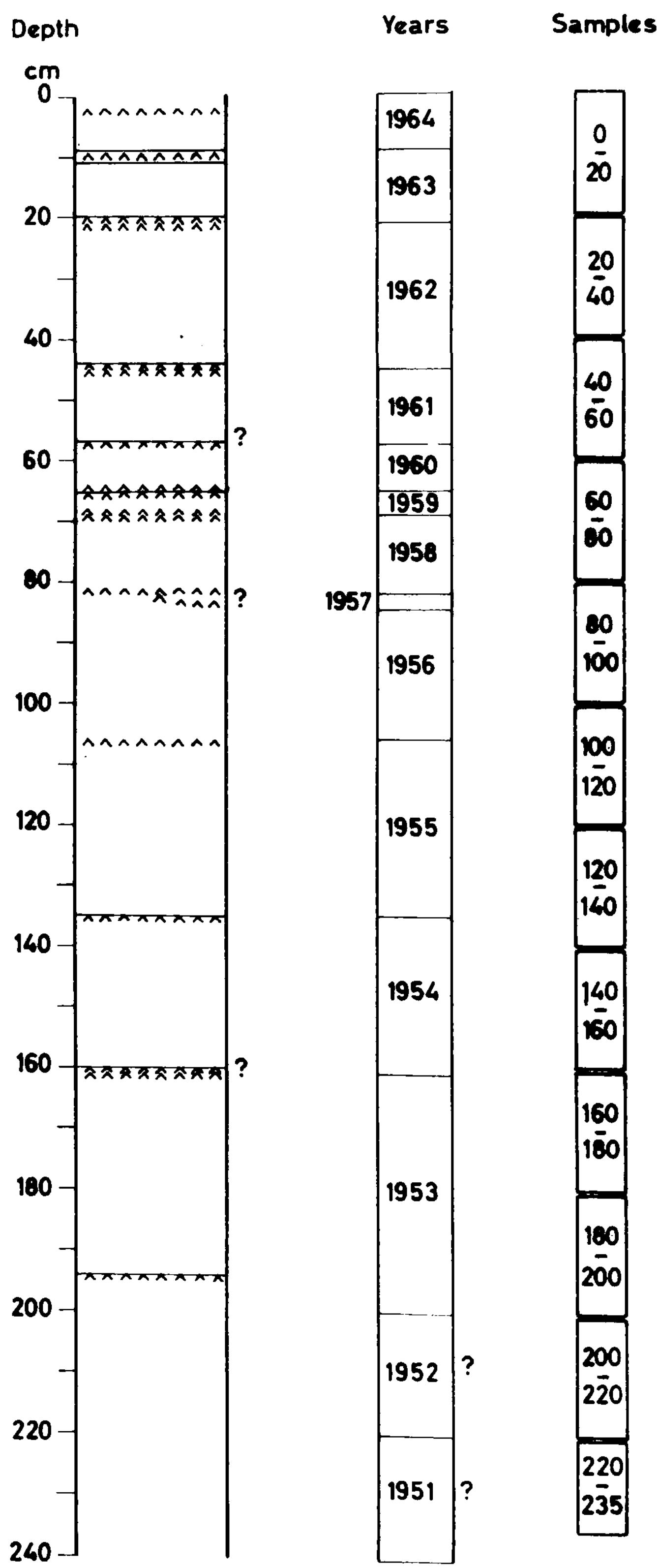
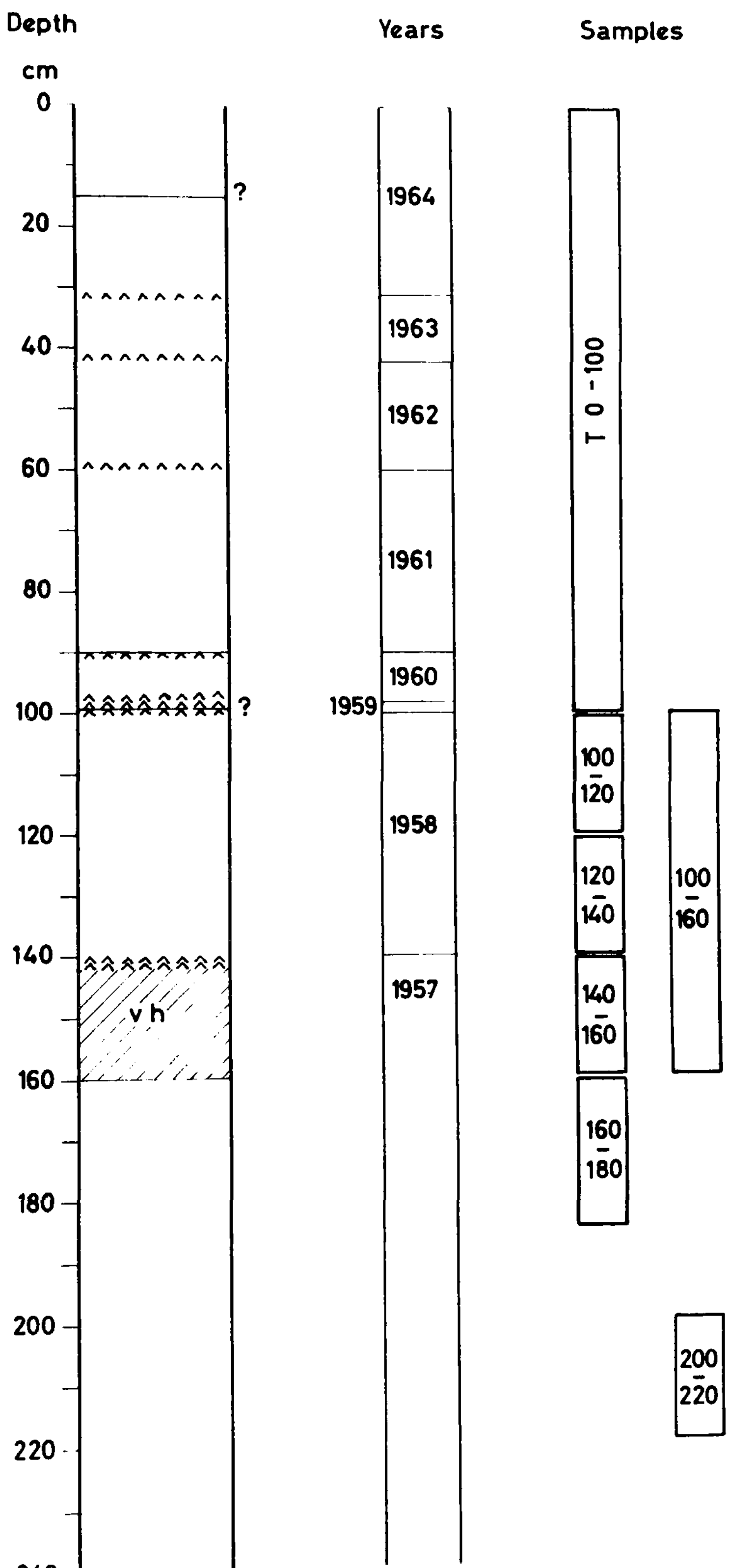
20
40
60
80
100
120
140
160
180
200
200
240
Years
1964
1963
1962
1961
?
1960
1959
1958
1957
1956
1955
Samples
T 0 - 100
T 100 - 200
200 - 285

St. 3 _ Mi. 72

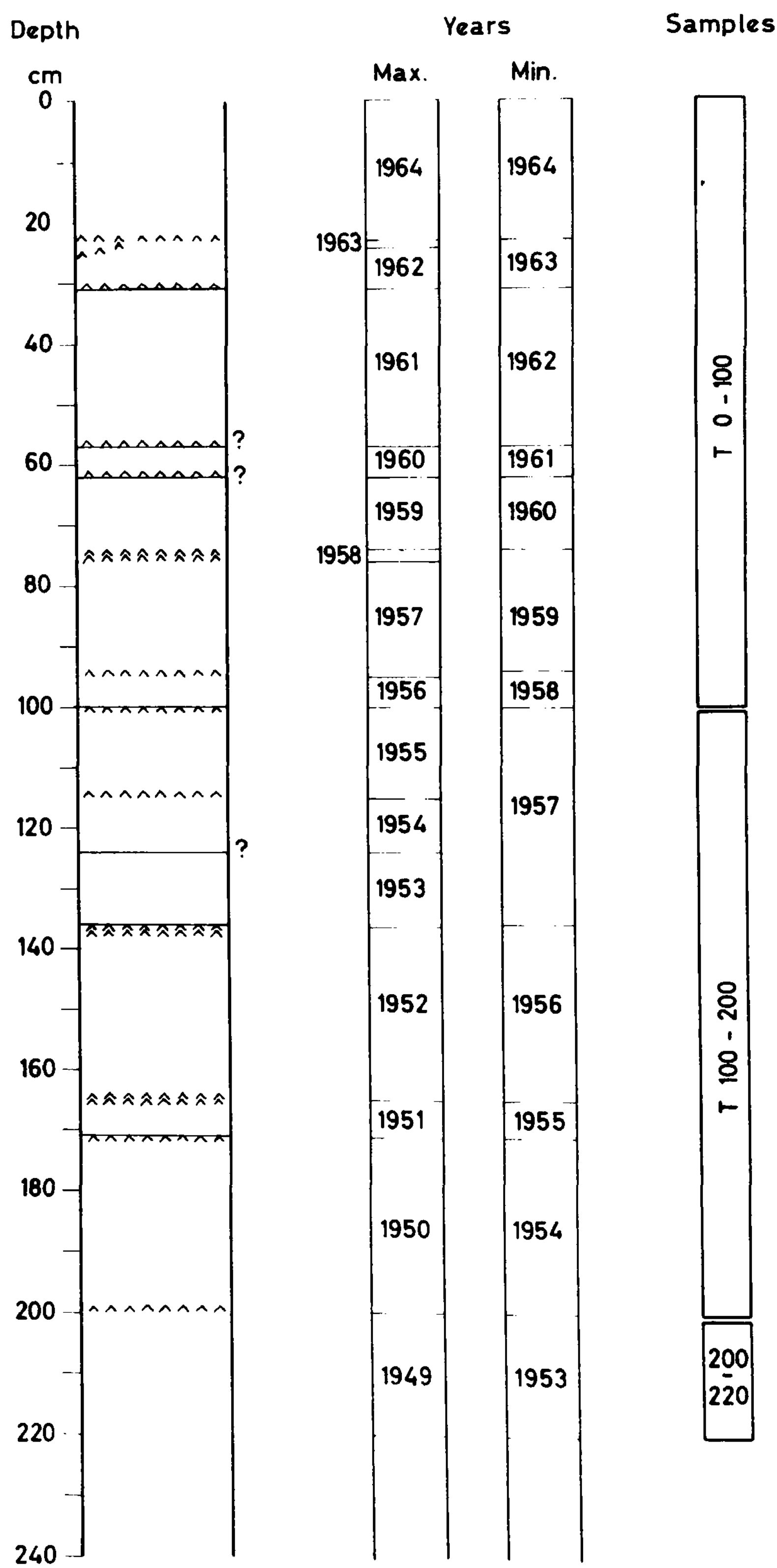

Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
?
?
Years
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952 ?
1951 ?
Samples
0 - 20
20 - 40
40 - 60
60 - 80
80 - 100
100 - 120
120 - 140
140 - 160
160 - 180
180 - 200
200 - 220
220 - 235

St. 4a – Mi. 110



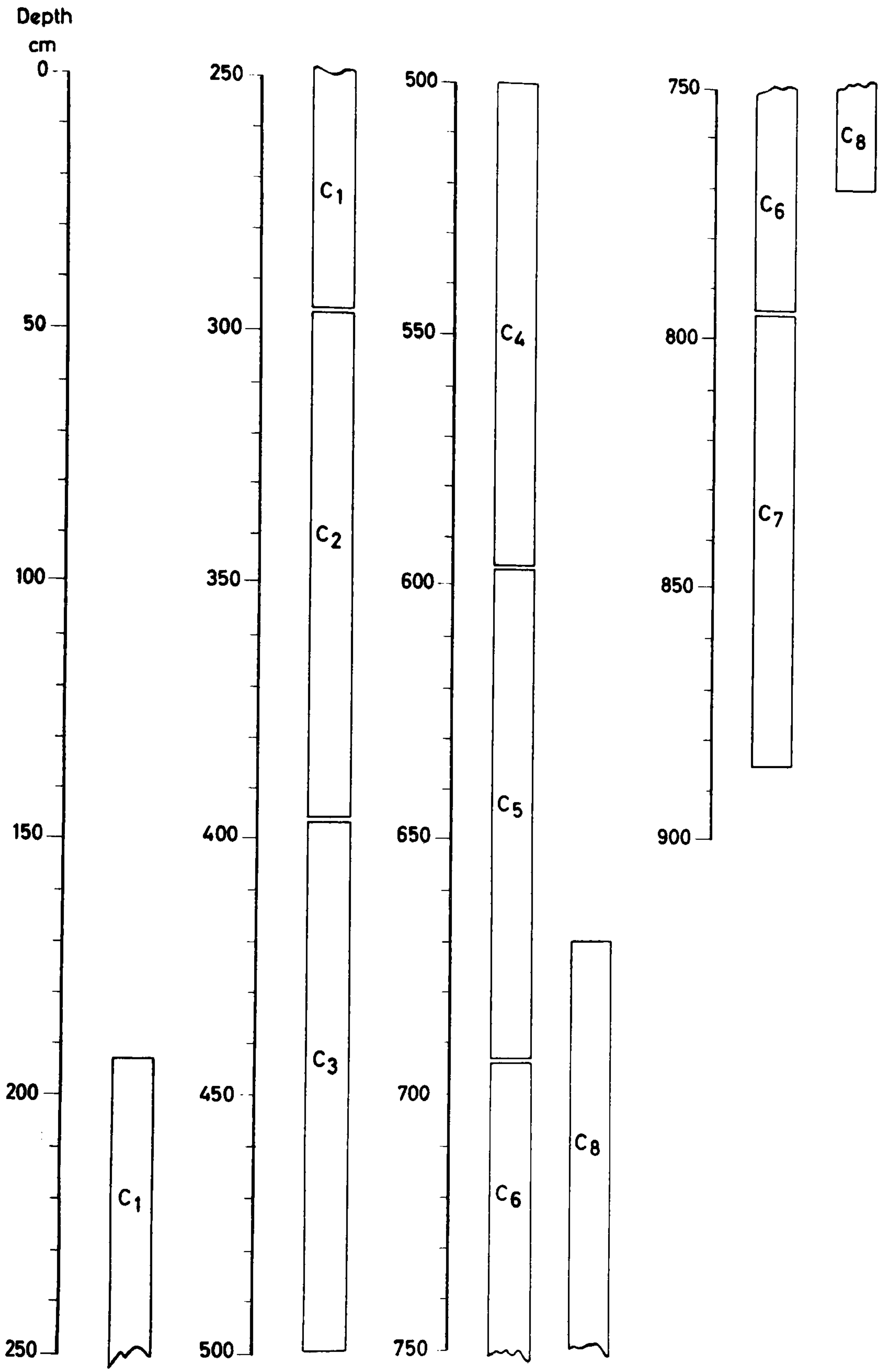
Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
?
v h
Years
1964
1963
1962
1961
1960
1959
1958
1957
Samples
T 0 - 100
100 - 120
120 - 140
140 - 160
160 - 180
100 - 160
200 - 220

St. 4 – Mi. 96



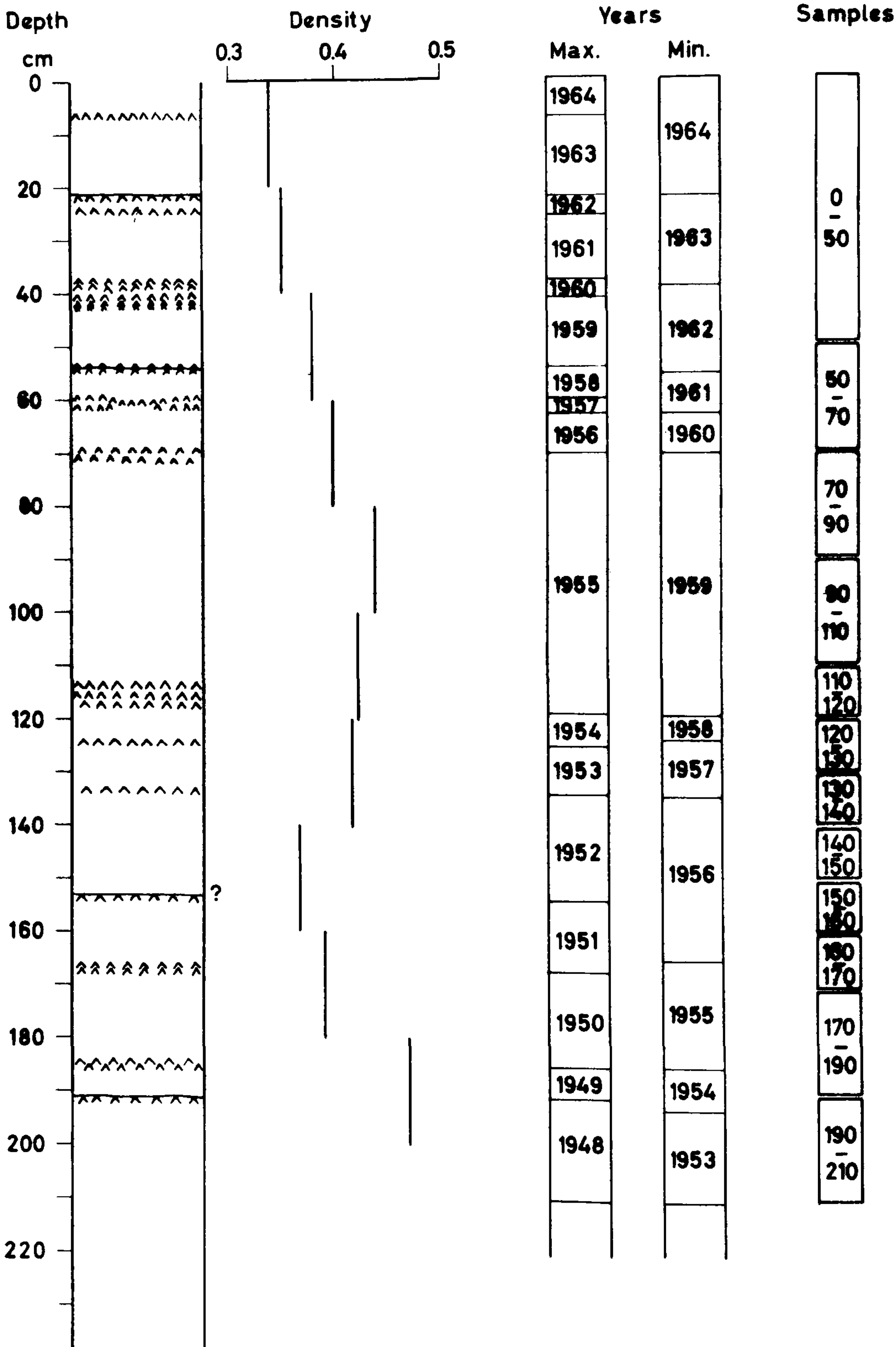
Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
?
?
Years
Max.
Min.
1964
1964
1963
1962
1963
1961
1962
1960
1961
1959
1960
1958
1957
1959
1956
1958
1955
1954
1957
1953
1952
1956
1951
1955
1950
1954
1949
1953
Samples
T 0 - 100
T 100 - 200
200 - 220

