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SNOW WATER ACIDITY IN WYOMING

Pierre Clement August, 1966

Key Words -- Snow, acidity, chemistry of snow

Abstract

The knowledge of snow chemical characteristics is of interest to many sciences. The acidity of snow water can explain the dissolution of calcareous rocks and soils and snow can carry chemical elements to soils on which it falls. A combination of these factors is important for plant production.

Acidity of snow waters found in Wyoming's mountainous areas are compared to results of measurements made by the Author in the French Alps in 1964. The study is based on observations made in Wyoming from December, 1965, to May, 1966. Charts and tabular results are presented and discussed.

INTRODUCTION:

Snow water acidity has been the subject of other articles. This author's purpose was to continue research started in the French Alps in 1964, to compare the earlier results with those he found in Wyoming's mountainous areas, and to investigate the evolution of the phenomenon.

Appreciation is expressed for the assistance of the Natural Resources Research Institute, the Water Resources Research Institute, the Wyoming Department of Agriculture, and those persons who made it possible for the author to attend the Sixth Yellowstone Field Expedition in January, 1966. Some of the equipment used in the course of carrying out the work was supplied by the Water Resources Research Institute and was purchased with funds made available by the Office of Water Resources Research, U. S. Department of the Interior, under Public Law 88-379.

Observations were made from December, 1965, to May, 1966, in the Medicine Bow Mountains, in Yellowstone Park at Old Faithful, and in the Laramie area at altitudes ranging between 7,000 and 12,000 feet (2,100 m. to 3,600 m.).

The author applied the same methods of observation he used earlier in the Alps. A portable pH meter was employed after it was standardized against a buffer of known pH before each set of measurements. Samples were melted at the sites where taken in Pyrex beakers to eliminate contact with outside materials. The procedure permits vital on-the-spot readings. Since water pHs change easily, laboratory measurements after transportation are of little interest. (pH is the negative logarithm (base 10) of the hydrogen-ion concentration. A pH below seven indicates the solution is acidic. pH values above seven indicate an alkaline condition).

For some samples, complete chemical analyses were made by the State Chemist. For others, conductivity, total hardness, calcium hardness, and total iron were the only determinations and were made by the author.

Figure 1 indicates the snow water was acid with pH values ranging from 4.5 to 7.5, grouped mainly around 5.5. This may be related to a balance between the carbon dioxide content of the atmosphere and that of the water.

The author attempted to establish relationships between pH variations and other factors. Results of the attempts are presented on Figures 2 to 5.

Figure 2 shows a relationship between pH and temperature wherein the general trend appears to be an increase in pH following an increase in maximum temperature with the progression of time. The sharp decreases in pH in mid-May might be caused by the sudden drop in air temperature which occurred concurrently.

Figure 3 shows the pH associated with snow types. A decrease in pH between fresh and powder snow values is followed by a gradual pH increase as the snow is transformed into large crystals, then into wet snow. This may be caused by:

1.) Wind effect: Meltwater obtained from many wind crusts was often turbid and showed high pH values. This may result from the dust and debris deposited by wind action as varved layers. These were obvious in freshly cut pits. Meltwater from these dirty layers exhibited pHs around neutrality.

2.) Natural melting: Wet snows usually found during spring, are old snows which have been subjected to dust pollution for a long time, which may explain the high pH values recorded. Also percolating melt water carries the various chemical elements through the snow mass which has a uniform pH.

3.) Altitude: Figure 4 shows the relationship of pH values with the variation in altitude from 7,000 to 12,000 feet. An increase in pH values may be associated with the wet snows and dirty layers more commonly found at lower elevations.

The shelter effect of trees may also be of significant importance, as indicated on Libby Flats where pHs were considerably lower under forest cover than in open areas subject to wind action.

The conclusion of the author is that there is a general trend of increasing pH with age of snow. Older snows are usually closer to neutral and new snows are more acid because of their purity.

