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PAPER 67-9

CHEMISTRY OF GROUND AND SURFACE WATERS IN THE
MOOSE MOUNTAIN AREA, SOUTHERN SASKATCHEWAN

(Report, 30 figures and Appendices)

A. Rözkowski

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Frontispiece. Shallow lake (slough No. 249), Moose Mountain area, Saskatchewan. SO_4-HCO_3 type of water with conductivity of 2,000 micromhos/cm.

ABSTRACT

Hydrochemical studies were carried out in the Moose Mountain area of southern Saskatchewan. The chemistry of the sloughs and lakes as well as that of the groundwaters in the glacial deposits was investigated.

The geological and geochemical studies indicated some lithological and mineralogical differentiation of glacial deposits.

The groundwater flow in this area is characterized by local, intermediate and regional flow systems which are hydraulically connected with the lakes and sloughs of Moose Mountain. The high salinity of the surface waters is produced by semi-arid climatological conditions whereas the variation of the salinity and chemistry of these waters depends mainly on the lithology and the groundwater flow conditions.

The following chemical zones of groundwater could be distinguished: the local and intermediate groundwater flow system is distinguished by the occurrence of HCO_3-Ca-Mg $\rightarrow$ HCO_3-SO_4-Ca-Mg $\rightarrow$ SO_4-HCO_3-Ca-Mg hydrochemical zones in the recharge and transmission areas, and SO_4-Mg hydrochemical zone in the discharge area.

The deeper regional flow of groundwater is represented by the appearance of SO_4-HCO_3-Na or SO_4-Na hydrochemical zone.

The chemistry of slough and lake waters is determined by the chemistry of groundwater and interflow. Further modification is effected by physico-chemical processes induced by intensive evaporation as well as by ion exchange processes and the biological activity of aquatic plants.

The comparison of surface and groundwater chemistry shows that sloughs and lakes are the areas of discharge of the local and intermediate groundwater flow systems only. The regional groundwater flow system discharges outside the area of the Moose Mountain hills.

CHEMISTRY OF GROUND AND SURFACE WATERS
IN THE MOOSE MOUNTAIN AREA
SOUTHERN SASKATCHEWAN

INTRODUCTION

The purpose of this paper is to show the regional distribution of hydrochemistry in the Moose Mountain area as well as to explain the origin and differentiation of the salinity and chemistry of slough and lakes waters and groundwater in the glacial deposits.

The high salinity of these waters is produced by climatic conditions but the variation of salinity and chemistry of these waters depends on the groundwater flow conditions and above all on the lithology of glacial deposits. Taking this last fact into account special boreholes were drilled. The results of the chemical and geochemical examinations of the cores of these holes showed the sources of ions delivered to the ground and surface waters. Especially good results were obtained from the soil and glacial deposits extracts; these indicated the amount and variation of soluble salts concentration and allowed us to explain the processes which form the water chemistry. The results of the hydrochemical field investigations and of the chemical analyses carried out in the laboratory, permitted us to demonstrate the chemical classification of waters and their regional distribution.

The analysis and comparison of the obtained results from the geological, hydrochemical and dynamic investigations gave the background for the final conclusions about the origin and development of ground and surface waters chemistry in the Moose Mountain area.

ACKNOWLEDGMENTS

DESCRIPTION OF THE STUDY AREA

TOPOGRAPHY

The area of study is bounded by longitudes 102°10' and 102°45' west, and latitudes 49°40' and 50°00' north, and occupies an elevated part of the southwestern Saskatchewan Plains. The region consists of an isolated group of hills surrounded by flat prairie (Fig. 1).

The elevation of Moose Mountain varies from 2,100 to 2,700 feet, with a local relief of 20 to 60 feet. The land forms, according to the topographic classes used in soil mapping (Moss, 1965) are moderately to strongly rolling, with local gradients between 10 and 19 per cent. A moderately undulating area forms the middle part of the Moose Mountain region, and similar terrain is found in the western area which is underlain by glacial lake deposits. E.A. Christiansen (1956) described the region as an area of hummocky moraine with typical knob-and-kettle topography.

The Moose Mountain area is the water divide of small streams: Moose Mountain Creek on the south and Pipestone Creek on the north. Owing to the hummocky nature of the glacial deposits there is no integrated drainage system, but instead there are a large number of unconnected sloughs and lakes without visible outlets. There are some large permanent lakes and a few thousand permanent, semipermanent and temporary sloughs. The most prominent lakes are White Bear, Kenosee and Little Kenosee Lakes, which are in the central part of the area.

CLIMATE, VEGETATION AND SOIL

The midcontinental position of Saskatchewan gives it a semi-arid climate with an average daily temperature of 65°F in July and 0°F in January. According to the meteorological reports from Carlyle, Saskatchewan, the annual average of precipitation over 5 years is 15.2 inches (snowfall 34 inches). The potential evapotranspiration of southern Saskatchewan is about 21 inches. The mean annual temperature is 36.3°F. Snowfall, which occurs between November and April, has an important effect especially in supplying the sloughs because melting occurs in the spring, when the ground is still frozen and the evaporation is low. Generally rain occurs from May until mid-June. Summer rains occur as local thunderstorms and showers, usually covering an area of a few square miles only. The sloughs freeze completely in winter.

The area of study lies in the parkland zone of the prairie area. The natural vegetation is a mixture of poplar, aspen, birch, willow and
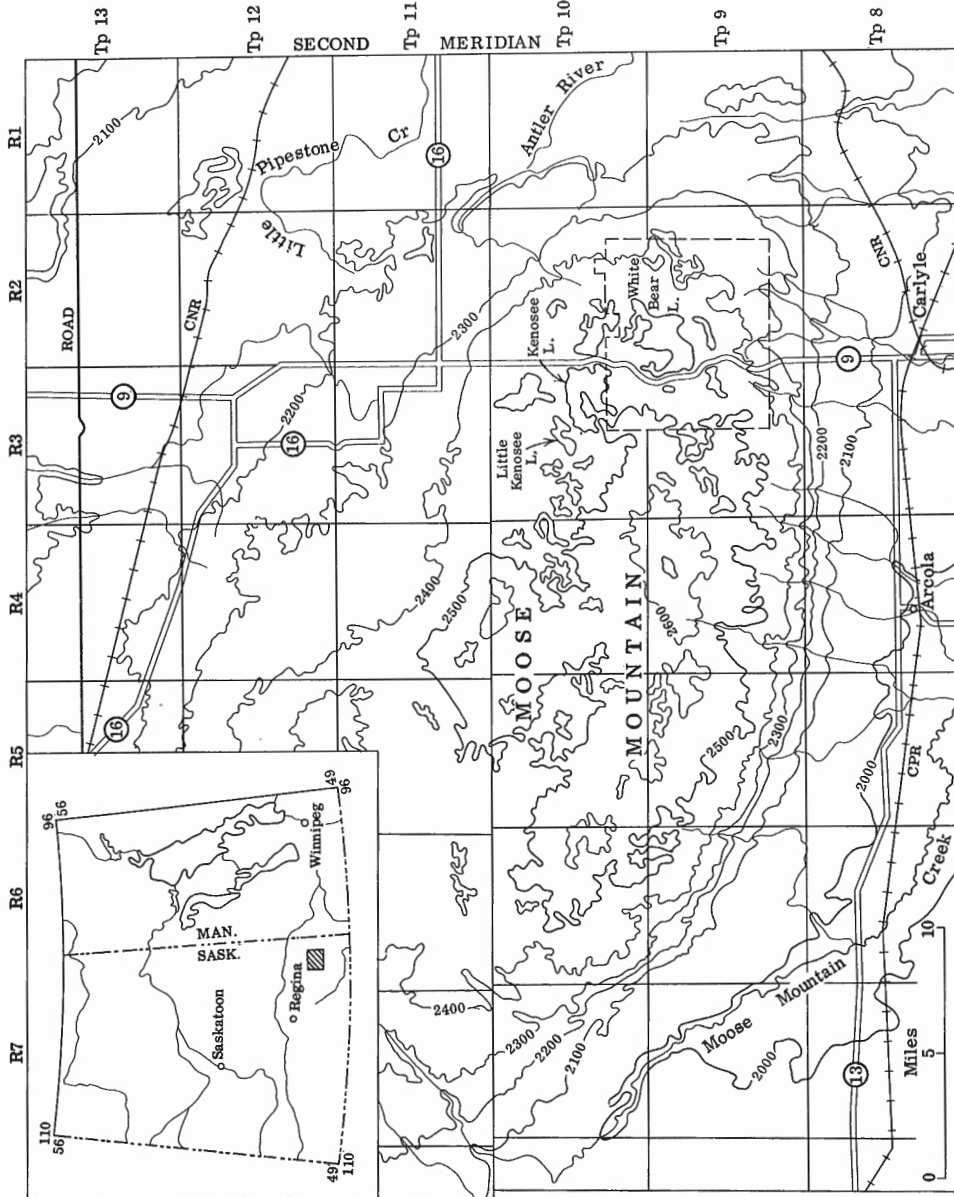
Figure 1. Location and topography of the Moose Mountain area

hazel, interspersed with grassland. Trees and bushes cover the eastern and central part of Moose Mountain which is a Provincial Forest Reserve. The western part of the area is under cultivation.

The soil, according to the investigations of Mitchell et al. (1944), is represented by mixed black Oxbow and dark brown Weyburn association. Such black chernozemic soils are typical of wooded prairie areas (Moss, 1965).

GEOLOGY

BEDROCK FORMATIONS

The geology of the Saskatchewan area has been described by Fraser and others (1935), and is shown on the Geological Survey's maps 895A and 1166A. According to these publications the surficial deposits in this area are underlain by the Tertiary Ravenscrag Formation, which overlies the Upper Cretaceous. The Ravenscrag Formation is represented by non-marine deposits, consisting of: sand, silt, shale and clay strata with lignite seams, ironstone concretions, and gypsum crystals. North of Moose Mountain no Ravenscrag strata are present and the Pleistocene deposits lie directly on non-marine Upper Cretaceous strata of Whitemud and Frenchman formations. These consist of sandy clays and silts crossbedded with sand, with a few lignite seams. The underlying Cretaceous Marine Shales Formation (or Riding Mountain Formation) consists of montmorillonite-illite shales with few sandstone layers and ironstone concretions.

GLACIAL DEPOSITS

The glacial geology of Moose Mountain has been studied most elaborately by Christiansen (1956); additional information can be obtained from the Geological Survey Water Supply Papers (e.g. MacKay et al., 1936). During the summer of 1966, the author obtained two cores, each 250 feet long, from the till deposits in the eastern part of Moose Mountain. These cores were augmented by 15 shallow auger holes, ranging in depth from 6 to 30 feet. Moreover, geological logs from the eastern part of Moose Mountain were available from the piezometer cross-section that was installed by Meyboom (1967).

Ground Moraine

According to Christiansen's map (Fig. 2) the ground moraine of Moose Mountain "comprises an area of low relief surrounding the Moose Mountain area, consisting predominantly of till modified locally by such features as drumlins, fluting, minor recessional ridges, crevasse fillings, eskers, and kames". It consists, basically, of till with lenses of gravel, sand and silt. Eskers and kames, which build some of the local elevations, are chiefly composed of poorly-sorted sands and gravels.
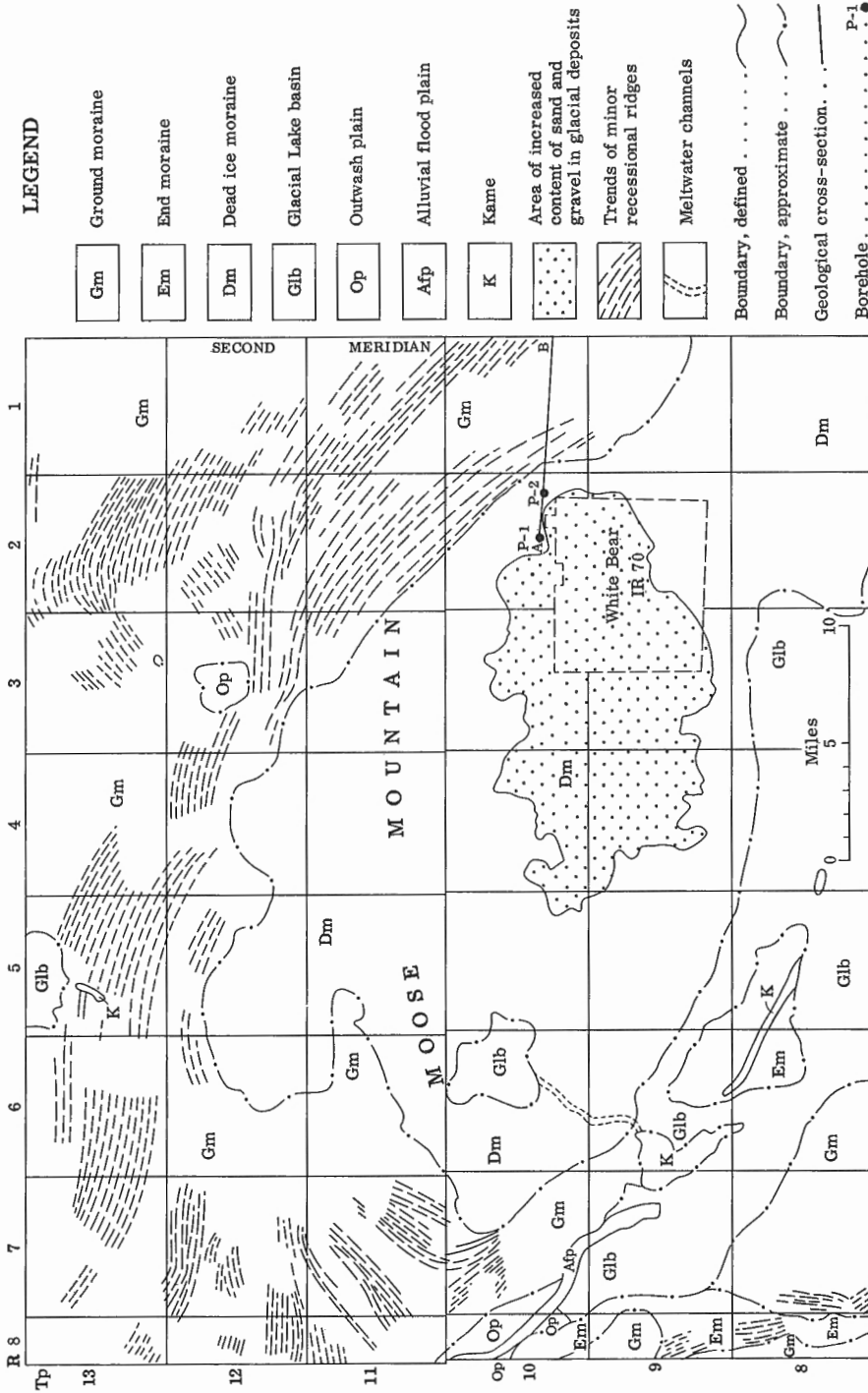
Figure 2. Glacial geology of the Moose Mountain area (after Christiansen, 1956)
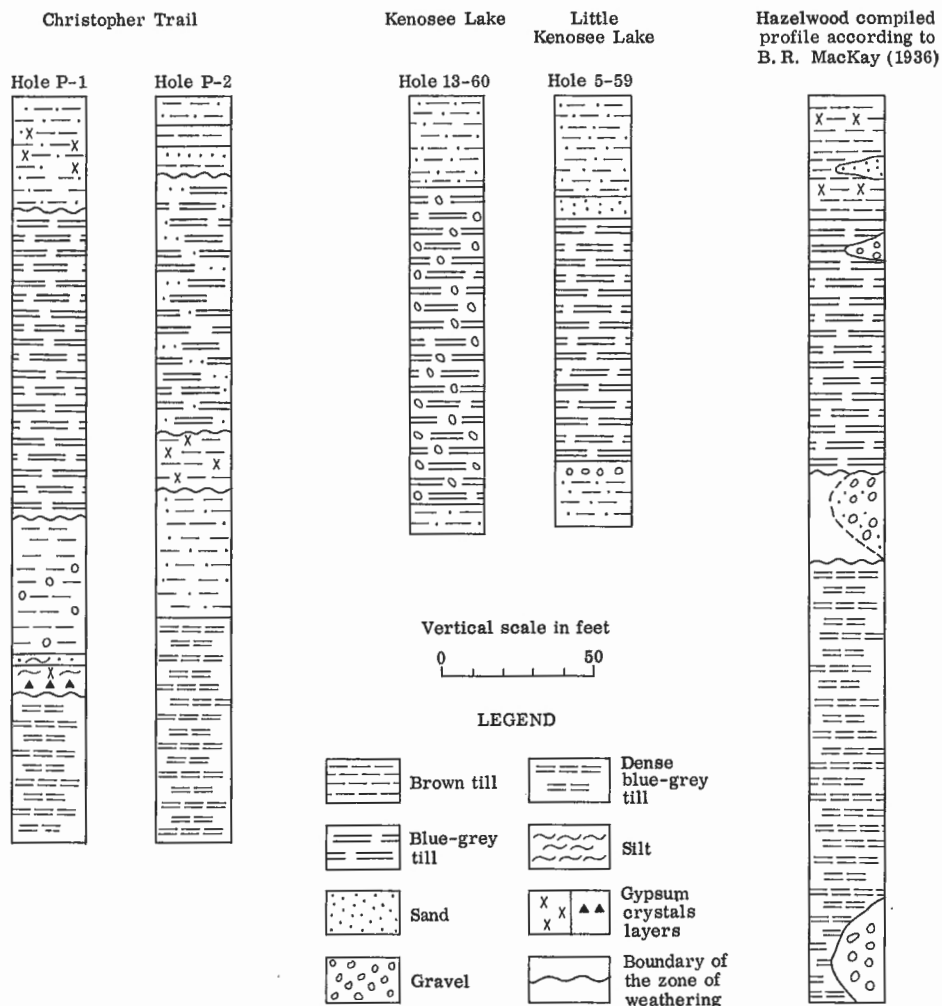
Figure 3. Lithological profiles of glacial deposits

Glacial Lake Deposits

The principal glacial lake basins are located in the Arcola-Kisbey area to the south and in the Kipling area to the north of the considered area, as well as in the western part of the Moose Mountain area where the moraine plateau is surrounded by hummocky moraine (Fig. 2). The lake deposits are composed of stratified sand, silt and clay.

Hummocky Moraine

The Moose Mountain hills are composed of hummocky moraine. The thickness of glacial deposits, taking into account the bedrock topography

(Meneley et al., 1957), varies from 100 to 350 feet. The drift deposits are composed of till with lenses of gravel, sand and silt. The moraine is cut by many, usually small and shallow, meltwater channels. The outwash channels are particularly noticeable along the edges of the Moose Mountain area, where tongues of glacial gravels extend into the flat area.

The author's field observations and the results of drilling show more sandy development of glacial deposits in the middle and eastern parts of the described area (Fig. 2). The drift deposits of these parts consist of sandy till with sand and gravel lenses. The present-day lakes are usually surrounded by kames, which are composed mainly of sand and gravel, or by ridges capped by layers of gravel and sand. A typical cross-section of such deposits is shown in Figure 3 by the log of borehole No. 13-60. The western part, as well as the northwestern and southern edges of Moose Mountain, are covered by more argillaceous till. Sand and gravel occur in meltwater channels and locally on the top and flanks of some ridges.

MacKay's (1936) observations allow us to distinguish five separate horizons in the vertical profile of glacial deposits (Table 1). MacKay's investigations were confirmed by the author's studies of boreholes P-1 and P-2 (Fig. 4).

TABLE 1

Generalized lithological profile of drift deposits

Number of horizon	Thickness of horizon (feet)	Lithological description	Remarks
1	10 – 40	till, yellow, with sand and gravel lenses	
2	40 – 120	till, blue-grey, with sand and gravel lenses	
3	about 25	gravel or sand	not continuous
4	50 – 170	till, blue-grey, dense	
5	about 20	gravel or sand	not continuous (preglacial?)