St. 4a - Mi. 110

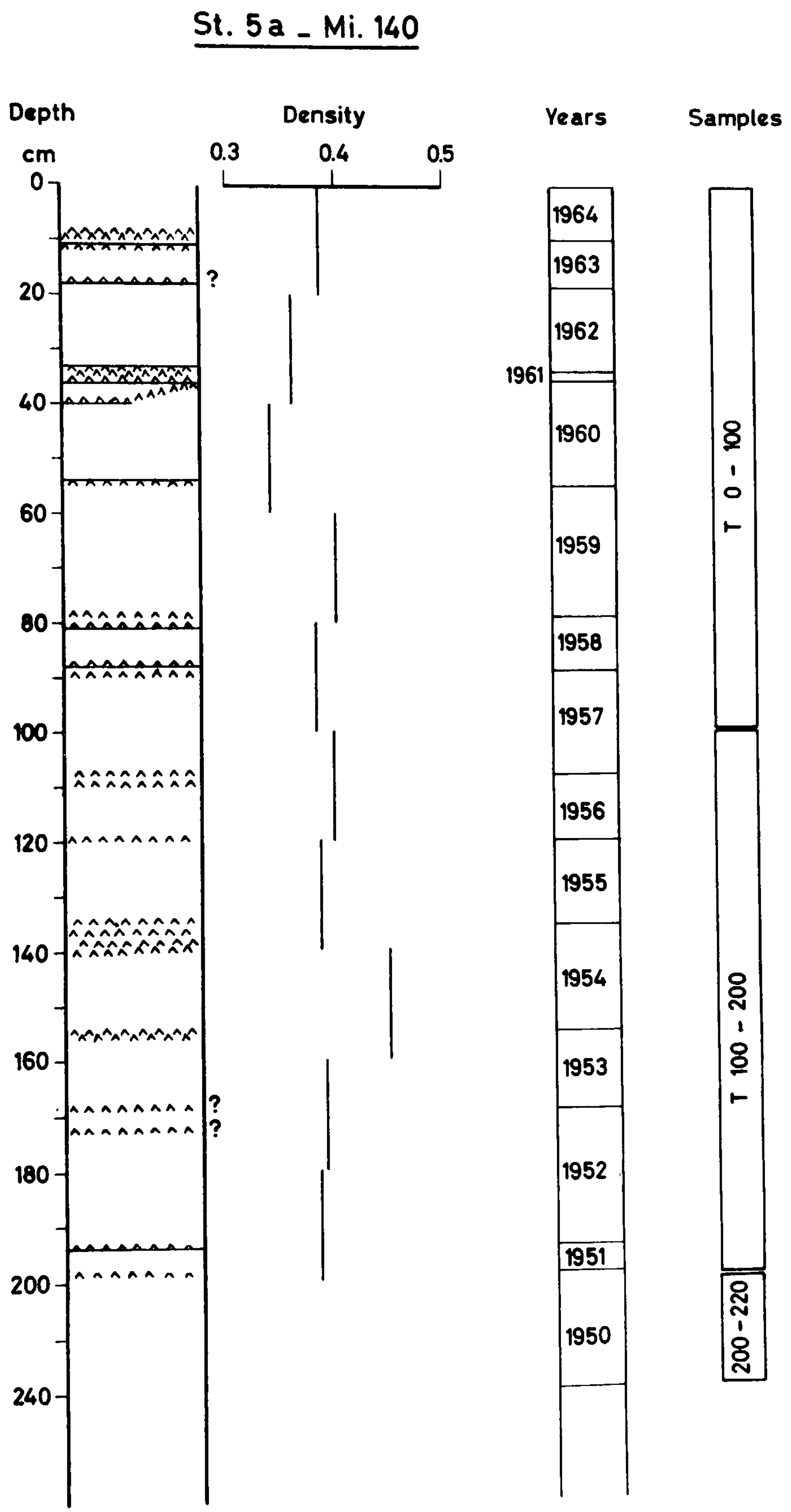


Depth
cm
0
50
100
150
200
250
C1
250
300
350
400
450
500
C1
C2
C3
500
550
600
650
700
750
C4
C5
C6
C8
750
800
850
900
C6
C7
C8

St. 5 _ Mi. 125



Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
Density
0.3
0.4
0.5
Years
Max.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1951
1950
1949
1948
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
Samples
0 - 50
50 - 70
70 - 90
90 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 190
190 - 210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Depth
cm
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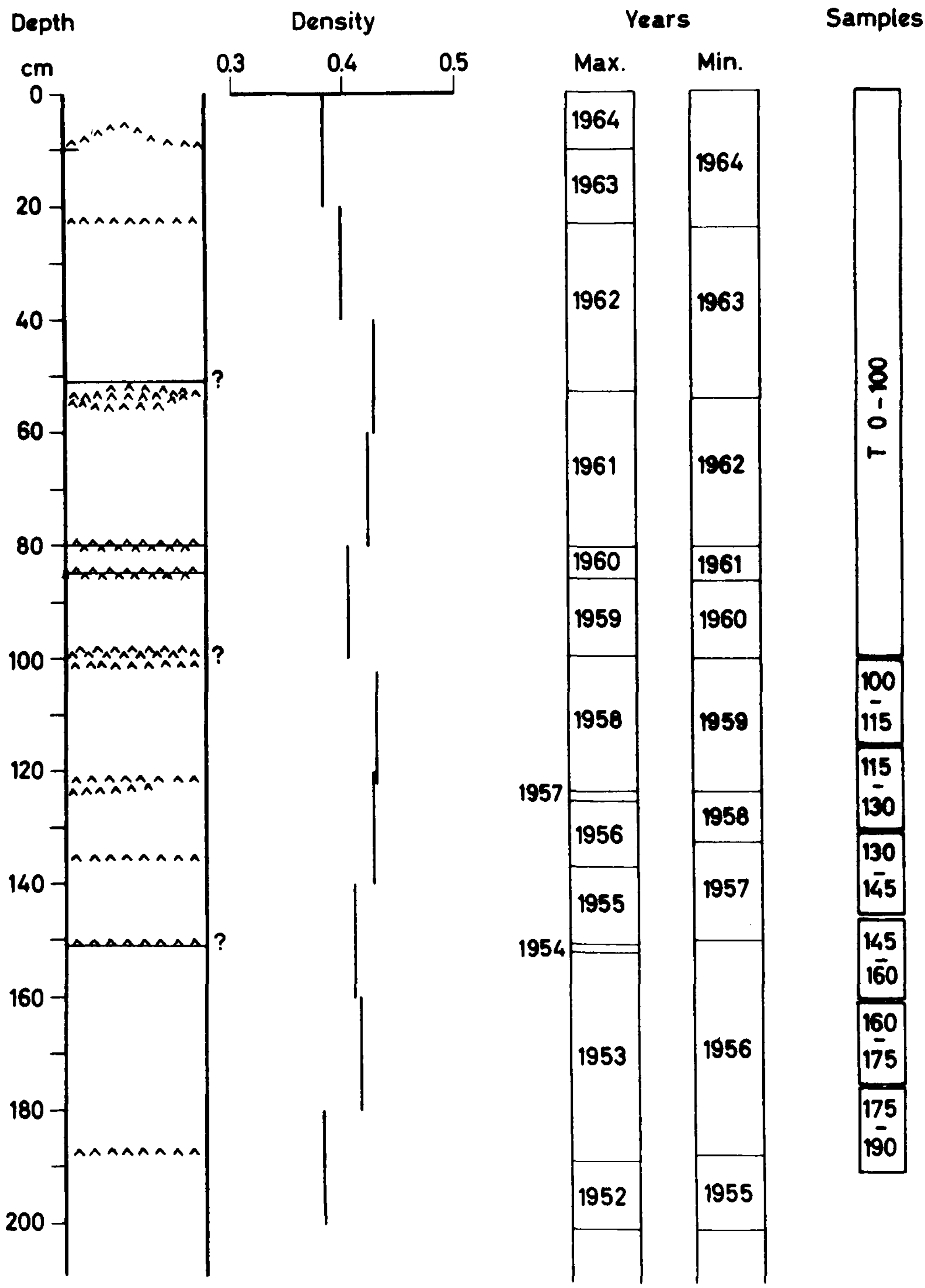
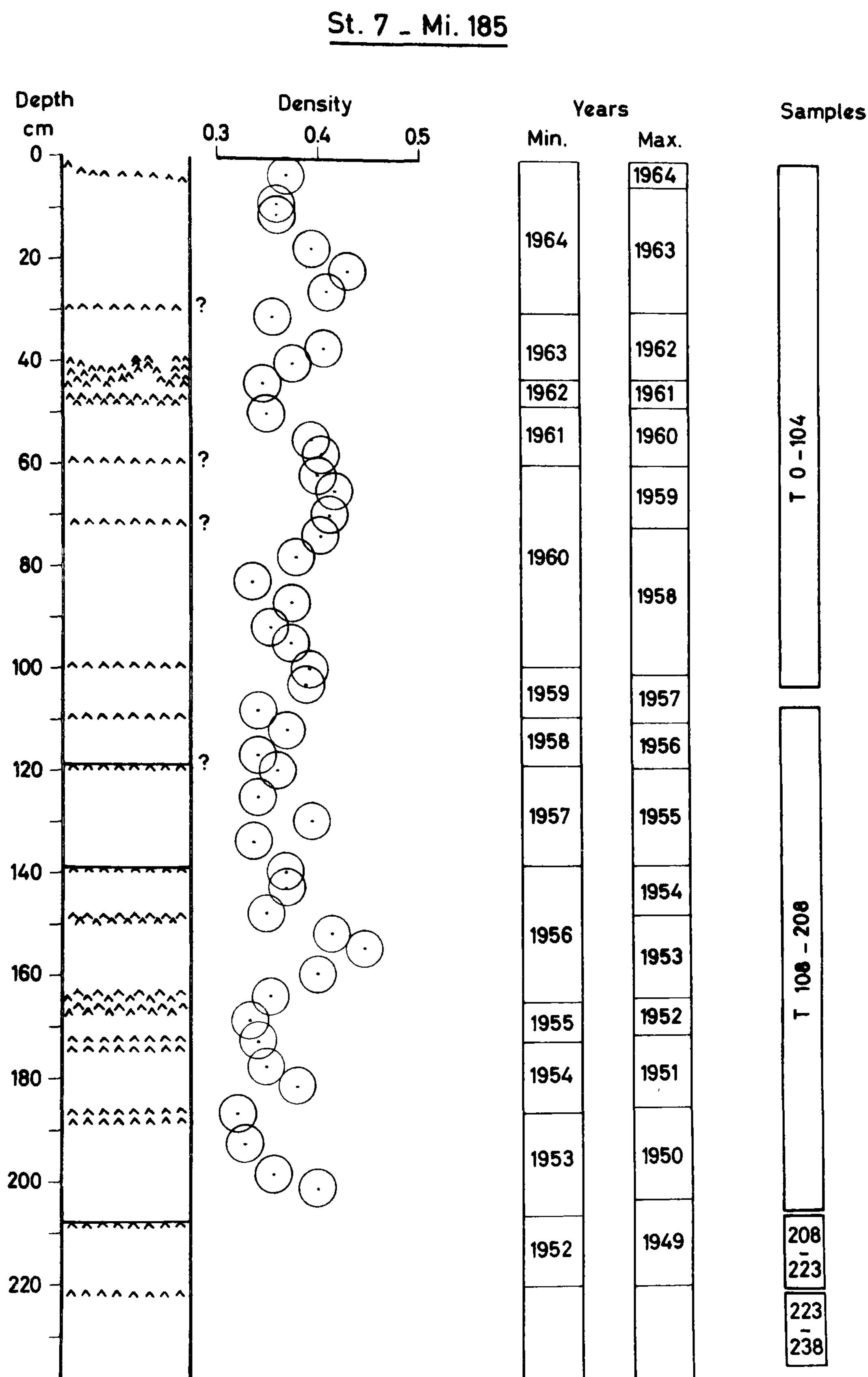
20
40
60
80
100
120
140
160
180
200
240
?
?
?
Density
0.3
0.4
0.5
Years
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1951
1950
Samples
T 0 - 100
T 100 - 200
200-220

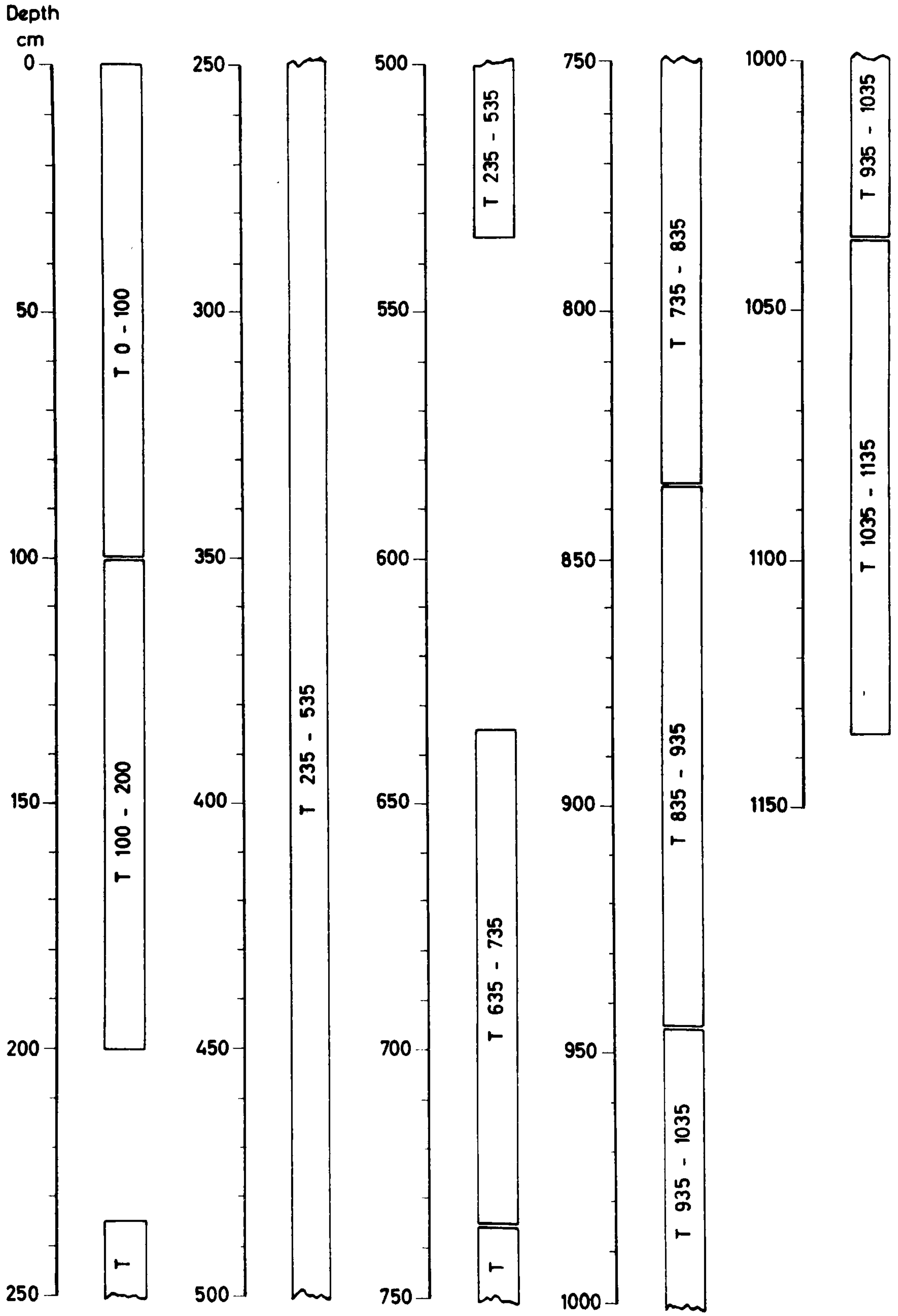
St. 6 _ Mi. 155


Depth
cm
0
20
40
60
80
100
120
140
160
180
200
Density
0.3
0.4
0.5
Years
Max.
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
Samples
T 0-100
100-115
115-130
130-145
145-160
160-175
175-190



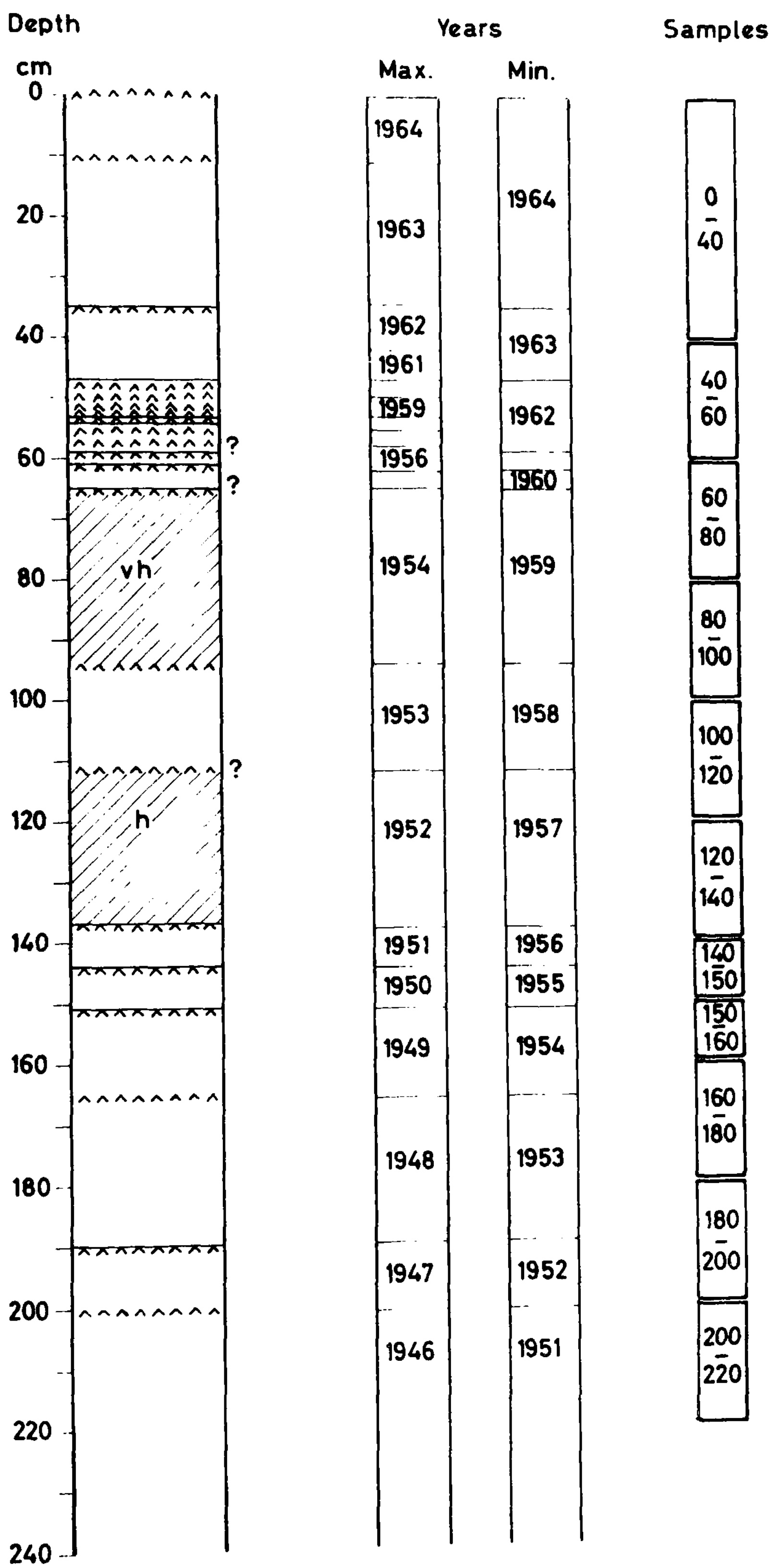
St. 7 _ Mi. 185
Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
?
?
?
Density
0.3
0.4
0.5
Years
Min.
Max.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1951
1950
1949
Samples
T 0 - 104
T 108 - 208
208 - 223
223 - 238

