V. Stratigraphic Observation of the Surface Snow Cover in West Enderby Land, East Antarctica, 1970 - 1971

Okitsugu WATANABE*

1. Introduction

Stratigraphic observations of the surface snow cover of the ice sheet in the West Enderby Land area were carried out along the oversnow traverse route of JARE 11 in 1970 - 1971 (see Fig. A attached to the end of this volume), as follows:

i) The stratigraphic observations of the surface snow cover by means of a 2 m deep snow pit at 6 stations and a 2 m long snow core from the surface at 44 stations.

ii) The stratigraphic analyses of snow cores of 5 and 10 m long from the surface at 15 stations. (The boring holes of these cores were used for measurement of snow temperature at the bottom and/or for seismic shots.)

iii) Sampling of snow cores of 5 and/or 10 m long from the surface at 7 stations. These cores were brought back to Japan and distributed to several laboratories for chemical analyses of $^{18}O/^{16}O$ and of gross β activity and also for precise stratigraphic analyses.

iv) Snow temperatures at the surface and 2 m below the surface were measured at 33 stations.

2. Stratigraphic Observations of Surface Snow Cover

2.1. Stratigraphic observations of snow cover

The stratigraphic studies of a snow core or snow pit wall are useful to make a quick estimate of annual accumulation of snow, especially at a new place where snow stakes have not been set up and measurements by stakes cannot be made; these studies give information on qualitative characteristics of sedimentary facies of a snow cover. However, these are not easily accomplished, since firstly the growth of depth-hoar in a snow cover could have changed the initial structure of the snow cover, and secondly there could have been no accumulation of snow at all, and

* Water Research Laboratory, Faculty of Science, Nagoya University, Chikusa-ku, Nagoya.

moreover, even erosion of snow surface could have occured depending upon locations, as disclosed occasionally by the results of stake measurements and stratigraphic observations. The annual accumulation of snow and the sedimentary facies of a snow cover will be discussed separately in other paper on the basis of further studies; the results of core analyses are given in this report.

2.2. Stratigraphic analyses of 2 m long snow cores

Stratigraphic observations and measurements of density and grain size were made on 2 m long snow cores at 44 stations in West Enderby Land. A vertical distribution of Ram hardness of snow was also measured near the boring hole at each station from the surface down to a level of 2 m deep. The method of stratigraphic profiling is described in Section 3 and in Figs. V-1 and V-3. The density was calculated from the volume and weight of an aliquot piece of snow core. The grain size was classified into 5 grades, as shown also in Section 3.

1) Sheet structure caused by discontinuity of deposition or erosion of snow:

- Snow surface
- Wind crust
- Stable surface (Glazed surface)
- Layer boundary

2) Layer structure indicating the conditions of deposition of snow:

- Soft snow layer
- Wind packed layer
- Wind packed layer with depth-hoar

3) Metamorphosed structure:

- □ □ □ □ □ □ Depth-hoar layer (very loose)
- ○ ○ ○ ○ ○ ○ Loose layer
- ○ ○ ● ○ ○ ● Comparatively loose layer
- ● ● ○ ● ● ○ Comparatively compact layer
- ● ● ● ● ● ● Compact layer

4) Structure formed by snow melt:

- Ice lens
- Ice gland

Fig. V-1. Stratigraphic symbols used in Figs. V-2-1 to V-2-44 (Not used in Figs. V-4-1 to V-4-3).

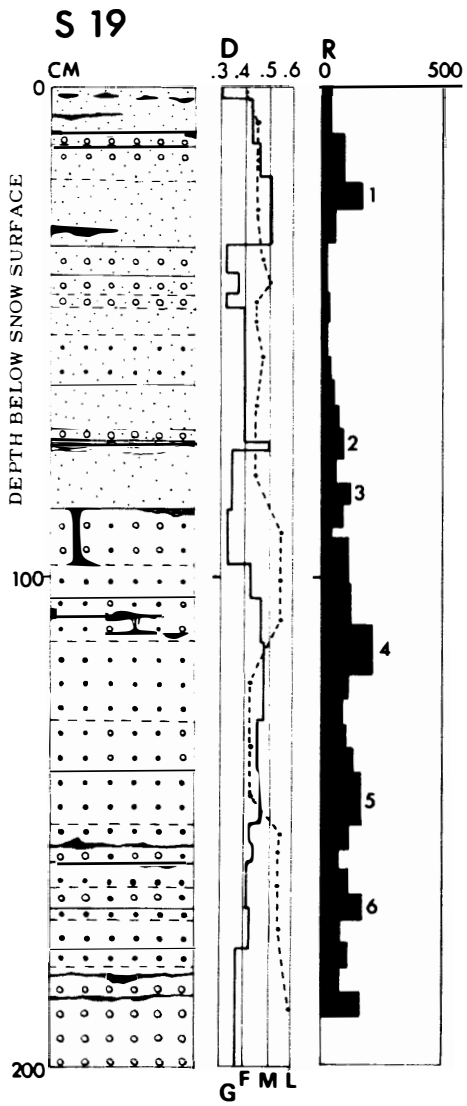


Fig. V-2-1.

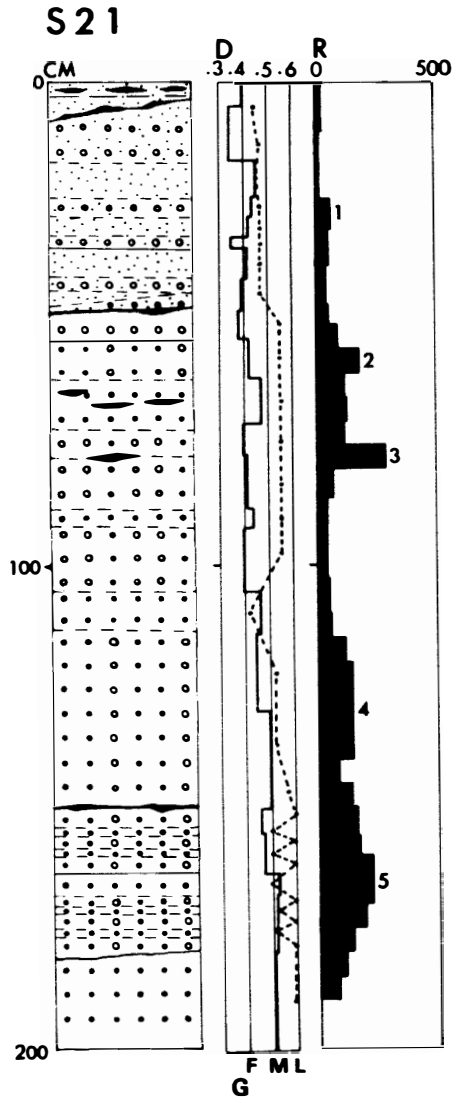


Fig. V-2-2.

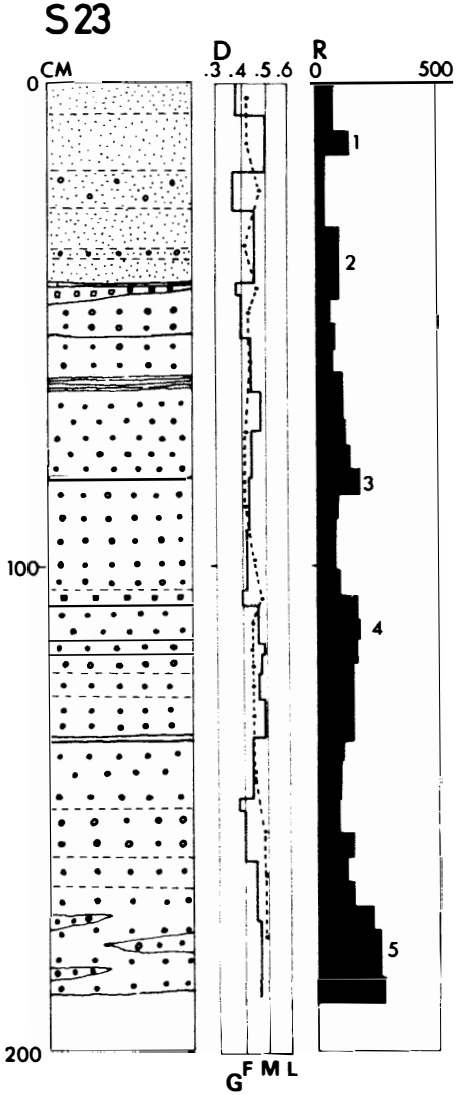


Fig. V-2-3.

Fig. V-2. Stratigraphic analyses on the 2 m long snow cores: a stratigraphy diagram at the left side (cf. Fig. V-1), a combination diagram of density D and grain size G at the center, and a Ram hardness diagram at the right side, for each core.

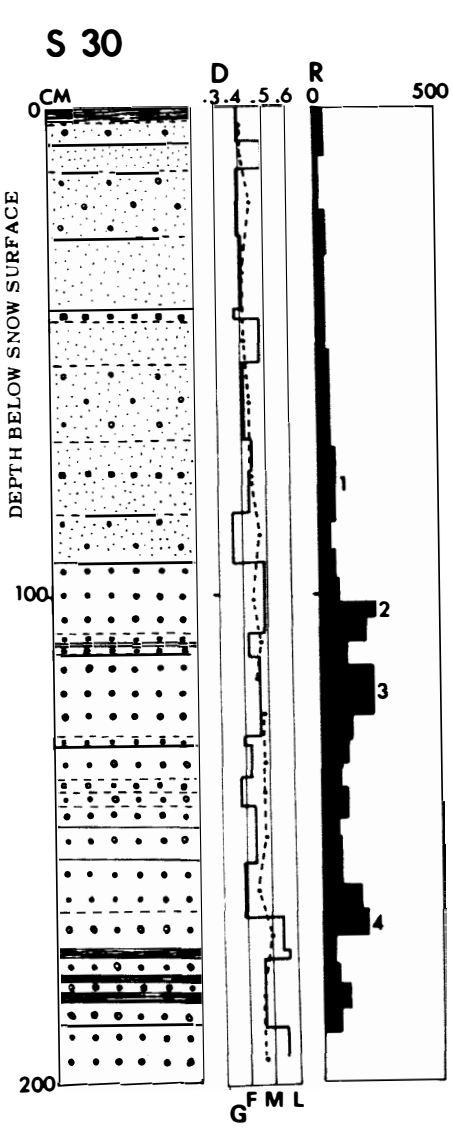


Fig. V-2-4.

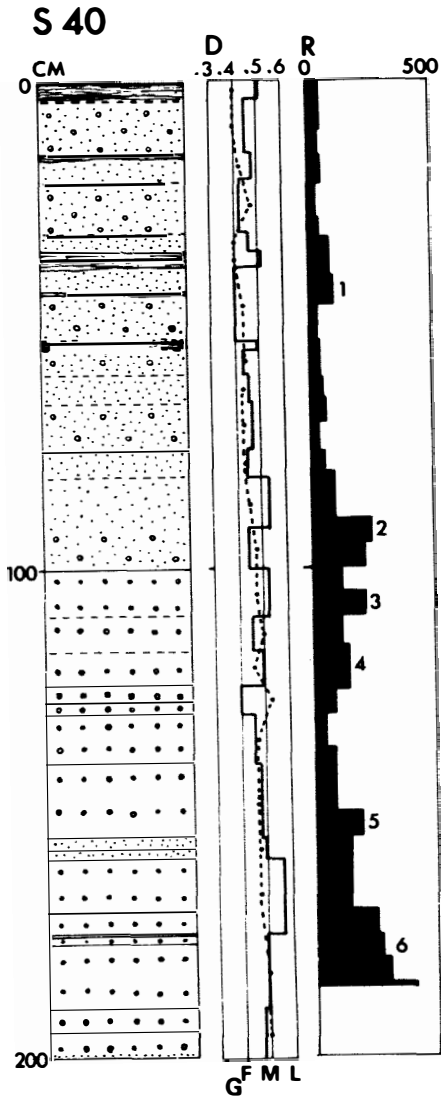


Fig. V-2-5.