The gravel and sand layers which occur at the bottom of the glacial deposits, may be of preglacial origin (Fraser, 1935; Meneley et al., 1957). The sedimentation of these deposits seems to be related to the intensive outwash activity after the uplift of the area and its denudation during the Pliocene period.

The results of the boreholes P-1 and P-2 allow us to describe the glacial deposits of the eastern side of Moose Mountain to the depth 250 feet (Fig. 3). According to the lithological, mineralogical, and chemical studies, the investigated profiles contain two zones of weathering, the first superficial and the second at a depth of about one hundred feet below surface. The
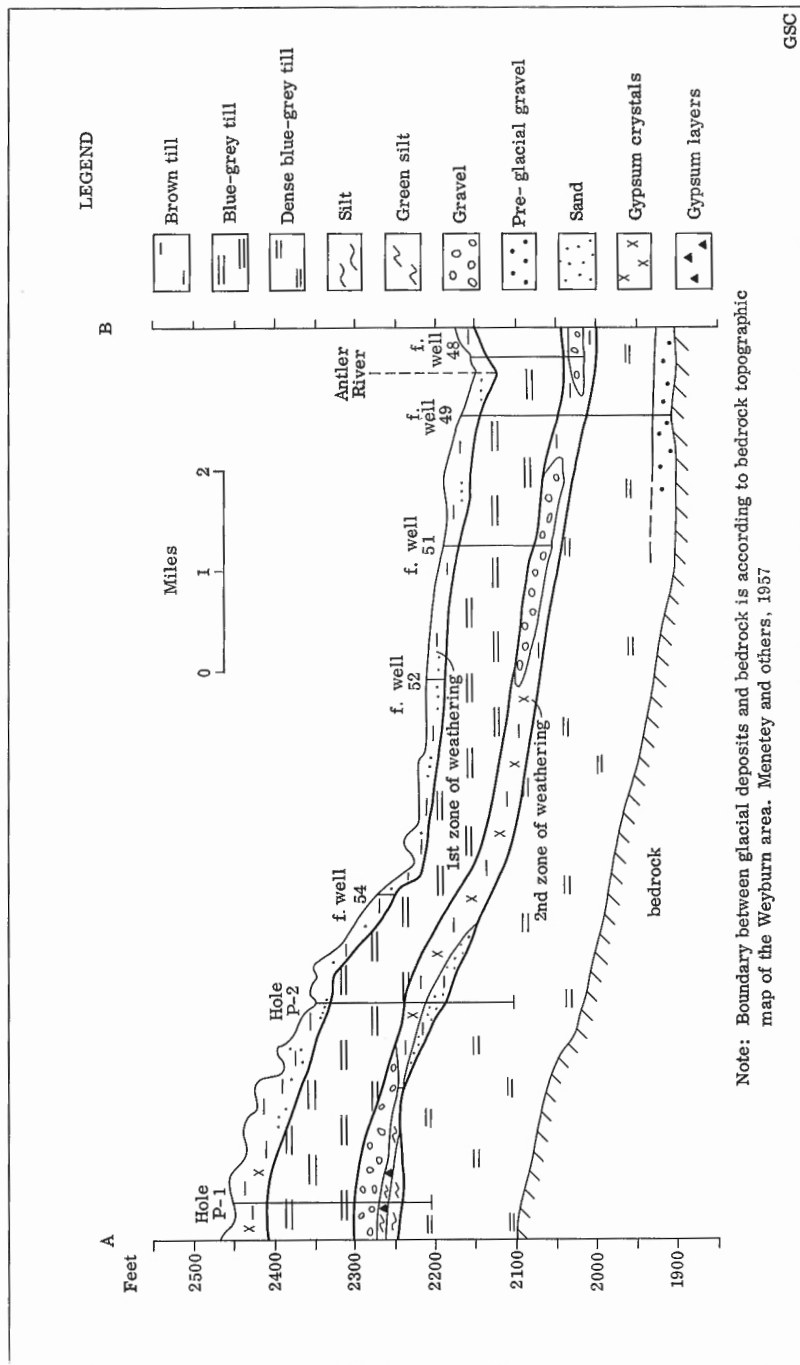
Figure 4. Geological cross-section of eastern Moose Mountain area (see Figure 2 for location of A-B)

described zones are separated by blue-grey till deposits. The distribution and stratigraphic position of these horizons are shown in Figure 4.

The upper zone of weathering is composed of yellow-brown, somewhat sandy, till, with pebbles and a few sand and gravel lenses. There is an increase of sand content towards the lower part of this horizon; gypsum crystals occur throughout. The upper zone of oxidation is underlain by blue-grey till with quartz pebbles, and a few thin lenses of sand.

The second zone of weathering is composed of various deposits. Borehole P-1 disclosed a 47-foot thick layer of gravel, underlain by glacial lake deposits consisting of a 2-foot layer of fine yellow-green sand and 9 feet of stratified silt with gypsum laminae. The continuation of the gravel layer was confirmed by logs of two farm wells, but was not discovered in borehole P-2. The second zone of weathering was represented there by brown sandy till with gypsum crystals. The lake deposits were restricted to borehole P-1.

The lower oxidized zone is underlain by dense blue-grey till with quartz and shale pebbles and a variable content of sand and silt.

The described results may indicate two glacial periods in the Moose Mountain area. Particularly the variation of the structure and the lithological content of the lower till suggest a different origin.

PHYSICAL AND CHEMICAL COMPOSITION OF GLACIAL DEPOSITS

The physical and chemical characteristics of the glacial deposits of Moose Mountain were determined from an analysis of the samples from boreholes P-1 and P-2. The laboratory investigations were carried out in the Geological Survey in Ottawa. The grain size analyses were done by R. A. Kelbe in the Sedimentology Laboratory. The X-ray mineralogical studies were carried out by R. N. Delabio in the Mineralogical Section. The classical chemical analyses of deposits were done by J. L. Bouvier and the spectrographic analysis of the concentration of minor elements by K. A. Church, both of the Chemical Section. The content and distribution of the soluble salts in drift deposits were investigated using the method of sample extraction. The extracts were prepared and analyzed by A. D. Rozkowski in the Geochemical Section. Taking into account the significant rule of soluble salts in the origin of groundwater chemistry, the methods of preparing the extracts as well as the results of chemical analysis of the extracts are described in some detail.

PHYSICAL COMPOSITION

GRAIN SIZE ANALYSIS

The investigated deposits from boreholes P-1 and P-2 include till, a heterogeneous mixture of gravel, sand, silt, and clay, and stratified deposits of gravel, sand, and silt. The respective sizes of these strata vary from about 50 mm to less than 0.001 mm.

For the purpose of defining the grain size characteristic of the individual layers, grain size analyses were done, and the effective size diameter D_{20} (Terzagi and Peck, 1948, p. 21) and the uniformity coefficient U, which equals D_{70}/D_{20} (Pazdro, 1964, p. 98), were calculated. The results
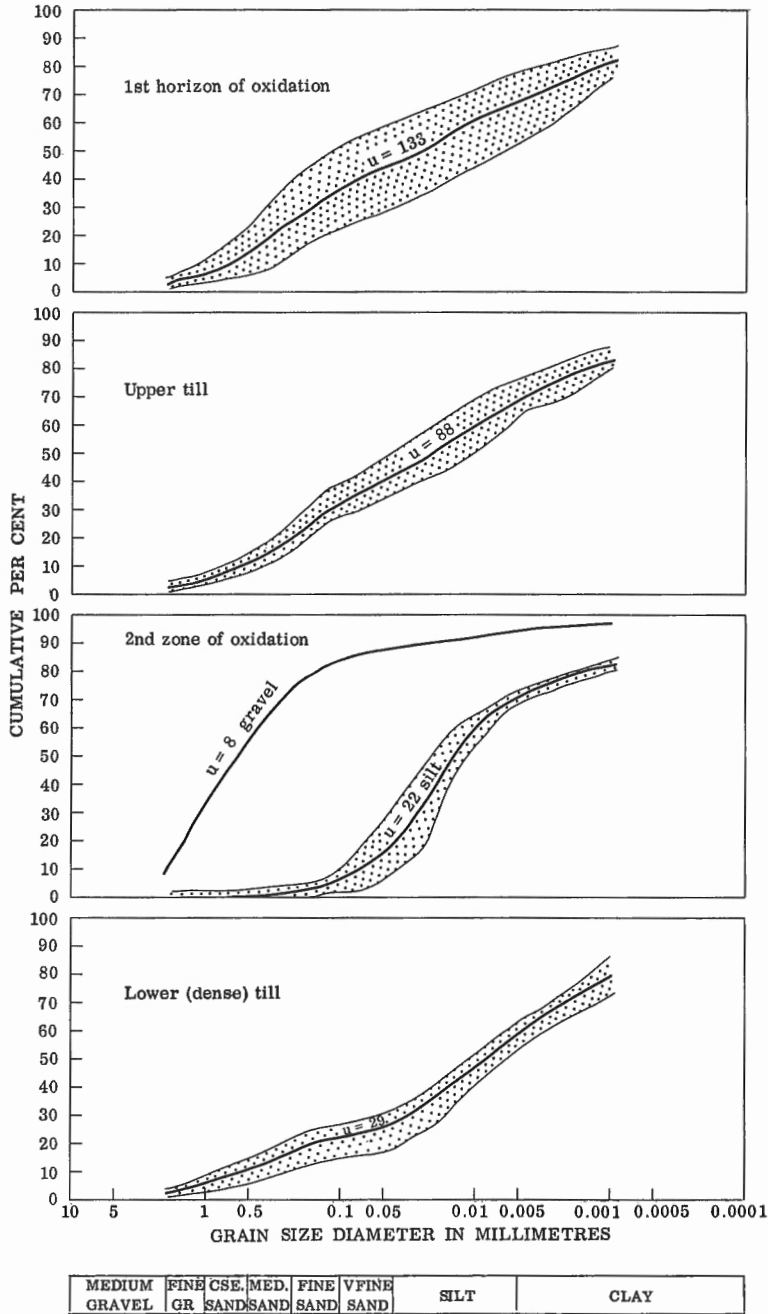
Figure 5. Grain-size distribution and uniformity coefficients (U) of samples from Moose Mountain area. Shading shows the range in grain size of several samples from each layer

Figure 6.   Texture of glacial deposits of the Moose Mountain area

of this analysis are shown on the grain size distribution diagrams (Fig. 5)
and on the texture classification triangle (Fig. 6). The comparison of the
shapes of the grain curves and the coefficient U values, shows that the coars-
est deposits occur in the oxidized zones. The narrow range of effective size
diameters (D_{20}), varying from 0.001-0.0032 mm, for all horizons except
those of the gravel deposits, indicate a significant content of clay fraction in
all investigated sediments. The largest amount of clay (34-45 per cent), was
observed in samples from the lower till, but on the whole, the textures of the
upper and lower till are similar (Fig. 6).

MINERALOGY

The mineralogical investigations were carried out by visual and
X-ray diffraction studies. The examination with a hand lens of the greater
than 1 mm fractions of the drift deposits indicates a predominant content of
quartz pebbles as well as some plagioclase, and dolomite pebbles.
The results of X-ray diffraction studies are shown in Table 2.
These investigations indicate the great mineralogical uniformity in the lith-
ological profile. In order of abundance the dominant minerals are: quartz,
plagioclase, dolomite, calcite and mica. The clay minerals are: montmorill-
onite, illite, kaolinite, chlorite. Quartz commonly exceeds plagioclase in
abundance and dolomite is much more abundant than calcite. The dolomite to
calcite ratio expressed in per cent, varies from 55 to 85. According to
Table 2 the value of this ratio is lowest in the upper part of the first zone of
oxidation as well as in the dense till.
Table 2 shows that the dominate clay mineral in all samples is
montmorillonite. No significant changes were observed in the mineral inter-
relation among the various layers.
Typical for the zone of oxidation is the appearance of visual gypsum
which may have been synsedimentic in the second zone of oxidation in hole
P-1, and probably secondary in the other zones. Its presence was also con-
firmed by X-ray investigations (Table 2). A lack of this mineral was observed
in the sandy deposits of the first zone of oxidation from borehole P-2.

CHEMICAL COMPOSITION

MAJOR CONSTITUENTS

The major constituents of eight representative samples of glacial
deposits collected from boreholes P-1 and P-2 were investigated. The
results of the analysis are shown in Table 3.
Judging from the results of grain size analysis, silica occurs
mainly as quartz, but is included in clay minerals and plagioclases also.
Alumina is included in plagioclase but chiefly in clay minerals. Ferric iron
may occur in feldspar and in hydroxide (Rankama and Sahama, 1950, p. 660),
as well as a primary constituent of clay minerals (Degens, 1965, p. 24). The
water soluble salts of ferrous iron may be present in some clay minerals
(Degens, 1965, p. 24), or in organic material, as well as in pyrite or in sid-
erite. Manganese, according to Rankama and Sahama (1950, p. 647), should

TABLE 2

The results of X-ray diffraction studies of minerals

Sample number	Horizon	Depth (in feet)	Main minerals	Dolomite/calcite ratio (in %)	Gypsum content % of sample weight (estimated)	Relative abundance of clay minerals (in %)		
						montmorillonite	illite	chlorite and kaolinite
	Borehole P-1							
1	1st zone of oxidation	2	quartz, plagioclase, dolomite, calcite, mica, clay minerals	58	not detected	77	14	9
2	" " " "	4		55	"	62	23	15
3	" " " "	10		70	1-1.5	71	16	13
4	" " " "	20		63	0.5	61	17	22
5	" " " "	30		85	0.5	66	24	10
6	blue-grey till	45		80	not detected	64	19	17
7	" " "	80		65	"	74	16	10
8	" " "	120		78	"	72	18	10
9	2nd zone of oxidation	197		80	1-1.5	72	15	13
10	compact blue-grey till	216		60	0.5 (?)	67	17	16
	Borehole P-2							
1	1st zone of oxidation	1	quartz, plagioclase, dolomite, calcite, mica, clay minerals	65	not detected	67	23	10
2	" " "	2		63	"	69	20	11
3	" " "	6		72	"	68	13	19
4	blue-grey till	20		70	"	75	16	9
5	" " "	70		65	"	71	16	13
7	2nd zone of oxidation	122		78	4-5	52	28	20
8	blue-grey till	160		60	<0.5	73	16	11
9	compact blue-grey till	220		58	not detected	69	17	14

TABLE 3

Chemical analyses of glacial deposits (in per cent)

Hole No. / Sample No.	Depth (in feet)	Horizon	SiO$_2$	Al$_2$O$_3$	Fe$_2$O$_3$	FeO	MnO	MgO	CaO	Na$_2$O	K$_2$O	H$_2$O$^-$	H$_2$O$^+$	CO$_2$	P$_2$O$_5$	SO$_3$	S	C	Cl	O S,Cl	Total
I/3	10	1st zone of oxidation	57.02	8.12	2.77	0.29	0.14	4.20	9.14	0.78	1.50	1.51	3.23	10.16	0.17	0.003	0.02	0.17			99.61
I/5	30	"	56.79	8.23	2.73	0.37	0.08	4.23	9.49	0.83	1.52	1.59	3.11	10.24	0.11	0.26	0.04	0.24		0.01	100.24
I/7	80	uncompact till	54.99	7.29	1.87	2.19	0.44	4.08	9.91	0.84	1.35	1.24	2.46	11.88	0.13	0.08	0.32	0.48		0.14	99.75
I/9	197	2nd zone of oxidation	52.11	9.37	0.01	3.42	0.11	3.84	8.88	0.54	1.68	3.84	4.14	7.76	0.11	3.12	0.05	0.35		0.02	99.81
I/10	216	compact till	61.47	11.12	2.00	1.10	0.08	2.76	5.47	0.76	1.73	2.71	3.93	5.60	0.11	0.12	0.62	0.36		0.27	100.18
II/2	2	1st zone of oxidation	58.99	8.74	1.46	0.89	0.05	3.18	9.46	1.33	1.86	0.84	2.48	9.04	0.10	0.02	0.01	0.63	0.03	0.01	99.42
II/5	70	uncompact till	61.69	7.52	1.71	0.69	0.09	4.43	7.96	1.20	1.62	0.90	2.38	8.44	0.11	0.05	0.18	0.17		0.08	99.42
II/7	122	2nd zone of oxidation	51.49	8.40	1.77	0.33	0.10	3.35	11.70	0.89	1.37	1.97	2.55	11.56	0.10	2.17	0.00	2.45	0.04	0.01	100.56

occur mainly in the described sediments as soluble bicarbonate and sulphate form and in the zone of weathering as manganic oxides and hydroxides. It is also present in clay minerals.

The main sources of calcium and magnesium are calcite and dolomite. These minerals also occur in clay structure as well as some small amount of calcium in plagioclase. Sodium and potassium occur chiefly in the structure of clay minerals. Phosphorus, taking into account its equal distribution, is probably adsorbed by clay minerals, but it is possible that the studied deposits include a small amount of apatite also. Sulphur occurs mainly in calcium sulphates in the zones of weathering and in a small amount as sulphides.

Organic matter is represented by organic carbon. Chlorine, analyzed in two samples only, is of uncertain origin. Probably it is included in feldspar or apatite or in clay minerals.

The distribution of the major constituents in the selected samples is shown in Table 3. The amount of silica varies from 52 to 61 per cent. More than the average amount of alumina oxide is observed in the lower till. Ferric iron is irregularly distributed. Its occurrence in the selected samples is in part in accordance with the degree of oxidation and in part with the clay mineral content. The distribution of ferrous iron is also uneven. The equilibrium between the ferrous and ferric iron content is probably in accordance with the degree of oxidation. A high content of the one goes with a low content of the other.

The content of manganese oxide in the described samples is uniform except for the 80-foot sample from hole No. 1. Both salts of manganese and iron are positively correlated with pH. High pH would favour oxidation and accumulation in insoluble form, low pH would favour solubility and removal (Presant, in press). The magnesium oxide distribution is not uniform. A significant decrease of this component is observed in the lower till. Calcium oxide varies from 5 to nearly 12 per cent. The higher percentages seem to be partly related to the appearance of secondary carbonate and sulphate salts in the zone of oxidation. A sharp decrease of calcium oxide is observed in the lower till.

The potassium oxide content is higher than sodium oxide. According to Grim (1953, p. 146), the differences in the distribution of these constituents are the result of weathering processes. During these, the sodium ions are more easily displaced from the clay structure than potassium ions.

Sulphates are most concentrated in the zones of weathering, particularly in the lower one. This constituent is included mainly in gypsum. The distribution of insoluble sulphides is closely related to the degree of oxidation.

The amount of organic carbon is uniform throughout the section with the exception of second zone of oxidation in hole P-2. Carbon dioxide, the indicator of carbonate content of the samples, varies from 5 to 12 per cent. The lowest concentration is in the lower till and a slight increase along the horizontal profile is observed, probably because of the presence of secondary calcium carbonates.

The results of X-ray analyses are too general and it is impossible to calculate from the chemical analyses all the main mineralogical components of the investigated samples. Therefore only the calcium and magnesium carbonates and calcium sulphate were calculated. The results of these calculations are shown in Table 4.

TABLE 4

Calculated mineralogical composition (in per cent)
(see: Table 3 for original analyses)

Hole No. Sample No.	Horizon	Depth (feet)	Gypsum	Dolomite	Calcite
P-1/1	1st zone of oxidation	10	0.006	17.60	4.04
P-1/3	1st zone of oxidation	30	0.56	19.32	2.36
P-1/5	upper blue till	80	0.17	18.63	6.83
P-1/7	2nd zone of oxidation	197	6.70	14.47	1.95
P-1/9	lower blue till	216	0.26	8.82	3.18
P-2/1	1st zone of oxidation	2	0.04	14.24	5.13
P-2/3	upper blue till	70	0.11	13.94	4.09
P-2/5	2nd zone of oxidation	122	4.67	15.29	9.71

MINOR ELEMENTS

The presence of minor elements in the samples was investigated by semiquantitative spectrographic analysis and, in the case of titanium, by chemical analysis. The results of these examinations are shown in Table 5.