St. 7 _ Mi. 185



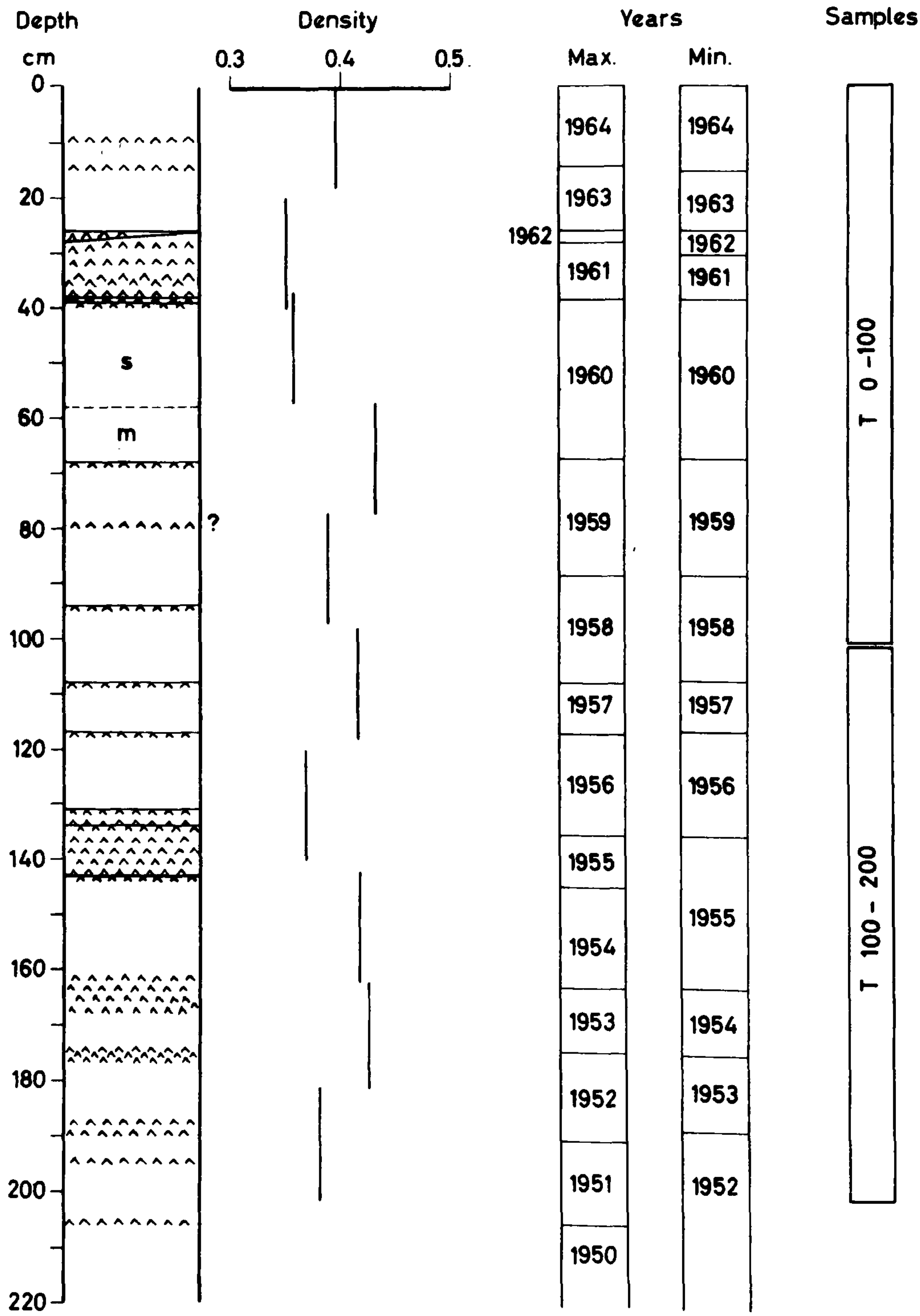
Depth
cm
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
1100
1150
T 0 - 100
T 100 - 200
T
T 235 - 535
T 235 - 535
T 635 - 735
T
T 735 - 835
T 835 - 935
T 935 - 1035
T 935 - 1035
T 1035 - 1135

St. 8 _ Mi. 215



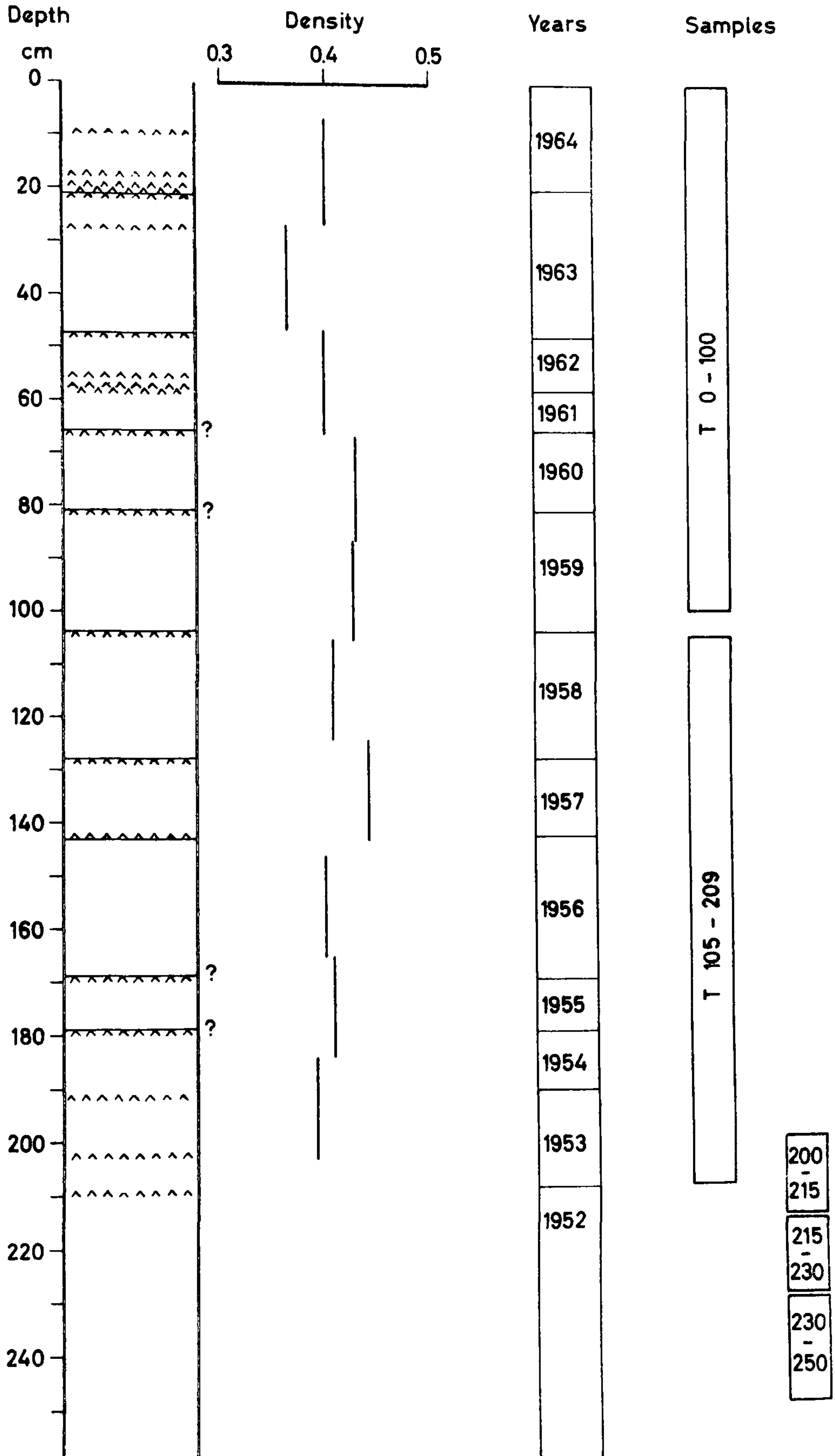
Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
vh
h
?
?
?
Years
Max.
Min.
1964
1963
1962
1961
1959
1956
1954
1953
1952
1951
1950
1949
1948
1947
1946
1964
1963
1962
1960
1959
1958
1957
1956
1955
1954
1953
1952
1951
Samples
0 – 40
40 – 60
60 – 80
80 – 100
100 – 120
120 – 140
140 – 150
150 – 160
160 – 180
180 – 200
200 – 220

St. 9 _ Mi. 245



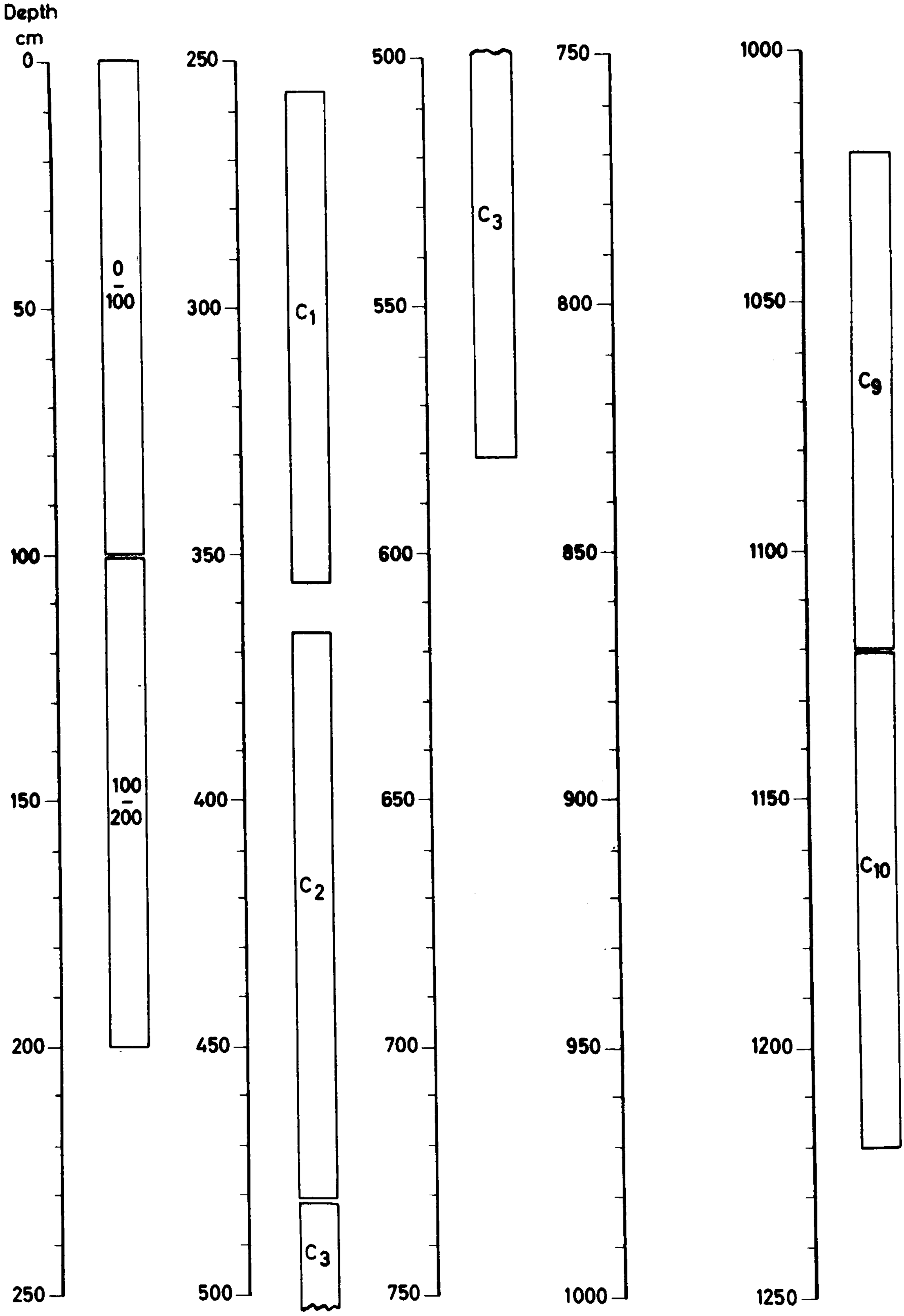
Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
s
m
?
Density
0.3
0.4
0.5
Years
Max.
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1951
1950
Samples
T 0-100
T 100-200

St.10 _ Mi. 275

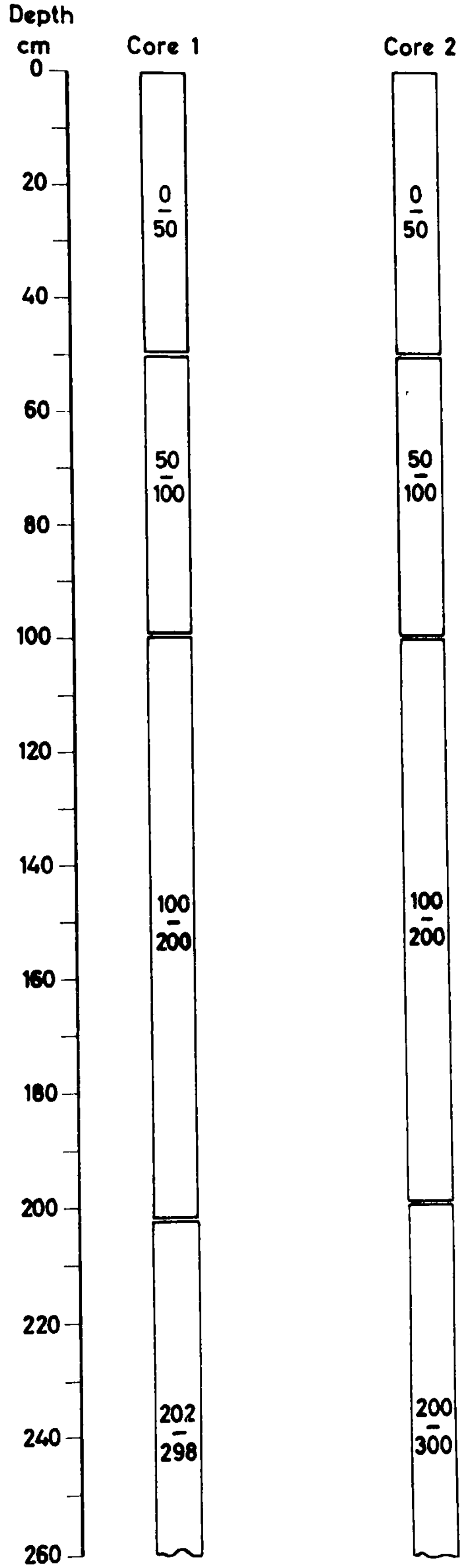


Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
260
?
?
?
?
Density
0.3
0.4
0.5
Years
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
Samples
T 0 - 100
T 105 - 209
200 - 215
215 - 230
230 - 250

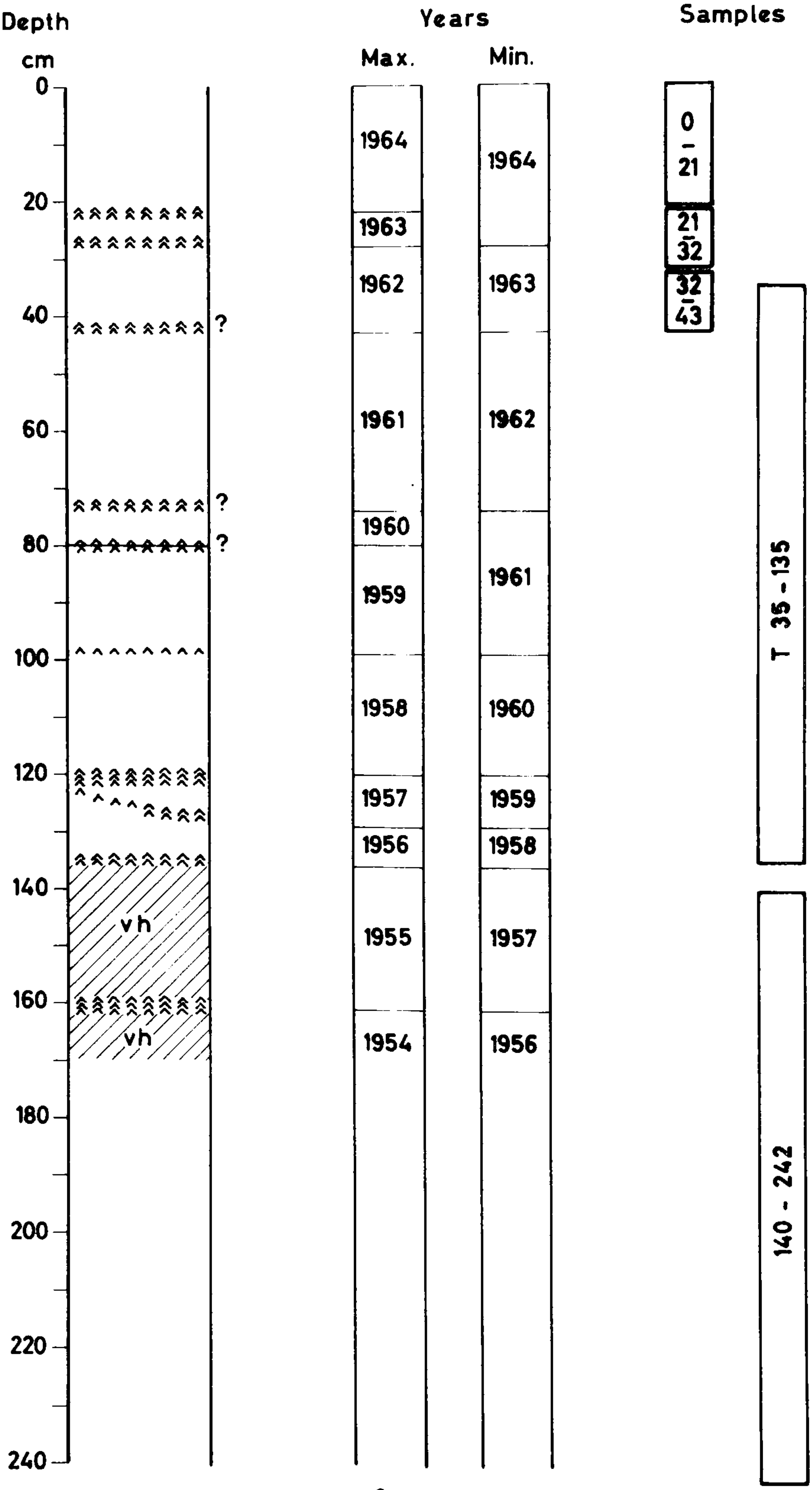
St. 10 - Mi. 275


Depth
cm
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
1100
1150
1200
1250
0
100
100
200
C_1
C_2
C_3
C_3
C_9
C_{10}