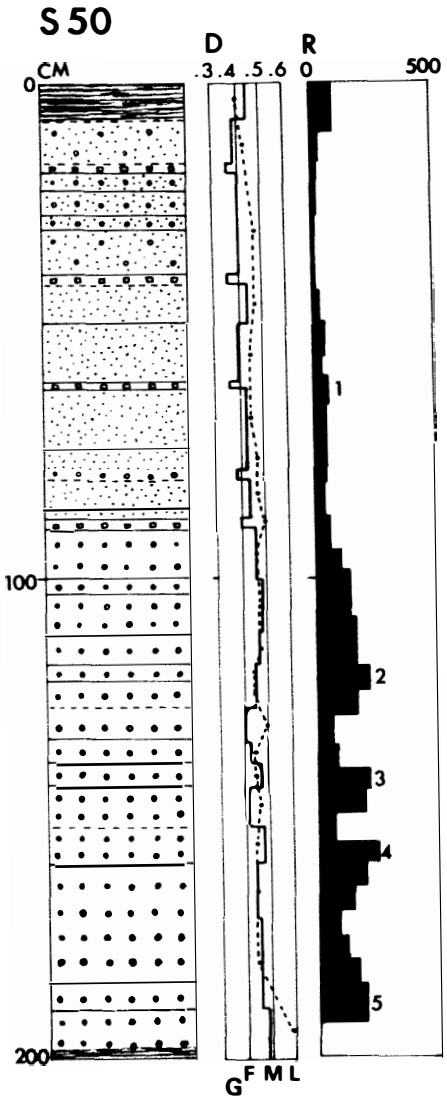


Fig. V-2-6.

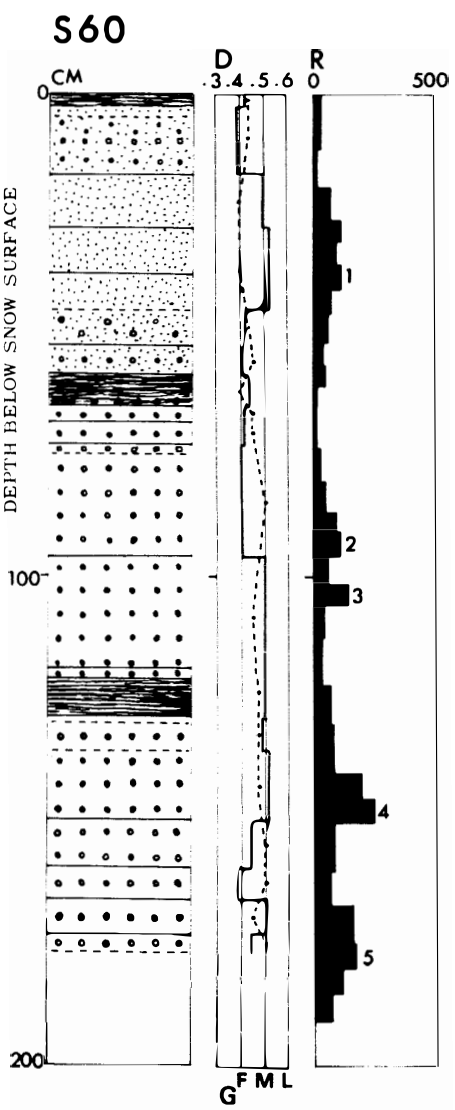


Fig. V-2-7.

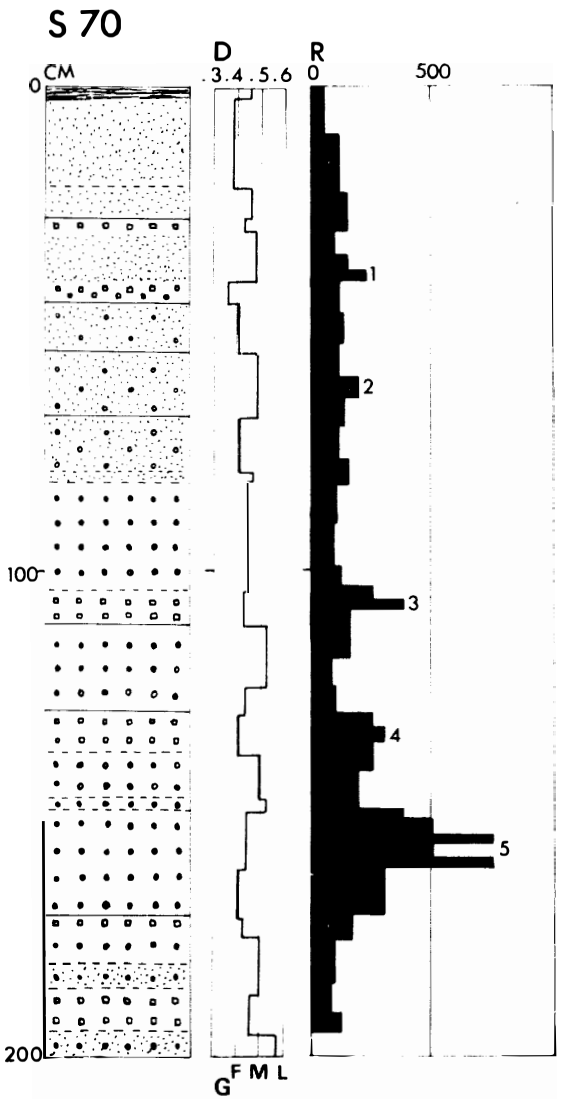


Fig. V-2-8.

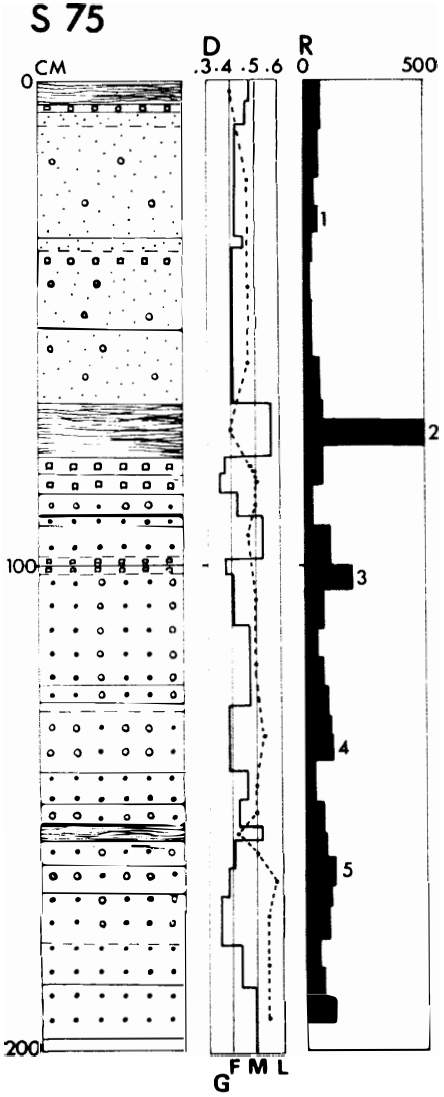


Fig. V-2-9.

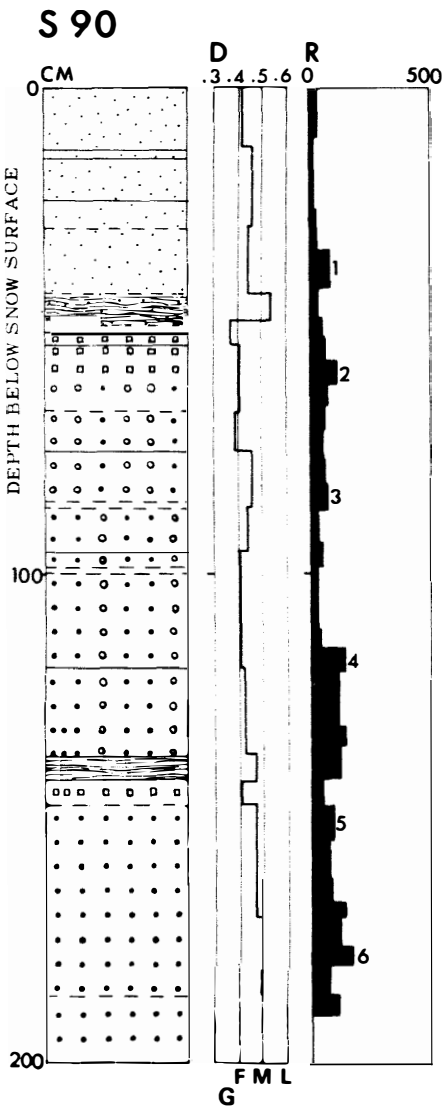


Fig. V-2-10.

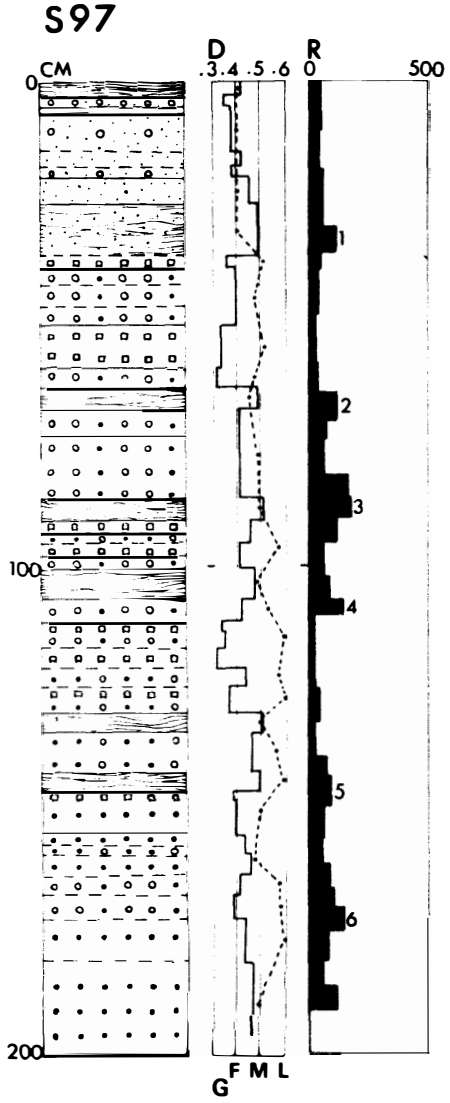


Fig. V-2-11.

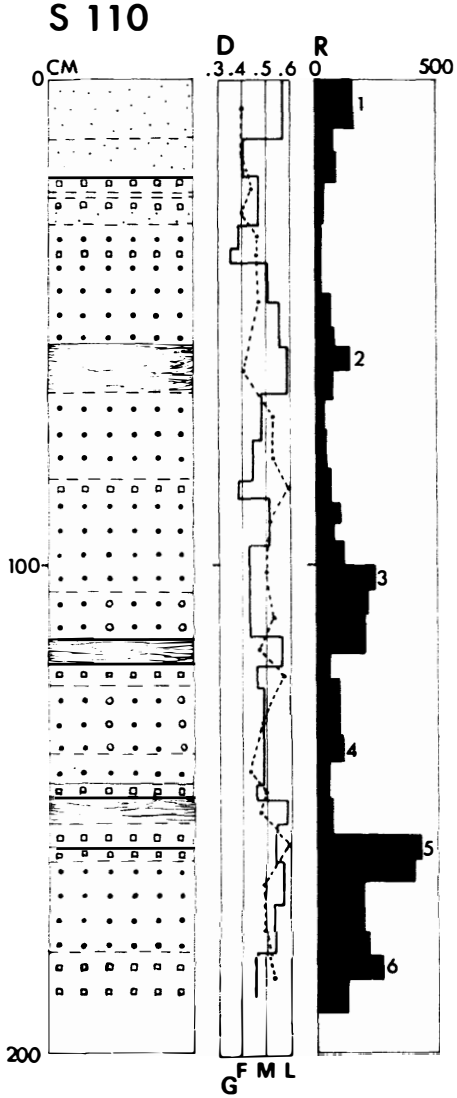


Fig. V-2-12.