Adsorption reaction seems to have been an important process affecting the accumulation of strontium and especially barium in clay minerals. Strontium and barium occur as soluble salts, mainly as bicarbonates, partly as sulphates and chlorides. The local increase of these elements in the first zone of oxidation can be explained by the precipitation of strontium and barium carbonates from solution through loss of carbon dioxide.

Chromium and zirconium are mainly adsorbed by exchange activity of clay minerals (Rankama and Sahama, 1955), which explains their increase in the lower till. The local increase in the zone of weathering may be related to the enrichment of these elements in the resistates. Very little chromium and zirconium can occur in solution.

Nickel was found in two samples only and therefore it is not a good indicator for the investigated deposits. Copper can be dissolved as sulphate and carbonate. The recent investigations of Presant (in press) show that this element is very sensitive to pH changes. Increasing acidity involved the removal of copper. According to Tourtelot's classification (1962, p. 46), the changes of copper concentration in the described samples can be explained by adsorption or by substitution in oxides, sulphides and organic material, as well as by precipitation as sulphides.

The uniform distribution of titanium is in accordance with its presence in the structure of clay minerals. Water soluble zinc is mainly present as zinc sulphate. Changes in its concentration are affected by adsorption reaction. Lead is rather uniformly distributed in the profile of glacial deposits (Table 5). The increase of this element in the zone of weathering is probably related to the variable acidity of the environment. Lead and silver

TABLE 5

Minor elements of glacial deposits

Hole No. Sample No.	Depth (in feet)	Horizon	Elements in per cent*						Elements in ppm**			
			Sr	Ba	Cr	Zr	Ni	Cu	Tl	Zn	Pb	Ag
I/1	2	1st zone of oxidation	.014	.048	.0029	.0069	N.F.	.0035		57	13	.14
I/2	4	"	.017	.047	.0060	.010	"	.0028		60	12	.15
I/3	10	"	.015	.045	.0048	.0080	"	.0023	.234	63	12	.21
I/4	19.8	"	.016	.041	N.F.	.011	"	.0023		46	7.2	.22
I/5	30	"	.018	.041	"	.0084	"	.0028	.234	64	21	.17
I/6	45	uncompact blue till	.015	.047	"	.010	"	.0037		63	11	.17
I/7	80	"	.015	.047	.0029	.0060	"	.0033		61	11	.20
I/8	120	"	.015	.054	<.002	.0046	<.002	.0058	.204	61	11	.16
I/9	197	2nd zone of oxidation	.015	.058	.0031	.0065	.0066	.0025	.300	87	13	.19
I/10	216	compact blue till	.015	.054	.0084	.012	N.F.	.0027	.306	100	11	.16
II/1	1	1st zone of oxidation	.016	.042	.0045	.0095	N.F.	.0023		25	10	.18
II/2	2	"	.017	.051	.0037	.011	"	.0021	.192	37	10	.12
II/3	6	"	.017	.057	.0049	.0095	"	.0038		56	11	.13
II/4	20	uncompact blue till	.016	.053	.0025	.0084	"	.0027		46	10	.14
II/5	70	"	.017	.057	<.002	.0054	"	.0015	.216	47	10	.15
II/7	122	2nd zone of oxidation	.015	.035	<.002	.0049	"	.0019	.198	43	8	.14
II/8	160	uncompact blue till	.017	.035	.0054	.0081	"	.0034		62	10	.14
II/9	220	compact blue till	.015	.047	.0063	.015	"	.0025		65	11	.16

* for Tl determination, conventional chemical analysis was used; the remaining elements determinations were made by spectrographic technique QN9A method.

** determined by spectrographic technique QN8 method.

(which was found in a very small amount only) are well correlated with pH (Presant, in press). These elements show greater mobility with greater acidity.

EXTRACTS OF SOIL AND GLACIAL DEPOSITS

METHODS OF PREPARING AND ANALYZING OF EXTRACTS

Extracts were prepared in accordance with the methods developed by Jackson (1958), Oradowskaja (1957), and Richards (1954). The preparation of the samples for extraction was as follows: one pound weight of sample was dried at room temperature, then crushed and screened through a standard sieve with 0.5 mm openings. The representative subsample was stored in a polyethylene bottle. For the moisture content determination, a representative sample of about 5 g was weighed, dried to constant weight at 105°C, and then weighed again.

Water Extracts

For the purpose of determining the maximum amount of soluble salts, two successive water extracts with a ratio of water to sample of 100:1 were made. The representative sample of 2 g weight was shaken with 200 ml distilled water for one hour. After shaking, the extracts were left for 24 hours and then filtered into a 250 ml volumetric flask. After drying the remainder of the sample, the second extract was prepared in the same fashion.

Ammonium Acetate Extracts

To determinate the amount of exchangeable cations, ammonium acetate extracts were prepared according to Richard's (1954, p. 101) method of extraction. A 2 g sample was shaken three times with 20 ml 1 N ammonium acetate, then centrifuged and filtered. The final volume of the extract was 100 ml of solution. For the ammonium acetate extracts samples after water extraction were used.

Acid Extracts

An acid extraction was made to determinate the content of moderately and poorly soluble salts. Two-tenth N HCl solution was used for extraction to avoid a decomposition of clay minerals. 2 g sample was mixed with 80 ml 0.2 N HCl and allowed to stand overnight. Then it was centrifuged, rinsed with 0.2 N HCl solution a few times (until sulphate ions disappeared), and filtered through 0.45 micron filter into a 200 ml volumetric flask. Acid extracts from the air-dry samples were made and on a parallel line from the samples after water and ammonium acetate extraction.

Chemical analysis of extracts

For the determination of calcium and magnesium a Perkin and Elmer Model 303 Atomic Absorption Spectrometer with an air-acetylene flame was used. To avoid interferences the calcium was analysed in 1 per cent strontium solution; magnesium was analysed in 1500 ppm strontium solution. Sodium and potassium were determinated by using a Perkin and Elmer Model 146 flame photometer with an air-propane flame.

According to Thomas and Lynch (1960, pp. 259-267) alkalinity was determined by the use of a pH-meter for the indication of the true equivalent point pH for dissociation of the bicarbonate ion to carbonic acid.

For the sulphates determination the turbidimetric method was used, and for the chlorides determination the Mohr method, according to the standard methods for the examination of water and sewage (Anon, 1960).

DISCUSSION OF RESULTS

Water Extracts

According to Oradowskaja (1957, p. 116) easily, moderately and poorly soluble salts are dissolved in water extracts. In conformity with the mineralogical investigations and the chemical analyses of rocks presented in this report, as well as the author's previous investigations (A. Rozkowski, 1966), poorly soluble salts are represented by calcite and dolomite, moderately soluble salts by gypsum, and easily soluble salts by hexahydrate, epsomite, langbeinite, mirabilite, thenardite, halite.

The results of the chemical analysis of the water extracts, recalculated for dry rock in ppm, are presented in Table 6. Table 6 also shows the qualitative and quantitative calculations of the hypothetical salts. The changes of concentration of the ions of the main soluble salts: CO_3^{2-}, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+, in the samples collected at the different depths are shown in Figures 7 and 8. These diagrams present the interpretation of the chemical analyses of water extracts.

Figure 7 shows the litho-chemical profile from borehole No. P-1, located in the upper part of the Moose Mountain hills (Fig. 1). The first horizon of oxidation, which is only a few feet thick and which is made up of sandy till, shows a low concentration of all ions. It is a characteristic zone of leaching. Below the water table there is an increase of salts. It is a typical phenomenon of enrichment of the poorly permeable zone of oxidation by soluble salts. These are, according to the calculation of the content of hypothetical salts (Table 6), mainly calcium and magnesium carbonates as well as calcium sulphate and magnesium sulphate. Easily soluble salts of sodium and potassium are present in small amounts. The dominant salts in the upper blue till are carbonate salts, followed by magnesium sulphates and sodium and potassium sulphates. The presence of calcium sulphates has not been confirmed there. The change of chemistry in the second zone of oxidation is well shown by the chemistry of the silt layer which underlies the gravel deposits. There the distribution and salts content is very similar to that described in the first zone of oxidation. The differences are in the increase of sodium and potassium sulphate salts. The lower, denser, blue till shows

TABLE 6

Chemical analyses of water extracts in ppm of absolutely dry rock*

Hole No. / Sample No.	Depth (in feet)	Moisture content (%)	Ca··	Mg··	Na·	K·	CO₃⁼	SO₄⁼	Cl⁻	Hypothetical salts**						
										KCl+NaCl	K₂SO₄+Na₂SO₄	MgSO₄	CaSO₄	K₂CO₃+Na₂CO₃	MgCO₃	CaCO₃
I/1	2	2.30	1854	243	73	188	3022	307	0	0	538.7	0	0	67.8	825.2	4577.8
I/2	4	2.16	1515	252	92	172	3290	179	0	0	323.2	0	0	278.5	884.3	4092.1
I/3	10	2.77	3182	491	111	235	2820	5040	0	0	844.6	2375.8	3912.1	0	0	4869.9
I/4	19.8	2.16	2715	363	91	333	2519	4216	0	0	1006.7	1768.2	3278.3	0	0	4271.0
I/5	30	2.47	3653	522	123	315	2335	6611	0	0	1004.8	2499.2	5896.9	0	0	4528.1
I/6	45	2.03	1818	290	152	320	2922	1378	0	0	1099.9	905.9	0	0	354.7	4488.6
I/7	80	1.68	2263	275	151	322	2900	1526	0	0	1191.2	1048.9	0	0	198.3	4682.4
I/8	120	1.63	1843	277	151	283	3138	1067	0	0	979.2	519.7	0	0	589.6	4572.0
I/9	197	3.61	6127	651	398	441	2654	14070	0	0	2187.7	3192.8	14573.6	0	0	4458.5
I/10	216	3.21	5011	572	535	457	2794	9854	0	0	2606.2	2759.8	8878.8	0	0	4782.3
II/1	1	1.45	1364	476	96	299	3057	431	123	265.1	630.4	60.9	0	0	1572.8	3332.1
II/2	2	1.71	1484	554	97	338	3065	432	99	227.6	812.2	45.8	0	0	1737.2	3442.6
II/3	6	1.97	1301	500	228	287	3008	383	0	0	715.3	0	0	399.1	1618.1	3037.3
II/4	20	1.53	1714	343	212	282	2945	1066	0	0	1239.0	435.4	0	0	840.4	4110.4
II/5	70	1.27	1709	227	206	305	2937	937	0	0	1301.5	189.9	0	0	645.7	4207.2
II/6	100	1.22	2341	300	256	215	3076	633	0	0	1071.8	68.3	0	0	826.3	4939.1
II/7	122	2.24	9494	627	321	272	2337	22587	0	0	1602.2	3109.7	27007.5	0	0	3887.1
II/8	160	1.38	1901	226	488	283	2925	1990	0	0	2104.0	831.5	0	0	197.7	4699.9
II/9	220	2.72	1895	233	902	419	3154	1349	0	0	2285.9	0	0	864.8	753.0	4398.4
II/10	250	2.57	2117	239	793	398	2587	1886	0	0	2826.4	440.1	0	0	395.2	4494.3

* combined results of two successive water extracts.

** for the hypothetical salts calculation the error between cations and anions was distributed proportionately.
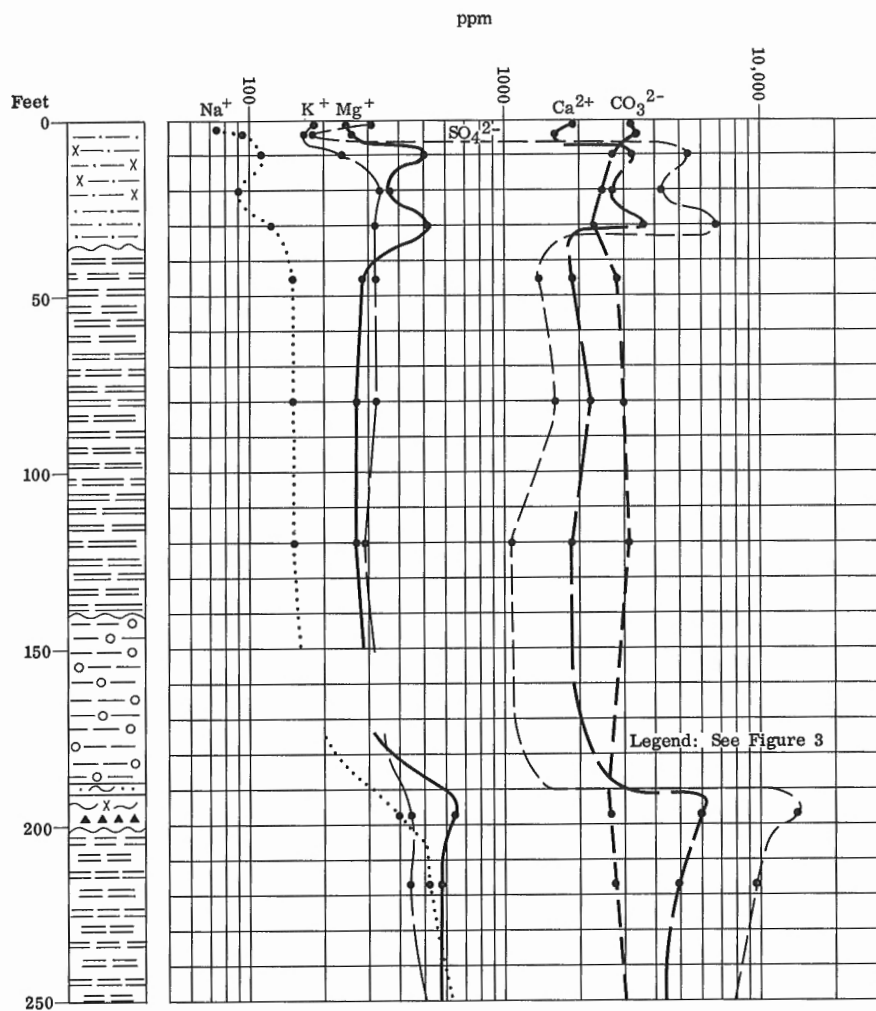
Figure 7.   Ion concentration in water extracts in ppm in absolutely dry rock
at Borehole P-1
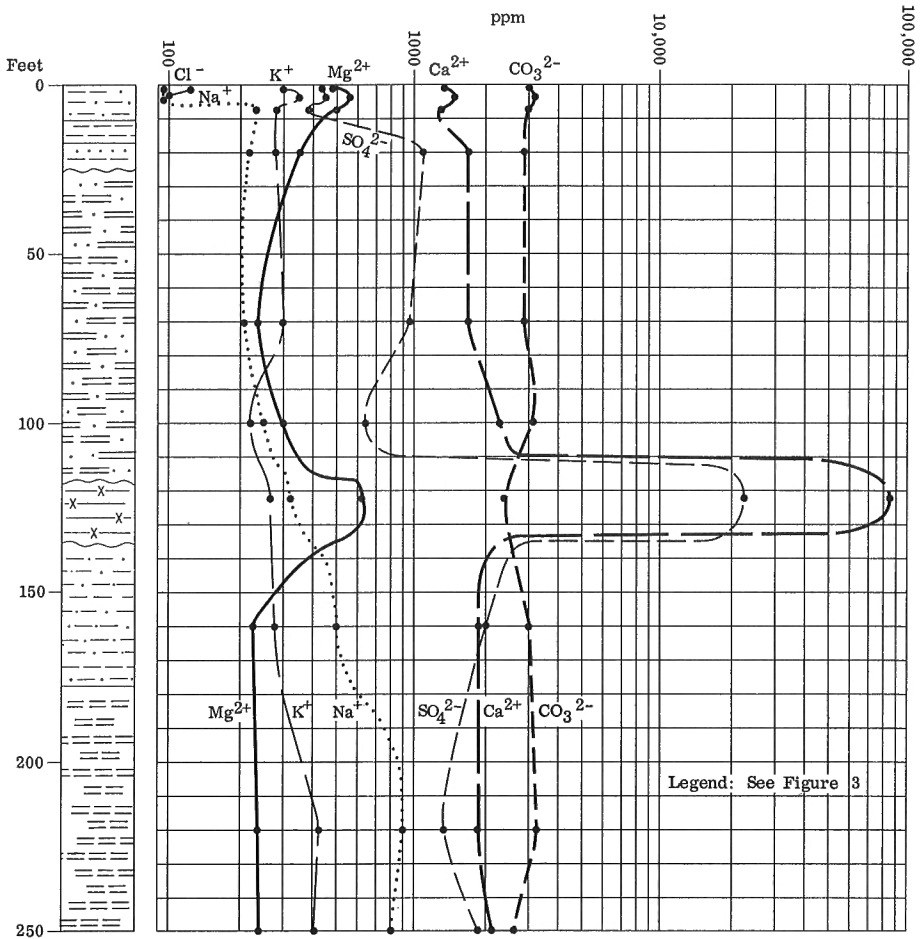
Figure 8. Ion concentration in water extracts in ppm in absolutely dry rock at Borehole P-2

a second decrease of soluble salts, particularly with respect to calcium sulphate. Lack of chloride salts is characteristic of all investigated samples.

The litho-chemical profile from borehole No. P-2 is shown in Figure 8. The borehole was located in the lower part of the area. The first horizon of oxidation is made up of sandy till and sand, therefore the total concentration of soluble salts is not high (Table 6). The zone of the leaching is at a depth of about 5 feet. Below the zone of concentration appeared what is probably the C horizon of the soil profile. The first oxidation zone contains mainly carbonates. The upper blue till shows the enrichment of soluble salts, particularly carbonates. The sulphates content, represented mainly by sodium sulphates, is significantly increased. The second zone of oxidation shows a spectacular enrichment of salts. It is characterized by an increase of sulphates, particularly calcium sulphate, and a slight decrease of carbonate salts. The lowest horizon of the dense blue till indicates, in comparison with the upper horizon of uncompacted till, an increase of soluble salts.

If we compare the litho-chemical profiles of holes P-1 and P-2 (Figs. 7 and 8) it can be said first of all that the different amounts of soluble salts in the first zone of oxidation depend on the differences in lithology. The common characteristic of the samples of both the boreholes is a stable content of carbonates, a very high concentration of calcium sulphates in the zones of

oxidation, and the absence or small amount of these salts in the other zones. The next most common factors are the absence of chloride salts and the significant increase of sodium sulphates toward the bottom of both sections. The concentration of both magnesium sulphates and calcium sulphates increases in the zones of weathering.

Ammonium Acetate Successive Extracts

The results of the ammonium acetate extracts are shown in Table 8. These data show the concentrations in the extracts of the following cations: Ca^{2+}, Mg^{2+}, Na^+, K^+, which were <u>exchanged</u> by ammonium ions. It seems that the variation in the adsorbed ion concentrations and the changes of their interrelation in the upper horizon of the first zone of oxidation are determined by the local differentiation of water mineralization and the alkalinity of the environment. The values of these factors vary at different points of the groundwater flow of the shallow groundwater system. On the other hand, the results of the studies of alkalinity and temperature of the environment, as well as the mineralization of water of deeper horizons, which will be presented in the following chapters, generally show the insignificant numerical changes of these factors. The slight increase of the adsorbed ions concentration of the deeper horizons would therefore be explained better by the increase of the content of clay minerals.