St. 11 – Mi. 305

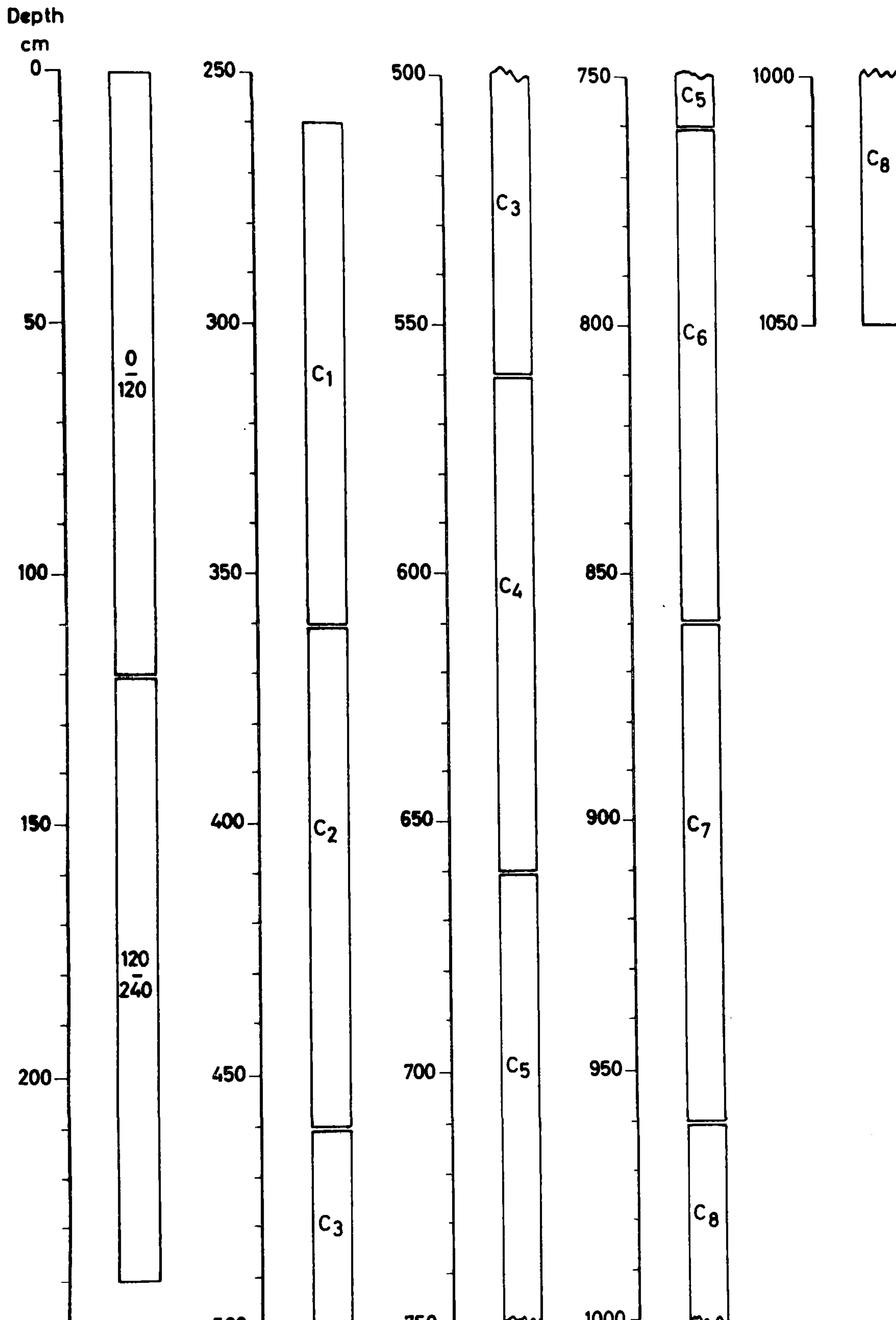

Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
260
Core 1
0 – 50
50 – 100
100 – 200
202 – 298
Core 2
0 – 50
50 – 100
100 – 200
200 – 300

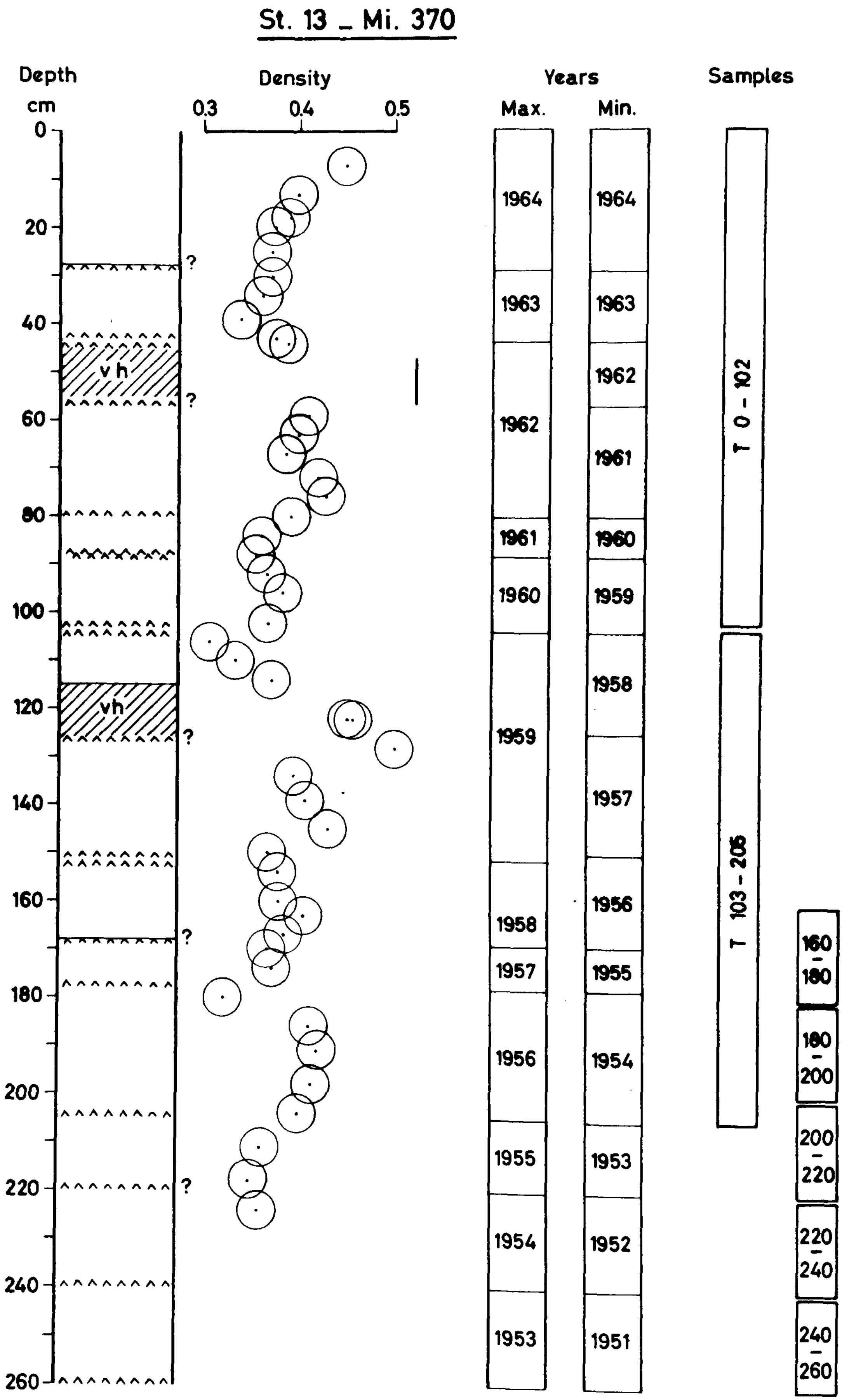
St. 12 - Mi. 338



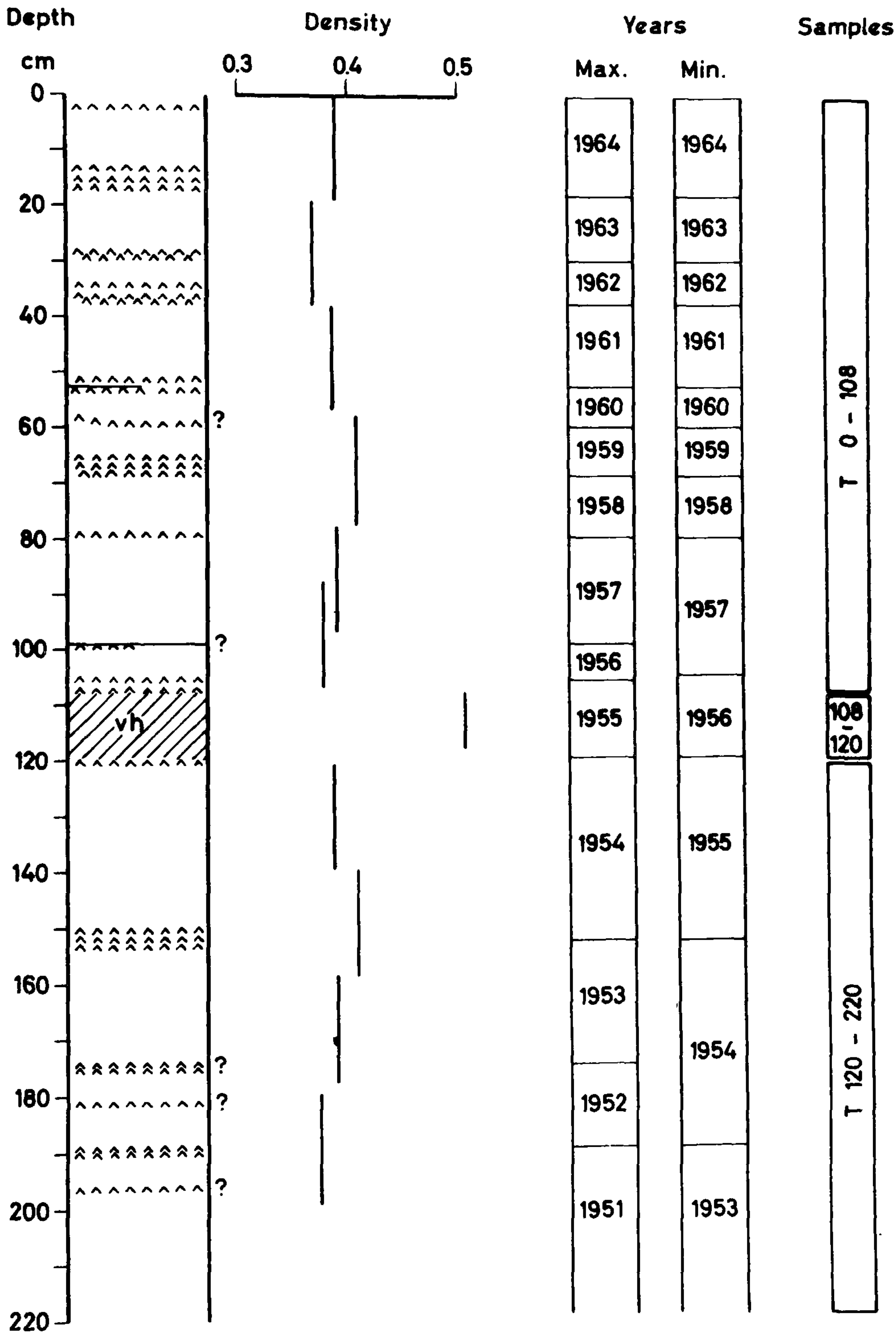
Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
?
?
vh
vh
Years
Max.
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1964
1963
1962
1961
1960
1959
1958
1957
1956
Samples
0 - 21
21 - 32
32 - 43
T 35 - 135
140 - 242

St. 13 _ Mi. 370

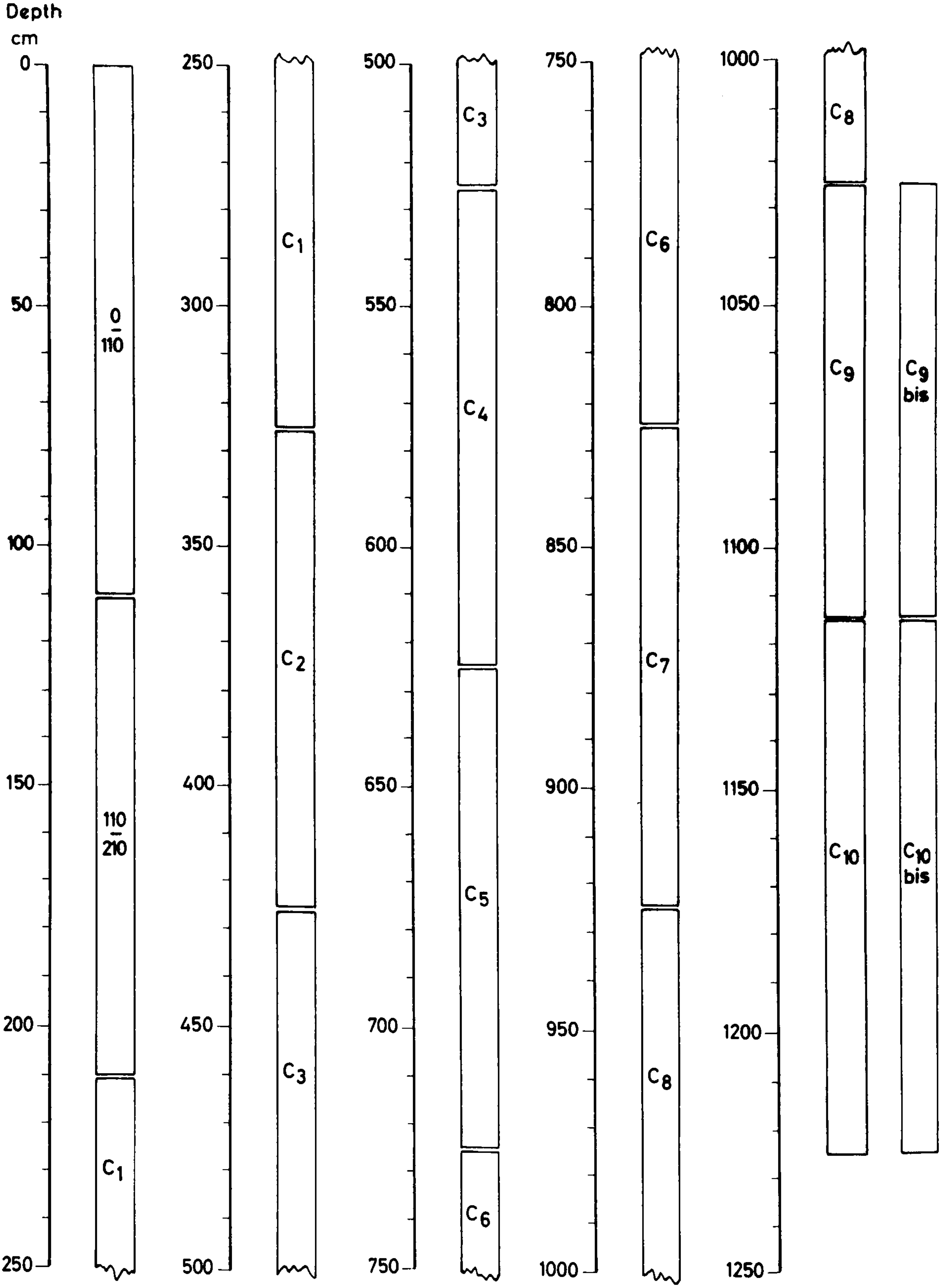

Depth
cm
0
50
100
150
200
250
0
120
120
240
250
300
350
400
450
500
C1
C2
C3
500
550
600
650
700
750
C3
C4
C5
750
800
850
900
950
1000
C5
C6
C7
C8
1000
1050
C8


St. 13 _ Mi. 370
Depth cm
Density
0.3 0.4 0.5
Years
Max.
Min.
Samples
0 20 40 60 80 100 120 140 160 180 200 220 240 260
vh
vh
?
1964 1963 1962 1961 1960 1959 1958 1957 1956 1955 1954 1953
1964 1963 1962 1961 1960 1959 1958 1957 1956 1955 1954 1953 1952 1951
T 0 - 102
T 103 - 205
160 - 180
180 - 200
200 - 220
220 - 240
240 - 260

St. 14 _ Mi. 395

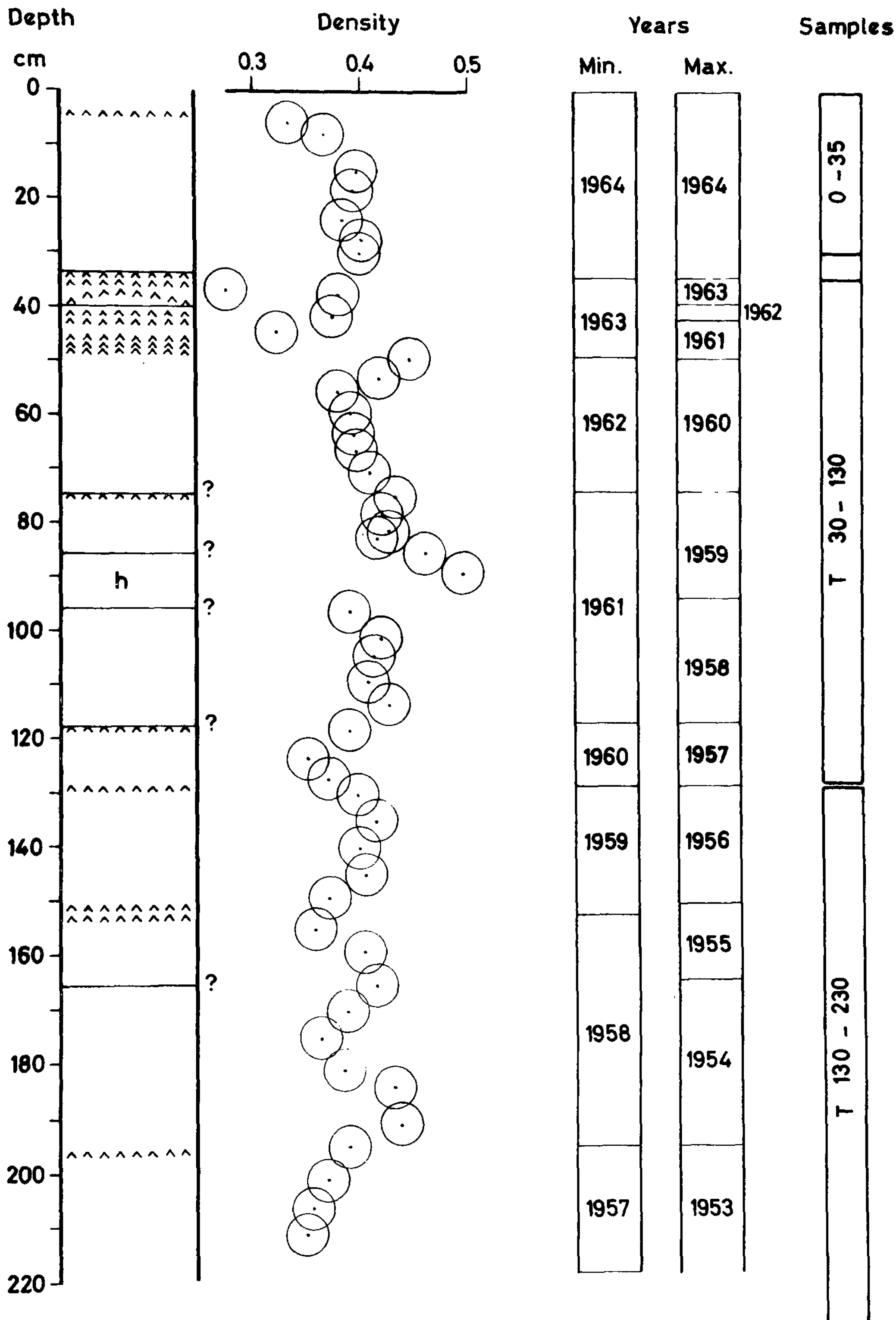

Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
vh
?
Density
0.3
0.4
0.5
Years
Max.
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1951
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
Samples
T 0 - 108
108
120
T 120 - 220