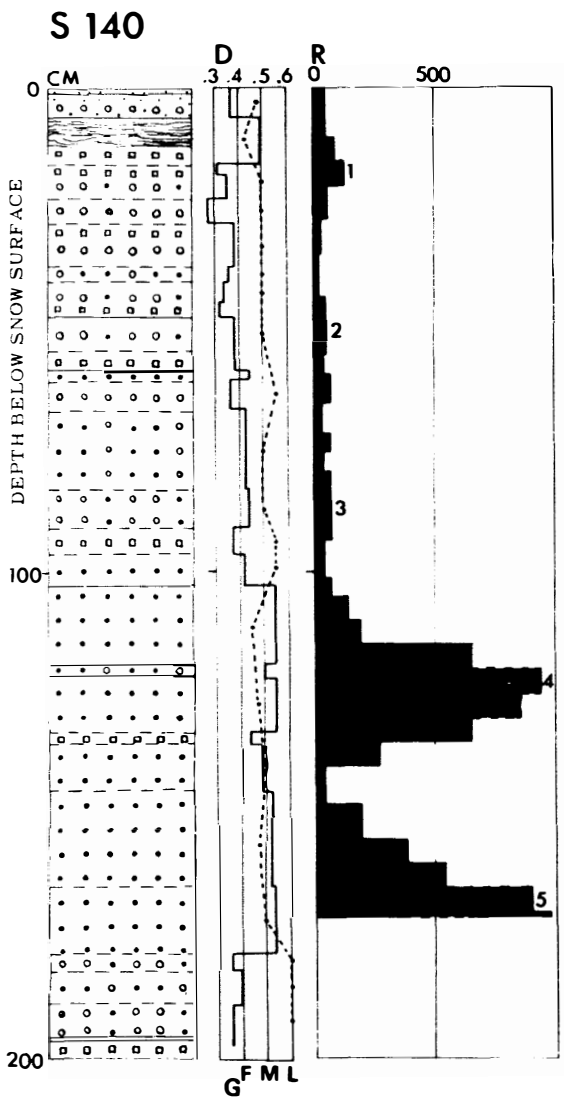


Fig. V-2-13.

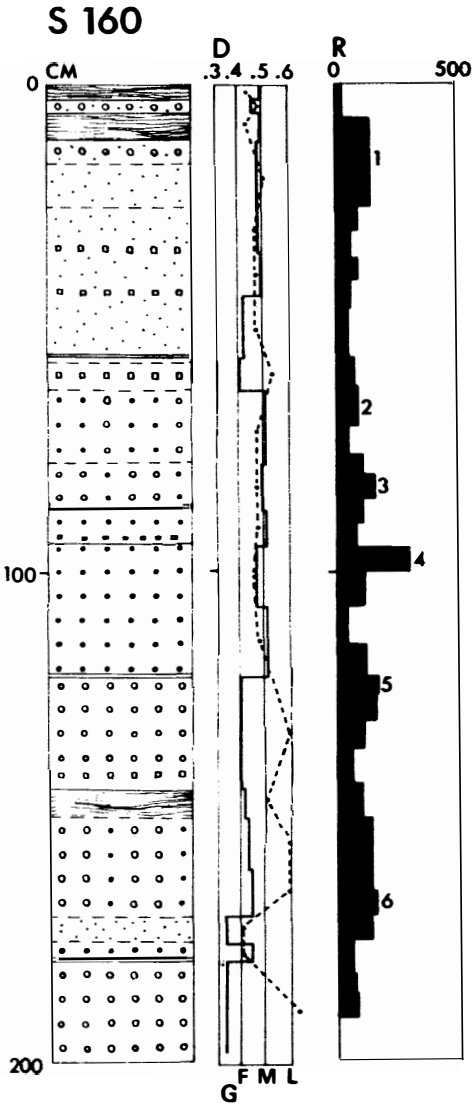


Fig. V-2-14.

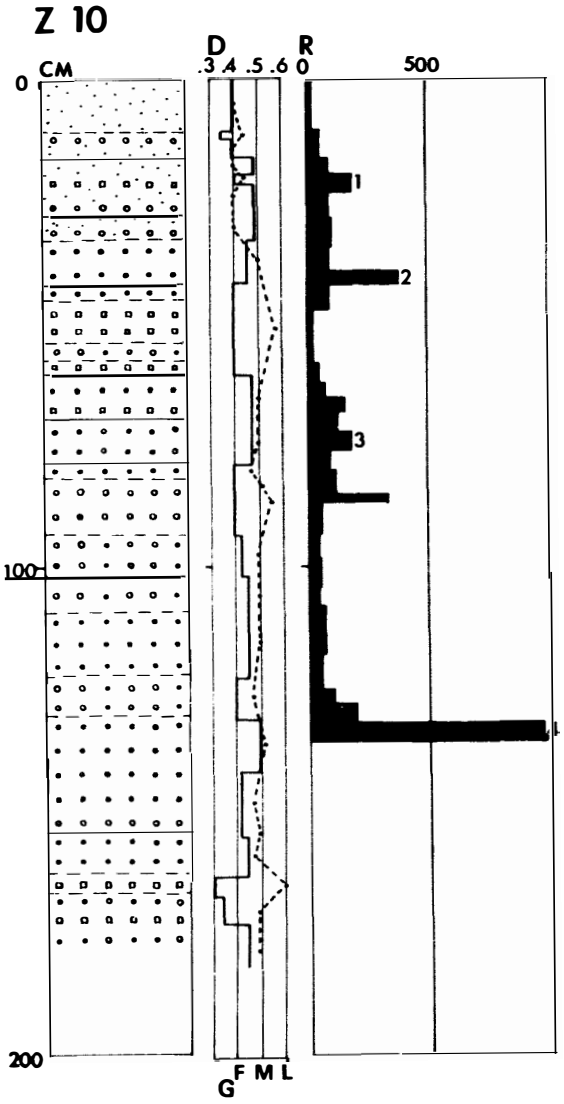


Fig. V-2-15.

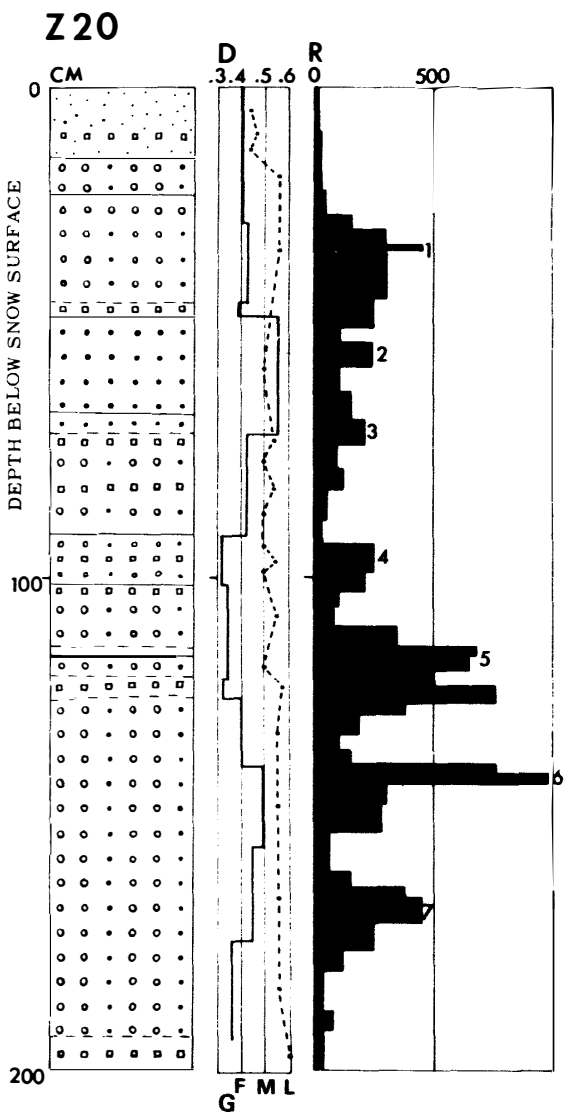


Fig. V-2-16.

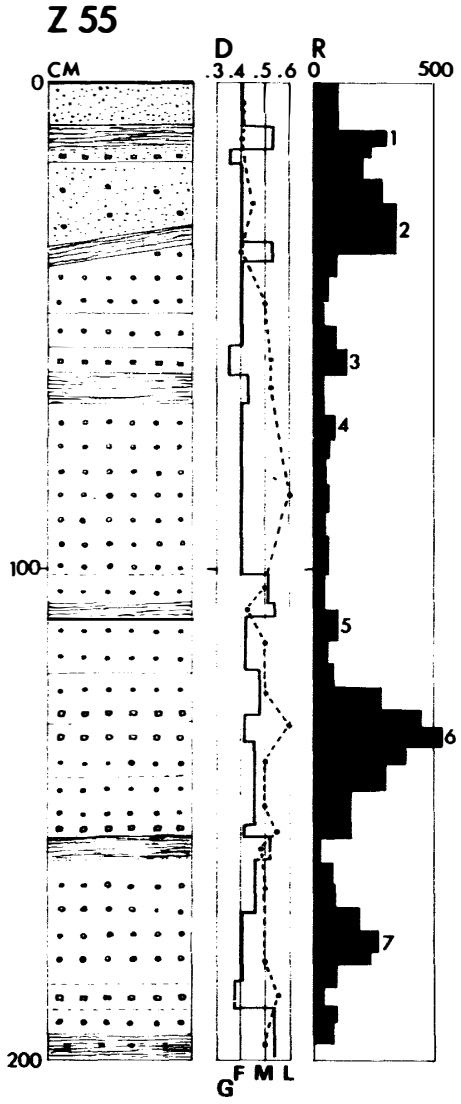


Fig. V-2-17.

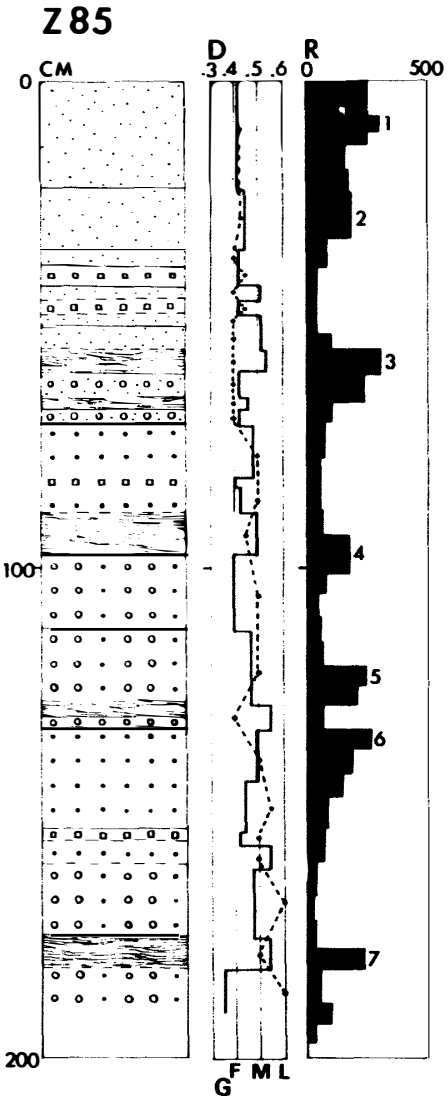


Fig. V-2-18.