Acid Extracts

The purpose of the acid extracts was to present the total content and distribution of the cations of the carbonate minerals. The results of the chemical analysis of acid extracts are shown in Table 8. These extracts were made from the fresh sample as well as from the sample after its successive extraction by water and ammonium acetate solution. Both methods for the preparation of acid extracts were used for the purpose of confirming the results. The data obtained by both methods, according to the calcium and magnesium concentration, after subtraction from the results of the analysis of the fresh sample the concentration of cations from the water and ammonium acetate extracts, are comparable. The differences between the concentration of calcium and magnesium ions are a few per cent only. On the other hand some differences exist in the content of sodium and potassium ions involved in adsorption processes.

According to the results presented in Table 8 there is a decrease of magnesium and calcium concentration in the deeper horizons of the investigated deposits, which confirmed a diminishing of the content of calcite and dolomite minerals. On the other hand the increased concentration of sodium and potassium in the same direction can be explained by the rise of clay minerals content in the lower horizons. Table 9 presents the comparison of the concentration of cations in the water, ammonium acetate, and acid extracts. These data show an insignificant concentration of calcium and magnesium ions in water extracts, some increase of their concentration in ammonium acetate extracts, and dominant content in acid extracts. These figures indicate that only an insignificant amount of calcium and magnesium ions is included in the

TABLE 7

Chemical analyses of ammonium acetate extract
Ratio: extraction 1:30 (2g sample +60ml IN CH_3CONH_4)
final volume 1:50 (2g sample/100ml IN CH_3CONH_4)

Hole No. / Sample No.	Depth (in feet)	Moisture content (%)	Ca·· (ppm)			Mg·· (ppm)			Na· (ppm)			K· (ppm)		
			1	2	3	1	2	3	1	2	3	1	2	3
I/4	19.8	2.16	258.7	12935	13239	3.59	179.5	183	1.08	54	55	4.5	225	230
I/7	80	1.68	247.5	12375	12586	3.48	174	177	1.08	54	55	5.0	250	254
I/9	197	3.61	245.0	12250	12709	4.60	230	239	1.35	67.5	70	6.72	336	349
I/10	216	3.21	245.0	12250	12656	4.33	216.5	224	1.48	74	76	7.85	392.5	406
II/3	6	1.97	227.5	11375	11604	4.53	226.5	231	1.12	56	57	3.6	180	184
II/5	70	1.27	220.0	11000	11142	2.70	135	137	0.82	41	42	3.05	152.5	154
II/7	122	2.24	231.25	16562.5	16942	2.15	107.5	110	0.95	47.5	49	3.58	179	183
II/10	250	2.57	216.25	10812.5	11098	2.95	147.5	151	1.58	74	76	7.0	350	359

Remarks: 1 - in extract
2 - in rock
3 - in absolutely dry rock

TABLE 8

Chemical analyses of acid extracts (in ppm of absolutely dry rock)

Ratio: extraction 1:40 (2g sample + 80ml 0.2N HCl)
final volume 1:100 (2g sample/200ml 0.2N HCl)

Hole No. / Sample No.	$Ca^{..}$		$Mg^{..}$		$Na^{.}$		$K^{.}$		$SO_4^{=}$	
	1	2	1	2	1	2	1	2	1	2
I/4	66435	49060	19726	18908	327	155	450	138	4293	143
I/7	76790	62805	23698	22935	386	171	460	132	1474	559
I/9	50316	31642	16132	14991	482	99	604	158	16184	124
I/10	38744	22730	10332	9402	608	90	620	167	9867	578
II/3	57890	42334	17750	16781	326	111	390	133	428	122
II/5	60772	46085	18434	17928	297	114	395	129	962	263
II/7	79480	55237	21992	21328	445	147	430	115	24805	20
II/10	41055	26173	10264	9237	887	106	556	166	2166	667

Remarks: 1 - the results of acid extract from fresh sample.
2 - the results of successive acid extract.

TABLE 9

The comparison of the cation concentrations of the successive extracts
(in ppm of absolutely dry rock)

Hole No. / Sample No.	Ca··			Mg··			Na·			K·		
	1	2	3	1	2	3	1	2	3	1	2	3
I/4	2715	13239	49060	363	183	18908	91	55	155	333	230	138
I/7	2263	12586	62805	275	177	22935	151	55	171	322	254	132
I/9	6127	12709	31642	651	239	14991	398	70	99	441	349	158
I/10	5011	12656	22730	572	224	9402	535	76	90	457	406	167
II/3	1301	11604	42334	500	231	16781	228	57	111	287	184	133
II/5	1709	11142	46085	227	137	17928	206	42	114	305	154	129
II/7	9494	16942	55237	627	110	21328	321	49	147	272	183	115
II/10	2117	11098	26173	239	151	9237	793	76	106	398	359	166

Remarks: 1 – water extracts
2 – ammonium acetate extract
3 – hydrochloric acid extract

secondary carbonate salts or is adsorbed by clay minerals. Described cations are mainly the constituents of primary calcite and dolomite minerals. The distribution of sodium and potassium shows a different trend. The higher concentration of these cations observed in water and ammonium acetate extracts indicates that the concentration of the described ions is ruled mainly by the processes of ion adsorption and ion exchange.

HYDROLOGY AND HYDROCHEMISTRY

HYDROLOGICAL INVESTIGATIONS IN THE MOOSE MOUNTAIN AREA

The first results of hydrological investigations of the described area were published by MacKay et al. (1936a, b, c, d). The purpose of these investigations was to study the water-bearing horizons for agricultural needs. They presented the lithological profiles of the glacial deposits and gave the characteristics of the water horizons of the glacial deposits and shallow bedrock. The general characteristics of the larger lakes of the Moose Mountain area was given by Rawson and Moore (1944) in their paper about saline lakes of Saskatchewan. Christiansen (1956), in his work on the glacial deposits of the Moose Mountain area, gave only general remarks about groundwater in these strata. He indicated the influence of topography and texture of the glacial deposits on the groundwater supply as well as the importance of the outwash plains, eskers, and kames as aquifers.

The groundwater flow in the glacial deposits of the described area was investigated by Meyboom (1967), who installed a piezometer cross-section through the eastern part of Moose Mountain. These studies of the seepage and evaporation of sloughs gave further indications about the position of these reservoirs in the hydrologic regime of the area under consideration.

Rutherford (1966) in his studies of the tritium concentration in the Saskatchewan waters obtained interesting hydrogeological results. The south and north parts of the Moose Mountain area were included in these investigations. The purpose of Rutherford's study was "to obtain a regional picture of the groundwater flow from tritium concentration gradients". The data presented by Rutherford gave further information about the conditions of groundwater flow in the till and bedrock strata of Moose Mountain.

Detailed hydrochemical investigations of the described area were carried out by the author of this paper. The suggestions about the origin and development of the surface and groundwater chemistry as well as the sketch of the distribution of the surface water mineralization were presented in a preliminary hydrochemical description of the Moose Mountain area (A. Rozkowski, 1966). The origin and development of the chemistry of the local groundwater system, based on the results of the detailed field and laboratory studies of a small basin in a hummocky moraine, has been explained (A. Rozkowski, 1967). The results of the regional investigations of the groundwater chemistry of the Moose Mountain area will be presented in this paper.

THE OCCURRENCE AND MOVEMENT OF GROUNDWATER

GENERAL STATEMENT

On the whole, the glacial deposits of the area are poorly permeable. The results of earlier hydrogeological investigations allow us to distinguish two hydrogeological complexes with somewhat higher permeability.

The first complex is represented by the sandy, oxidized till in the zone of weathering and sometimes, especially in the north part of the area, by the upper part of the uncompacted blue-grey till with pebbles. The thickness of this unit varies from a few to 50 feet. This complex includes the small local outwash channels filled up with permeable gravel and sand. In the area of the Glacial Lake Arcola (Fig. 2) the first complex is also represented by a layer of fine sand. It occurs at the depth of 20 to 40 feet and is covered by blue clay. The aquifers of the first complex may be both 'unconfined' and 'confined'. They supply the farms with a small amount of water.

The second complex was observed in the sandy till or in the sand gravel layer between the upper and lower, blue till. These are the deposits of the second zone of weathering which was detected in boreholes P-1 and P-2 (Fig. 4). The depth to this complex varies usually from 100 to 150 feet with a tendency to increase in the direction of the top of the hills.

The sand and gravel layers of 'preglacial' deposits may be considered as a third complex of higher permeability. It is a typical 'artesian' aquifer, limited to the outwash forms of the bedrock surface, which can be in hydraulic interrelation with the bedrock water-bearing strata.

PERMEABILITY OF GLACIAL DEPOSITS

The studies of permeability were based on visual field observations, laboratory grain size analysis of the samples from boreholes P-1 and P-2, and on the results of two pumping tests. On account of the limited sphere of investigations, only very general suggestions can be made. The results of the laboratory studies, shown in Table 10, indicate generally the low permeability of the described deposits as well as their regional and vertical variation. For instance some gravel lenses indicate a very high specific permeability about $K_s = 200$ gpd/ft (Table 10). The area which is characterized by higher permeability, is shown on Figure 2. It comprises the southeastern part of Moose Mountain. The strata of the first zone of weathering and in part the blue-till horizon, consist of the more porous sandy till with boulders and sand or gravel lenses. The lateral increase of permeability takes place at the depth of the appearance of the main water-bearing horizons described earlier.

GROUNDWATER FLOW

The studies of the groundwater flow which were carried out (Meyboom, 1967) explain the conditions of the groundwater circulation in the glacial deposits. They also point out the hydraulic connection between the surface and groundwater. Meyboom distinguished three types of flow systems:

TABLE 10

Permeability of glacial deposits

Borehole	Zone	Layer	Depth (in feet)	Field measurements Specific permeability "K_s" (inches/hr.)	Laboratory measurements coefficient of permeability "K" (inches/hr.)
Well 7	I zone of weathering	sand	16	8.69	
P-1	"	till sandy	5		3.9×10^{-2}
P-2	"	till sandy	18		4.5×10^{-2}
Well 9 (Kenosee L.)	blue till	sand and gravel	83	15.8	
P-2	"	till sandy	50		3.1×10^{-2}
P-2	"	"	80		3.2×10^{-2}
P-1	2nd zone of weathering	gravel and silt	147		1.9
P-1	"	silt	188		0.1
P-1	"	silt	192		0.31
P-1	blue compact till	till sandy	215		2.1×10^{-2}

local, intermediate and regional flow (Fig. 9). Groundwater flow in humm-
ocky moraine of the prairie is determined by the topography of the area
(Meyboom, 1966; Toth, 1962). Recharge of the local flow takes place under-
neath the knobs, and discharge into the kettles. Superimposed on these
effects of local topography is the effect of the regional topographic configura-
tion which gives rise to intermediate and regional groundwater flow systems.
The permanent sloughs and lakes, which are located in the kettles of humm-
ocky moraine, are the areas of discharge of groundwater. Field meas-
urements made by Meyboom (1967) indicated that the local and intermediate
flow systems are restricted to the upper part of the glacial deposits of the
considered area. According to the subdivision presented in the previous sec-
tion, these flows exist in the first hydrogeological complex which consists of
the first zone of weathering and the upper part of the uncompact blue till.
The regional flow takes place in the permeable strata of the second zone of
weathering (second complex), and in the 'preglacial' drift deposits, which are
in hydraulic connection with the bedrock aquifer (third complex). The main

LEGEND

▓ Region of local groundwater flow system

▒ Region of intermediate groundwater flow system

░ Region of regional groundwater flow system

→ Direction of groundwater movement

- - - - Boundary between flow systems of different magnitude

Vertical exaggeration of scale, 100 times (approx.)
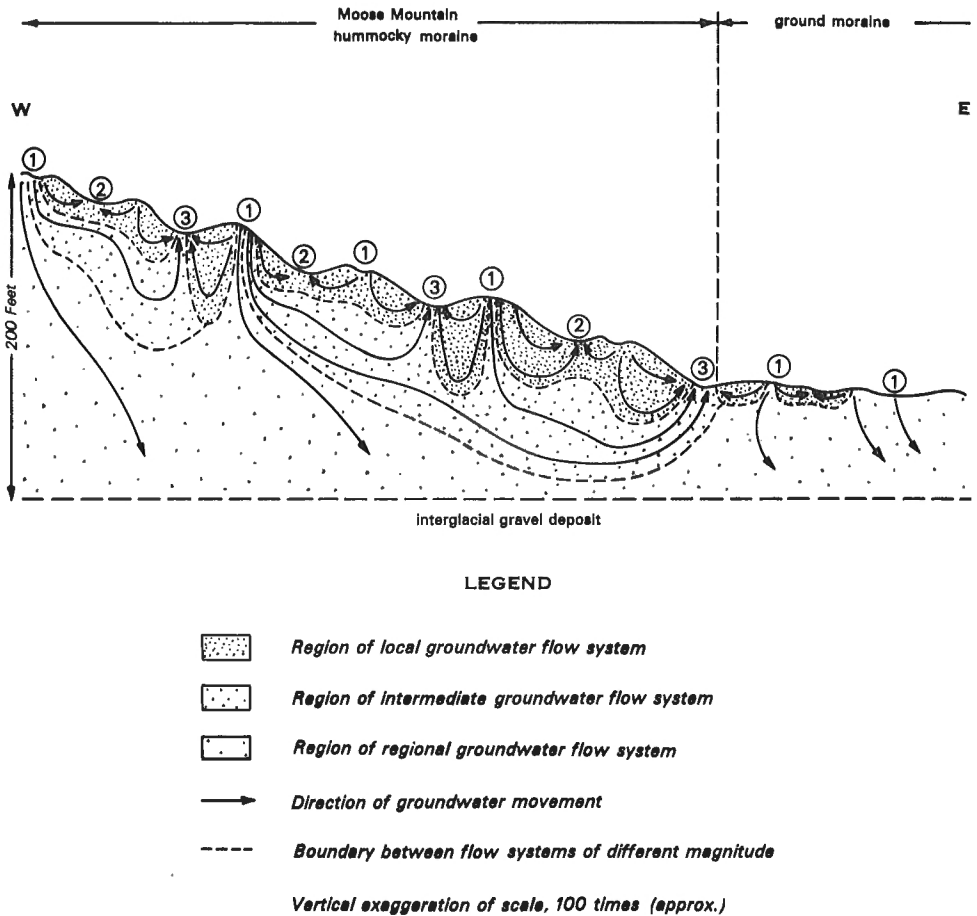
Figure 9. The flow systems of Moose Mountain (after Meyboom, 1967)

recharge area for the regional flow seems to be mainly in the southeast part of the Moose Mountain area, where deep outwash deposits exist.

The discharge areas for the local and intermediate groundwater flow systems (Fig. 9), are sloughs and lakes of the Moose Mountain area. The larger lakes, especially Kenosee and Carlyle Lakes, are discharge areas of both local and intermediate flow systems, which appear in the more permeable part of the stratigraphic column.

The results of the tritium examinations, carried out by Rutherford (1966), confirm this picture. The significant differentiation of the values of the tritium units in the upper part of glacial deposits indicates clearly the areas of recharge as well as discharge of the local and intermediate ground-water flow system. The low, slightly changing values of the tritium units in the groundwater of the lower part of the glacial deposits and in the Ravenscrag strata are characteristic of the regional flow.

GROUNDWATER CHEMISTRY

SAMPLING AND ANALYTICAL PROCEDURE

The study of the chemistry of groundwater of Moose Mountain is based on the results of the analyses of 132 selected samples of water (Appendix I). Most were collected from farm wells, some from the observation wells and a few from springs. Most of the samples (111) represent water from the upper groundwater complex. The second hydrogeological complex is represented by 16 samples, whereas 6 samples were collected from the third complex. A few of these are from outside the investigated area.

The location of the various samples is shown in Figure 10. The majority of the samples (78) were collected and analyzed by the Saskatchewan Research Council. The rest were partly analyzed in the field with HACH chemical kit and partly in the laboratory of the Inland Waters Branch in Ottawa.

SALINITY OF GROUNDWATER

The salinity of groundwater of the described zones varies from 276 ppm to 5,400 ppm. In a few cases it rises to tens of thousands ppm, when the infiltration of highly mineralized water from slough to the surrounding ground takes place (A. Rozkowski, 1967). The largest variation of the total dissolved solids concentration is observed in the water of the first complex (see Appendix I). The water of the second and especially of the third complex indicates a more stable mineralization. These various types of water will be discussed below.