St. 15 _ Mi. 415

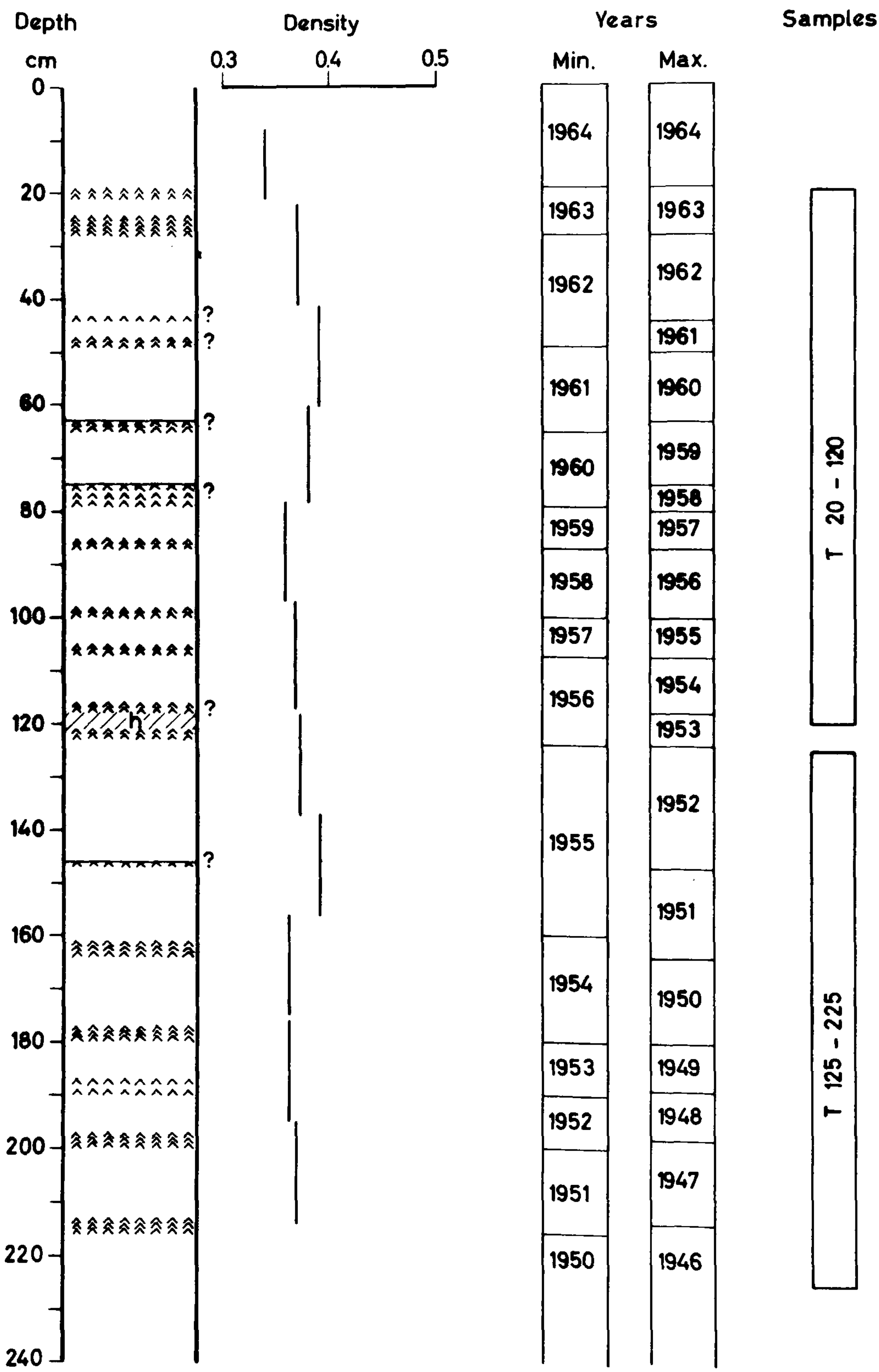


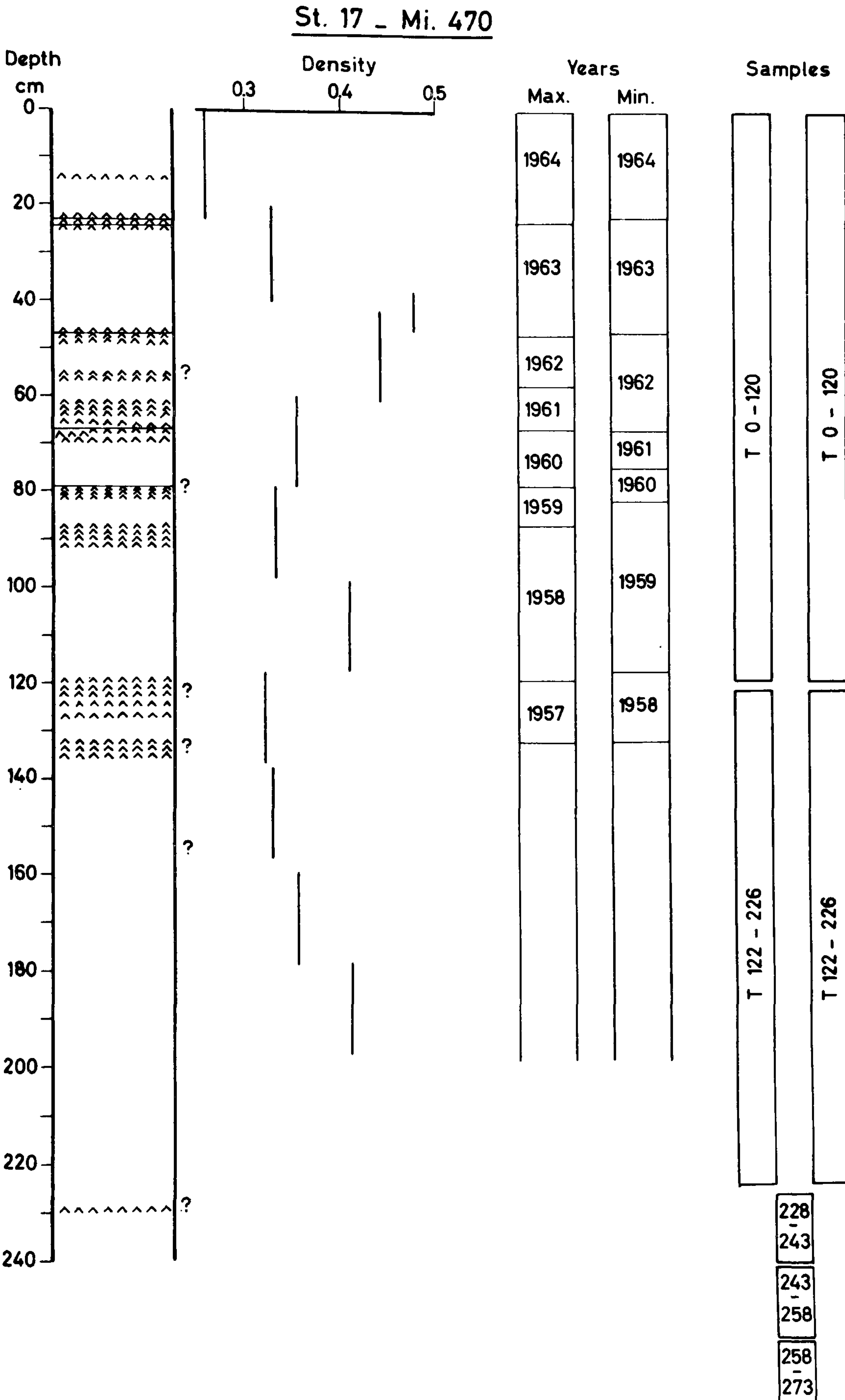
Depth
cm
0
50
100
150
200
250
0/110
110/210
C1
250
300
350
400
450
500
C1
C2
C3
500
550
600
650
700
750
C3
C4
C5
C6
750
800
850
900
950
1000
C6
C7
C8
1000
1050
1100
1150
1200
1250
C8
C9
C10
C9 bis
C10 bis

St. 15 _ Mi. 415

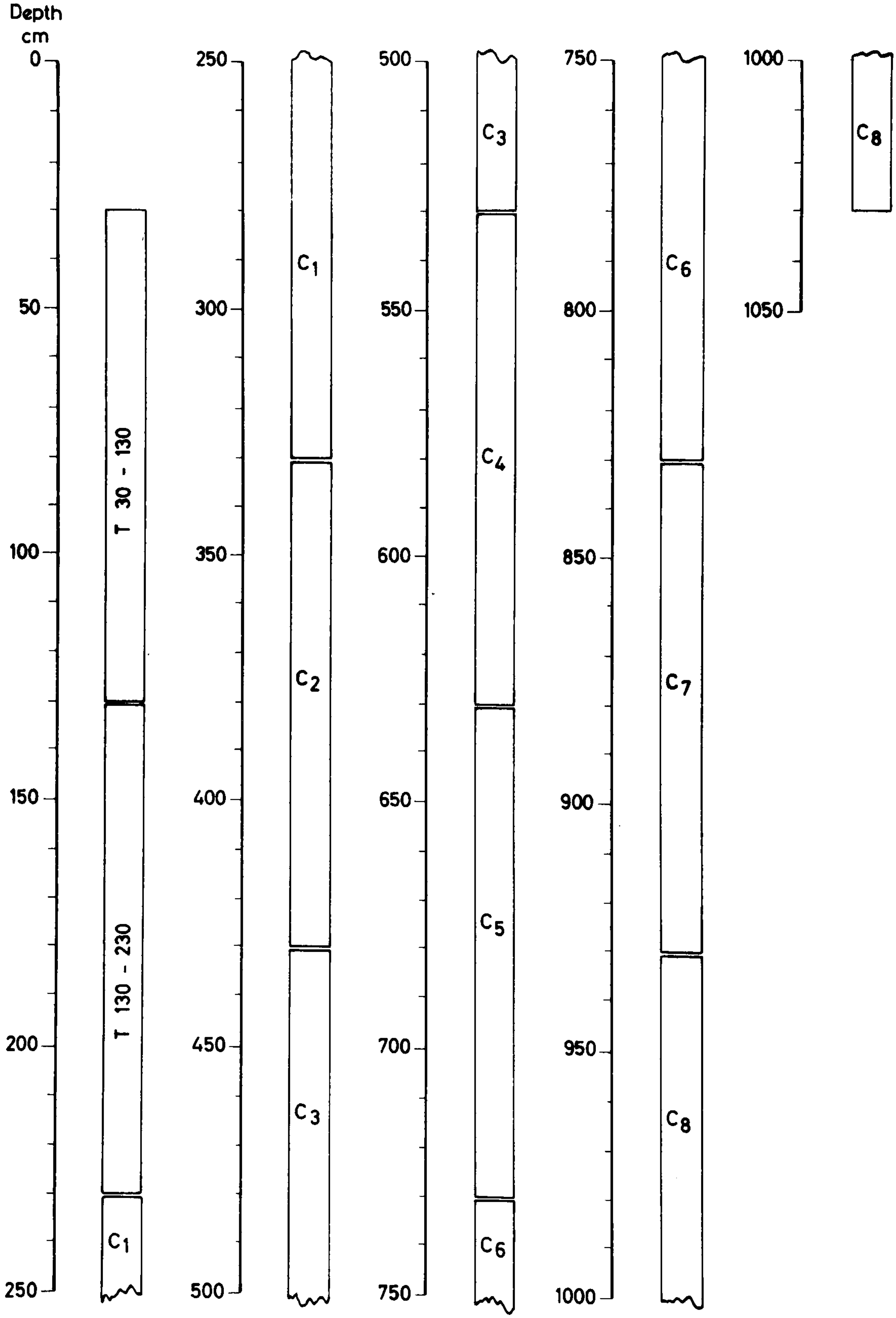

Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
h
?
Density
0.3
0.4
0.5
Years
Min.
Max.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
Samples
0 - 35
T 30 - 130
T 130 - 230

St. 16 _ Mi. 445

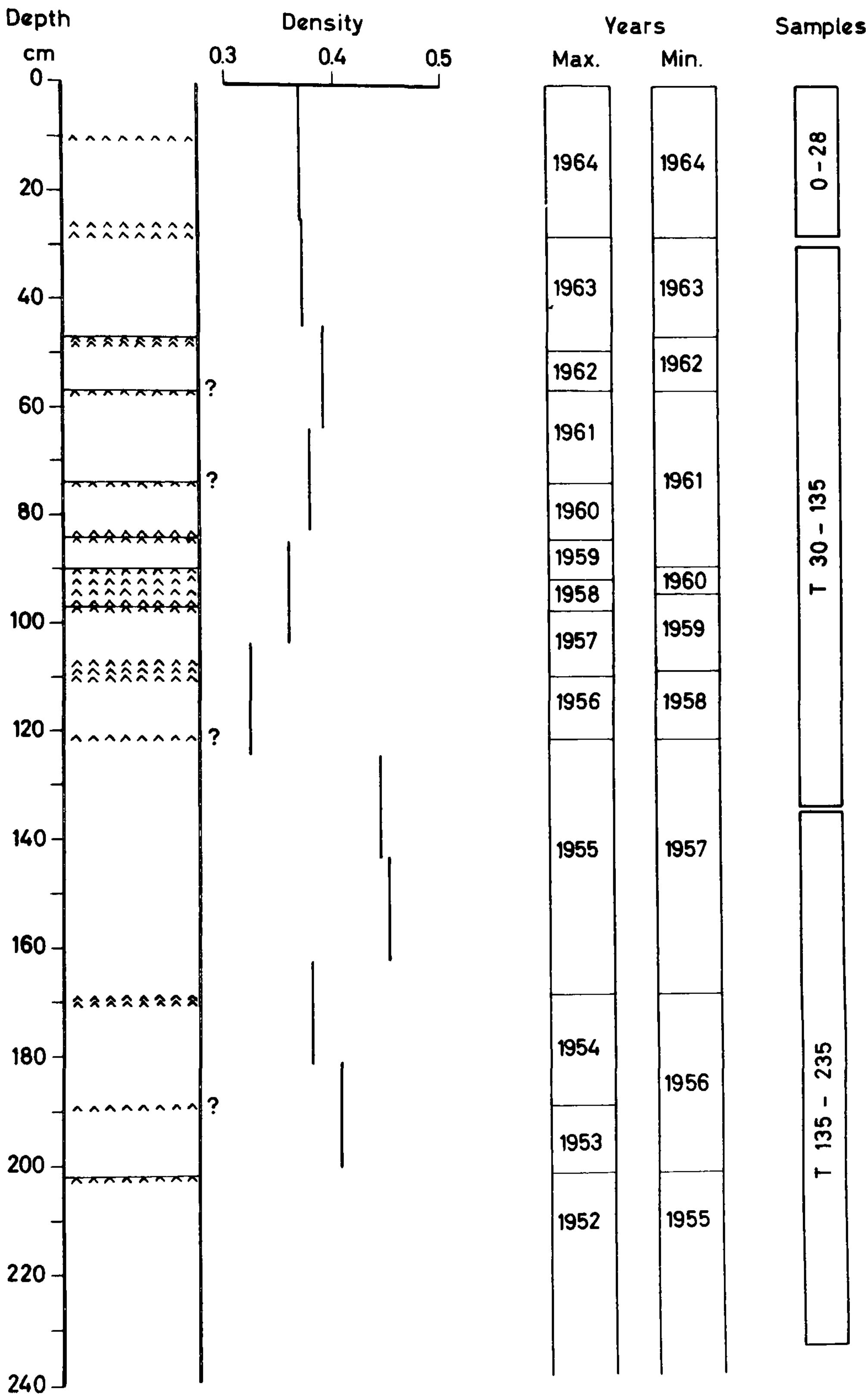

Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
h
?
Density
0.3
0.4
0.5
Years
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1951
1950
Max.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1951
1950
1949
1948
1947
1946
Samples
T 20 - 120
T 125 - 225


St. 17 _ Mi. 470
Depth cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
?
?
?
?
?
Density
0,3
0,4
0,5
Years
Max.
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1964
1963
1962
1961
1960
1959
1958
Samples
T 0 - 120
T 0 - 120
T 122 - 226
T 122 - 226
228 - 243
243 - 258
258 - 273

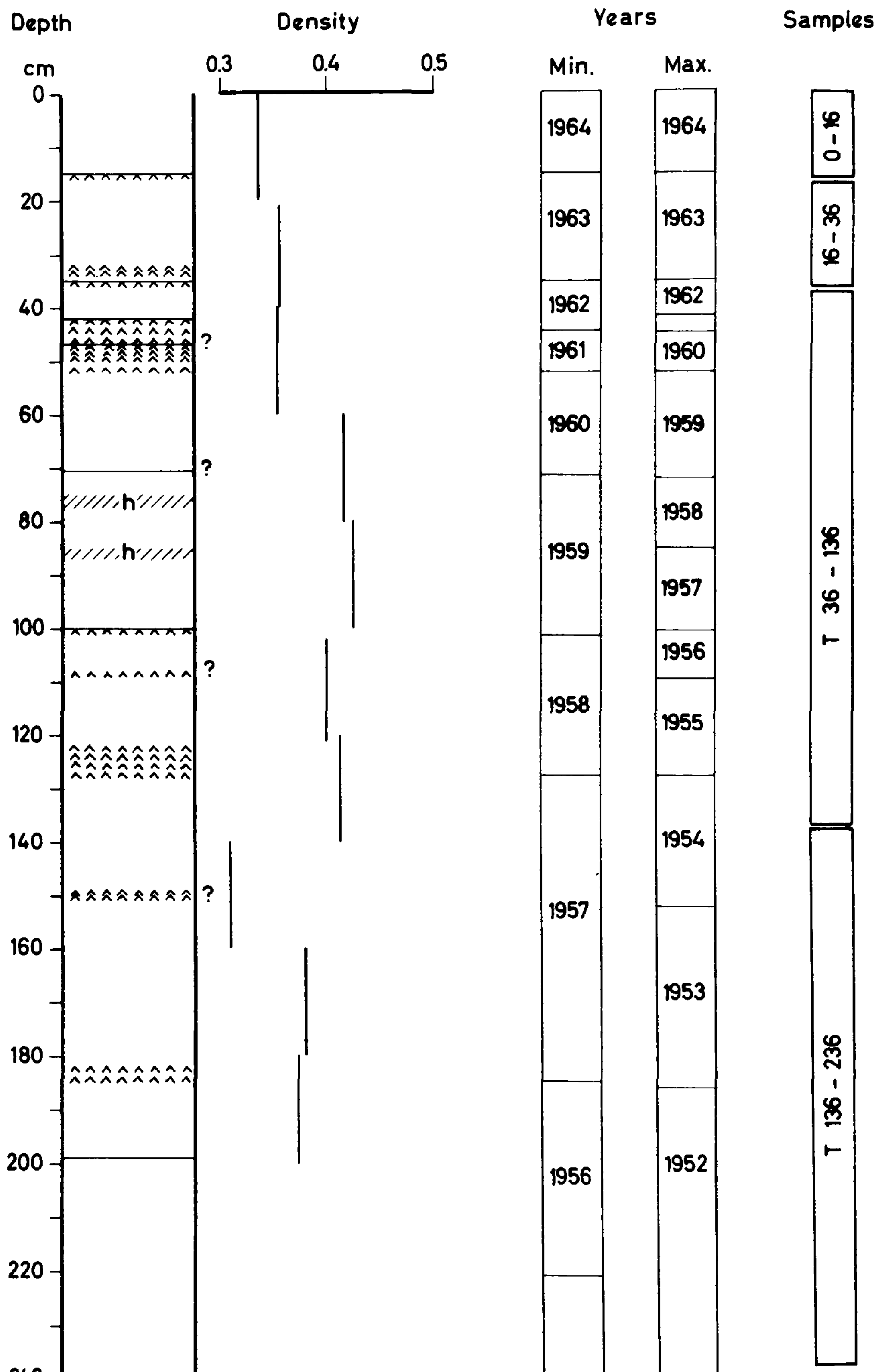
St. 18 _ Mi. 496


Depth
cm
0
50
100
150
200
250
T 30 - 130
T 130 - 230
C1
300
350
400
450
500
C1
C2
C3
550
600
650
700
750
C3
C4
C5
C6
800
850
900
950
1000
C6
C7
C8
1050
C8