CHEMICAL COMPOSITION:

Complete chemical analyses for some of the samples taken are shown on Table A. The value of the dissolved solid contents may be seen to range between 4 and 22 parts per million. Some substances such as calcium (Ca^{++}), magnesium (Mg^{++}), iron (Fe^{+}), carbonate (CO_3^{--}), and nitrate (NO_3^{--}) were almost always absent. Potassium (K^{+}) and sodium (Na^{+}) were the most frequently represented cations. The most common anions were bicarbonate (HCO_3^{-}), sulphate (SO_4^{--}), and cloride (Cl^{-}). This is the type snow to be expected in continental areas far removed from oceans and is similar to the chemical composition of snow in Transbaikalia (steppe and mountain taiga) (10). In regions closer to the sea, precipitation composition may be expected to show a distribution with more Cl^{-} and SO_4^{--}, and more Na^{+} and Ca^{++}.

Selected ions are plotted in relation to pH on Figure 5. It appears that the lowest chemical contents are associated with samples showing a pH around 5.5. It is interesting to note that a pH of 5.5 is considered to be the neutral point of atmospheric water (3).

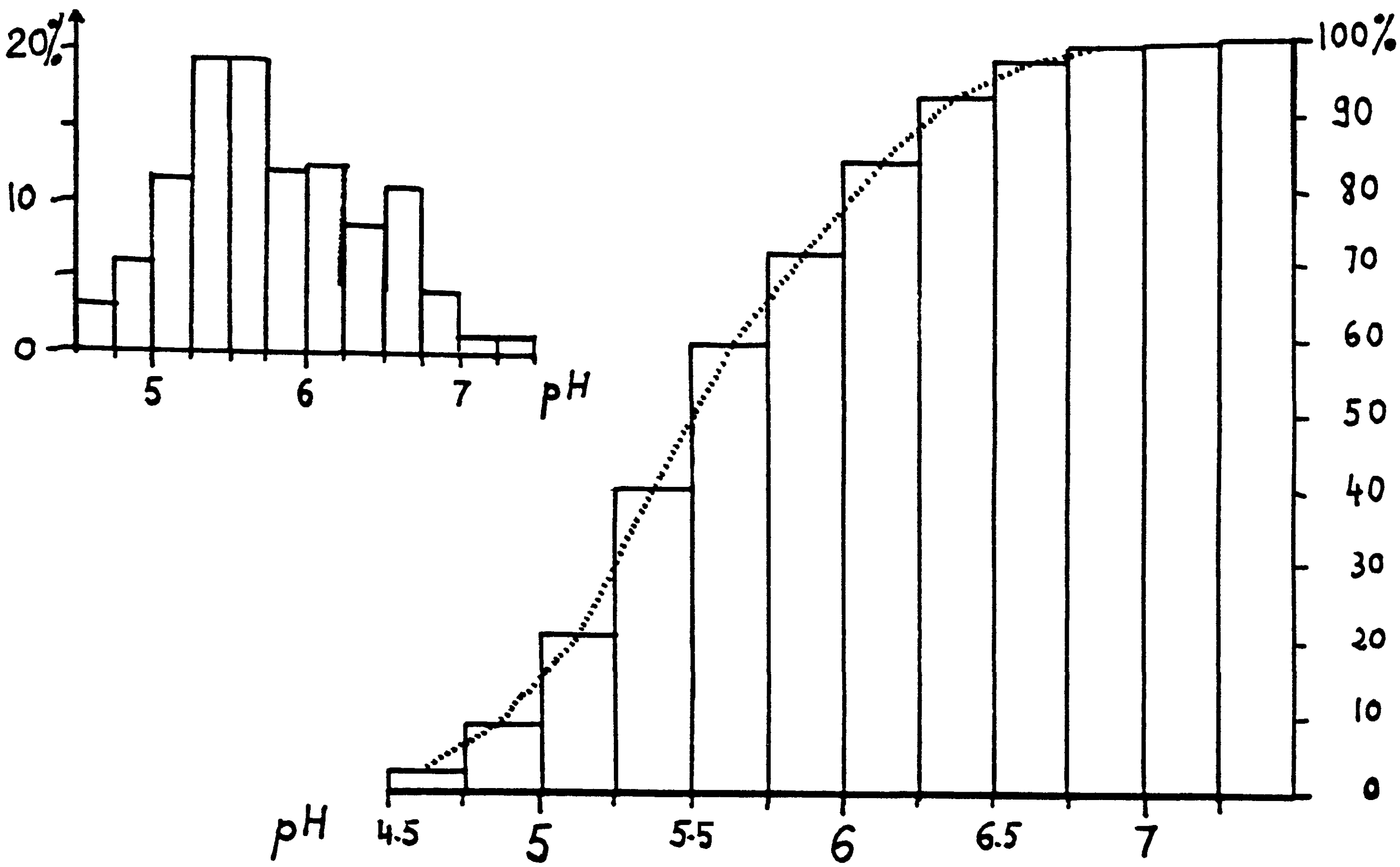
CONCLUSION:

The results of snow melt studies conducted in Wyoming generally confirm those obtained by the author from a study made in the Alps in 1964. A comparison of the results would indicate that the mean values of pH obtained from snowmelt studies in Wyoming are generally slightly higher than those obtained in the Alps even though the range of values is the same. The difference in average wind velocity and the percentage of vegetation cover may be a factor in the variation in mean pH.

APPENDIX

Figure 1

FREQUENCY HISTOGRAM



CUMULATIVE CURVE

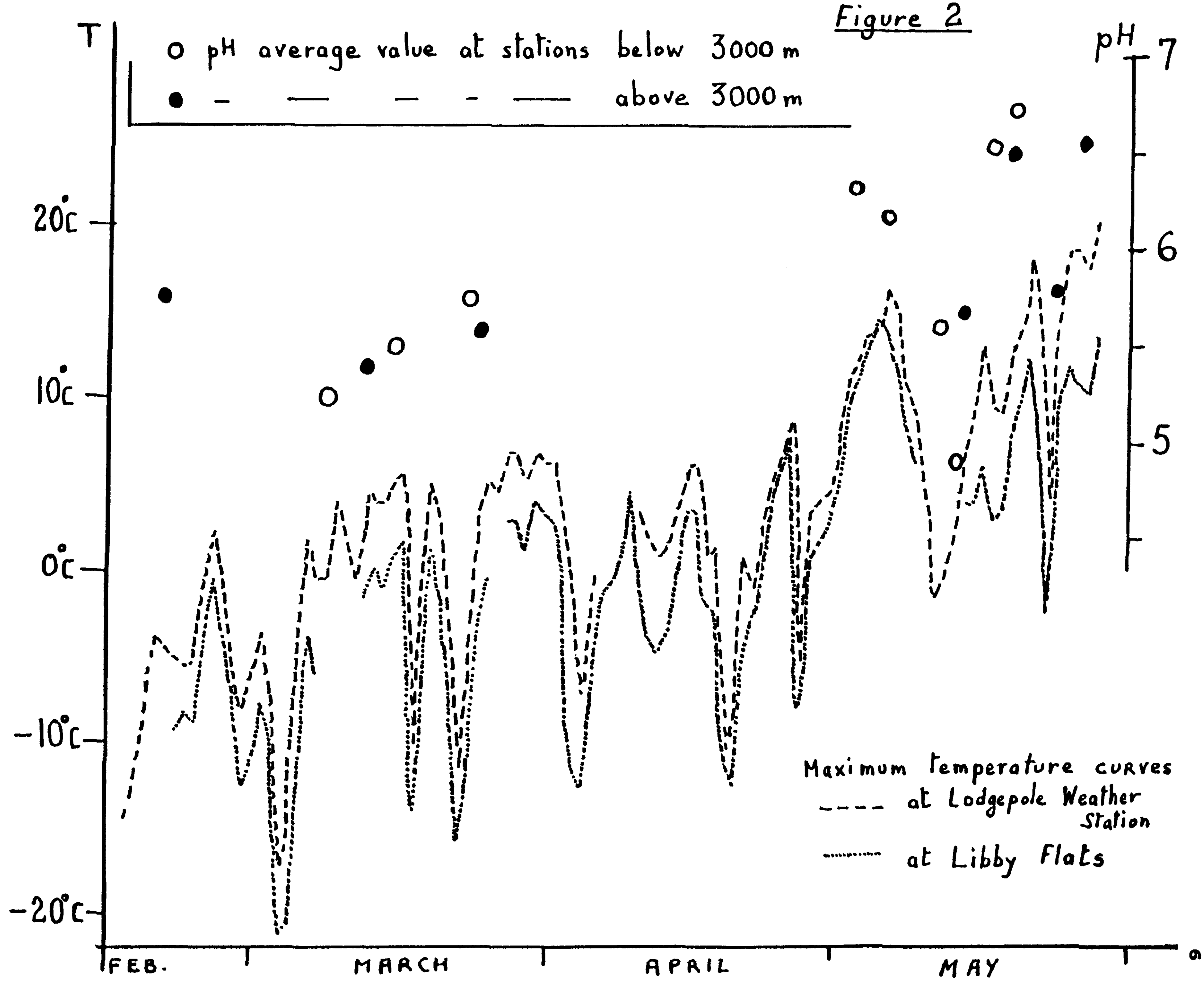
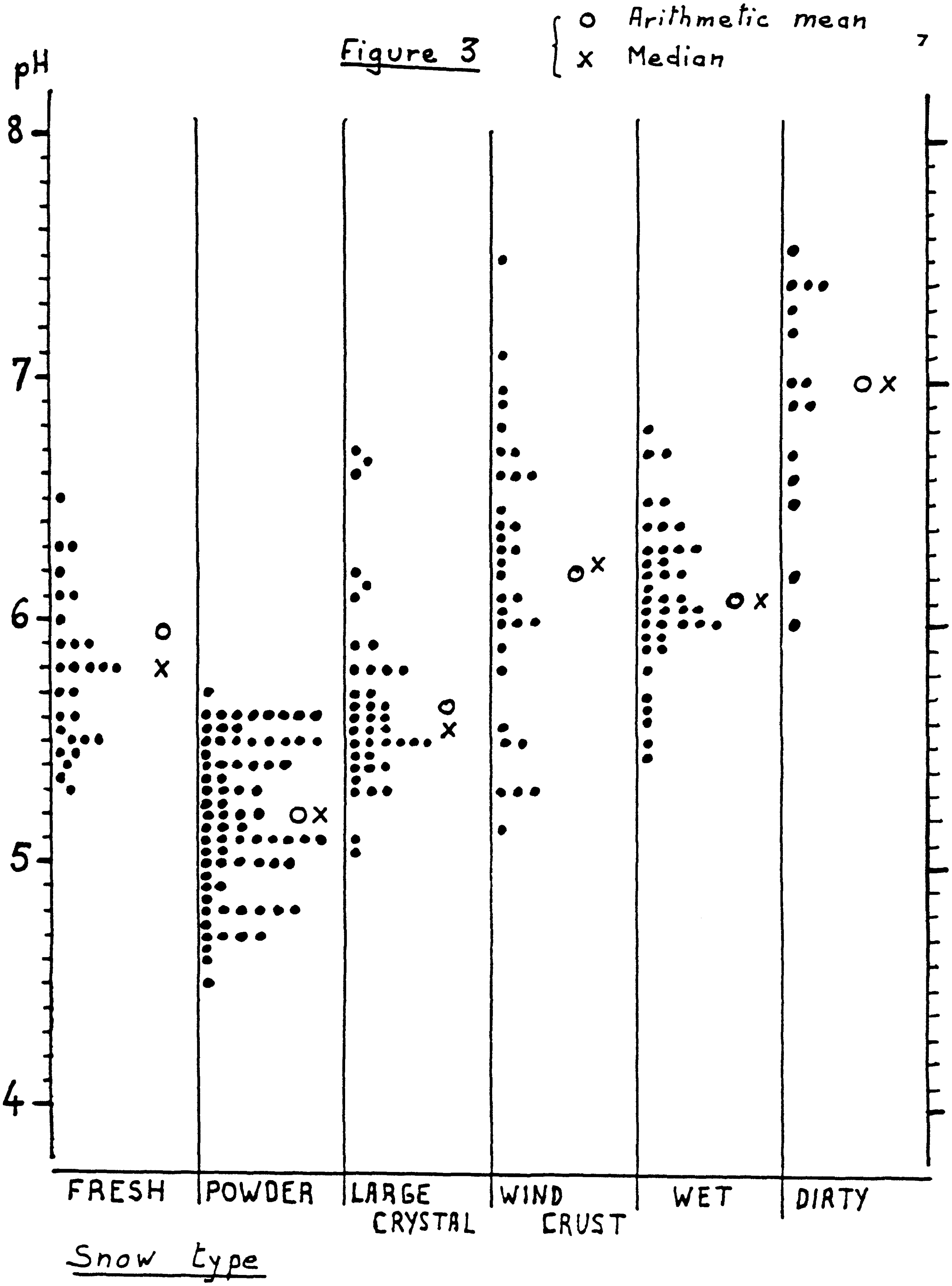