The variation in the amount of total dissolved solids in the first complex is shown in Figure 11. The graph shows the interrelation between the sum of constituents and the depth of sampling. The striking relation does not become clear until a differentiation is made between water in recharge and discharge areas (Fig. 11). The mineralization of groundwater increases in the downward direction (Fig. 11) reaching the maximum at the foot of the separate groups of hills. This phenomenon takes place everywhere along the slopes of the Moose Mountain hills which reflects the existence of the
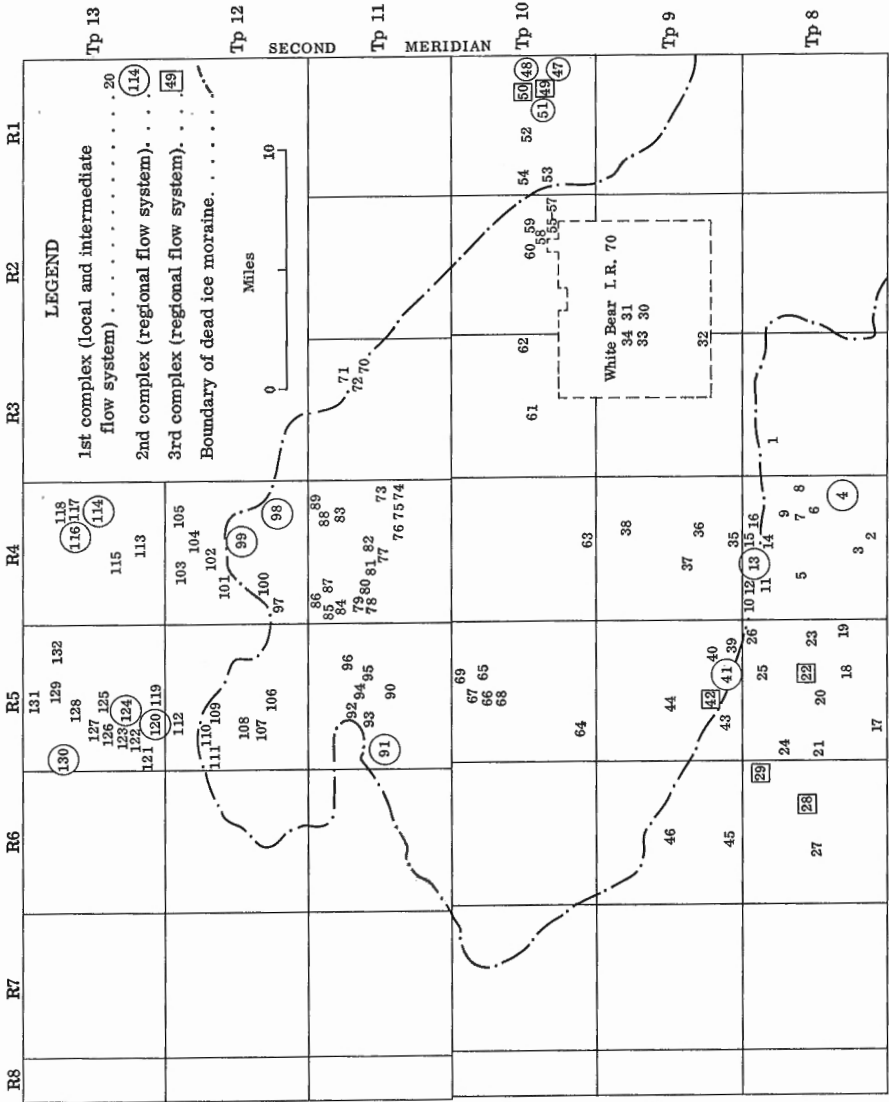
Figure 10. The areal distribution of groundwater sampling
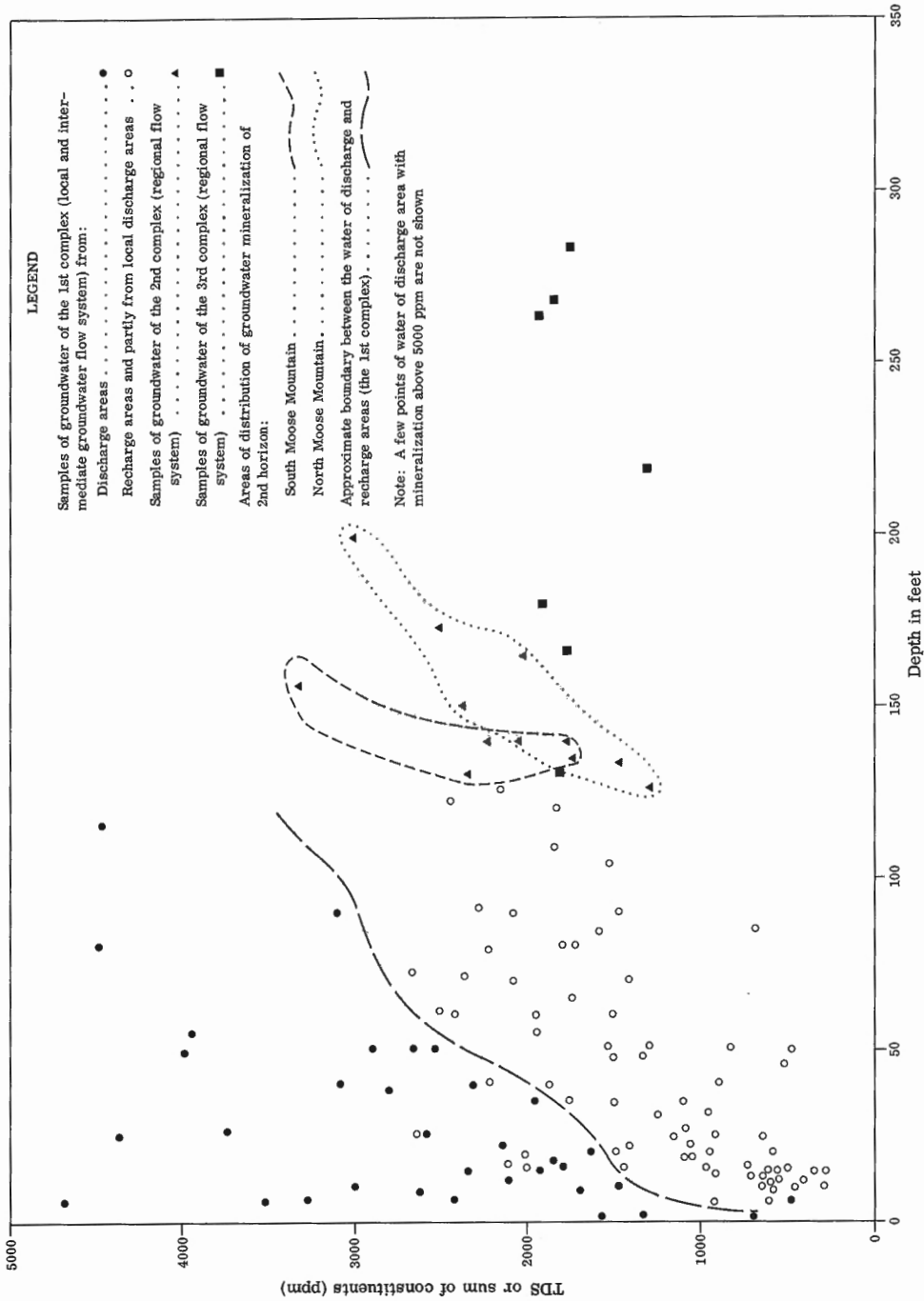
Figure 11. Interrelation between the mineralization of groundwater and the depth of sampling

numerous separate local and intermediate systems. The low mineralization of the recharge areas and high mineralization of the discharge areas is confirmed by Rutherford's tritium measurements. The mineralization of groundwater of the discharge areas varies from 2,000-3,000 ppm in wells of about 20 feet deep. The wells of the same depth in the recharge areas indicate that the mineralization of the water is usually below 1,000 ppm.

The average salinity of groundwater of the regional flow system (second hydrogeological complex) is about 2,100 ppm. It is somewhat higher in comparison with the mineralization of shallow groundwater in the recharge areas of the local and intermediate flow systems. According to Figure 11 an increase of salinity is observed with increasing depth. The variations of salinity observed in the different parts of the described area (Fig. 11) are probably a result of the varying permeability of the strata.

In comparison with the water of the glacial horizons, the groundwater of the regional flow system, which occurs in the preglacial and Ravenscrag strata, shows an almost constant content of dissolved solids. Only slight changes of mineralization in range from 1,315 ppm to 1,930 ppm were observed.

IONIC RELATIONSHIPS AND CHEMICAL CLASSIFICATION OF GROUNDWATER

Interrelations among the main ions: HCO_3^-, CO_3^{2-}, SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, Na^+, K^+, are demonstrated by ratios and formulas presented in Appendices I and II, as well as by the graphs in Figures 12, 13.

The results of the chemical analysis of groundwater are presented in Appendix I. The location and position in the hydrogeological profile of each sample is shown. Ionic relationships are demonstrated clearly by ratios and formulas in Appendix II. The Kurlov formula gives a presentation of total salinity and shows in per cent the content of analyzed anions and cations. It is based on the following scheme:

$$ M \; \frac{\Sigma \; \text{Anions}}{\Sigma \; \text{Cations}} $$

where: M – total mineralization g/l

Σ Anions – total concentration of main anions = 50%

Σ Cations – total concentration of main cations = 50%

The Priklonski classification demonstrated in Appendix II is based on the absolute, above 25 per cent epm, or the relative predomination of some anions or cations (Priklonski and Laptiew, 1955). The chemical ratios determine the interrelations among some ions. Based on these it is possible to draw conclusions about the origin of the chemistry. The ratios of $Na^+/Cl^- > 1$ indicate a sulphate or carbonate type of water; the sulphate type of water with regard to the value of the ratio $Na^+-Cl^-/SO_4^{2-} < 1$ is presented in greater detail. The author's observations show that in the Moose Mountain area the most valuable ratios are $SO_4^{2-}/HCO_3^- + CO_3^{2-}$ and Mg^{2+}/Ca^{2+}. These ratios as well as Na^+/Ca^{2+} ratio also yield information on the processes which form groundwater chemistry. Depending on the various ratios, especially

TABLE 11

Chemical classification of groundwater according to the ratios:
$SO_4^{2-}/HCO_3^- + CO_3^{2-}$

Type and subtype of chemistry	Type of ground-water flow (complex)	Type of chemistry according to Priklonski classification	Mineralization g/l (extremes in brackets)	Values of ratio $SO_4^{2-}/HCO_3^- + CO_3^{2-}$
I	1	HCO_3-Ca, HCO_3-Ca-Mg, HCO_3-Mg-Ca	0.3-0.6(0.7)	0.04-0.3
	3	HCO_3-Na	1.3	-
II/1a	1	HCO_3-SO_4-Ca-Mg, HCO_3-SO_4-Mg-Ca	0.6-1.1(1.7)	0.3-1
	3	HCO_3-SO_4-Na	1.9	0.6
II/1b	1	SO_4-HCO_3-Ca-Mg, SO_4-HCO_3-Mg-Ca, SO_4-HCO_3-Mg	(0.5)1.1-2.1(2.5)	1-2.9
	2	SO_4-HCO_3-Na-Ca SO_4-HCO_3-Ca-Na, SO_4-HCO_3-Ca-Mg-Na	1.7-2.4	2.4-2.9
	3	SO_4-HCO_3-Na-Ca SO_4-HCO_3-Na	1.8-1.9	1.5-2.5
III	1	SO_4-Ca-Mg, SO_4-Mg-Ca, SO_4-Na-Mg-Ca, SO_4-Mg	(0.6)2.1-4.7(50.2)	2.9
	2	SO_4-Ca-Na-Mg, SO_4-Ca-Na, SO_4-Na, SO_4-Mg	1.3-3.0(5.4)	2.9-9.5
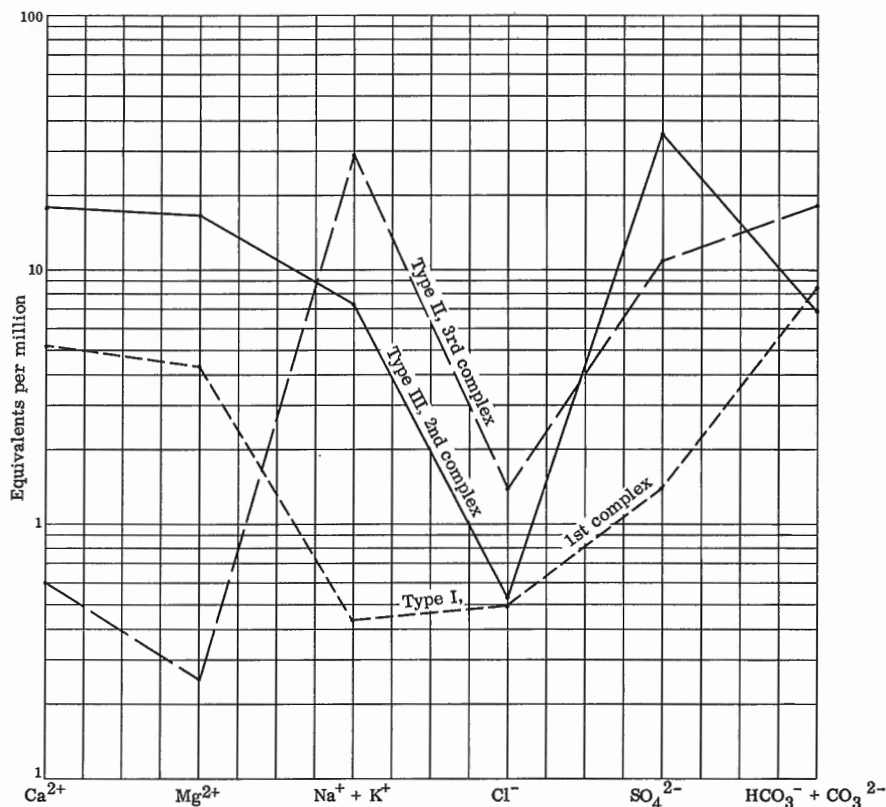
Figure 12. Schoeller's diagram for the groundwater of the local
intermediate and regional flow system (for numerical
classification see Table 14)

$SO_4^{2-}/HCO_3^-+CO_3^{2-}$ ratio, three types of groundwater chemistry could be
distinguished: (1) HCO_3; (2) HCO_3-SO_4, SO_4-HCO_3; (3) SO_4. The obtained
results are correlated with Priklonski classification (Appendix II). The
characteristic of the above mentioned types of water with regard to the hydro-
geological complexes of Moose Mountain are presented in Table 11. The low
mineralized waters of the local and intermediate groundwater system which
exist on the first complex consist of calcium and calcium-magnesium. These
cations in combination with bicarbonates and carbonates create the basic
salts. The waters of the described flow system characterized by higher
mineralization are magnesium waters. The amount of calcium ion is usually
below 20 per cent of cations concentration. An increase of the sodium ion to
about 20 per cent of total cation concentration was observed. The waters
collected at the bottom of the Moose Mountain hills show a significant increase
of the sodium content. The concentration of this ion varies here from 20-40
per cent of the total cation concentration. The cation of alkaline earths are
balanced mainly by sulphates.

The waters of the regional groundwater flow, especially in the case
of the third complex, present a different type of chemistry. They are repre-
sented by alkaline and alkaline earth ions with a significant predominance of
sodium ion. These cations are balanced by sulphate and bicarbonate ions.
The chemical type of the groundwater of the second complex in the northern
part of Moose Mountain is similar to the water of the high mineralized inter-
mediate groundwater system.

A low content of chloride ion is typical of all the described waters.
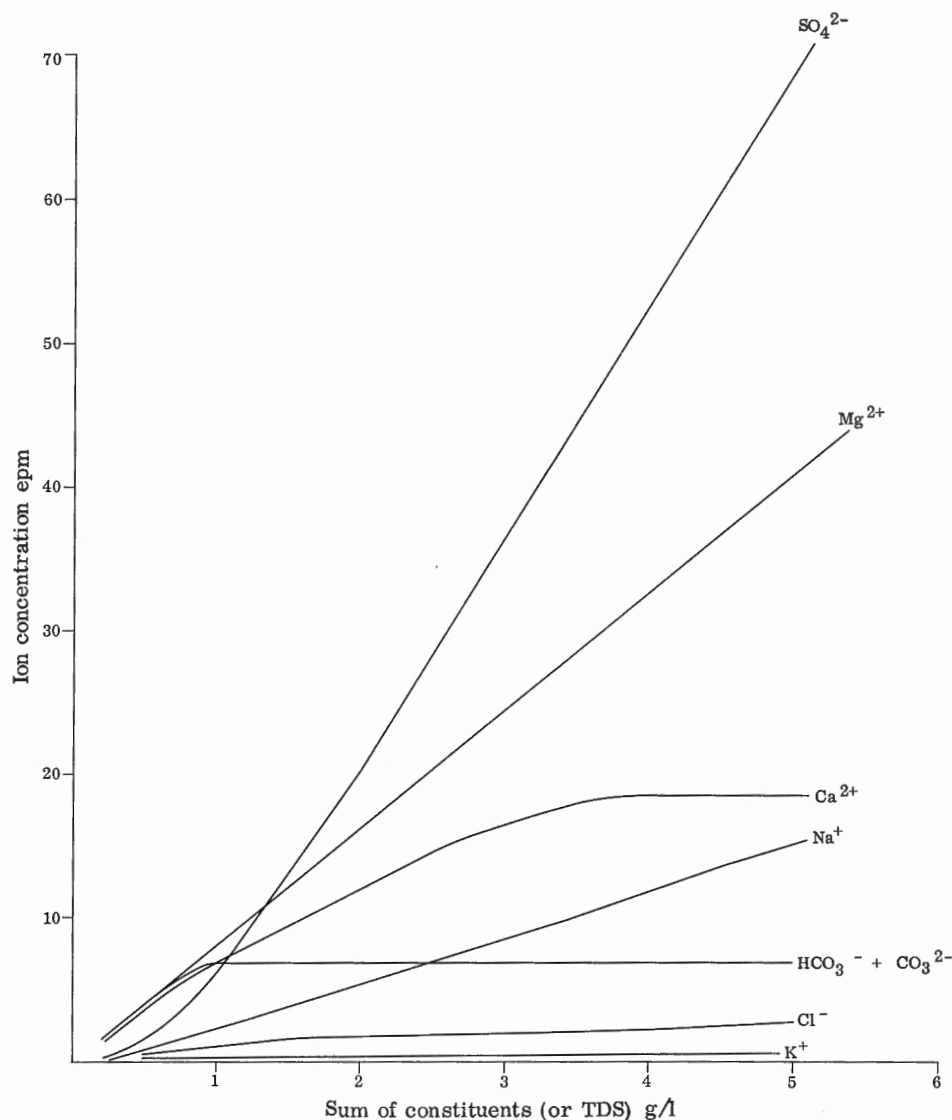
Figure 13. Interrelation between the ion concentration and groundwater mineralization

Schoeller's semilogarithmic diagrams were constructed (Fig. 12) for the purpose of presenting the ionic relationships of separated hydrochemical types of water as well as to point out the distinction among these types. The inclination of lines joining the separate ions in these diagrams indicates the various concentrations of the analyzed ions. It shows clearly the difference of the water chemistry of the local and intermediate as well as regional groundwater systems. The shapes of the $HCO_3^- + CO_3^{2-}$ and Ca^{2+} curves are approximate and demonstrate the trend only. The shapes of the curves of the remaining ions give clear evidence of increasing of the ions concentration with the rise of the groundwater salinity. Low mineralized waters are distinguished by a high content of Ca^{2+} which surpasses the Mg^{2+} concentration. The basic anions are HCO_3^- and SO_4^{2-}. The increase of groundwater salinity involves the significant rise of Mg^{2+}. The Ca^{2+} ion has a tendency to a slight increase only or steady concentration. A distinct rise of the sodium concentration is observed. Among the anions the most significant is SO_4^{2-}. The HCO_3^- ion has a tendency to steady concentration. The concentrations of Cl^- and K^+ ions, both in the low and high mineralized waters are insignificant.

SLOUGHS AND LAKES

GENERAL CHARACTERISTICS

Studies of hydrology and hydrochemistry of the lakes in Saskatchewan were carried out by Cole (1926), Rawson (1939), Rawson and Moore (1944), and Tomkins (1954). However, of particular importance for understanding the position and participation of the lakes and sloughs in the hydrologic system of the prairie area are the recent investigations of Meyboom (1962, 1966a, b, 1967), Toth (1962, 1966), Freeze (1964), Freeze and Whitherspoon (1966) and other hydrogeologists.

Temporary Sloughs

The temporary surface water bodies are usually surrounded with willows thus Meyboom (1962) called them willowrings. During summer they dry up completely and are covered by grass. These sloughs are situated in shallow depressions usually less than one acre in extent, and not more than a few feet deep. They fill up after spring thaw or heavy rains. According to Meyboom (1966a), groundwater flow near these willowrings is characterized by downward flow during winter, infiltration during spring and early summer and groundwater discharge during summer and early fall. The discharge takes place mainly as evapotranspiration by the phreatophytic willows.

Permanent Sloughs and Lakes

Permanent sloughs and lakes do not dry up during the summer. The area of permanent sloughs is variable, but is usually less than 10 acres. Their depth is generally not more than 10 feet. The seasonal variations of the water volume are significant. Meyboom's investigations (1967) of sloughs

No. 153 and 154 (Fig. 14) indicated clearly that the permanent sloughs receive inflow from surface run off and from local or intermediate groundwater flow system. During summer a flow from the slough towards the surrounding phreatophytic fringe was also detected. Most permanent sloughs of Moose Mountain occupy the areas of more permeable glacial deposits.

Lakes in the Moose Mountain area are Kenosee and Carlyle Lakes each with surfaces of about 6 square miles (3, 840 acres) and depths of about 30 feet, and a few smaller lakes, usually less than 2 square miles (1, 280 acres) in extent with depths of about ten feet. The seasonal variations of the water volume of these lakes are negligible in comparison with the sloughs. They occupy the larger depressions of the central and east-central parts of the Moose Mountain area (Fig. 14). Taking into account the hydrological regime of these lakes they are probably recharged mainly by groundwater.

Hydrodynamic relations

The results of Meyboom's investigations (1967) allow us to recognize the hydrodynamic interrelation between groundwater and surface water as well as among the separate bodies of surface water.

The participation of the temporary sloughs in the water flow system has been described previously. The detected hydrodynamic interrelation between adjacent permanent sloughs, manifested by shallow leakage, shows that permanent sloughs and lakes are evidently not only the areas of discharge for local and intermediate groundwater flow systems, but that they also take part in the general water flow which exists in the Moose Mountain area.

CHEMISTRY OF SLOUGHS AND LAKES WATER

The purpose of chemical investigations of slough and lake water was to present the regional variation of their salinity and ionic relationships. The results of the investigations as illustrated by tables and graphs also give the bases for the chemical classification of the described waters. The final interpretation of the hydrochemical results is demonstrated on the map of the sloughs and lakes chemistry (Fig. 14).

Field and Laboratory Investigations

Field investigations consisting of the measurements of specific conductance of waters, and the sampling and analyzing of their chemistry, were carried on mainly in the field season 1966. For the final interpretation the results of Meyboom's hydrochemical investigations of the year 1965 were also used.