St. 18 – Mi. 496

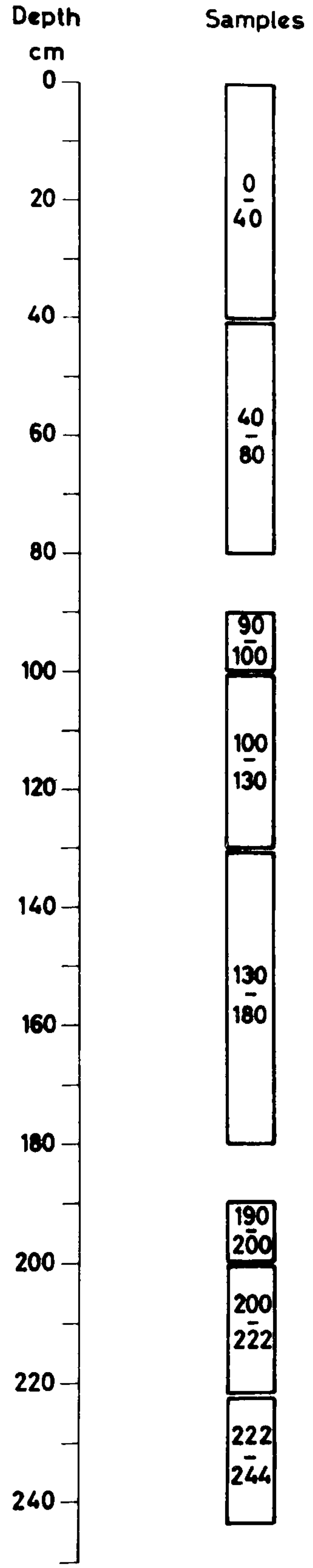

Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
Density
0.3
0.4
0.5
Years
Max.
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
Samples
0 – 28
T 30 – 135
T 135 – 235

St. 19 – Mi. 519

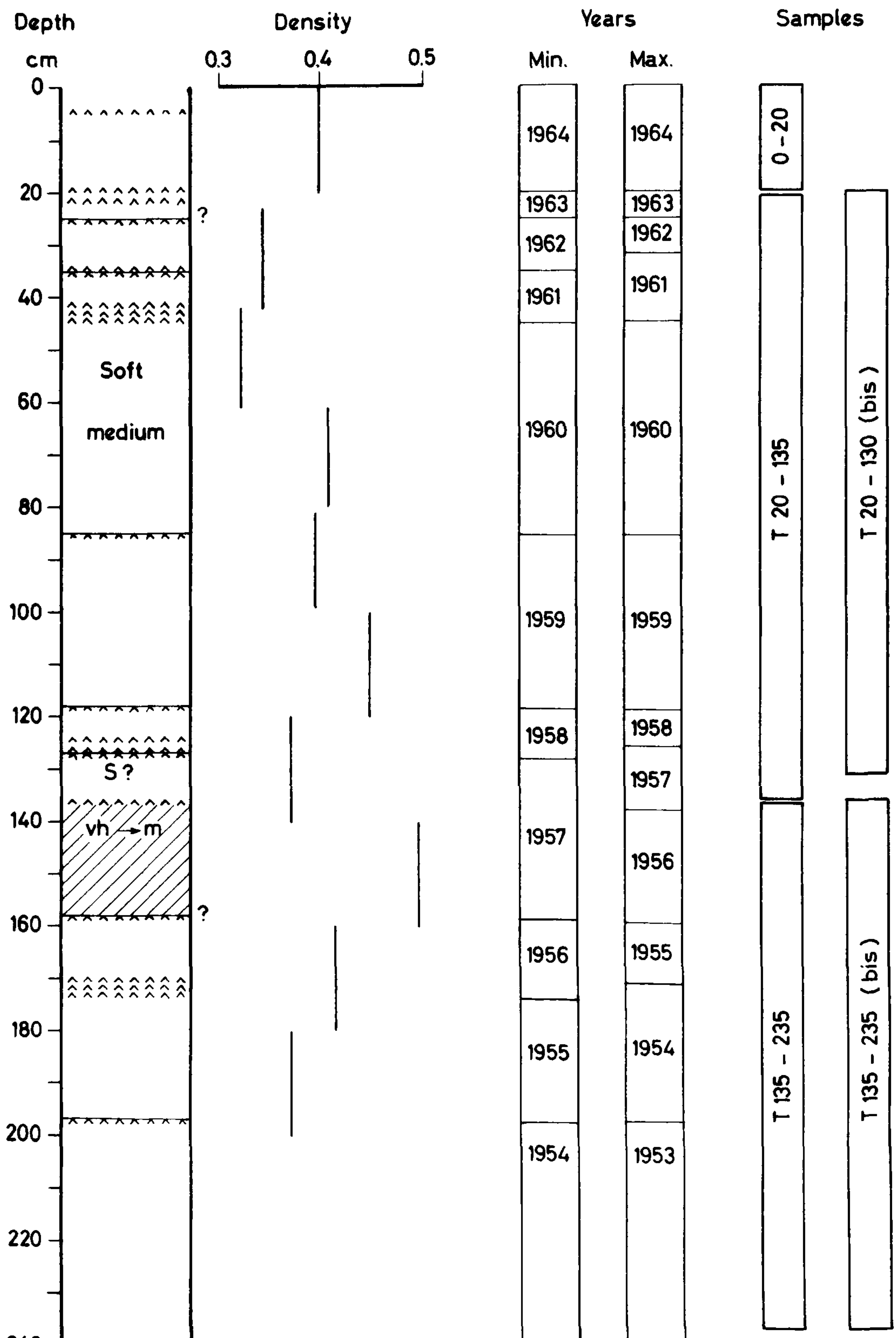


Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
h
h
?
?
?
?
Density
0.3
0.4
0.5
Years
Min.
Max.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1964
1963
1962
1960
1959
1958
1957
1956
1955
1954
1953
1952
Samples
0 – 16
16 – 36
T 36 – 136
T 136 – 236

St. 19 a - Mi. 536

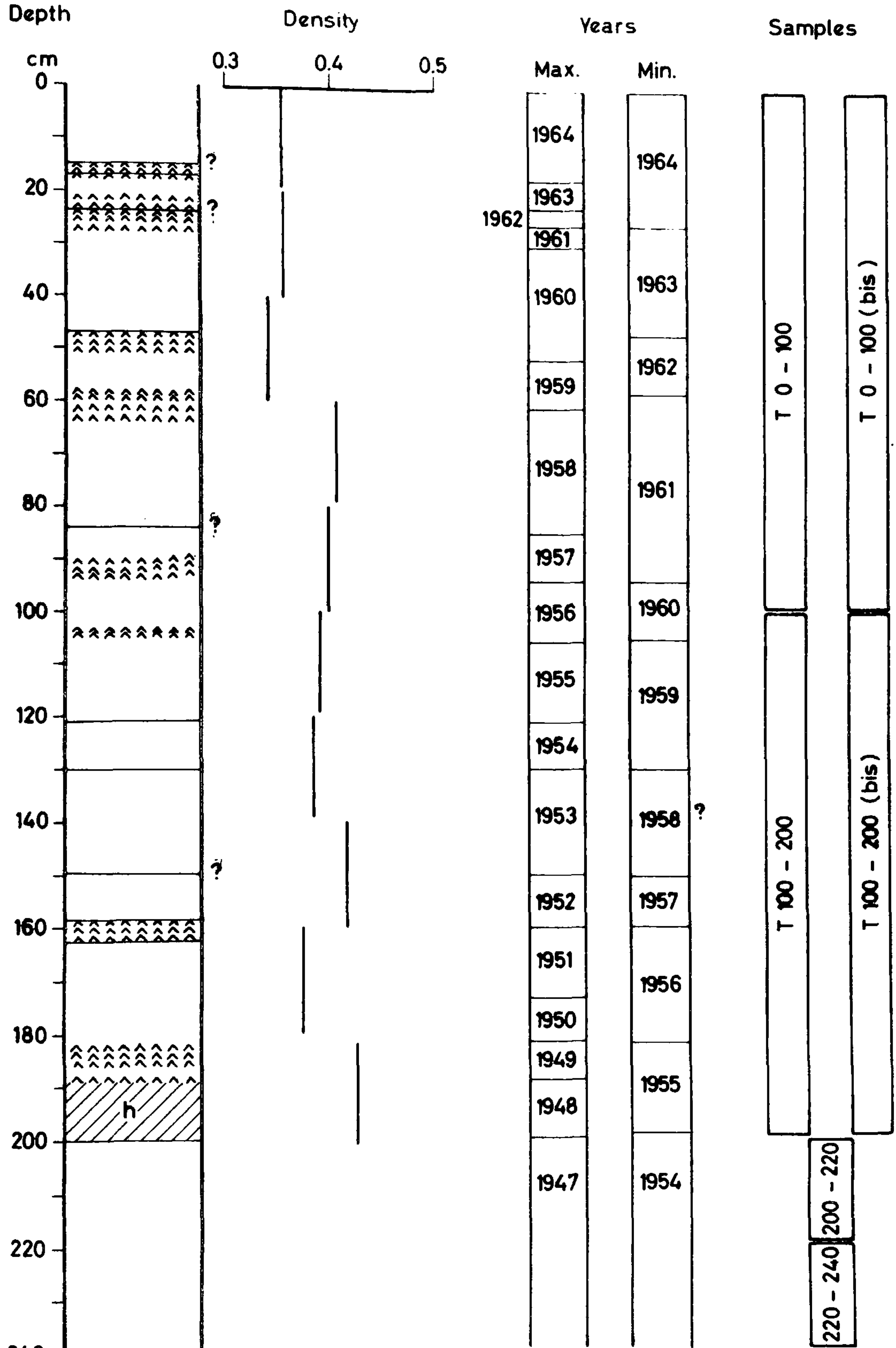

Depth
cm
Samples
0
20
40
60
80
100
120
140
160
180
200
220
240
0 - 40
40 - 80
90 - 100
100 - 130
130 - 180
190 - 200
200 - 222
222 - 244

St. 20 _ Mi. 545



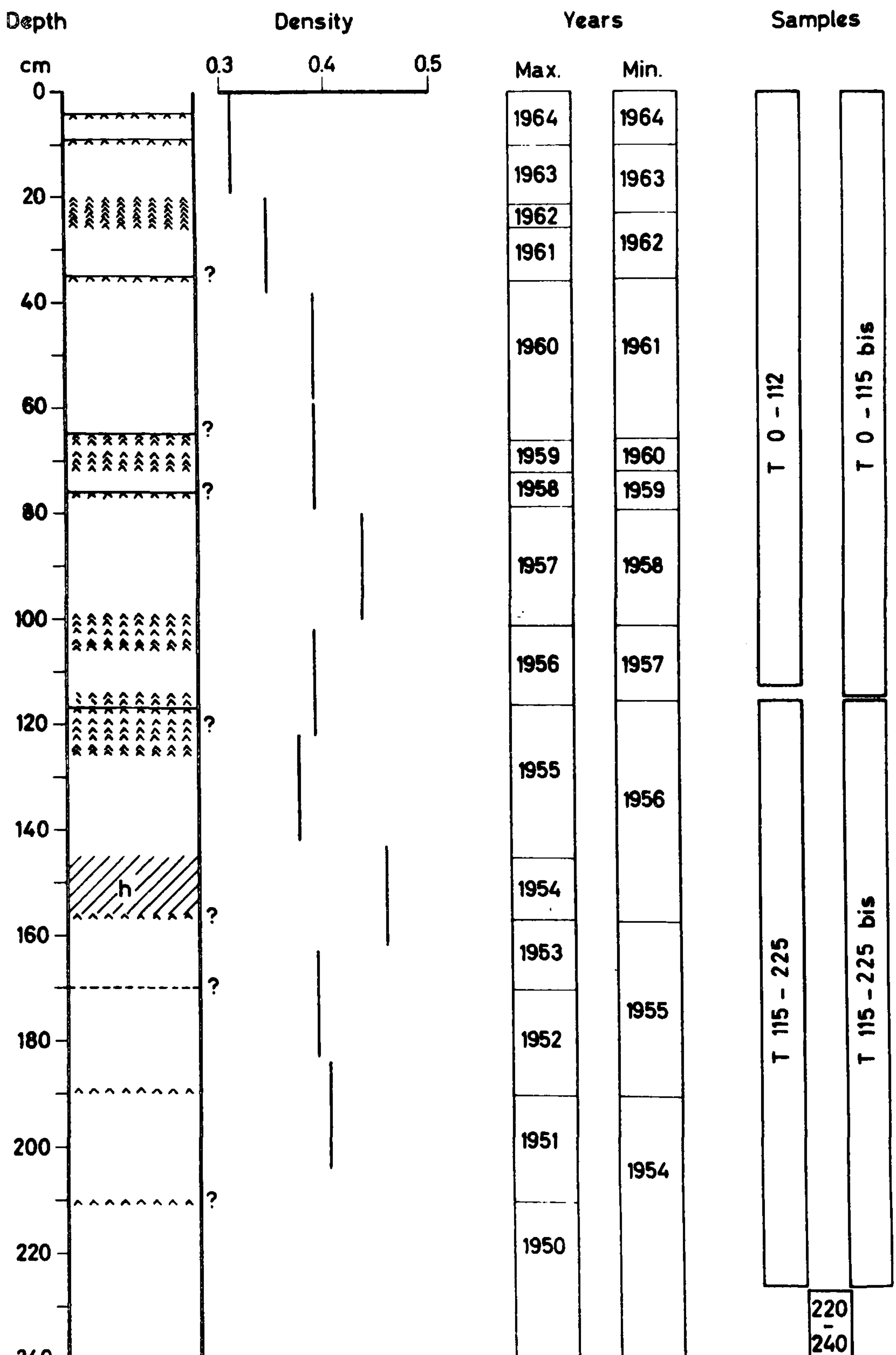
Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
Soft
medium
S ?
vh → m
?
Density
0.3
0.4
0.5
Years
Min.
Max.
1964
1964
1963
1963
1962
1962
1961
1961
1960
1960
1959
1959
1958
1958
1957
1957
1956
1956
1955
1955
1954
1954
1953
Samples
0 - 20
T 20 - 135
T 20 - 130 (bis)
T 135 - 235
T 135 - 235 (bis)

St. 21 _ Mi. 570

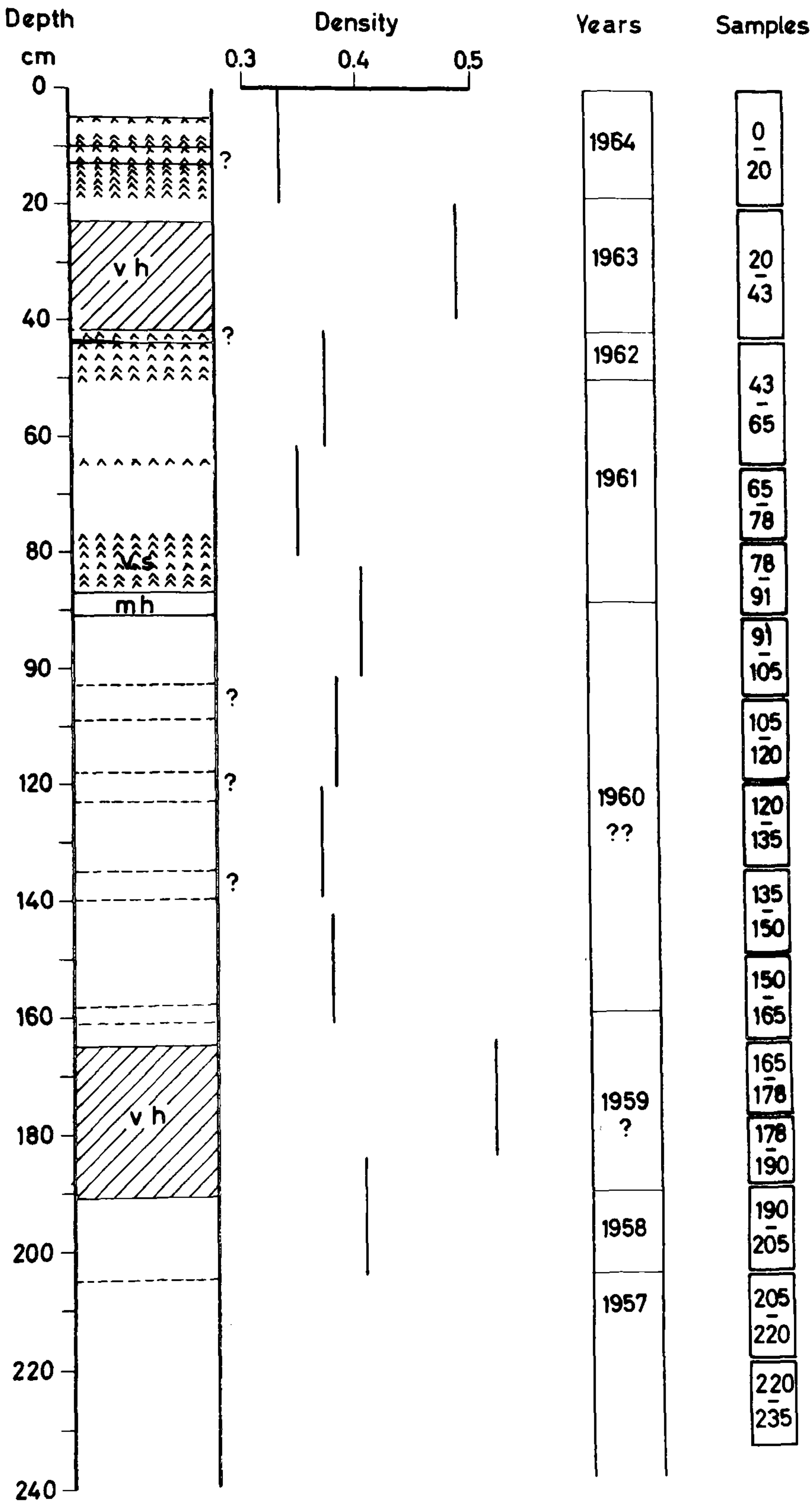


Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
h
?
Density
0.3
0.4
0.5
Years
Max.
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1951
1950
1949
1948
1947
1964
1963
1962
1961
1960
1959
1958 ?
1957
1956
1955
1954
Samples
T 0 - 100
T 0 - 100 (bis)
T 100 - 200
T 100 - 200 (bis)
200 - 220
220 - 240