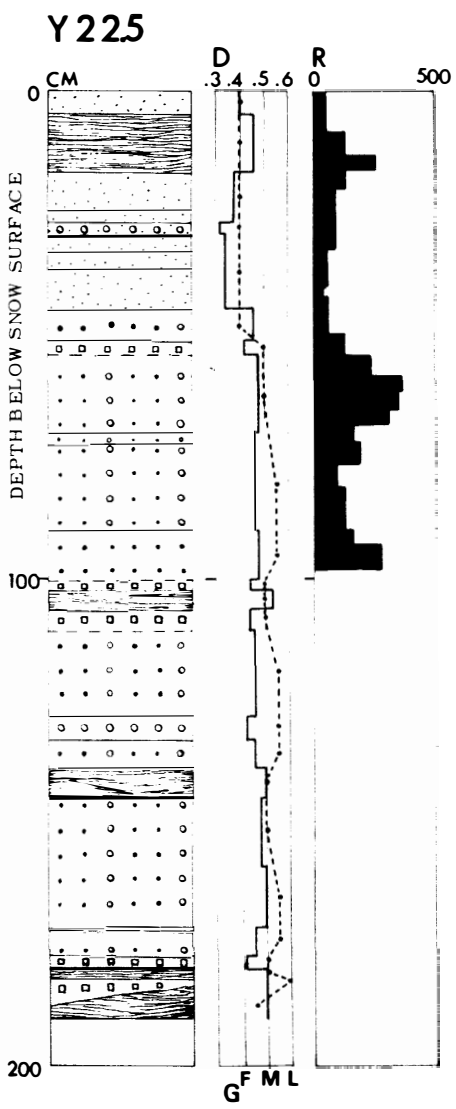


Fig. V-2-19.

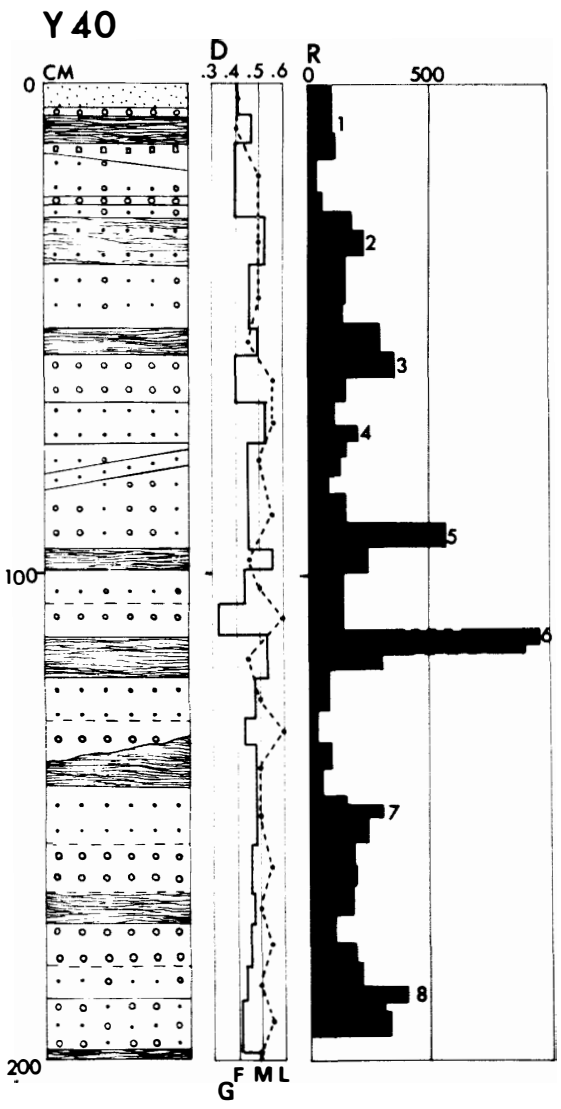


Fig. V-2-20.

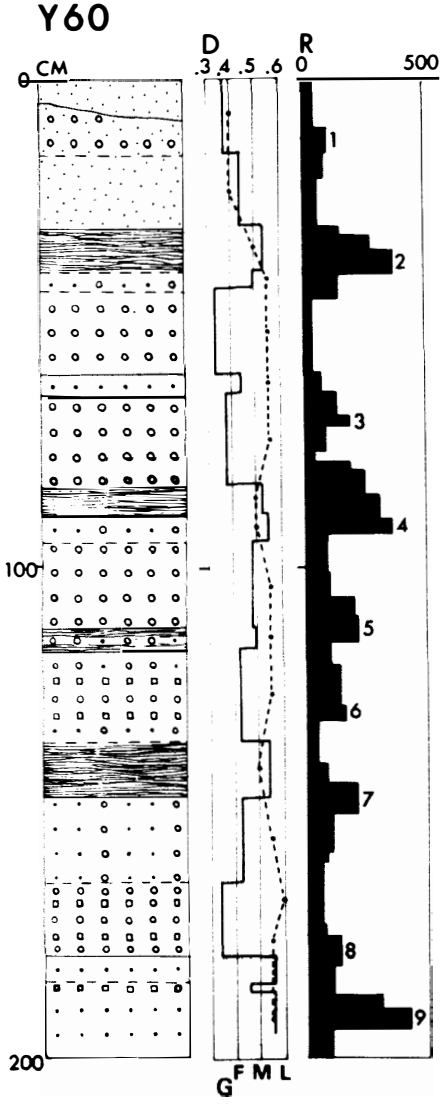


Fig. V-2-21.

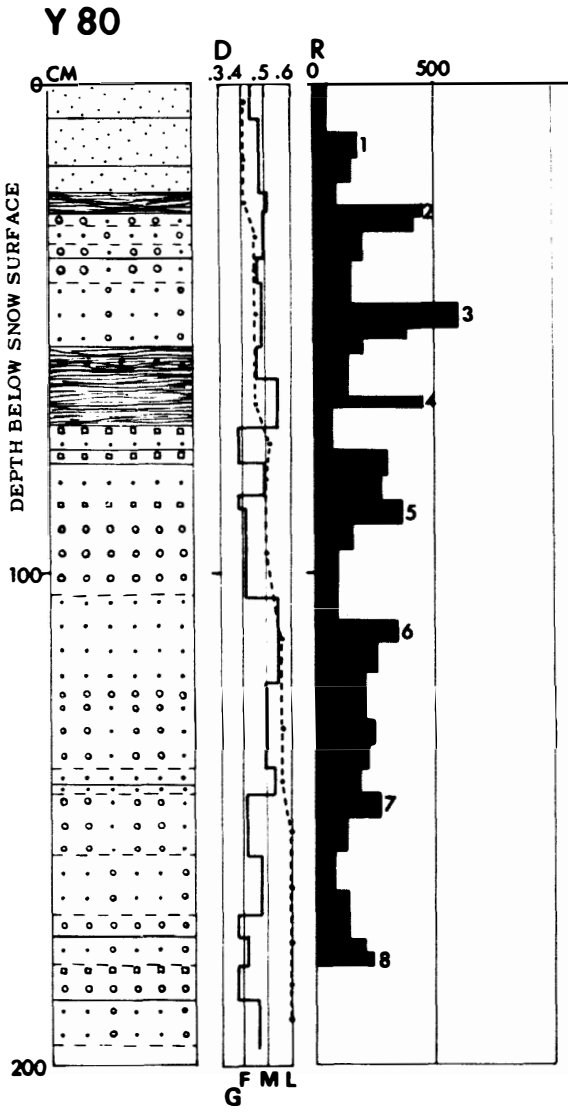


Fig. V-2-22.

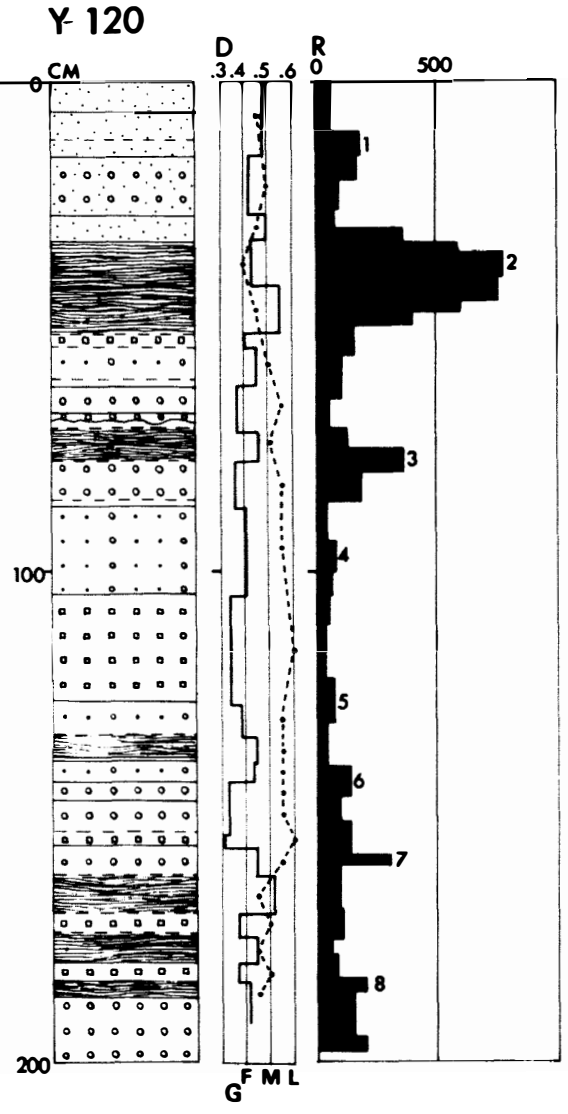


Fig. V-2-23.

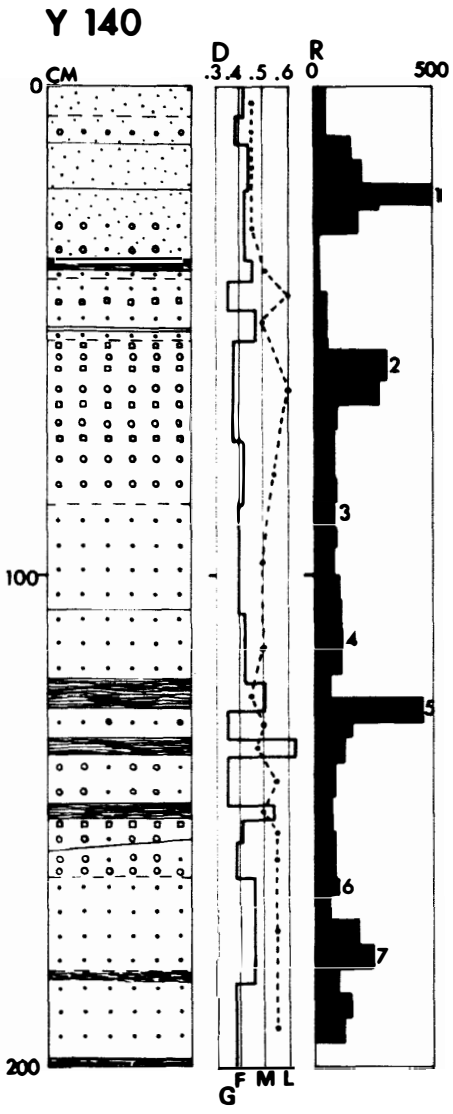


Fig. V-2-24.

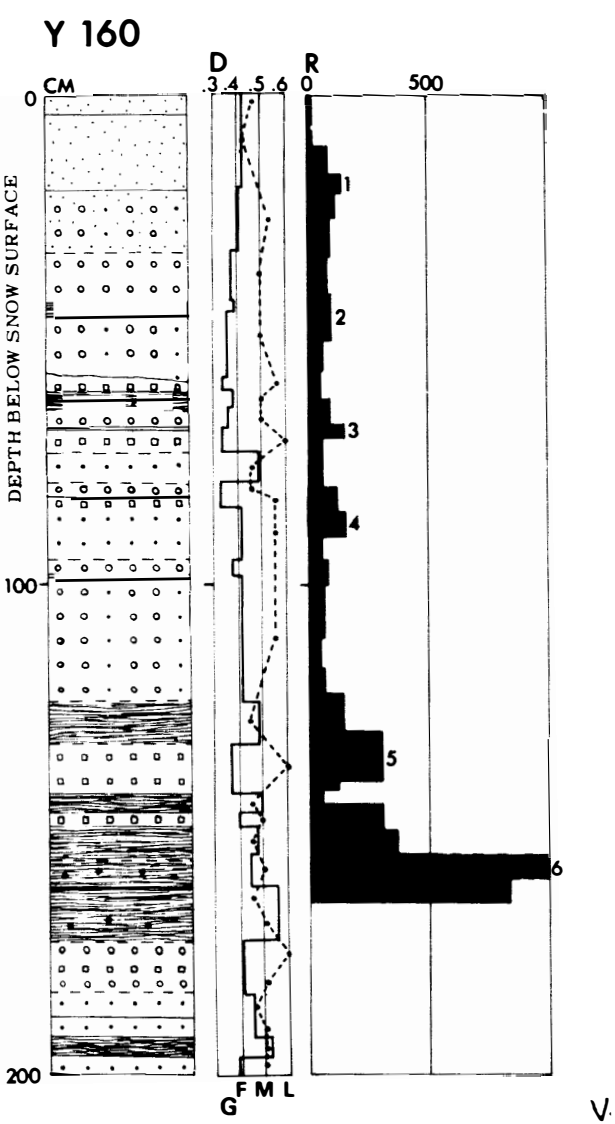


Fig. V-2-25.