The basic data for the regional study of slough and lake salinity were obtained by the measurements of the water conductivity. This method, based on the correlation between specific conductance of water expressed in micromhos and the concentration of total dissolved solids, allows us to estimate (Hem, 1959) the amount of total dissolved solids. William's (1966) investigations showed that this method gives the best results in salt water of homogeneous ionic composition. In the case of the slough and lake waters

investigated, no linear relationship between specific conductance and concentration of total dissolved solids exists (Fig. 15). The reason for this seems to depend mainly on the differences in ionic composition of low and high mineralized waters inducing the different specific conductances. Therefore in the Moose Mountain area the estimation of the amounts of total dissolved solids by measuring specific conductance requires different coefficients for different salinities. In order to exclude this discordance the comparison of the obtained results of water salinity is shown in micromhos only or is presented both in micromhos and in ppm (epm). In the last case a sum of constituents is obtained directly from chemical analyses. The conductivity measurements were carried out mainly according to the natural grid pattern that is provided by the roads in this area. The conductivity measurements of some selected lakes and sloughs were repeated periodically to observe the seasonal variation in salinity. About 1,200 measurements of conductivity were made of 744 sloughs and lakes. Based on these results the samples of water for chemical analysis were collected to present the regional and seasonal variation of the chemistry of the sloughs and lakes. The waters were analyzed partly in the field with an HACH chemical kit and partly in the laboratory of the Inland Waters Branch in Ottawa. The location of sloughs and lakes with measured specific conductance as well as the sample locations are presented in Figure 14.
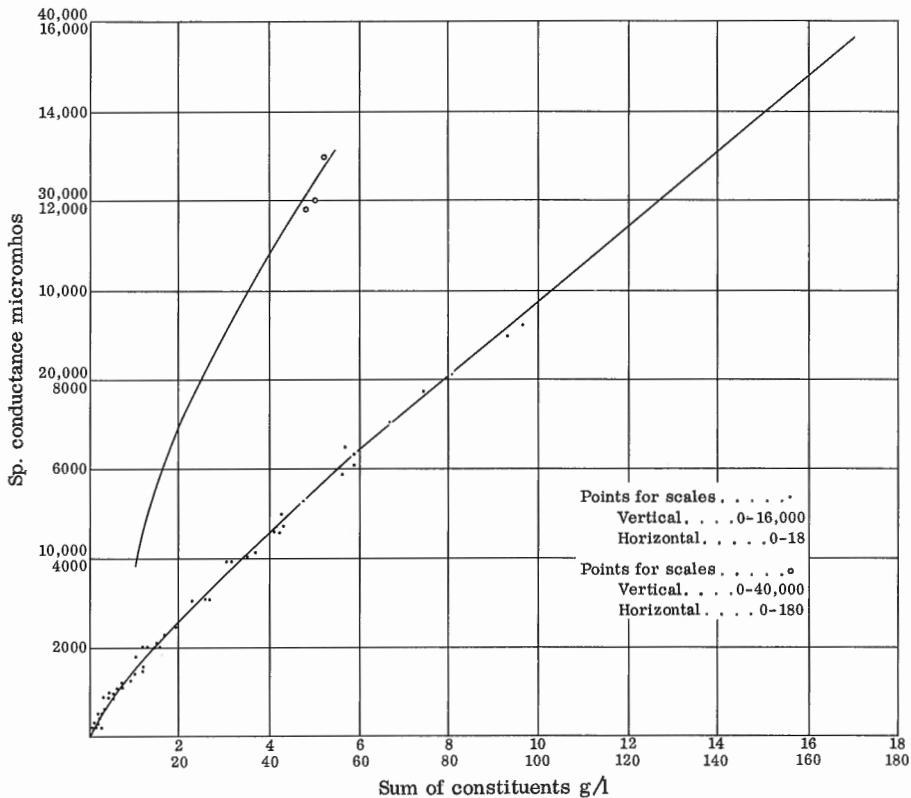
Figure 15. Interrelation between the conductivity and sum of constituents of surface water
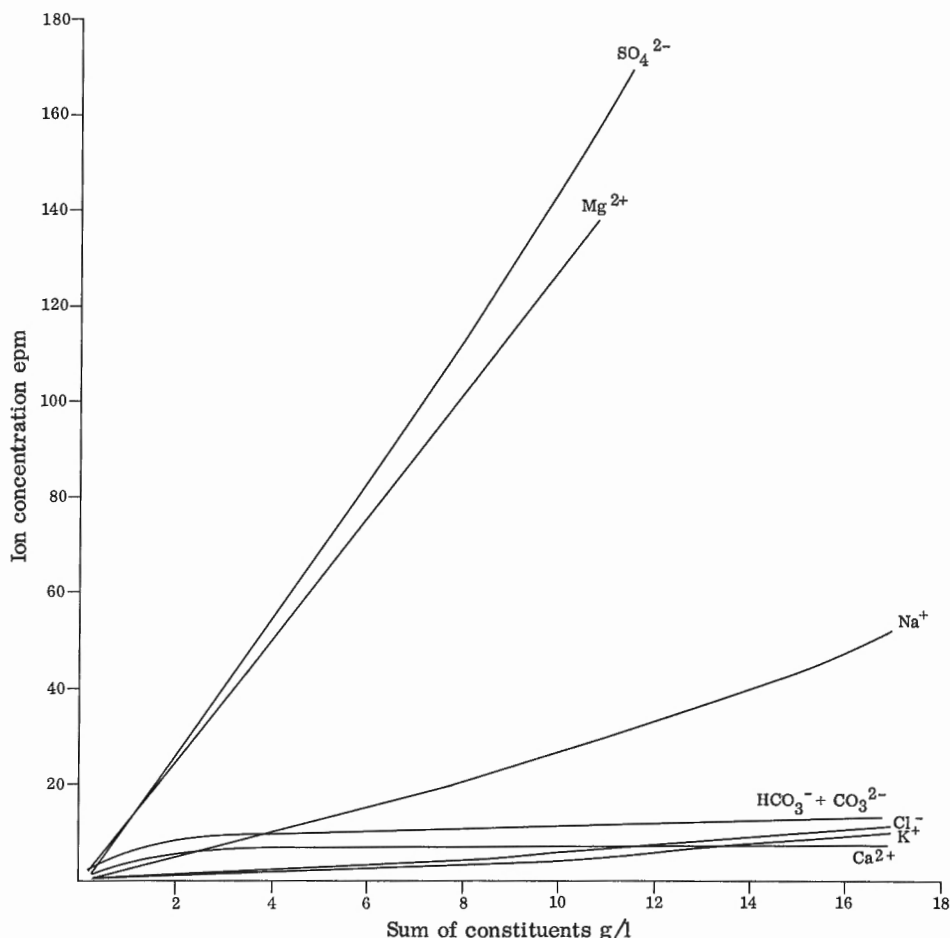
Figure 16. Interrelation between the ion concentration and surface water mineralization

Salinity, Ionic Relationships and Chemical Classification

The results of the chemical analyses and specific conductance measurements of slough and lake waters are included in Appendix III. Ionic relationships of slough and lake waters are given in Appendix IV by the Kurlov formula and the Priklonski classification. The relation is shown graphically in Figure 16. The composition of some typical waters is shown graphically in Figure 17.

The salinity of the water of the sloughs and lakes varies from 120 ppm to 129, 144 ppm. Their specific conductance ranges from about 100 to above 60, 000 micromhos. The measurements of the highest conductivity could not be done because they were outside the instrument range.

The variation of the ionic relationships are shown in Figure 16. The shapes of the $HCO_3^- + CO_3^{2-}$ and Ca^{2+} curves, like those of the described groundwaters (Fig. 13) are approximate and demonstrate the trend only. The dominant ions are magnesium and sulphate, the amounts of which increase
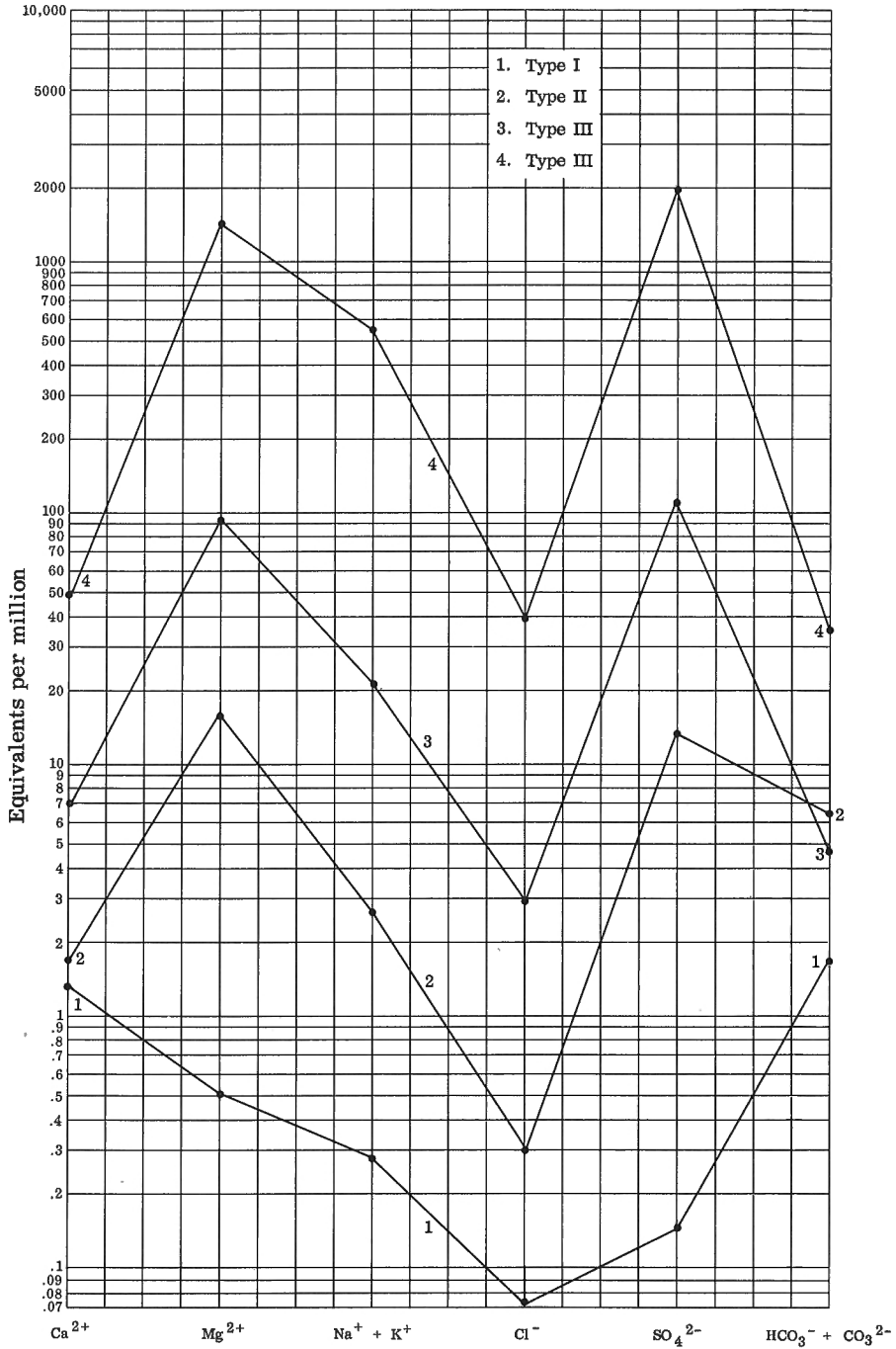
Figure 17. Schoeller's diagram of chemical types of sloughs and lake waters

TABLE 12

Results of chemical classification of slough and lake waters based on the values of the ratio $SO_4^{2-}/HCO_3^-+CO_3^{2-}$

Type and subtype of hydrochemistry	Type of chemistry according to Priklonski classification	Mineralization of water g/l (the extremes in brackets)	Values of ratio $SO_4^{2-}/HCO_3^-+CO_3^{2-}$
I	HCO_3-Ca, $HCO_3-Ca-Na$, $HCO_3-Ca-Mg$, HCO_3-Mg	0.1 – 0.4 (0.7)	0.038 – 0.344
II/1	$HCO_3-SO_4-Mg-Ca$, HCO_3-SO_4-Mg	0.4 – 1.1	0.545 – 0.719
II/2	$SO_4-HCO_3-Ca-Mg$, $SO_4-HCO_3-Mg-Ca$, SO_4-HCO_3-Mg	0.5 – 2.0 (2.5)	1.2 – 3
III	$SO_4-Mg-Ca$, SO_4-Mg	(1.0) 2.0 – 50.0 (129)	> 3

Remarks: as HCO_3 is described the content of $CO_3^{2-} + HCO_3^-$ ions.

sharply with increasing salinity.   This can be seen also from the Kurlov formulas in Appendix IV.   The increase of a total salinity induces a distinct, but gentle rise of sodium ion concentration, evidently surpassing the rise of calcium ion concentration.   The last fact is well confirmed by the values of Na^+/Ca^{2+} ratio (Appendix IV).   The concentration of calcium, bicarbonate, and carbonate ions in the water of higher salinity is small and relatively stable.   Their concentration is determined by the changeable carbonate equilibria, which is clearly manifested by the pH values which vary from 7.1 to 9.6 pH (Appendix III).   The content of potassium and chloride ions is insignificant in all waters.

Based on the various values of the ratios $SO_4^{2-}/HCO_3^-+CO_3^{2-}$ presented in Appendix IV three chemical types of sloughs and lakes could be distinguished.   The first is represented by carbonate, the second by mixed carbonate-sulphate and sulphate-carbonate, and the last by a sulphate type of water.   The general characteristics of these types of water is shown on Table 12.   The described waters belong to the earth alkaline type of water, in which cations make up more than 60 per cent of total cation concentration. These cations in combination with sulphates, carbonates and bicarbonates create the basic salts.

For the purpose of pointing out the separate types of hydrochemistry a Schoeller diagram was constructed (Fig. 17).   It presents clearly the differences of the ionic relationships of the three types of water distinguished.

MANIFESTATION OF REGIONAL DISTRIBUTION OF SLOUGHS AND LAKES WATER CHEMISTRY

Based on the results of field hydrochemical mapping, a hydrochemical map of the Moose Mountain area was made (Fig. 14).   Two basic hydrochemical zones, each of which includes two subzones, were distinguished on the basis of the data collected.   The chemical division is based on the ratio presented in Table 12.

The First Hydrochemical Zone

The first hydrochemical zone (I) contains the sloughs and lakes with HCO_3^- and HCO_3-SO_4 types of water subzone I/1 and with SO_4-HCO_3 type of water subzone I/2 (Fig. 14).   All sloughs in zone I contain less than 2,000 ppm total dissolved solids.

The first subzone (I/1) occupies the highest areas of central and east-central Moose Mountain, as well as the west-central part of this area and the flat ground moraine surrounding Moose Mountain.   It is represented by the waters of temporary and permanent sloughs and lakes on Moose Mountain and mainly by temporary sloughs of the ground moraine.   These lakes and sloughs occupy general recharge areas or the discharge areas of local flow systems (see Fig. 9).

The main hydrochemical characteristics of the described subzone are as follows:

1. type of water chemistry: HCO_3-Ca, HCO_3-Ca-Mg, HCO_3-SO_4-Ca-Mg;

2. salinity of water: <1,000 ppm;

3. specific conductance of water: <1,500 micromhos;

4. summer increase of water salinity; about 20 per cent of spring water mineralization;

5. values of hydrochemical ratios: $SO_4^{2-}/HCO_3^- + CO_3^{2-} \leqslant 1.2$; $Mg^{2+}/Ca^{2+} < 3$; $Na^+/Ca^{2+} < 1$; some small lakes: $SO_4^{2-}/HCO_3^- + CO_3^{2-} \leqslant 0.8$; $Na^+/Ca^{2+} > 1$.

      The second subzone (I/2) surrounds the I/1 subzone and occurs locally at the foot of Moose Mountain. It is represented by the waters of Carlyle and Kenosee Lakes and by other smaller lakes as well as by permanent and temporary sloughs. These bodies of water are in discharge areas of local and intermediate flow systems. The main hydrochemical factors of this subzone are:

1. type of water chemistry: SO_4-HCO_3-Ca-Mg, SO_4-HCO_3-Mg-Ca, SO_4-HCO_3-Mg;

2. salinity of water: 1,000-2,000 ppm;

3. specific conductance of water: 1,500-2,500 micromhos;

4. summer increase of water salinity; about 20-50 per cent of spring water mineralization;

5. values of hydrochemical ratios: $SO_4^{2-}/HCO_3^- + CO_3^{2-}$: 1.2-3; Mg^{2+}/Ca^{2+}; 1.0-15 (45); $Na^+/Ca^{2+} < 1$; large lakes: $SO_4^{2-}/HCO_3^- + CO_3^{2-} \sim 2$; Na^+/Ca^{2+}: 1-2;

      In the areas occupied by the second subzone occur also the lower mineralized sloughs with HCO_3 and HCO_3-SO_4 type of water, which are located in the local recharge and discharge areas.

The Second Hydrochemical Zone

      The second hydrochemical zone is represented by SO_4 type of water. Taking into account the significant changes of water mineralization within it, two hydrochemical subzones were distinguished.

      The first subzone (II/1) occurs in the northern part of the Moose Mountain area and surrounds the I hydrochemical zone. It is represented chiefly by the waters of permanent sloughs and lakes located in the intermediate and local discharge areas. The main hydrochemical factors of the subzone are as follows:

1. type of water chemistry: SO_4-Mg, SO_4-Mg-Ca;

2. salinity of water: 2,000-11,000 ppm;

3. specific conductance of water: 2,500-10,000 micromhos;

4. summer increase of water salinity varies from 25 to 100 per cent of spring water mineralization;

5. values of hydrochemical ratios: $SO_4^{2-}/HCO_3^-+CO_3^{2-}$: 3.5-29; Mg^{2+}/Ca^{2+}: 4-59; Na^+/Ca^{2+}: 0.1-9 (20).

There occur also sloughs with HCO_3, HCO_3-SO_4, SO_4-HCO_3 types of water located in the local recharge and discharge areas. Alkali Lake (see Appendix III, No. 211) is an 'inlier' of the second hydrochemical zone within the first one.

The second subzone (II/2) was distinguished in the areas of poorly permeable glacial deposits in the low-lying land surrounding the central-west high and at the foot of the northern slopes of the Moose Mountain hills. It is represented by waters of the permanent sloughs of the local and intermediate discharge area, located in deep kettles. The main hydrochemical factors of the described subzone are as follows:

1. type of water chemistry: SO_4-Mg;

2. salinity of water: 11,000-129,000 ppm;

3. specific conductance of water: greater than 10,000 micromhos;

4. summer increase of water salinity rises a few hundred per cent above spring salinity;

5. values of hydrochemical ratios: $SO_4^{2-}/HCO_3^-+CO_3^{2-}$: 13-176; Mg^{2+}/Ca^{2+}: 11-54; Na^+/Ca^{2+}: 1.6-16.7.

In the area occupied by the described subzone the lower mineralized sloughs with HCO_3, HCO_3-SO_4, SO_4-HCO_3 and SO_4 types of water also occur, which represent the local recharge and discharge areas.

DEVELOPMENT AND ORIGIN OF WATER CHEMISTRY

The development and origin of the prevailing hydrochemical patterns of the Moose Mountain area are discussed and explained in this section. The hydrochemical relations between the sloughs and groundwater are demonstrated by detailed investigations of some local basins.

FACTORS PRODUCING THE CHEMISTRY OF NATURAL WATERS

The high salinity of the surface and groundwater of the area is produced primarily by the semi-arid climate, in which there is an excess of evapotranspiration over precipitation. Superimposed on the climatic effect are variations of salinity and hydrochemistry caused by local factors. In the case of groundwater these factors are:

1. permeability and soluble salt content of the soil and glacial deposits;
2. conditions of groundwater flow.