Figure 2
T
pH
o pH average value at stations below 3000 m
● - — - - — above 3000 m
20°C
10°C
0°C
-10°C
-20°C
7
6
5
FEB.
MARCH
APRIL
MAY
Maximum temperature curves
---- at Lodgepole Weather Station
.... at Libby Flats

Figure 3


o Arithmetic mean
x Median
pH
8
7
6
5
4
FRESH
POWDER
LARGE CRYSTAL
WIND CRUST
WET
DIRTY
Snow type

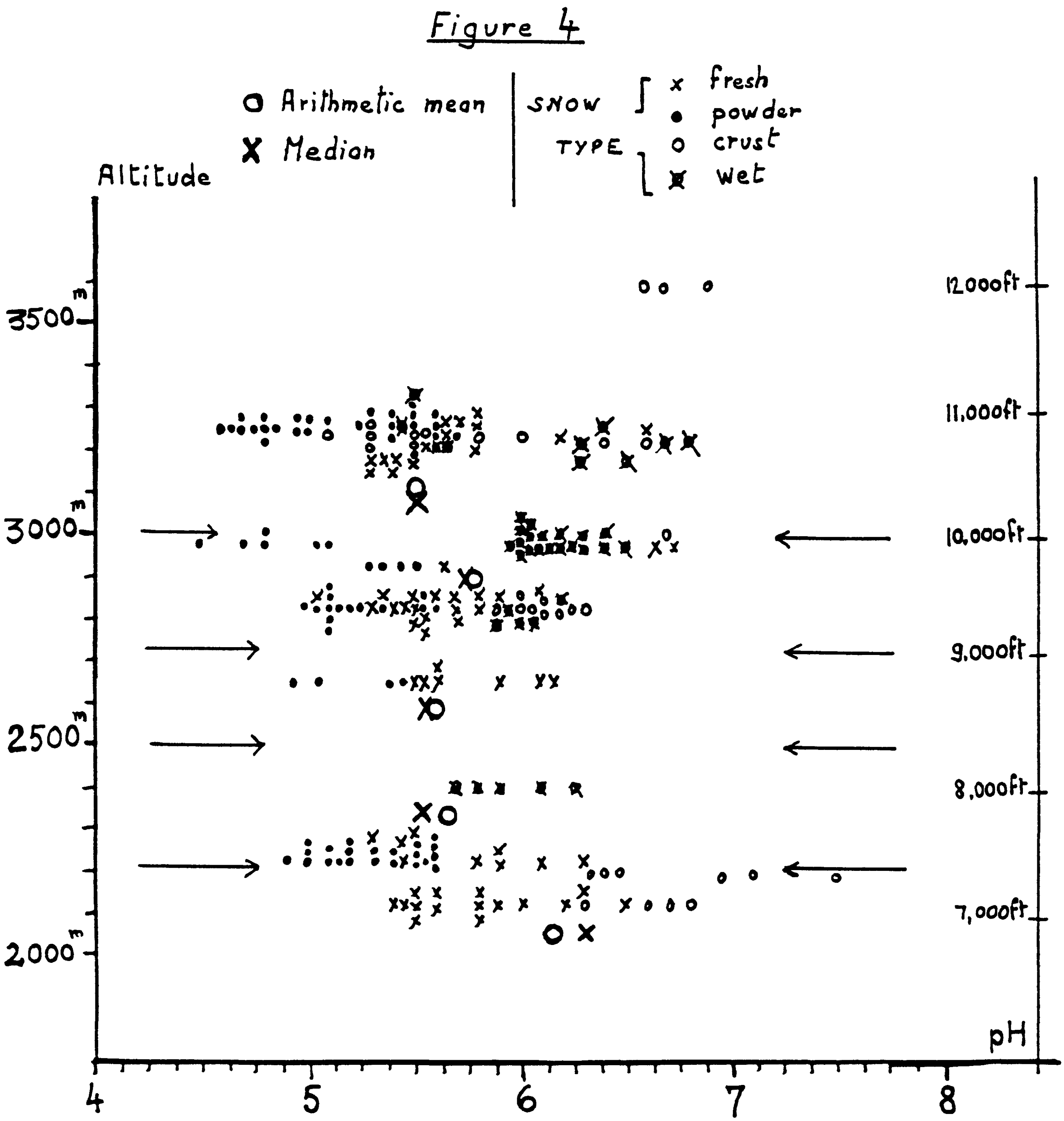


Figure 4
Arithmetic mean
Median
SNOW TYPE
fresh
powder
crust
wet
Altitude
3500m
3000m
2500m
2000m
12,000ft
11,000ft
10,000ft
9,000ft
8,000ft
7,000ft
pH
4
5
6
7
8