St. 22 _ Mi. 595

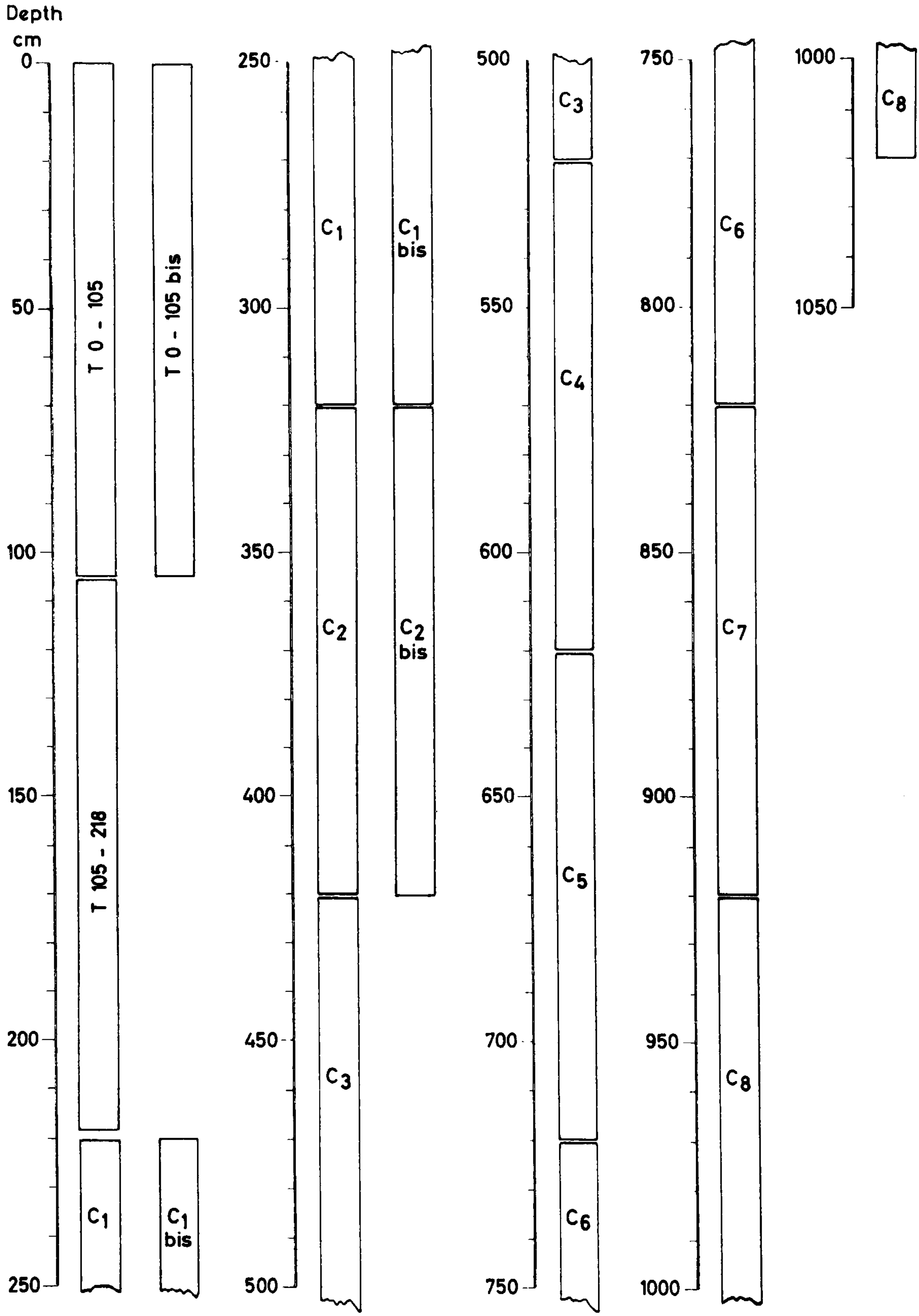

Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
h
?
Density
0.3
0.4
0.5
Years
Max.
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1951
1950
Samples
T 0 - 112
T 0 - 115 bis
T 115 - 225
T 115 - 225 bis
220 - 240

St. 23 _ Mi. 620



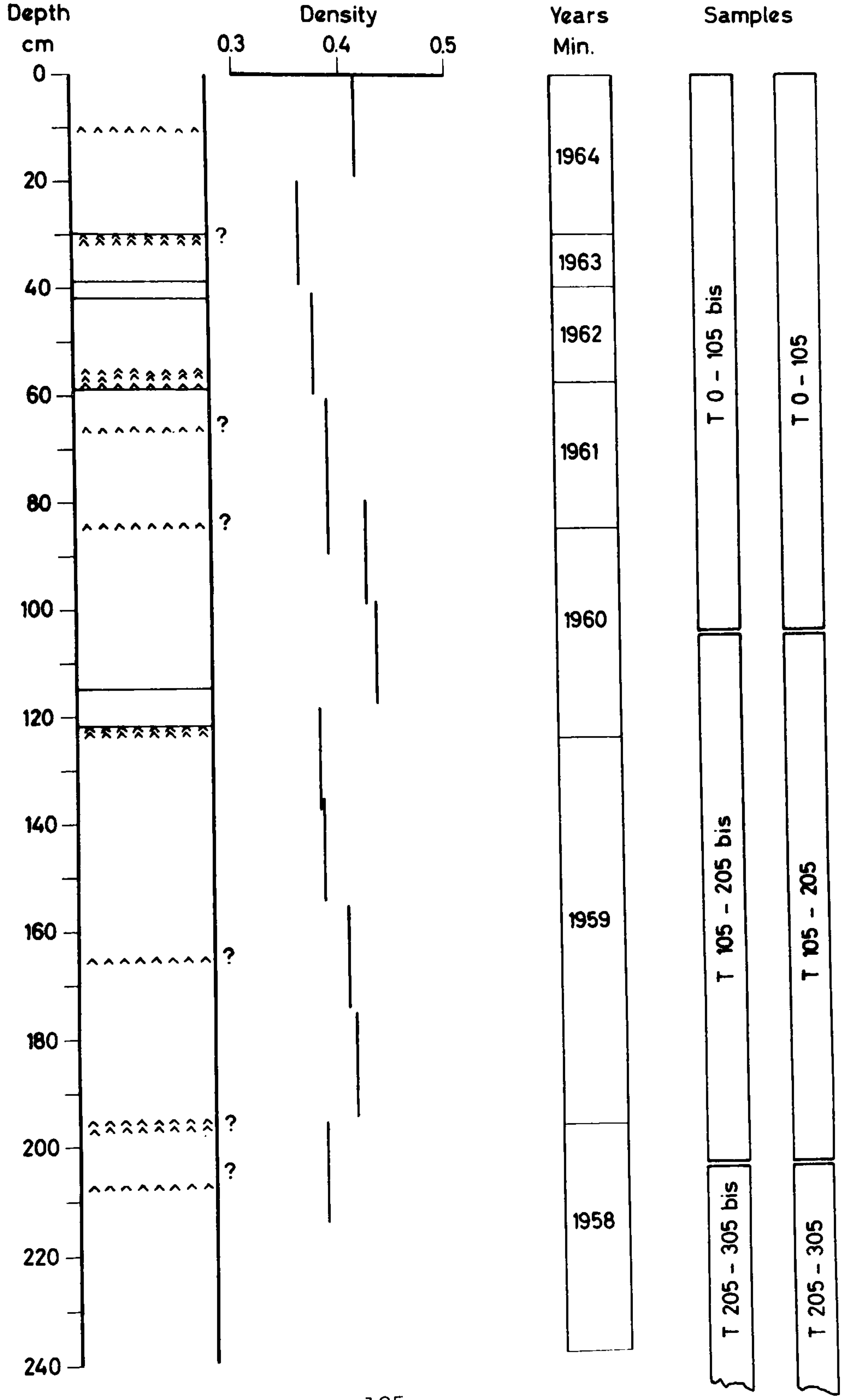
Depth cm
Density
0.3
0.4
0.5
Years
Samples
0
20
40
60
80
90
120
140
160
180
200
220
240
vh
vs
mh
?
1964
1963
1962
1961
1960 ??
1959 ?
1958
1957
0-20
20-43
43-65
65-78
78-91
91-105
105-120
120-135
135-150
150-165
165-178
178-190
190-205
205-220
220-235

St. 23 _ Mi. 620

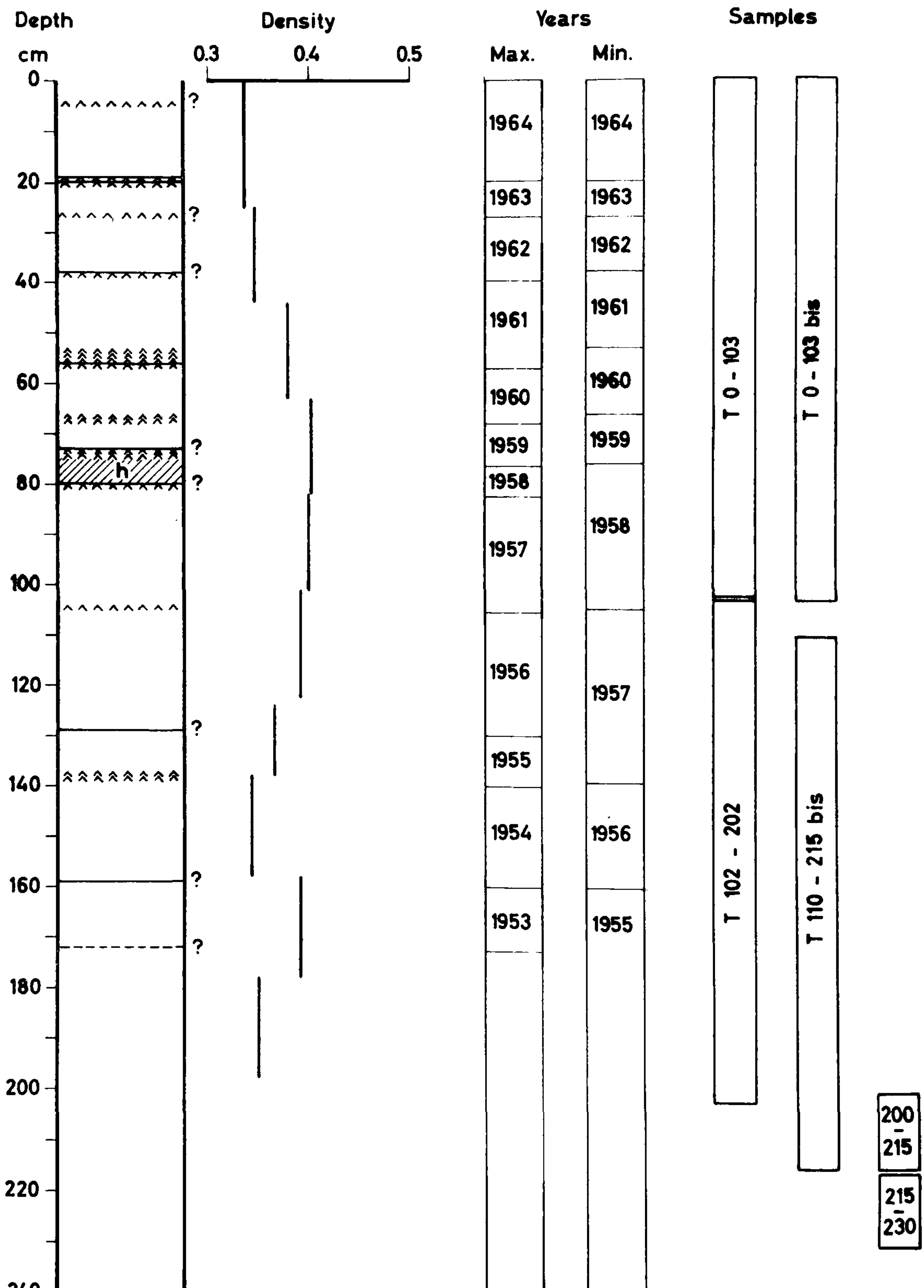


Depth
cm
0
50
100
150
200
250
T 0 - 105
T 0 - 105 bis
T 105 - 218
C1
C1 bis
250
300
350
400
450
500
C1
C1 bis
C2
C2 bis
C3
500
550
600
650
700
750
C3
C4
C5
C6
750
800
850
900
950
1000
C6
C7
C8
1000
1050
C8

St. 24 _ Mi. 640

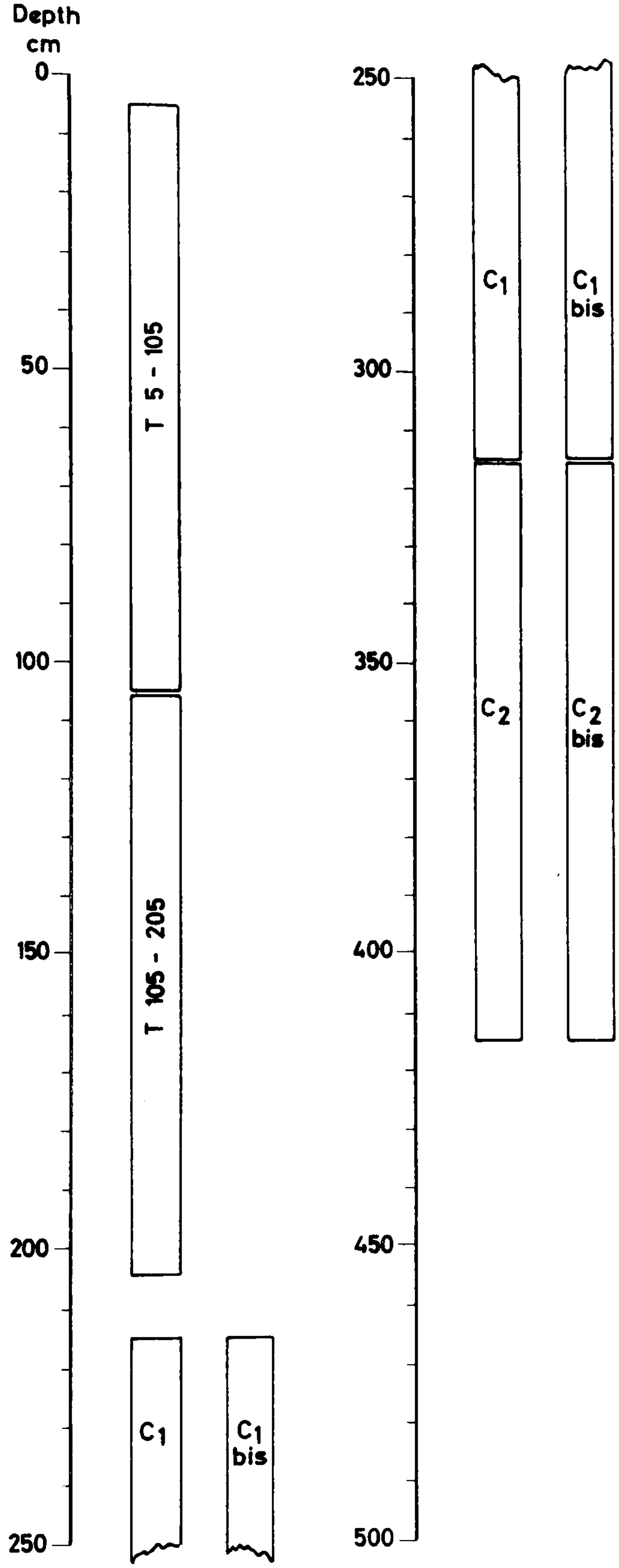

Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
Density
0.3
0.4
0.5
Years
Min.
1964
1963
1962
1961
1960
1959
1958
Samples
T 0 - 105 bis
T 0 - 105
T 105 - 205 bis
T 105 - 205
T 205 - 305 bis
T 205 - 305

St. 25 – Mi. 680

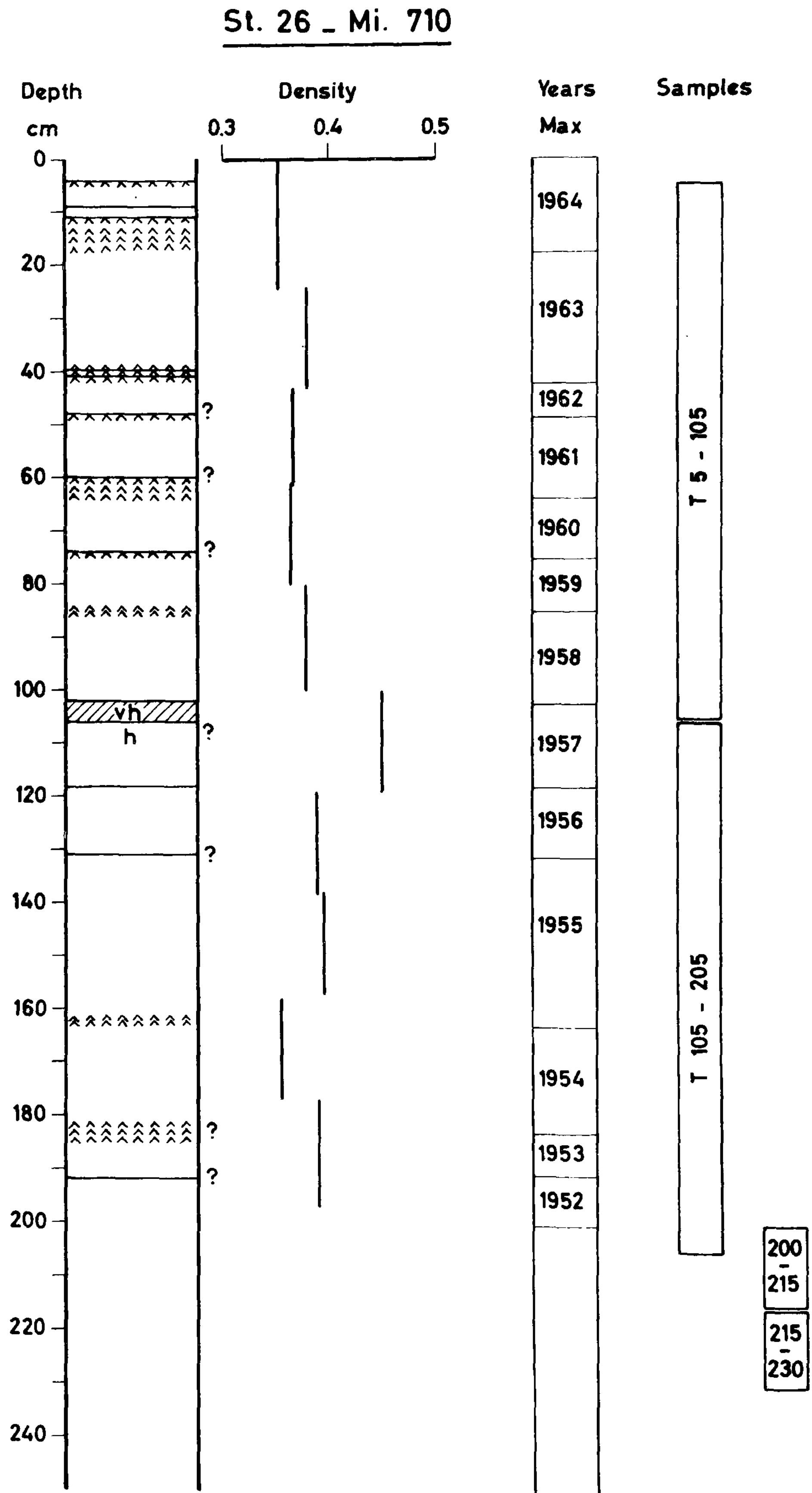


Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
h
Density
0.3
0.4
0.5
Years
Max.
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
Samples
T 0 - 103
T 102 - 202
T 0 - 103 bis
T 110 - 215 bis
200 – 215
215 – 230