The development of the slough and lake water chemistry is the result of their hydrographic and hydrologic character. The most important factors are:

1. hydrographic conditions;
2. inflow and outflow conditions.

The hydrographic conditions can be shown by the mean depth and variability of the lake area. Inflow conditions determine the quality and quantity of waters which feed the bodies of surface water. Outflow conditions depend on the effects of evapotranspiration and intensity of leakage.

THE ORIGIN OF HYDROCHEMICAL PATTERNS
OF MOOSE MOUNTAIN

The demonstration of the origin of the hydrochemistry patterns in the glacial deposits is based on the detailed studies carried out in the eastern part of the Moose Mountain area. For the explanation of the origin of hydrochemistry the chemical analyses of some selected ground and surface waters are used (Table 13) as well as the results of geochemical analyses of the soil and glacial deposits from boreholes P-1 and P-2. The results of these studies enabled us to draw the hydrochemical cross-section (Fig. 18), which shows the appearance and distribution of hydrochemical zones in the described area.

LOCAL AND INTERMEDIATE FLOW SYSTEMS

The local and intermediate groundwater flow systems of the first hydrogeological complex take place in the first zone of weathering and in the upper till (Figs. 4, 9). The processes of leaching and dissolution in the zone of aeration are indicated by low concentration of all ions in water extracts (Figs. 7, 8). The dissolution of poorly soluble salts also takes place here, because of the enrichment of water with CO_2 from the air and from the biological activity in the root zone. In the case of the permeable deposits (borehole P-2) the easily soluble salts are already washed out (Fig. 8) and therefore only a calcium and magnesium bicarbonate type of groundwater is produced.

The alkalinity changes of the lower soil horizons, under the conditions of strong evaporation, involve precipitation of calcium, magnesium, strontium and barium carbonates (Table 6, Figs. 7, 8), as well as some minor elements, the concentration of which is governed by pH of the environment. The groundwater in this environment amounts to a few hundred ppm (e.g. well 62, Fig. 18). On account of the semi-arid climate and insignificant

TABLE 13

Calculation of hypothetical salt content and water saturation
of ground and surface water

(cross-section A-B)

Number of well or slough or lake	complex	Depth (in feet)	Hypothetical salts											NaCl coefficient	Saturation of water with $CaSO_4$			Saturation of water with $CaCO_3$			
			$KNO_3+KCl+NaCl$		$K_2SO_4+Na_2SO_4$		$MgSO_4$		$CaSO_4$		$MgCO_3$		$CaCO_3$			$S_0(20°C)$	S_1	comparison of calculated values	temperature of water (°C)	pH of water equil.	pH calculated	comparison of calculated values
			epm	%	epm	%	epm	%	epm	%	epm	%	epm	%		epm	epm					
w. 48[*]	2-nd	140	0.751	2.82	15.760	59.07	3.907	14.64	0.651	2.44	–	–	5.611	21.03	1.22	30-31	11.28	$S_1 < S_0$	22.8	6.5	7.6	$pH_w > pH_{eq}$
w. 49[*]	3-rd	265	0.680	2.25	11.674	38.64	6.900	22.84	3.849	12.74	–	–	7.190	23.53	1.13	30-31	15.67	$S_1 < S_0$	22.7	6.2	7.5	$pH_w > pH_{eq}$
w. 51	2-nd	135	0.917	3.34	9.605	34.93	5.596	20.35	4.578	16.65	–	–	6.799	24.73	1.53	30-31	15.00	$S_1 < S_0$	21	6.2	8.0	$pH_w > pH_{eq}$
w. 52	1-st	27	0.423	3.70	0.416	3.64	2.187	19.14	–	–	3.508	30.71	4.890	42.81	0.71	30-31	3.57	$S_1 < S_0$	21	6.5	7.65	$pH_w > pH_{eq}$
w. 53[*]	1-st	14	0.309	2.53	0.739	6.06	6.222	51.03	–	–	0.191	1.57	4.732	38.81	0.42	30-31	5.74	$S_1 < S_0$	–	6.75	8.3	$pH_w > pH_{eq}$
w. 58[*]	1-st	6	0.233	0.31	8.466	11.16	53.690	70.77	8.357	11.02	–	–	5.116	6.74	0.21	30-31	30.83	$S_1 \approx S_0$	–	6.2	8.6	$pH_w > pH_{eq}$
w. 62	1-st	60	1.579	12.52	0.055	0.44	1.985	15.73	–	–	2.611	20.69	6.387	50.62	2.63	30-31	3.61	$S_1 < S_0$	21	6.5	7.3	$pH_w > pH_{eq}$
122 Antler R.	–	–	1.19	5.81	1.81	8.83	9.90	48.29	–	–	0.31	1.51	7.29	35.56	1.98	30-31	9.24	$S_1 < S_0$	–	6.4	8.3	$pH_w > pH_{eq}$
sl. 152	–	–	1.805	2.68	4.029	5.98	54.267	80.54	–	–	2.289	3.40	4.990	7.40	3.01	30-31	17.05	$S_1 < S_0$	23	6.6	8.9	$pH_w > pH_{eq}$
sl. 165[*]	–	–	0.297	1.32	2.011	8.97	11.410	50.86	3.803	16.95	–	–	4.912	21.90	0.35	30-31	12.25	$S_1 < S_0$	–	6.7	7.8	$pH_w > pH_{eq}$
sl. 172	–	–	0.199	2.40	0.450	5.42	3.945	47.51	0.579	6.97	–	–	3.131	37.70	0.20	30-31	4.29	$S_1 < S_0$	–	6.6	8.0	$pH_w > pH_{eq}$
215[*] Kenosee L.	–	–	0.468	1.96	2.754	11.52	12.924	54.00	–	–	5.622	23.51	2.156	9.01	0.66	30-31	5.81	$S_1 < S_0$	–	6.95	8.7	$pH_w > pH_{eq}$
206[*] Kenosee L.	–	–	0.538	2.61	2.171	10.52	11.499	55.71	–	–	4.728	22.91	1.703	8.25	0.50	30-31	4.82	$S_1 < S_0$	–	6.9	7.6	$pH_w > pH_{eq}$

* for hypothetical salt calculation the error between amount of cations and anions was distributed proportionately.
** the calculation of the water saturation with $CaSO_4$ and $CaCO_3$ salts was done according to H. Schoeller's formulas.

TABLE 14

Calculation of hypothetical salt content and water saturation in the ground and surface waters of the local basin

(based on field-analyses)

Slough or hole	Depth (in feet)	Conductivity of water (micromhos/cm)	Hypothetical salts										* Saturation of water with CaCO$_3$			
			NaCl		Na$_2$SO$_4$		Na$_2$CO$_3$		MgCO$_3$		CaCO$_3$		water temperature (°C)	pH of equil.	pH of water	comparison of calculated values
			epm	%	epm	%	epm	%	epm	%	epm	%				
slough # 175	-	450	0.169	3.75	0.042	0.93	0.606	13.44	0.799	17.71	2.894	64.17	23	7.0	7.35	pH$_w$ > pH$_{eq}$
hole I	9	800	0.212	2.26	0.354	3.78	0.810	8.65	3.397	36.28	4.591	49.03	23	6.5	7.9	pH$_w$ > pH$_{eq}$
hole II	15	950	0.169	1.42	0.146	1.23	0.809	6.79	8.294	69.62	2.495	20.94	23	6.7	8.45	pH$_w$ > pH$_{eq}$

* the calculation of the water saturation with CaCO$_3$ is done according to H. Schoeller's formulas.

LEGEND

Chemical type of water (mainly):

1 HCO_3 – Ca; HCO_3 – Ca – Mg; HCO_3 – SO_4 – Ca – Mg

2 SO_4 – HCO_3 – Ca – Mg; SO_4 – HCO_3 – Mg – (Ca)

3 SO_4 – Ca – Mg; SO_4 – Mg – (Ca); SO_4 – (HCO_3) – Ca – Mg; SO_4 – (HCO_3) – Mg – (Ca)

4 SO_4 – and SO_4 – (HCO_3) – type of water with increasing amount of Na^+ ion

    Boundary of hydrochemical zones (approximate)

Number of slough . . . . sl. 184
Number of well . . . . w. 54
Mineralization of water in g/l. . 2.9

Figure 18. Schematic hydrochemical cross-section (see Figure 14 for location of A–B)

runoff the poorly permeable deposits (borehole P-1) show a high concentration of soluble salts in the zone of weathering (Fig. 7). The enrichment of groundwater with easily soluble $MgSO_4$ salts, together with the saturation of the water with carbonates and calcium sulphates take place here. The salinity of the water usually varies between 1,000 and 2,000 ppm. Based on the results of geochemical investigations it had to be concluded that groundwater acquires most of its chemical characteristics in the zone of weathering. Further but less evident changes of water chemistry are produced by the enrichment of easily soluble salts, mainly sulphate magnesium salts, and by the steady precipitation of an excess of the poorly soluble carbonate salts. The low content of sodium salts shows the insignificant role of the processes of ion exchange. Subsequent modification of groundwater chemistry takes place under the influence of evapotranspiration in the areas of discharge represented by sloughs and lakes. The shallow appearance of groundwater and its capillary rise in the till deposits as well as the biological activity of deep rooted plants, increase this effect. The total increase of salinity to a few thousand ppm and the enrichment of groundwater with easily soluble salts and the simultaneous precipitation of less soluble salts take place in the shallow zone close to the surface which is clearly shown in the results of the hydrochemical investigations carried out in the vicinity of the sloughs 153 and 154 (Fig. 19). The entire sequence of dissolution, leaching, precipitation and ion exchange is presented schematically in Figure 20.

The following examples show in detail how hydrochemical patterns originate in local flow systems. The first example deals with a local flow system in permeable till, the second is from a region with poorly permeable till.

The First Example – Sloughs 174 and 175

The development and origin of the hydrochemistry within a local flow system in permeable till is demonstrated by sloughs 174 and 175. These sloughs are located in the shallow depressions in the eastern area of sandy glacial deposits. Borehole P-2 (Fig. 7) may be considered to be representative for the litho-chemical composition of this area. According to the hydrochemical mapping (Fig. 14) the sloughs and lakes in this area belong to the first hydrochemical zone (I/1). The hydraulic relations between sloughs 174 and 175 are schematically shown in Figure 21. The water that infiltrates from slough 175 flows through glacial deposits. According to Table 14 the HCO_3-Ca type of water which was analyzed from this slough, changes along the shallow groundwater flow from HCO_3-Ca-Mg to HCO_3-Mg-Ca type of water chemistry. These changes are clearly demonstrated by the values of the ratio Mg^{2+}/Ca^{2+} which varies from 0.28 in slough 175 to 3.3 in hole II (Table 14). The differences of the chemical composition of the water are induced mainly by precipitation of $CaCO_3$ salts, which is clearly shown by the calculations of water saturation (Table 14) and by the enrichment of groundwater by more soluble salts. The small amount of sulphates is evident and typical of the described water. The small increase of sodium ions can be explained by a slight solution of weathered silicates and an insignificant activity of ion exchange processes. The participation of the main ions in the origin of water chemistry as well as the influence of the processes of dissolution, leaching and precipitation, which produce the chemistry of the described groundwater, are presented on the schematic graph Figure 21.
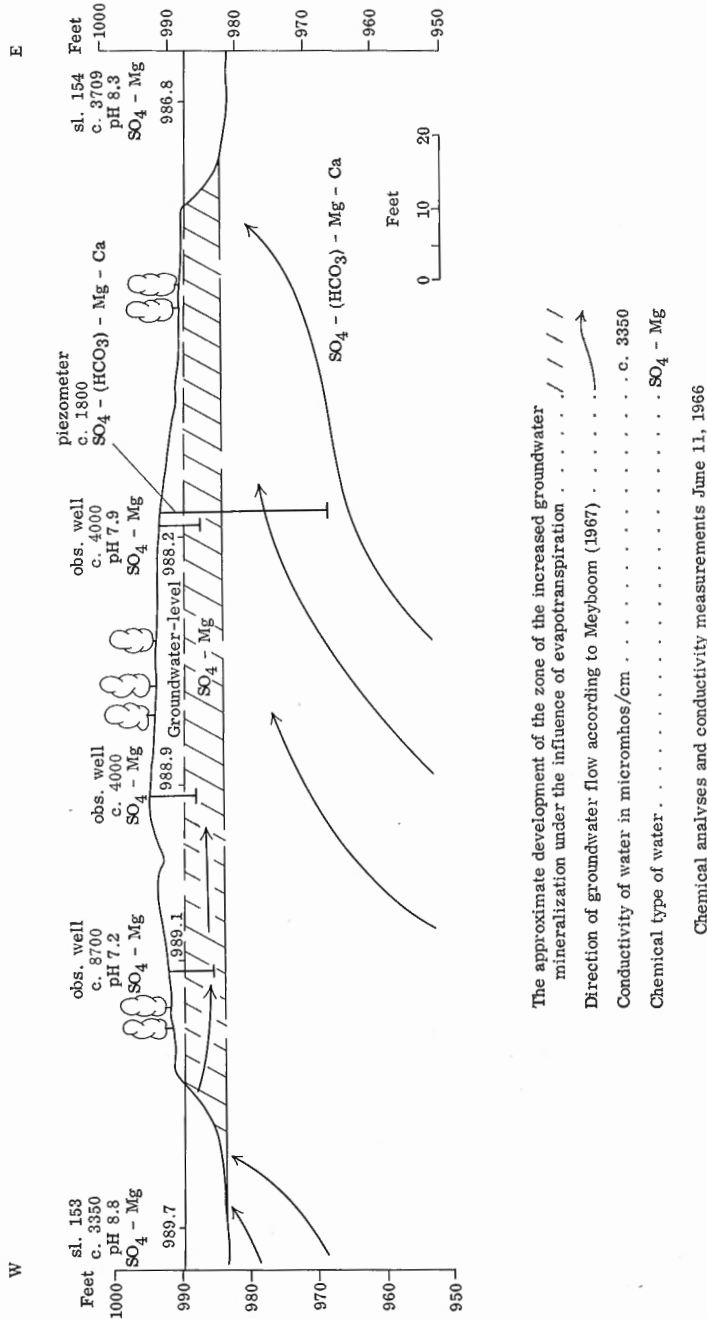
Figure 19. The influence of evapotranspiration on the differentiation of groundwater chemistry

The approximate development of the zone of the increased groundwater
mineralization under the influence of evapotranspiration . . . . / / / /

Direction of groundwater flow according to Meyboom (1967) . . . . ↗

Conductivity of water in micromhos/cm . . . . c. 3350

Chemical type of water. . . . . $SO_4 - Mg$

Chemical analyses and conductivity measurements June 11, 1966
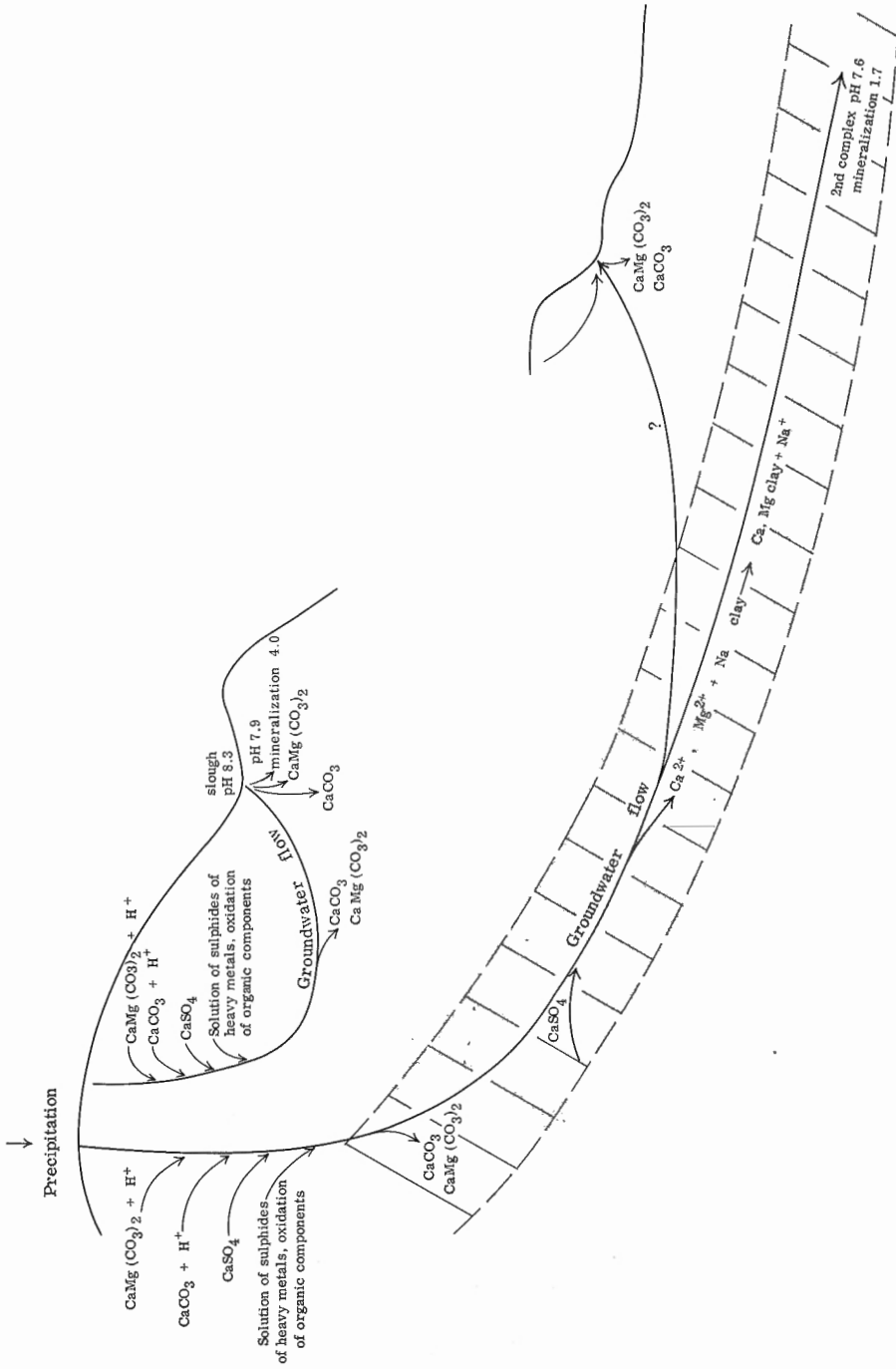
Figure 20. Generalized ion cycles in the groundwater flow system of the glacial deposits
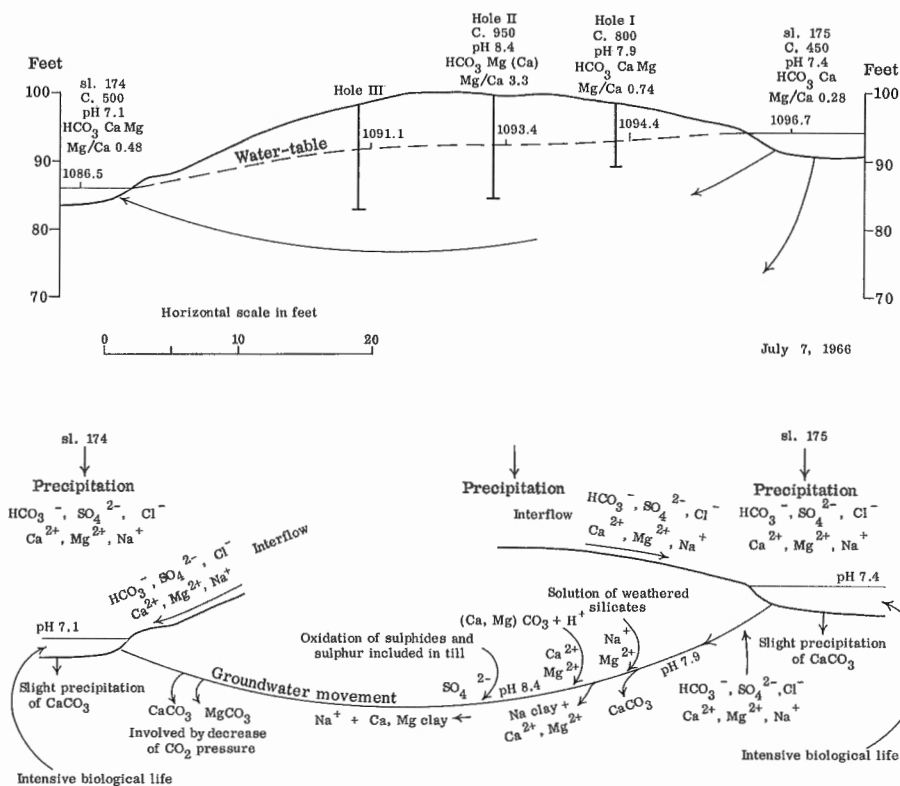
Figure 21. Development of water chemistry in the local groundwater flow system (flow system according to Meyboom, 1967)

According to the results of chemical analyses demonstrated in Appendix III the water of slough 175 is dominated by the HCO_3-Ca ions and slough 174 by HCO_3-Ca-Mg ions. The salinity of the water in slough 175 is about 140 ppm. The sources of the ions delivered to this slough are, interflow and atmospheric precipitation (Fig. 21); but the characteristic hydrochemistry is created mainly by a biological factor which plays a significant role in these low mineralized, well-heated waters with an active development of aquatic vegetation. Evapotranspiration increases the total concentration of water but respiration and decay keep the carbon dioxide concentration high. The carbon dioxide concentration causes the carbonate equilibrium and pH value. These facts explain the slight increase of total salinity and carbonate content as well as the decrease of pH values observed during the summer. According to Mitten's (1965) studies some visible diurnal variations of the chemical quality of water take place in such sloughs also.