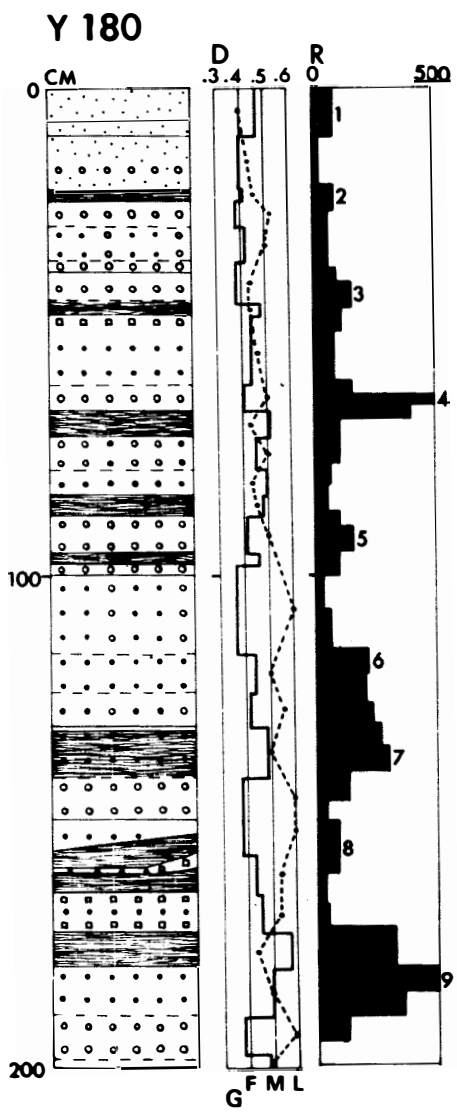


Fig. V-2-26.

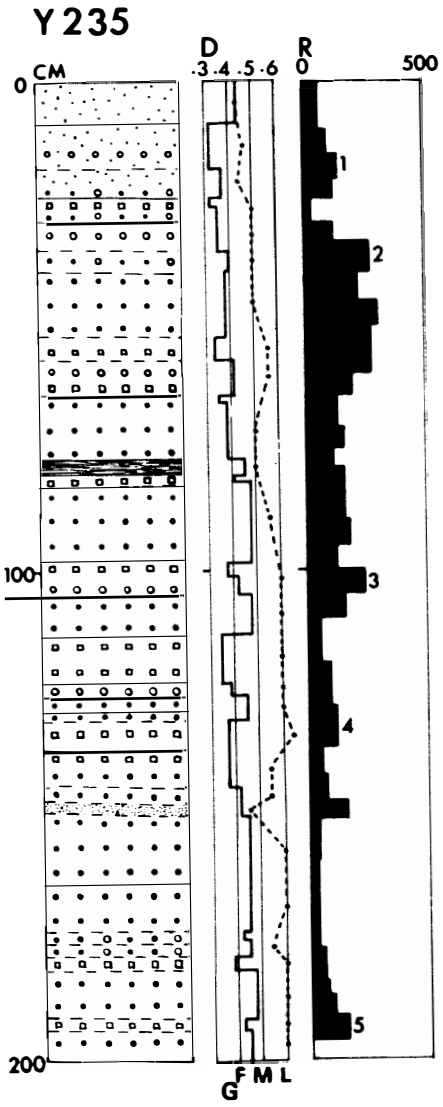


Fig. V-2-27.

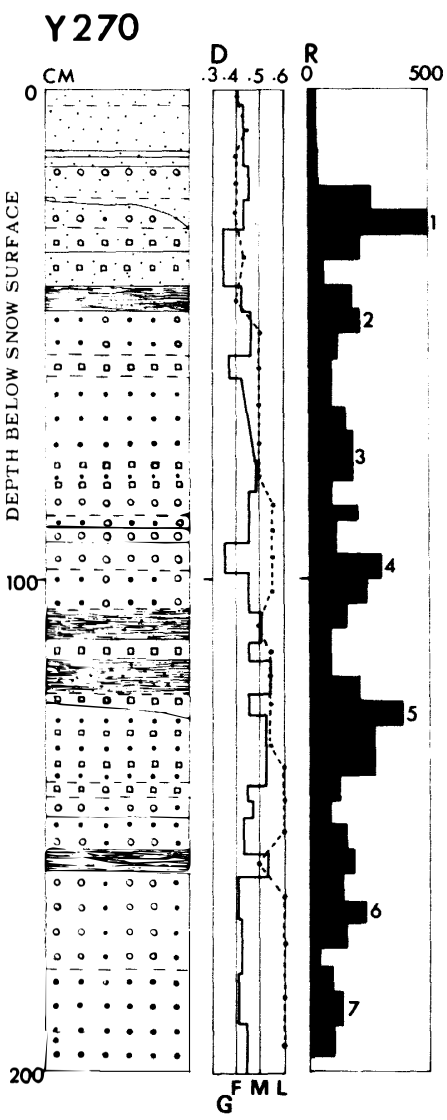


Fig. V-2-28.

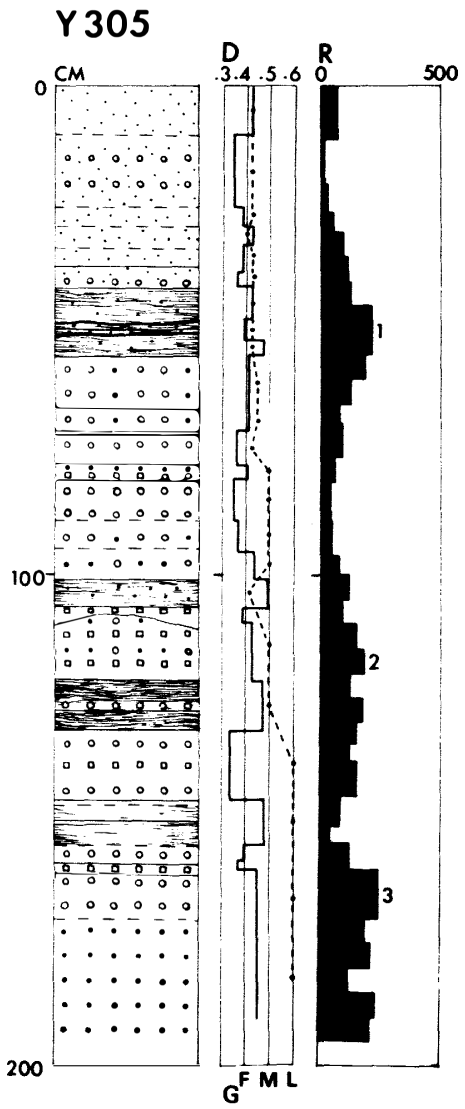


Fig. V-2-29.

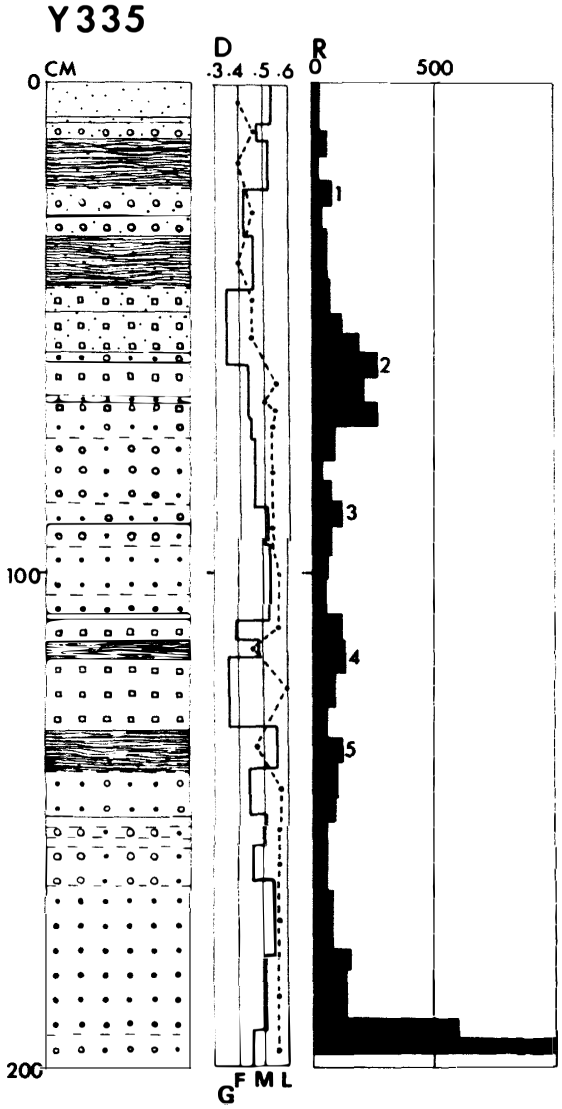


Fig. V-2-30.

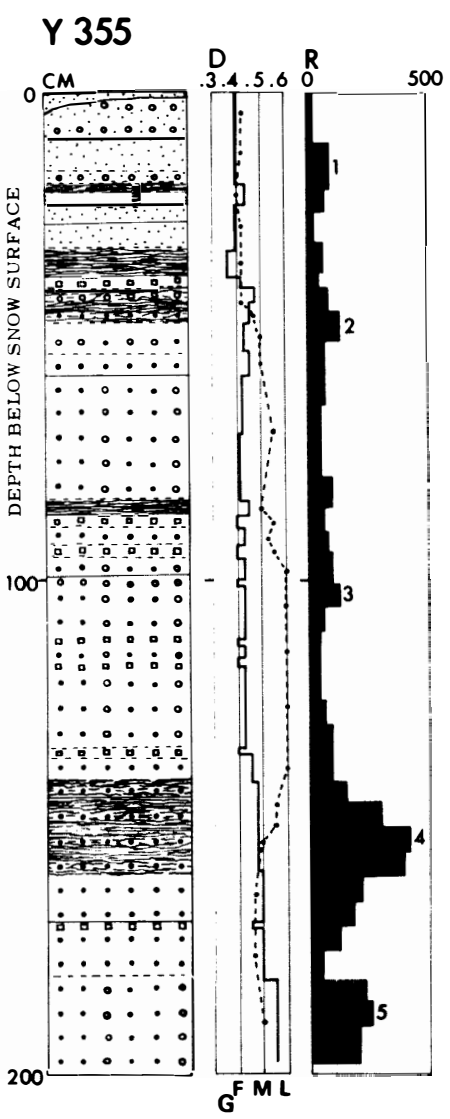


Fig. V-2-31.