TABLE A CHEMICAL COMPOSITION

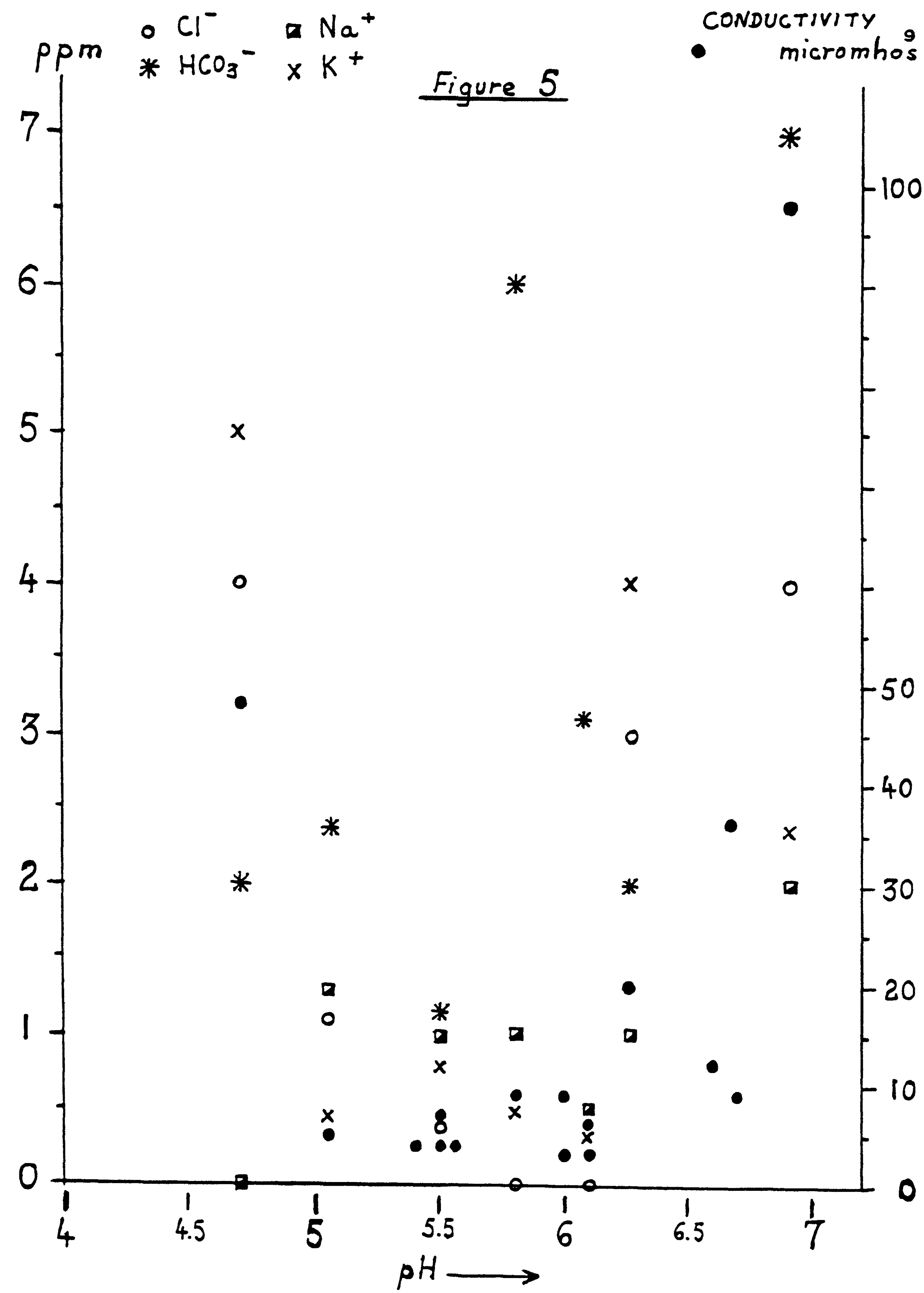
	pH	C	d.s	t.h	Ca++	Mg++	Na+	K+	Fe++	CO_3^{-}	HCO_3^{--}	SO_4^{--}	Cl^{-}	NO_3^{-}	Altitude
1	5.8	9	4	5	0	0	1.0	0.5	0.0	0	6	0.0	0.0	0.0	2200 m
2	5.5	4	6	-	0	0	1.0	0.8	0.0	0	1.2	4.8	0.4	0.0	2830 m
3	4.7	-	-	-	-	-	-	-	0.0	-	-	-	-	-	2970 m
4	5.5	7	-	-	-	-	-	-	-	-	-	-	-	-	2830 m
5	4.7	48	16	2	0	0	0.0	5.0	-	0	2.0	1.0	4.0	0.0	3240 m
6	5.4	4	-	0	0	0	-	-	0.0	-	-	-	-	-	2830 m
7	5.1	5	6	-	0	0	1.3	0.4	0.0	0	2.4	0.0	1.1	0.0	2830 m
8	5.5	4	-	0	0	0	-	-	0.0	-	-	-	-	-	2830 m
9	6.1	3	4	0	0	0	0.5	0.4	-	0	3.1	0.0	0.0	0.0	2970 m
10	6.0	3	-	0	0	0	-	-	0.0	-	-	-	-	-	2830 m
11	6.6	12	-	2	0	0	-	-	0.0	-	-	-	-	-	3250 m
12	6.7	9	-	1	0	0	-	-	0.0	-	-	-	-	-	2200 m
13	6.7	36	-	15	15	0	-	-	tr.	-	-	-	-	-	2130 m
14	6.1	6	-	1	1	0	-	-	0.0	-	-	-	-	-	2830 m