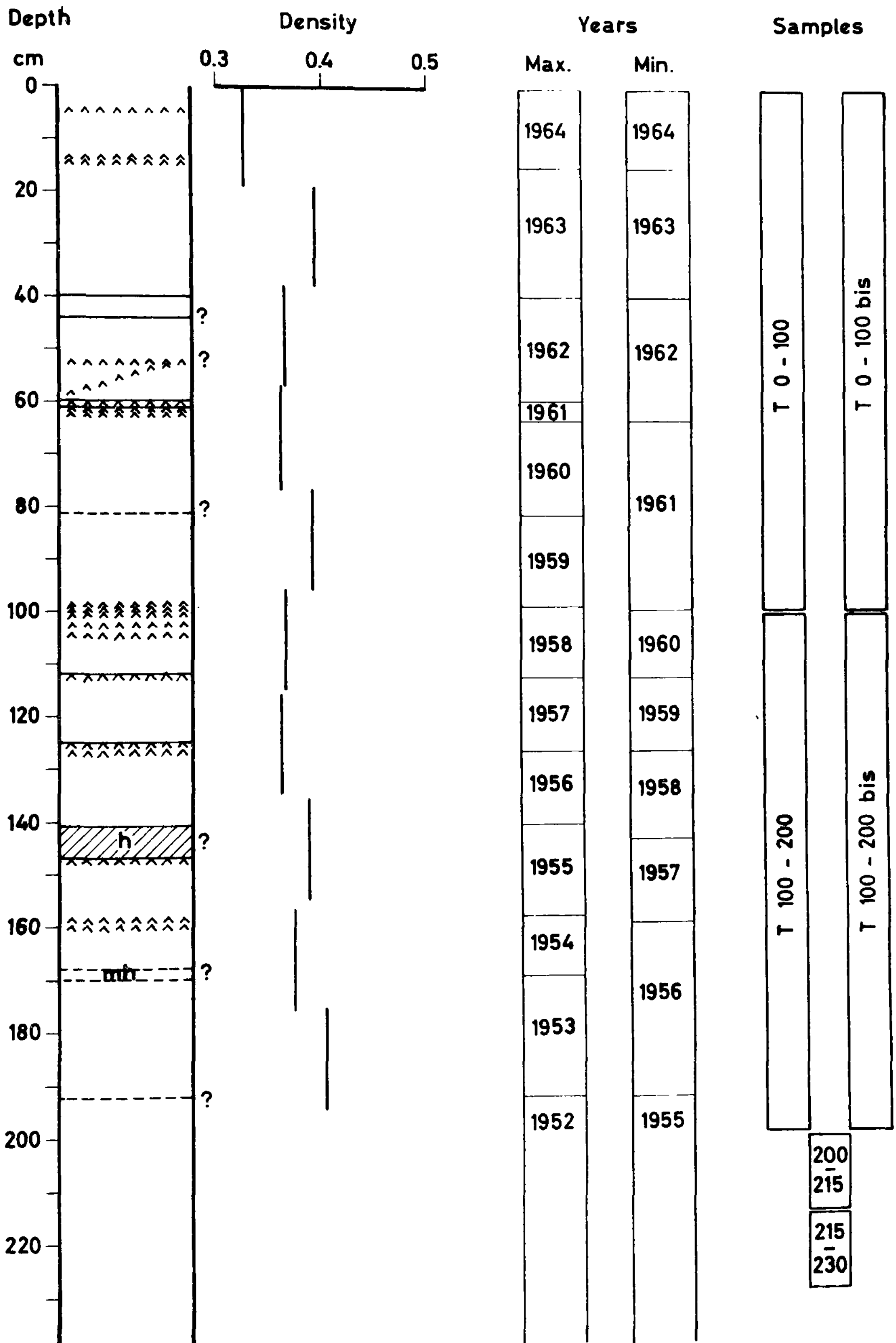
St. 26 _ Mi. 710



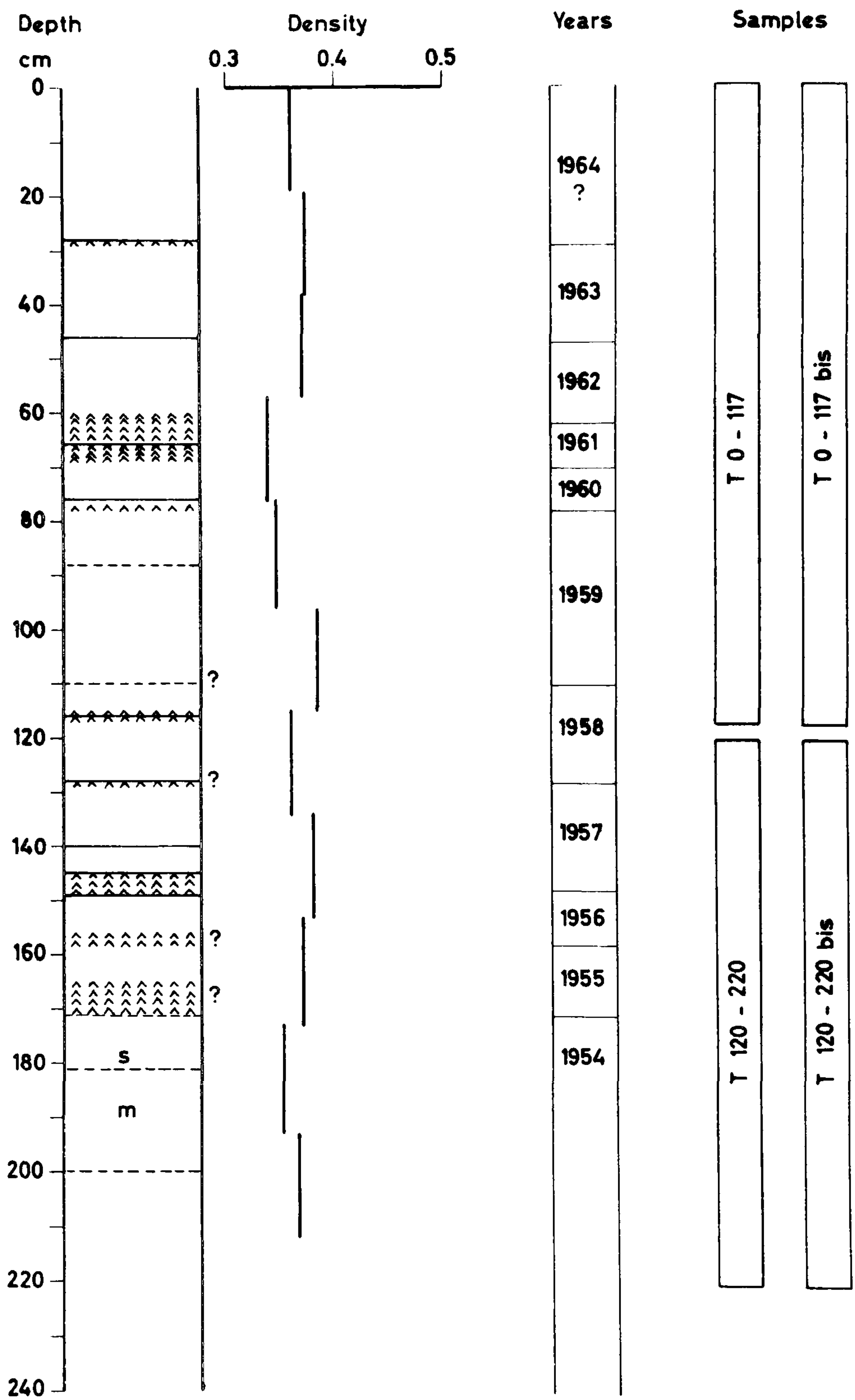
Depth cm
0
50
100
150
200
250
T 5 - 105
T 105 - 205
C_1
C_1 bis
250
300
350
400
450
500
C_1
C_1 bis
C_2
C_2 bis


St. 26 _ Mi. 710
Depth
cm
Density
0.3
0.4
0.5
Years
Max
Samples
0
20
40
60
80
100
120
140
160
180
200
220
240
vh
h
?
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
T 5 - 105
T 105 - 205
200 - 215
215 - 230

St. 27 – Mi. 740

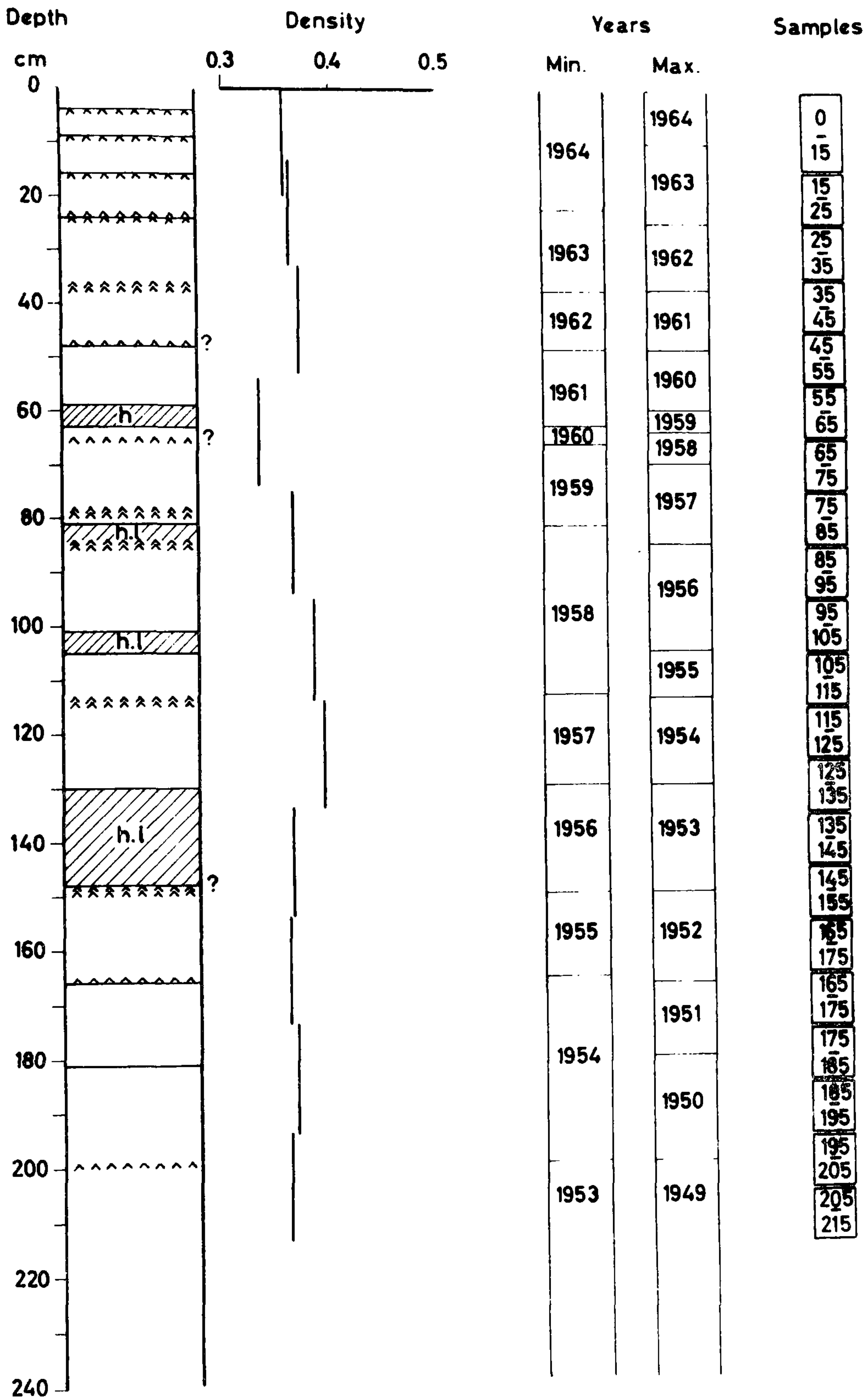

Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
?
?
h
?
?
?
Density
0.3
0.4
0.5
Years
Max.
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
Samples
T 0 - 100
T 0 - 100 bis
T 100 - 200
T 100 - 200 bis
200
215
215
230

St. 28 _ Mi. 770



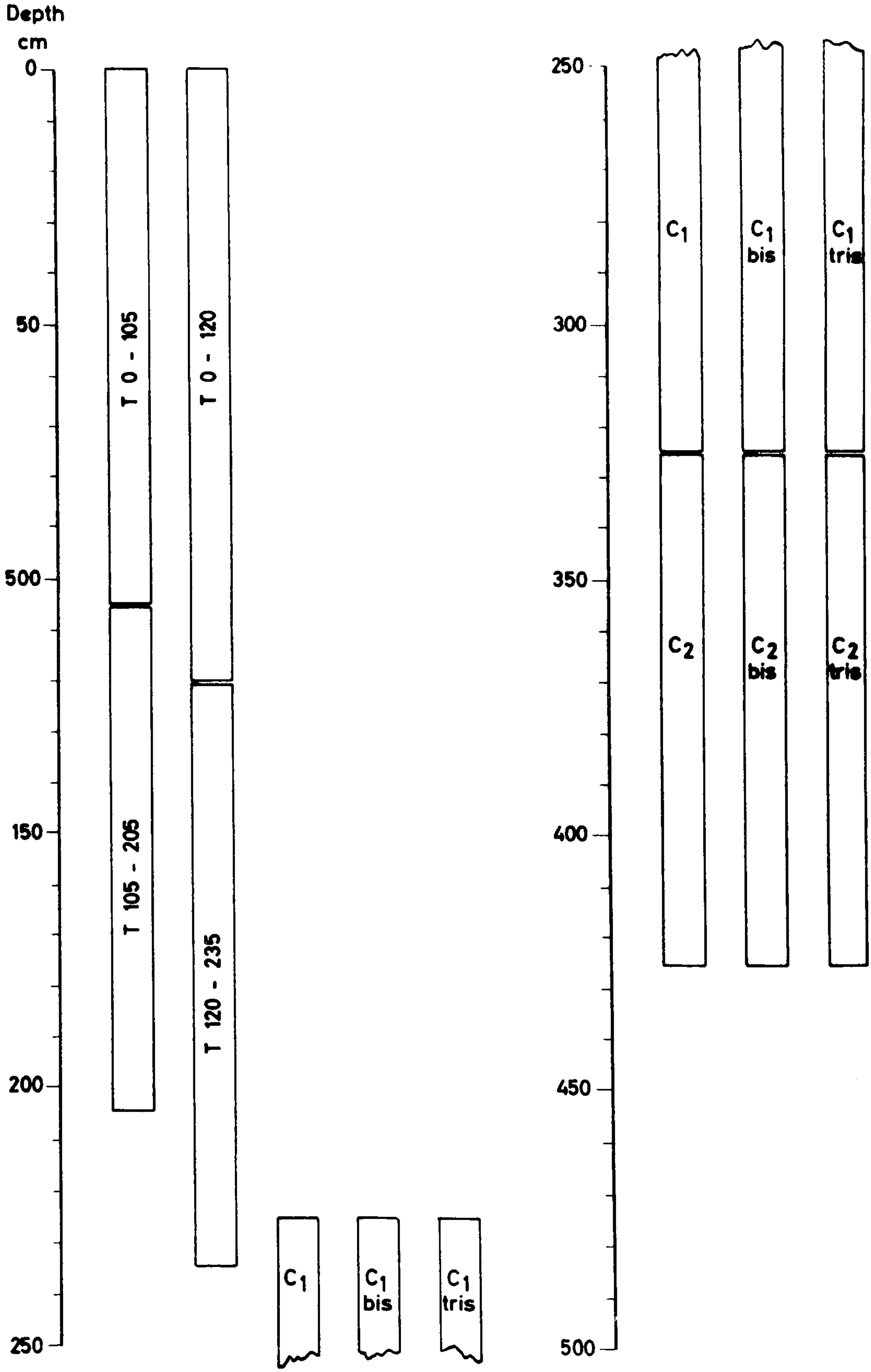
Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
?
?
?
?
s
m
Density
0.3
0.4
0.5
Years
1964
?
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
Samples
T 0 - 117
T 0 - 117 bis
T 120 - 220
T 120 - 220 bis

St. 29 – Mi. 797



Depth
cm
0
20
40
60
80
100
120
140
160
180
200
220
240
h
h.l
h.l
h.l
?
?
?
Density
0.3
0.4
0.5
Years
Min.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
Max.
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
1953
1952
1951
1950
1949
Samples
0-15
15-25
25-35
35-45
45-55
55-65
65-75
75-85
85-95
95-105
105-115
115-125
125-135
135-145
145-155
165-175
165-175
175-185
185-195
195-205
205-215

St. 29 _ Mi. 797


Depth
cm
0
50
500
150
200
250
T 0 - 105
T 105 - 205
T 0 - 120
T 120 - 235
C1
C1 bis
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250
300
350
400
450
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C1
C1 bis
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C2
C2 bis
C2 tris

APPENDIX VI - LOG OF THE QUEEN MAUD LAND TRAVERSE, 1964-1965
(Distances are in nautical miles)

4 December 1964	Left South Pole Station - Traveled 8 miles to Station 0 (Mile 8)
5 December	Traveled 16 miles to Station 1 (Mile 24)
6 December	Station 1 - Traveled 6 miles to Mile 30
7 December	Traveled 18 miles to Station 2 (Mile 48)
8 December	Traveled 24 miles to Station 3 (Mile 72)
9 December	Station 3
10 December	Traveled 24 miles to Station 4 (Mile 96)
11 December	Station 4
12 December	Traveled 14 miles to Station 4a (Mile 110) Station 4a - Hand auger stuck and lost at 9 m
13 December	Traveled about 13 miles
14 December	Traveled about 2 miles to Station 5 (Mile 125) Traveled 15 miles to Station 5a (Mile 140)
15 December	Traveled 15 miles to Station 6 (Mile 155)
16 December	Traveled 50 miles to Station 7 (Mile 185)
17 December	Station 7
18 December	Station 7
19 December	Traveled west 15 miles from Station 7 (first turning point) to Mile 200 - Breakdown (oil leak from engine)
20 December	Completed repair - Traveled 15 miles to Station 8 (Mile 215)
21 December	Station 8 - Traveled 20 miles to Mile 220 - Breakdown (oil leak) - Oil cooling system repaired
22 December	Traveled 15 miles to Mile 235
23 December	C 130 plane dropped fuel - Traveled about 9 miles

24 December	Traveled about 1 mile to Station 9 (Mile 245) - Station 9 - Traveled about 10 miles
25 December	Traveled about 5 miles to Mile 260 - Traveled 15 miles to Station 10 (Mile 275)
26 December	Station 10
27 December	Traveled 50 miles to Station 11 (Mile 305)
28 December	Station 11
29 December	Traveled 33 miles to Station 12 (Mile 338) Station 12
30 December	Traveled 32 miles to Station 13 (Mile 370)
31 December	Station 13
1 January 1965	Traveled 25 miles to Station 14 (Mile 395) - Station 14
2 January	Station 14 - Traveled 20 miles to Station 15 (Mile 415) - Breakdown (front differential broken)
3 January	Station 15
4 January	Station 15
5 January	Station 15
6 January	Traveled 5 miles back to find a suitable landing site - C 130 plane landed
7 January	Traveled east from Mile 420 (second turning point) 25 miles to Station 16 (Mile 445)
8 January	Traveled 25 miles to Station 17 (Mile 470) - Mile 460: sighted 2 skuas - Station 17
9 January	Station 17 - Traveled about 25 miles
10 January	Traveled about 1 mile to Station 18 (Mile 496) - Station 18 - Breakdown (gear-box broken) - unable to repair
11 January	Station 18
12 January	C 130 plane dropped spare parts

13 January	Completed repair - Traveled 23 miles to Station 19 (Mile 519) - Breakdown (front differential broken)
14 January	Station 19 - Traveled about 2 miles
15 January	Traveled about 15 miles to Station 19a (Mile 536) - Breakdown (Steering gear broken) - Completed repair - Traveled 9 miles to Station 20 (Mile 545) Station 20
16 January	Station 20 - Traveled to Mile 550 - Breakdown (back tie-rod broken) - Repaired - Traveled about 16 miles
17 January	Traveled about 4 miles to Station 21 (Mile 570) - Station 21 - Traveled about 1 mile
18 January	Traveled about 15 miles to Station 22 (Mile 595) - Station 22
19 January	Traveled 25 miles to Station 23 (Mile 620) - Station 23
20 January	Station 23
21 January	Station 23
22 January	Traveled 30 miles to Station 24 (Mile 650) - Station 24
23 January	Traveled 30 miles to Station 25 (Mile 680) - Station 25
24 January	Station 25 - Traveled 30 miles to Station 26 - (Mile 710) Station 26
25 January	Station 26 - Traveled 30 miles to Station 27 - (Mile 740) Station 27
26 January	Traveled 30 miles to Station 28 (Mile 770) - Station 28
27 January	Station 28 - Traveled 15 miles to Mile 785 - Breakdown (differential broken) - First Sno-Cat traveled 12 miles to Station 29 (Mile 797) - Pole of Relative Inaccessibility - arrived at 2130 GMT
28 January	Station 29 - Second Sno-Cat arrived at 0120 GMT - Third Sno-Cat stopped for breakdown (tracks broken) at 500 m from the Station
29 January	Station 29 - Scientific work, repairs and runway for landing prepared

30 January	Station 29 - Scientific work, repairs and runway for landing prepared
31 January	Station 20 - Scientific work, repairs and runway for landing prepared
1 February	C 130 plane landed at 1940 GMT - C 130 plane took off with party at 2030 GMT - Front ski damaged in takeoff
2 February	Landing at McMurdo Station at 0300 GMT