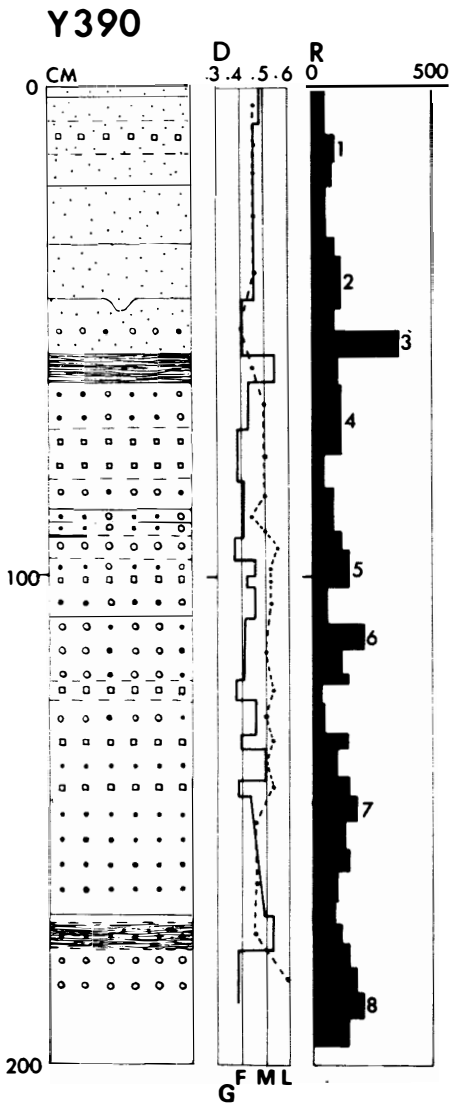


Fig. V-2-32.

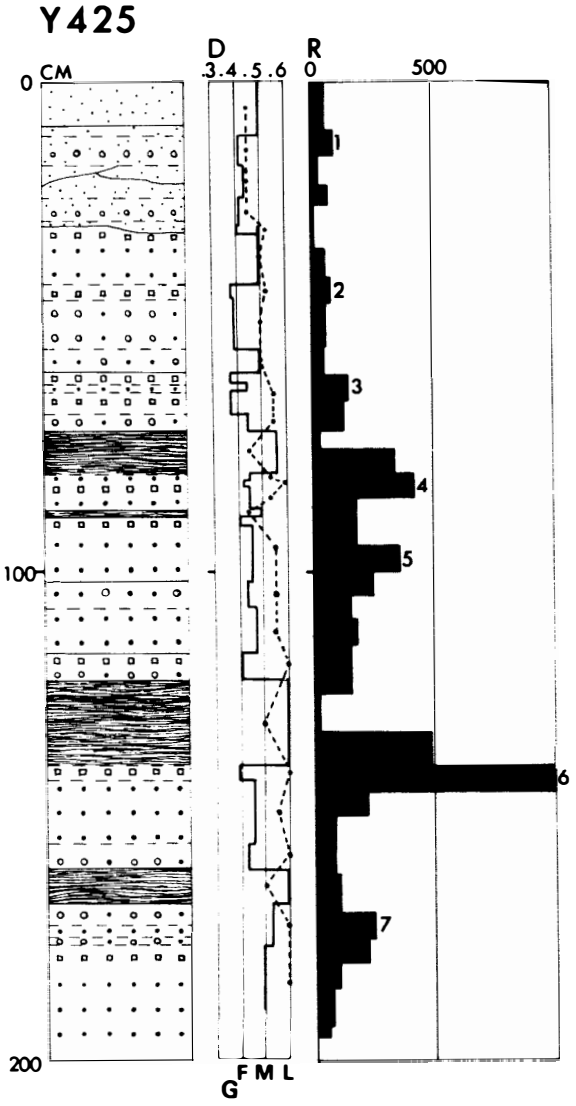


Fig. V-2-33.

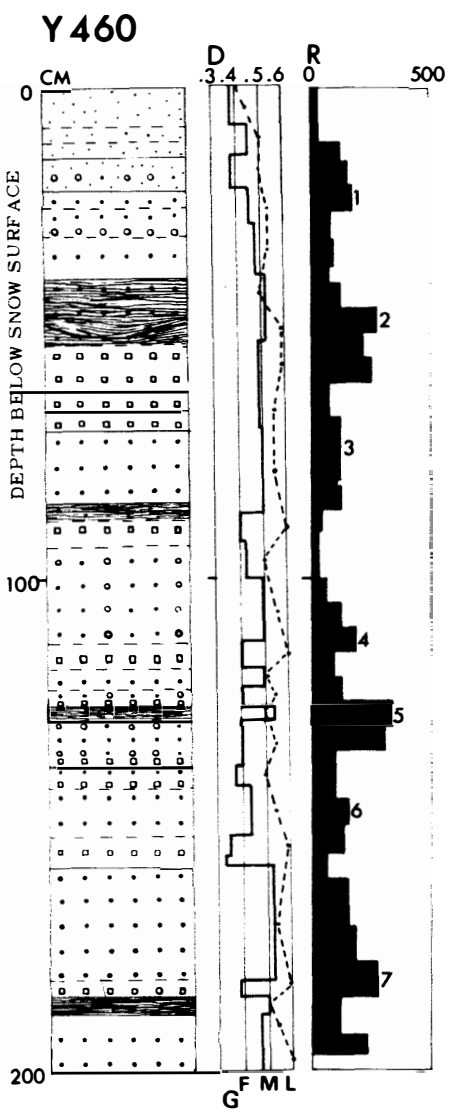


Fig. V-2-34.

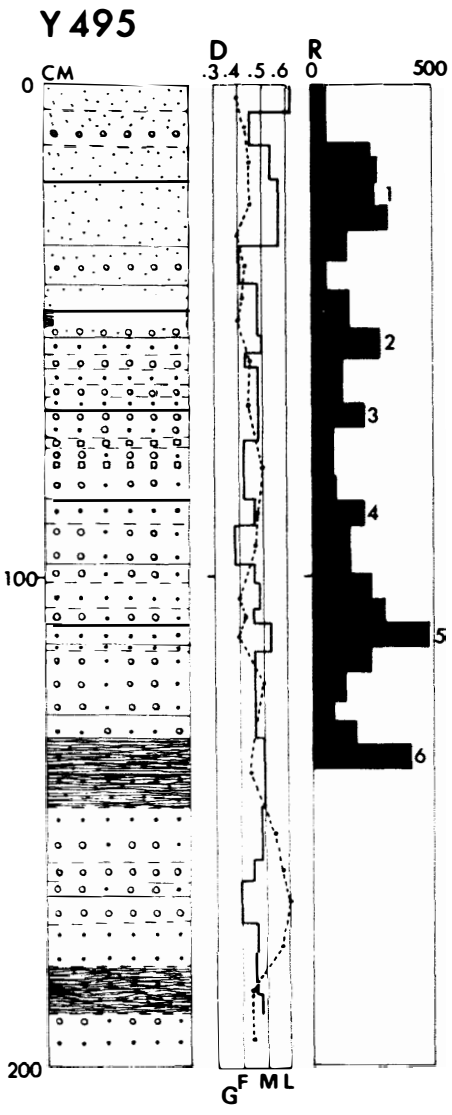


Fig. V-2-35.

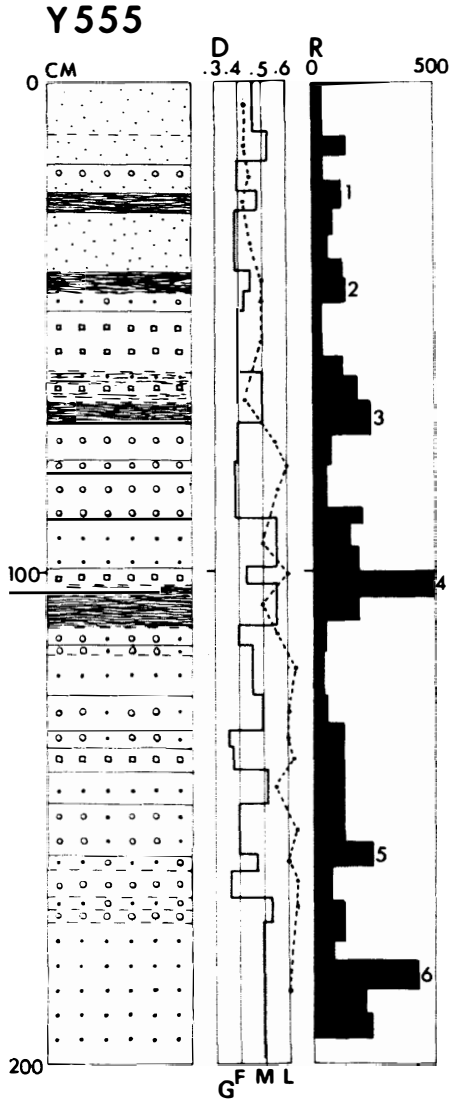


Fig. V-2-36.

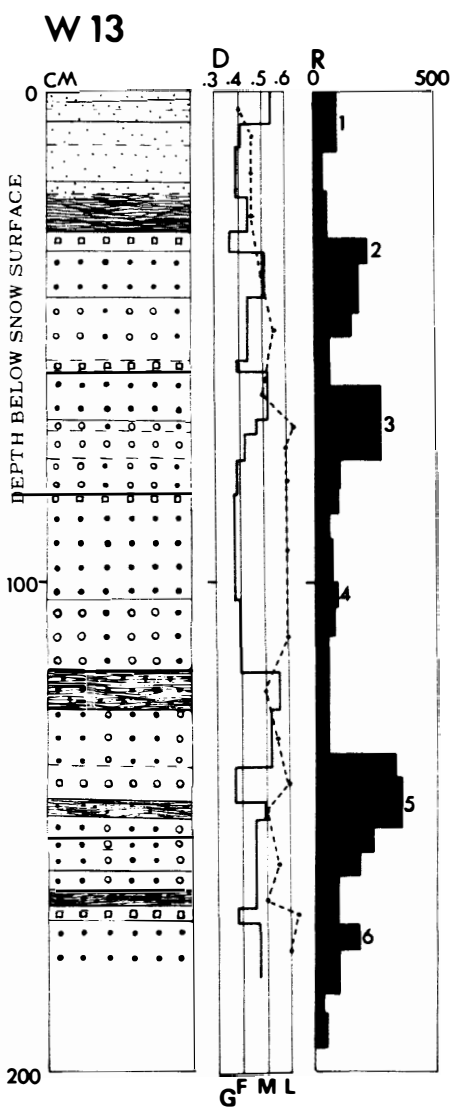


Fig. V-2-37.

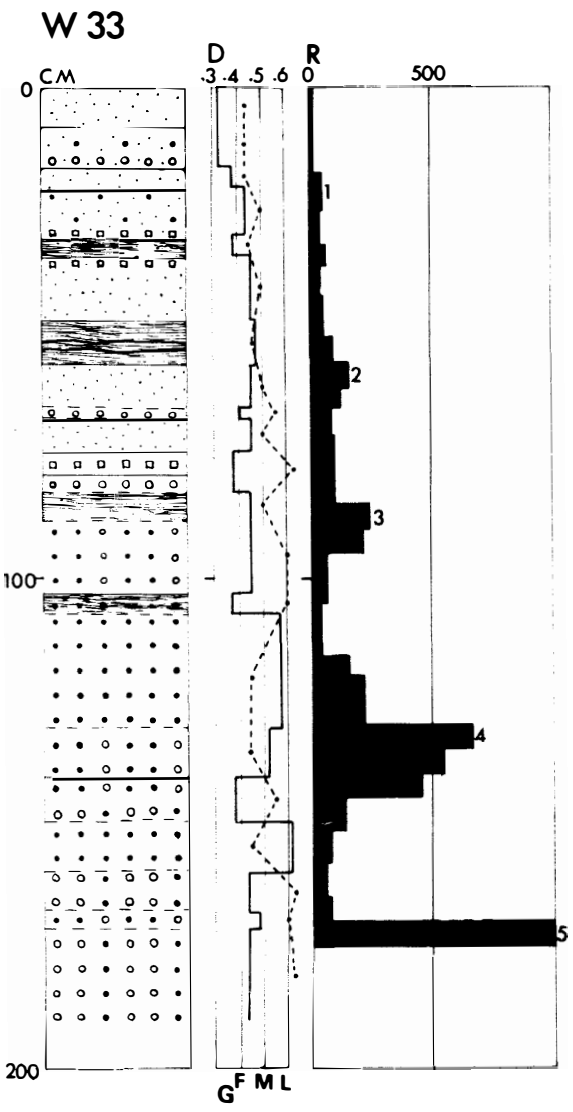


Fig. V-2-38.