15	6.3	20	16	1	1	0	1.0	4.0	0.2	0	2.0	5.0	3.0	0.0	2220 m
16	6.9	98	22	0	0	1	2.0	2.4	tr.	0	7.0	3.0	4.0	0.6	2220 m
17	6.9	24	14	0	0	0	2.0	1.3	0.0	0	7.0	0.0	2.0	1.1	2220 m

Types of snow:
- 1, 2, 3, and 4 = FRESH
- 5 and 6 = POWDER
- 7 and 8 = LARGE CRYSTALS
- 9, 10, and 11 = WET
- 12, 13, and 14 = WIND CRUST
- 15 and 16 = DIRTY
- 17(Yellowstone) = ARTIFICIAL SNOWFALL seeded with silver iodide

Date: Samples taken in December = 1
in January = 15, 16, 17
in February = 5
in March = 2, 6, 7, 8, 10, 11, 12, 13, 14
in May = 3, 4, 9

C = Conductivity in micromhos
d.s = Dissolved solids in ppm
t.h = Total hardness in ppm

All the other data are in parts per million (ppm)


ppm
o Cl⁻
✱ HCO₃⁻
◪ Na⁺
x K⁺
CONDUCTIVITY
● micromhos
Figure 5
7
6
5
4
3
2
1
0
100
50
40
30
20
10
0
4
4.5
5
5.5
6
6.5
7
pH →

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