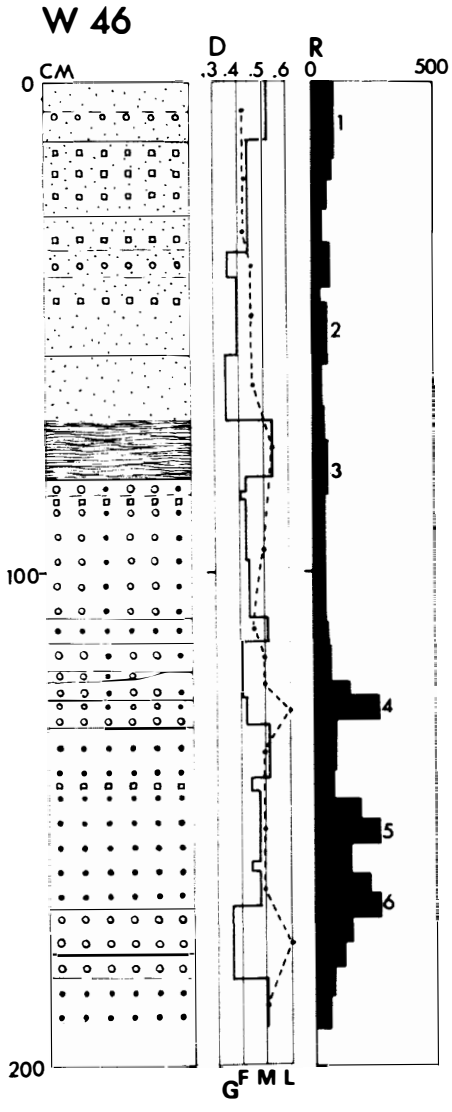


Fig. V-2-39.

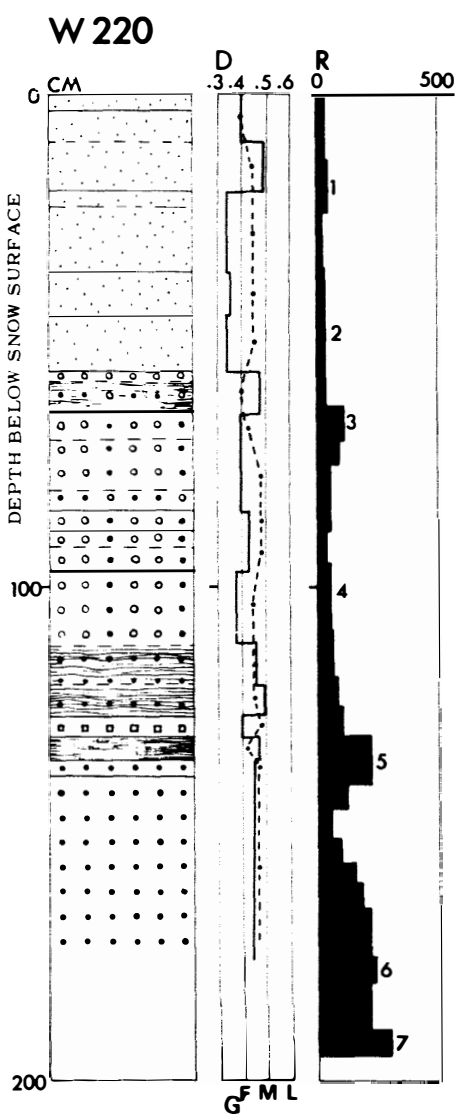


Fig. V-2-40.

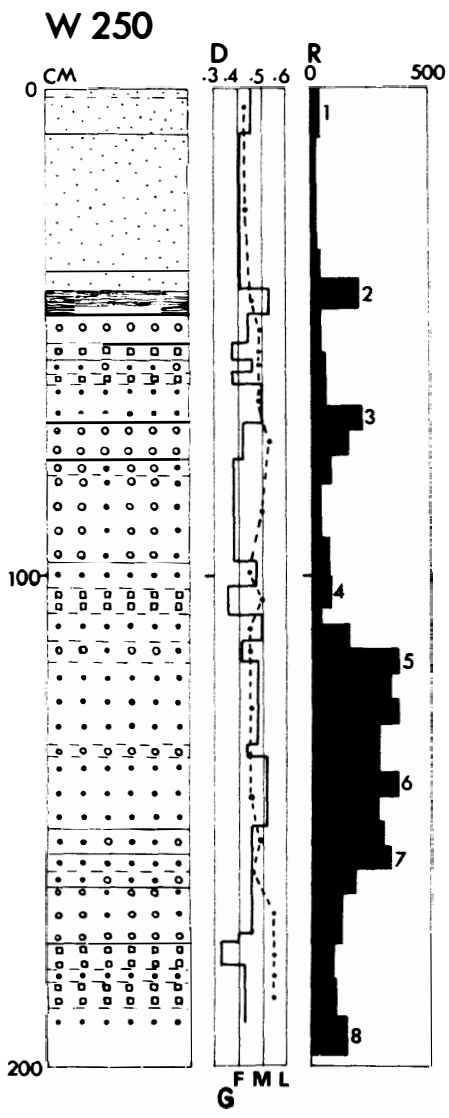


Fig. V-2-41.

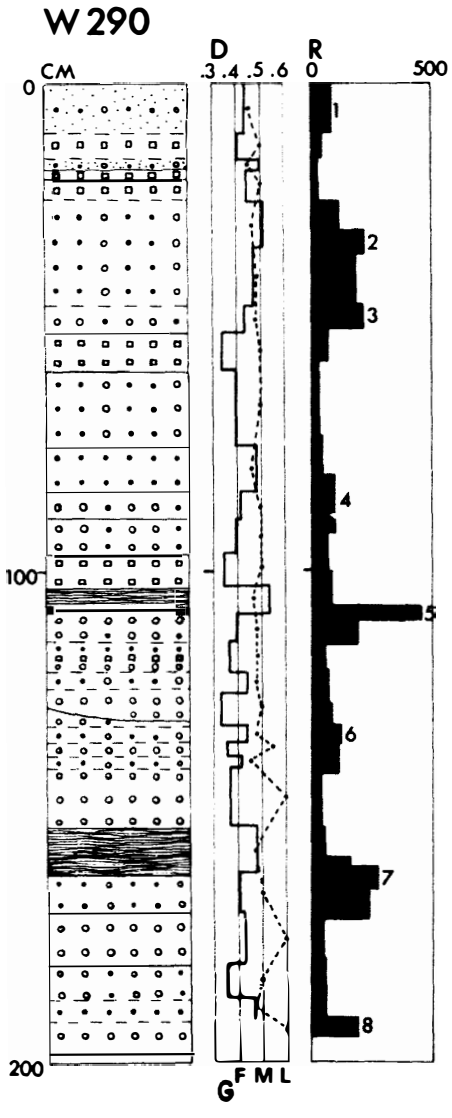


Fig. V-2-42.

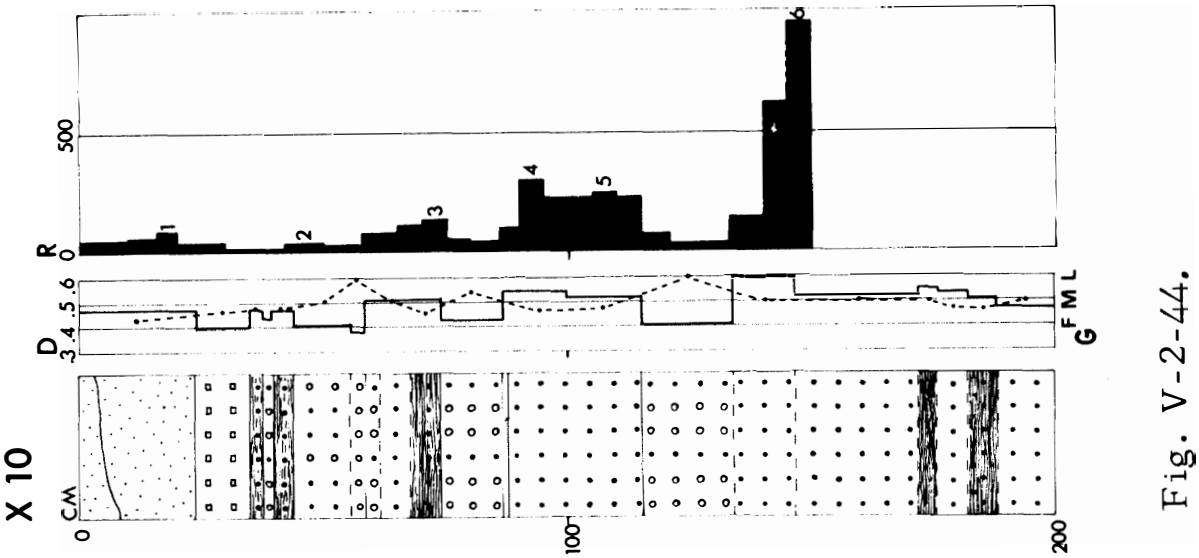


Fig. V-2-44.

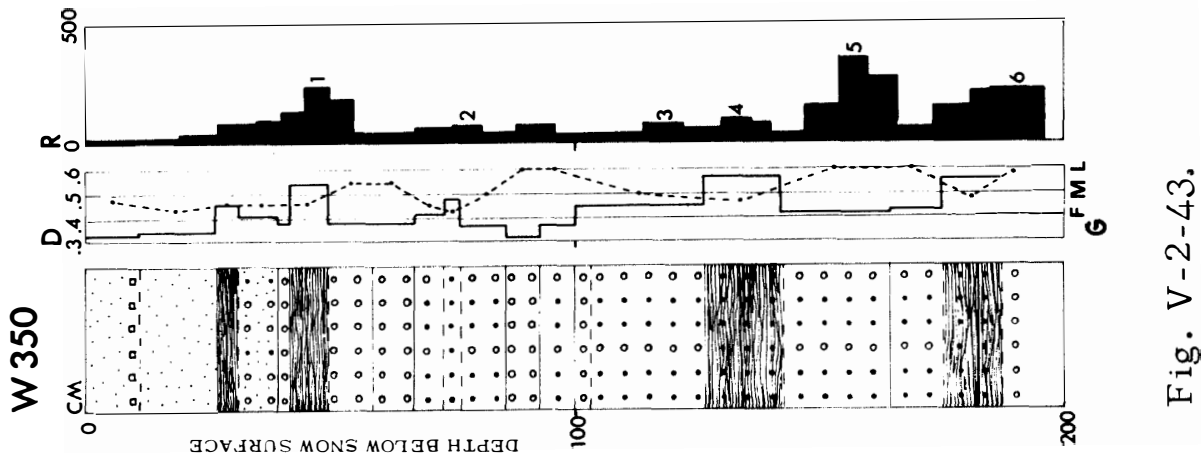


Fig. V-2-43.

The results of the analyses of the 2 m long snow cores are shown in Figs. V-2-1 to V-2-44. As seen in these figures, the stratigraphic profile generally does not fully correspond to the Ram hardness profile. For such disagreements two reasons are considered: firstly, since the obtained value of Ram hardness of snow is a mean value of a snow layer 5 cm thick, a layer thinner than 5 cm cannot be detected by this method; secondly, the stratigraphic structure of a snow cover at a hardness measurements site could be different from that at a boring site even when the two sites are very close location, as was very frequently revealed by the stratigraphic profile of a wall of snow pit.

2.3. The observational results and discussions as regards studies on 2 m deep pits will be published separately.

2.4. Analyses of 5 and 10 m long snow cores and sampling of snow cores for analyses in laboratory

Detailed stratigraphic profiling and density measurements were made on 5 m long snow cores at 4 stations and 10 m long snow cores at 11 stations. The results of these analyses are shown in Figs. V-4-1 to V-4-3.

Five 5 m long snow cores, one each at Stations S97, S169, Y200, Y370 and W55, two 10 m long snow cores, one each at Stations S122 and Y100 were sampled with a SIPRE type hand auger and were kept in 5 cm thick casted foam-styrene containers, to be brought back to Japan. The containers were transported by a sledge during the oversnow traverse, and were placed in a cold storage of the icebreaker Fuji during the homeward voyage to Japan, then were carried by a refregirator truck to the laboratories*.

Comparative studies of the vertical profile of $^{18}O/^{16}O$ ratio to the detailed stratigraphic profile (such as micro-texture, grading of depth hoar layers and detailed measurements of density) on the cores from Stations S97 and Y100 are under way. The full results and discussions on these studies will be published separately. A part of the results up to date is shown in Fig. V-4-1.

---

* Snow cores from the surface down to a depth of 20 m were sampled at Mizuho Camp in July 1970. These cores were also transported to Japan.

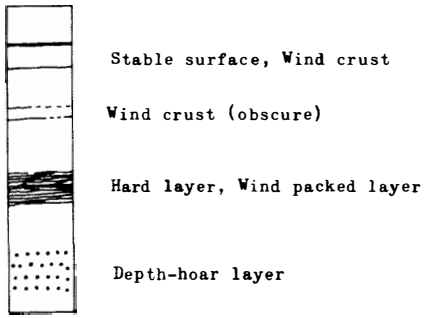
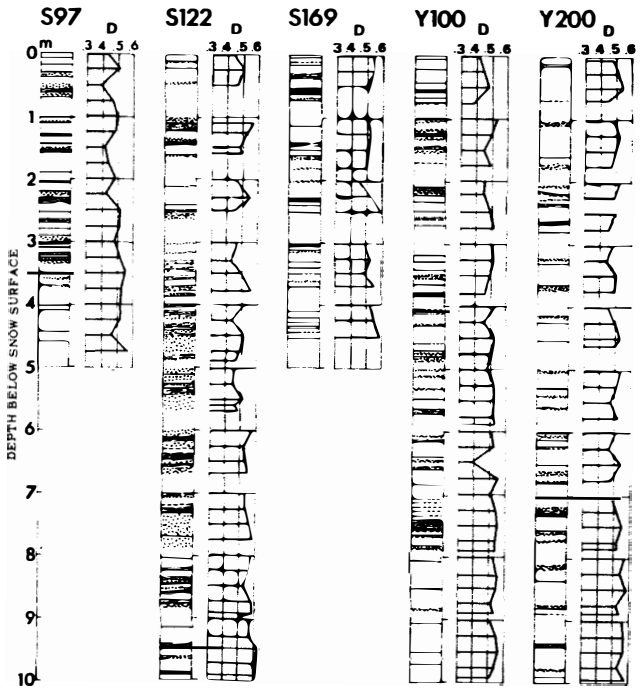


Fig. V-3. Stratigraphic symbols used in Figs. V-4-1 to V-4-3 (Not used in Figs. V-2-1 to V-2-44).



(1)

Fig. V-4. Stratigraphic analyses on the 5 or 10 m long snow cores: a stratigraphy diagram at the left side (cf. Fig. V-3), and a density diagram at the right side, for each core. Observation of stratigraphy of snow core at Station Y 510 was missed.

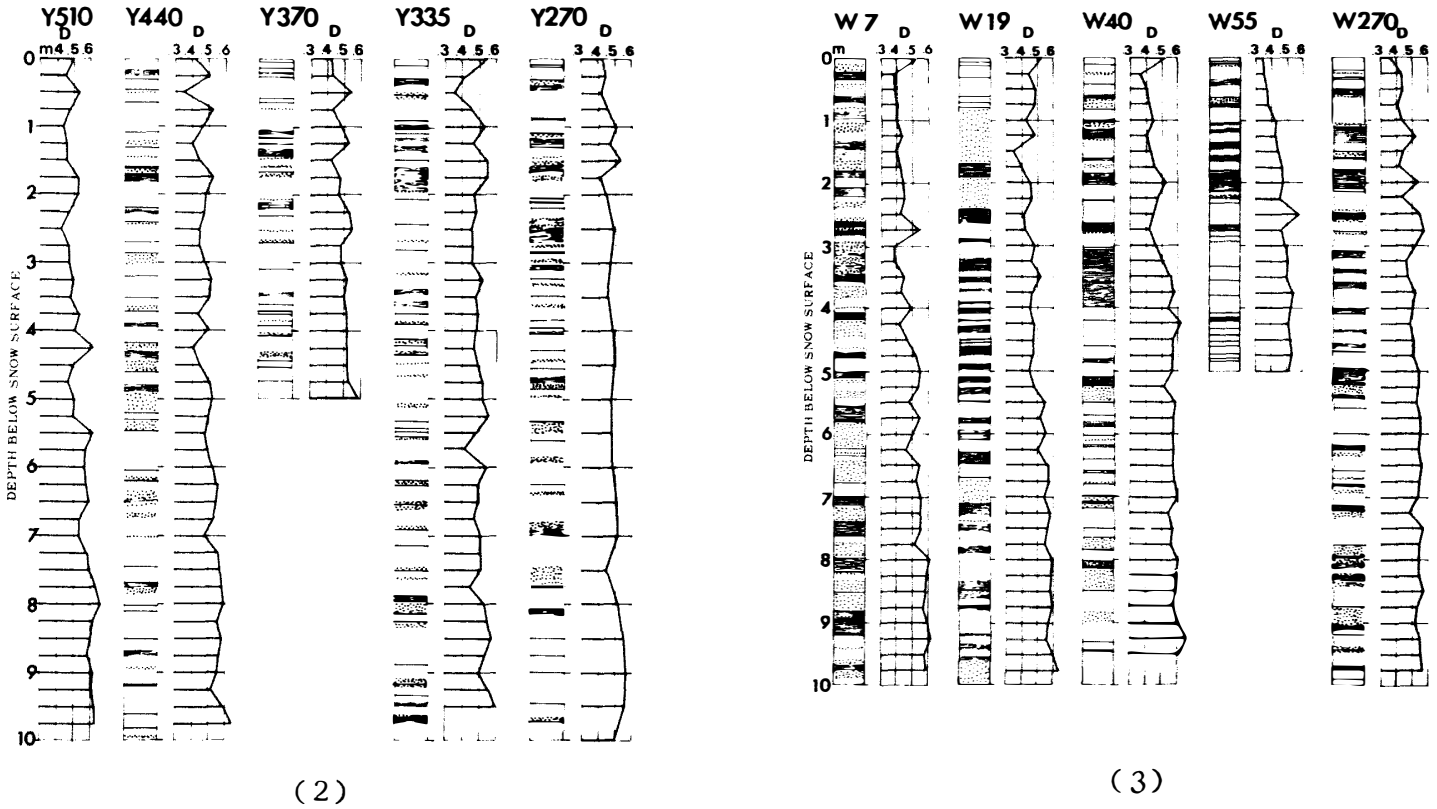


Fig. V-4. Stratigraphic analyses on the 5 or 10 m long snow cores: a stratigraphy diagram at the left side (cf. Fig. V-3), and a density diagram at the right side, for each core. Observation of stratigraphy of snow core at Station Y510 was missed.

Table V-1: Snow temperature.

Elevation (A): Elevation measured by the barometric altimetry by JARE 10 and 11 (see Report I of this volume).

Station No.	Elevation (A) (m)	Snow temperature (-°C)		L.T.	Date
		At the surface (-1cm)	At 2 m depth		
S 16	553	-	-9.1	12.00	Jan. 27, 1971
19	634	-5.6	-11.2	18.00	26
21	699	-4.7	-10.8	18.00	25
23	771	-7.0	-11.3	12.00	26
26	870	-6.8	-13.8	15.00	26
30	961	-8.8	-15.2	12.00	25
40	1112	-0.7	-15.6	15.00	22
50	1215	-7.5	-16.3	20.30	21
60	1332	-3.2	-16.7	15.30	21
75	1435	-14.2	-18.0	21.00	20
97	1605	-11.5	-20.5	22.00	19
140	1934	-19.4	-24.8	20.30	17
160	2008	-7.5	-24.5	18.00	16
X 10	2094	-9.5	-23.0	17.00	12
W350	2252	-14.5	-26.5	17.00	8
290	2337	-13.5	-26.3	14.00	7
250	2312	-17.0	-27.7	17.00	6
220	2248	-9.0	-29.5	15.30	2
46	1897	-15.2	-28.0	21.00	Dec. 27, 197
33	1851	-16.0	-23.5	21.00	25
13	1962	-	-25.3	-	18
Y555	2086	-11.5	-27.4	16.00	12
495	2119	-15.8	-29.2	16.00	9
460	2219	-21.4	-29.8	16.00	8
425	2335	-19.8	-32.4	16.00	7
390	2433	-17.2	-35.2	16.00	6
355	2532	-	-41.0	17.00	3
305	2612	-26.7	-38.0	20.00	1
180	2777	-22.5	-45.9	13.00	Nov. 26, 1970
160	2707	-25.8	-47.0	18.00	25
140	2655	-23.8	-43.8	12.00	25
120	2603	-21.4	-35.9	16.00	24
100	2545	-	-45.6	-	21

2.5. The measurements of snow temperature at the surface and at a depth of 2 m of the snow cover were made during the travel. The results are given in Table V-1.

3. The Method of Stratigraphic Analysis of the Snow Cover

3.1. The stratigraphic structures of the snow cover were classified into 4 groups in this report from the standpoints of sedimentation and metamorphosis of snow, as follows (Fig. V-1):

1) Sheet structure caused by discontinuance of deposition or errosion of snow: wind crust and glazed surface. Such a sheet structure which was once a surface of the snow cover for a long period of time can easily be conserved at a deep level in the snow cover after it was buried by a new deposition of snow.

2) Layer structure indicating the conditions of deposition of snow, properties of which vary with the condition of deposition: soft snow layer and wind packed layer.

3) Metamorphosed structure: a newly deposited snow layer changes its structure through metamorphosis by lapse of time into a loose layer, a compact layer and sometimes a depth hoar layer, depending upon the meteorological/physical condition under which the snow layer was exposed.

4) Structure formed by snow melt: snow melting at the surface and percolation of melt water make ice lense and ice gland.

3.2. As described in Section 2.2., the results of stratigraphic observations on 44 of the 2 m long snow cores are shown in Figs. V-2-1 to V-2-44.

Each of Figs. V-2-1 to V-2-44 consists of 3 diagrams: (1) a stratigraphy diagram at the left side, (2) a combination diagram of snow density D by a white histogram, and grain size G by a broken line, at the center, and (3) Ram hardness R by a black histogram at the right side.

Stratigraphic symbols used in the stratigraphy diagrams of Figs. V-2-1 to V-2-44 are given in Fig. V-1. The unit of snow density is g/cm^3. The grain size was classified into 5 grades, ranging in diameter d as follows:

F	(Fine grain):	$d < 0.3$ mm
MF	(Medium fine grain):	$0.3 \leq d < 0.7$ mm
M	(Medium grain):	$0.7 \leq d < 1.0$ mm
ML	(Medium large grain):	$1.0 \leq d < 1.3$ mm
L	(Large grain):	1.3 mm $\leq d$

The unit of Ram hardness is kg-force. The results of all the Ram hardness measurements along the traverse route of JARE 11 have been described in Report III of this volume. Numerous 1, 2, $\cdots\cdot$ 8 in the Ram hardness diagram indicate "key beds", which definition is given in Report III of this volume.

3.3. As described in Section 2.4., results of stratigraphic analyses on four of the 5 m and eleven of the 10 m long snow cores are given in Figs. V-4-1 to V-4-3: a stratigraphic diagram at the left side, and a density diagram at the right side for each snow core. Stratigraphic symbols used in Figs. V-4-1 to V-4-3 are given in Fig. V-3. The unit of snow density D is g/cm^3. In the density diagram, a solid line connecting density values at the respective depths gives the density profile of the snow cover, while a profile line is missing where a core is lost.