The increase of magnesium ions in the water of slough 174 shows clearly its discharging position in this local flow system. The decrease of the specific conductance of its water in comparison to the groundwater

(Table 14) is caused by the decrease of the CO_2 pressure which induces the precipitation of carbonates. The possibility of the dilution of slough water by rain water should also be taken into account.

The Second Example – Slough 294

The second example was described by the author in a previous paper (A. Rozkowski, 1967). Under investigation was the groundwater flow system which feeds slough 294 which is in a deep kettle in the area of low permeability glacial deposits and is rich in soluble $CaSO_4$ and $MgSO_4$ salts. According to the hydrochemical mapping (Fig. 14) it is the area with the most saline sloughs all being of the SO_4-Mg type and belonging to the second hydro-chemical zone (II/2). The constructed Teledeltos flow model of the area of slough 294 shows the typical pattern of groundwater flow near permanent lakes, where the hills are areas of recharge and the sloughs are areas of discharge. During the summer a seepage from the sloughs towards the plants which surrounded them was observed. The schematic direction of the groundwater flow is presented in Figure 22.

The participation of the main ions in the origin and development of the groundwater chemistry of the described flow system is shown as a general ion cycle on Figure 22. This schematic cycle demonstrates the influence of dissolution, leaching, precipitation, and ion-exchange processes on the ion concentration in the groundwater of the local flow system, from the aerated and saturated recharge area along the transmission area to the saturated and aerated discharge area. The influence of the discharge of the intermediate groundwater flow in the vicinity of the slough as an additional source of ions, is also considered as is the periodic feeding of the groundwater by seepage from the slough. The effect of the summer evapotranspiration is demonstrated by the periodic appearance of a salt crust and the precipitation of the easily soluble salts in the capillary fringe zone and in the zone of saturated discharge. The leaching of these salts by rain water, mainly during spring precipitation, is also indicated.

Groundwater movement produces three hydrochemical zones (Fig. 22). The recharge area is represented by SO_4-Ca-Mg type of water with salinity 3,199 ppm. Under the conditions of groundwater flow, SO_4-Mg-Ca type of water is produced which is modified in the discharge area to the SO_4-Mg type of water. Under the effects of intensive evapotranspiration the shallow groundwater of the discharge area becomes SO_4-Mg type of water with an increased content of Na^+ ions once it emerges in the slough.

The sources of the ions delivered to the slough are groundwater and interflow. Therefore, the chemical type of slough water is basically determined by the chemistry of these waters. However, this chemistry is further modified by the intensive evaporation of slough water, which induces the increase of salinity as well as an increased concentration of easily soluble salts and the precipitation of less soluble salts. The ion exchange processes between water and clay minerals play an important role also. The decrease of CO_2 gas pressure in the surface water is indicated by changes in carbonate equilibrium:

$$H^+ + HCO_3^- = 2H^+ + CO_3^{2-}$$

2500

sea-level

Feet above

2400

2300

Slough 294   Holes

Hole   Hole

Groundwater   surface

SO_4 - (HCO_3) - Ca - Mg

SO_4 - Mg - Ca

SO_4 - Mg - (Na) SO_4 - Mg - (Na)

SO_4 - Mg SO_4 - Mg

Feet

0   150   300

Direction of flow . . . .

Chemical type of water . . . SO_4 - Mg

Summer 1966

Solution of weathered
silicates (Mg^{2+}, Na^+)

Solution of sulphates of heavy metals
Oxidation of organic
compounds (SO_4^{2-})

$CaCO_3 + H^+$

$CaMg (CO_3)_2 + H^+$

Solution $CaSO_4$

Salt crust (periodically)
Mg SO_4, Na_2 SO_4, NaCl

Spring $MgSO_4$, Na_2 SO_4
Summer
$CaCO_3$, $CaMg (CO_3)_2$

$CaSO_4$

Summer

Ca^{2+}, Mg^{2+}, Na^+,
SO_4^{2-}, HCO_3^{2-},
CO_3^{2-}

pH 7.3   SC 46807

$MgSO_4$ Spring
Summer

$CaCO_3$
$CaMg(CO_3)_2$
$CaSO_4$

Precipitation

HCO_3^-, SO_4^{2-}, Cl^-
Ca^{2+}, Mg^{2+}, Na^+

Interflow

AB horizon

Recharge
aerated

Discharge
aerated

pH 9.6   SC 48149

Spring
Summer $MgSO_4$, Na_2 SO_4, NaCl

$CaSO_4$
$CaMg (CO_3)_2$
$CaCO_3$

pH 7.7   SC 3199

C horizon
capillary fringe

Ca^{2+}, Mg^{2+}, Na^+, SO_4^{2-}, HCO_3^-

Solution of weathered
silicates (Mg^{2+}, Na^+)
Oxidation of sulphides and sulphur
included in till (SO_4^{2-})

Water
movement   SC 3751

Na^+ +
Ca, Mg clay Ca^{2+}, Mg^{2+} Na clay +

$CaCO_3$

pH 7.4

$CaSO_4$ $CaMg(CO_3)_2$

Ca^{2+}, Mg^{2+}, Na^+, SO_4^{2-}, HCO_3^-
from intermediate flow system

Discharge saturated

Recharge saturated

Figure 22.   Development of water chemistry of the local and intermediate groundwater
flow system

This phenomenon causes the appearance of CO_3^{2-} ions which were not observed in the groundwater of the recharge area, as well as an increase of pH of water (8.8) and the precipitation of carbonate salts. The described processes result in the enrichment of slough water with magnesium, sodium, potassium, sulphate and chloride ions, and the origin of SO_4-Mg-(Na) type of water with salinity 48, 149 ppm.

THE REGIONAL FLOW SYSTEM

The development of water chemistry of the regional flow system takes place first along its way from the areas of recharge to the second hydrogeological complex (Figs. 9, 18) and then along this complex. The flow through overlain deposits produces the occurrence of the earlier described SO_4-HCO_3-Mg-Ca and SO_4-Ca-Mg types of water (Fig. 18), saturated with carbonate salts. The chemistry of these is changed when they flow through the second hydrogeological complex, which is rich in soluble salts (Table 6). The dominant ions, according to the results of the chemical analyses of extracts, are Ca^{2+} and SO_4^{2-}. An increase of the concentration of Na^+ ions is also observed (Figs. 7, 8). The enrichment of the content of the last ions is effected by the higher ion exchange capacity of clay minerals which increases in the compact till deposits. The processes of leaching, dissolution and ion exchange between the clay minerals and water, produce the enrichment of the groundwater in $CaSO_4$ and Na_2SO_4 salts (Table 13). These processes and the simultaneous precipitation of carbonates induce the creation of the SO_4-(HCO_3)-Na-Ca and SO_4-Na types of waters (Fig. 18). The participation of the main ions in the origin and the development of the water chemistry is shown generally on the ion cycles diagram (Fig. 20). Because of the significant depth of the regional flow system, evapotranspiration does not increase its salinity.

The chemistry of the ground and surface waters of the area at the bottom of the Moose Mountain hills (Fig. 18) suggests that some discharge from the regional flow system may take place in this area.

HYDROCHEMICAL ZONATION

The described physico-chemical processes produce the existence of hydrochemical zonation which are shown generally on the Figures 18, 23. In the sandy glacial deposits on the top of Moose Mountain and locally on the slopes of the hills a HCO_3-Ca and HCO_3-Ca-Mg type of water exists.

Under conditions of groundwater flow the SO_4-HCO_3-Ca-Mg and SO_4-Mg-Ca types of water are produced and are modified in the discharge areas of the local and intermediate groundwater flow system to the SO_4-Mg type of water.

The deeper flow of water to the second hydrogeological complex is further modified to SO_4-(HCO_3)-Na-Ca and SO_4-Na types of waters.

According to the Figure 23 the main discharge areas of the local and intermediate groundwater flow systems in the direction from east to west are as follows:
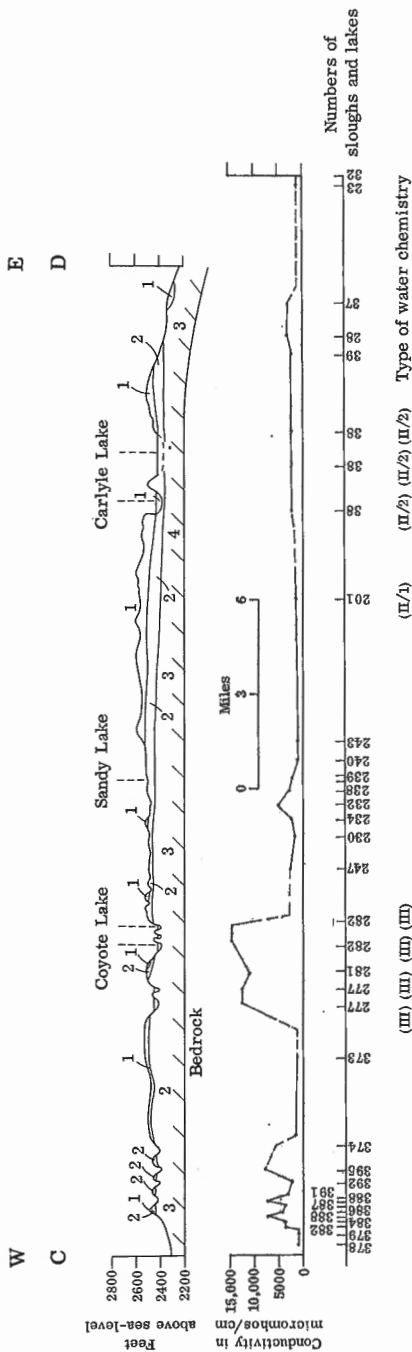
LEGEND

Chemical types of waters (mainly)

A. Groundwater hydrochemical zones

1. HCO_3^- – Ca^{2+}, HCO_3^- – Ca^{2+} – Mg^{2+} (I/1); HCO_3^- – SO_4^{2-} – Ca^{2+} – Mg, HCO_3^- – SO_4^{2-} – Mg^{2+} – Ca^{2+} (II/1a)

2. SO_4^{2-} – HCO_3^- – Ca^{2+} – Mg^{2+}, SO_4^{2-} – HCO_3^- – Mg^{2+} (II/1b)

3. SO_4^{2-} – Ca^{2+} – Mg^{2+}, SO_4^{2-} – Mg^{2+} (III/1-2)

4. SO_4^{2-} – Ca^{2+} – Na^+, SO_4^{2-} – Ca^{2+} – Na^+ – Mg^{2+} (III/2); SO_4^{2-} – HCO_3^- – Na^+Ca (II/2)

Extension of zones is shown approximately

B. Sloughs and lakes water

1. HCO_3^- – Ca^{2+}, HCO_3^- – Ca^{2+} – Na^+, HCO_3^- – Ca^{2+} – Mg^{2+} (I)

2. HCO_3^- – SO_4^{2-} – Mg^{2+} – Ca^{2+}, HCO_3^- – SO_4^{2-} – Mg^{2+} (II/1)

3. SO_4^{2-} – HCO_3^- – Mg^{2+} – Ca^{2+}, SO_4^{2-} – HCO_3^- – Mg^{2+} (II/2)

4. SO_4^{2-} – Mg^{2+} – Ca^{2+}, SO_4^{2-} – Mg^{2+} (III)

Figure 23.   Schematic hydrochemical cross-section (see Figure 14 for location of C-D)

Figure 24. Moose Mountain hills.

Figure 25. Carlyle Lake – SO$_4$-Mg type of water; conductivity 2,000 micromhos/cm.

Figure 26. Outcrop of glacial deposits near the top of Moose Mountain.

1. the sloughs of the east slopes of Moose Mountain;
2. the large lakes;
3. Coyote Lake with a group of sloughs;
4. the sloughs of the west slopes of Moose Mountain.

        The salinity of the water of the discharge areas of the eastern part
of the described cross-section is low in comparison with the salinity of the
western discharge areas, although their bases of drainage are deeper. The
reason is that the large lakes and eastern sloughs drain the more permeable
deposits, while the sloughs of the neighbouring discharge areas drain low
permeable deposits.
        The zone of low-conductivity sloughs, located in shallow depress-
ions, is the area of drainage of the low mineralized waters of the local
groundwater flow system.
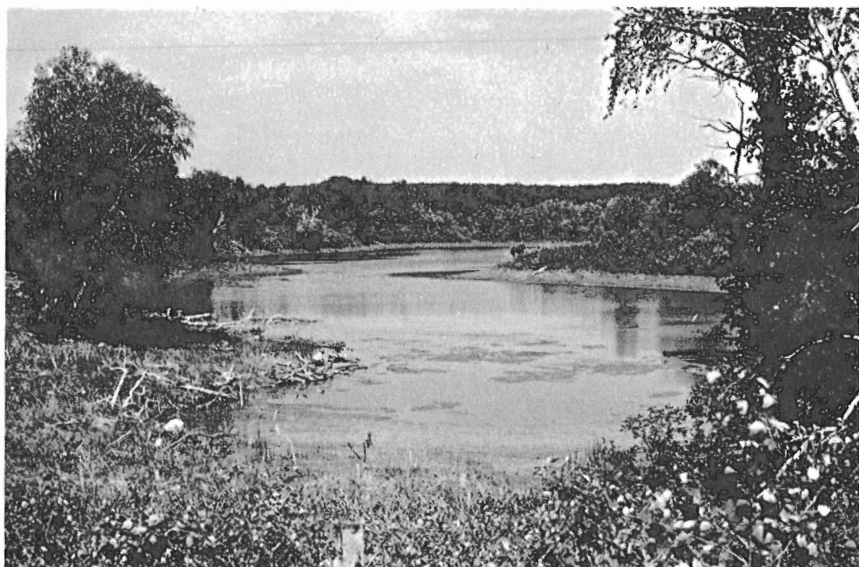
Figure 27. Slough No. 148. SO_4-Mg type of water; conductivity 6,500 micromhos/cm.

Figure 28. Slough No. 175. HCO_3-Ca type of water; conductivity 200 micromhos/cm.

Figure 29. Knob-and-kettle topography.
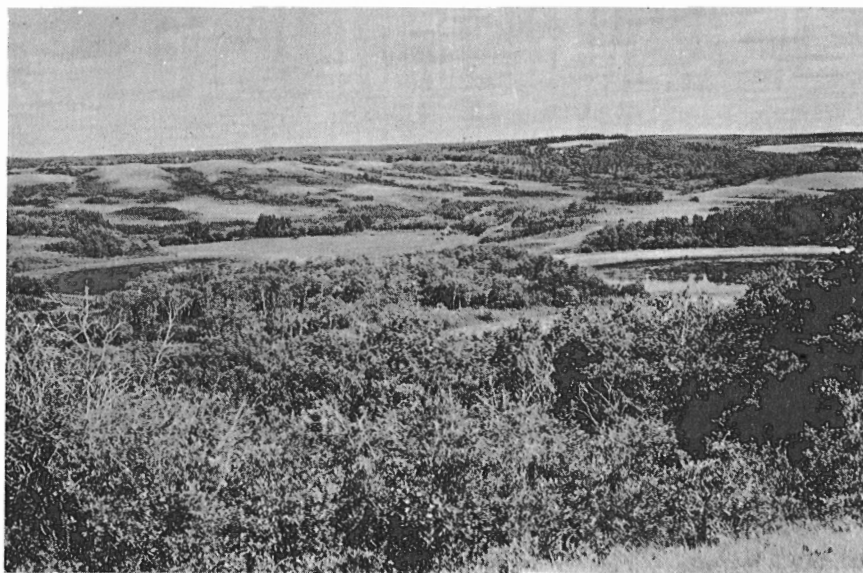
Figure 30. Discharge area of the intermediate groundwater flow systems. Highly mineralized sloughs with SO_4-Mg type of water.

GENERAL CONCLUSIONS

The field and laboratory studies of the glacial deposits of the Moose Mountain area show two zones of weathering. The distinguishable strata indicate differences in the concentration of soluble salts and ion exchange capacity. The ion exchange capacity increases in the lower layers of glacial deposits. The differentiation of permeability of strata enabled two hydro-geological complexes to be distinguished of which the upper is occupied by the local and intermediate groundwater flow systems and the lower by the regional groundwater flow.

Meyboom's investigations show the hydraulic interrelation between the sloughs and lakes on the one hand and groundwater on the other. The permanent sloughs and lakes are areas of groundwater discharge, whereas the temporary sloughs are infiltration ponds.

High salinity of waters is produced by semi-arid climatic conditions with an excess of evapotranspiration over precipitation. The variation of salinity and chemistry of the water is dependent mainly on the soluble salt content in the soil and glacial deposits and on groundwater flow conditions. The processes of leaching, dissolution, precipitation and ion exchange form the groundwater chemistry and in the case of the local and intermediate flow system produce the following hydrochemical zones: HCO_3-Ca-Mg $\rightarrow$ HCO_3-SO_4-Ca-Mg $\rightarrow$ SO_4-HCO_3-Ca-Mg $\rightarrow$ SO_4-Mg-Ca.

The effect of evapotranspiration in the zone of discharge produces more saline water with SO_4-Mg type of chemistry. The deeper regional flow of groundwater is distinguished by the appearance of the SO_4-HCO_3-Na-Ca or SO_4-Na hydrochemical zone in the southern part of described area.

The sources of the ions delivered to the sloughs and lakes are groundwater and interflow, the chemical type of slough water is basically determined by the chemistry of these waters. However, this basic chemistry is modified by the intensive evaporation of surface waters which induces the increase of salinity as well as an increased concentration of easily soluble salts and a precipitation of less soluble salts. The ion exchange processes between water and clay minerals also play an important role as does the biological activity of aquatic plants especially in the case of temporary sloughs.

The comparison of surface and groundwater chemistry shows that the permanent sloughs and lakes are areas of discharge of the local and intermediate groundwater flow systems only. The regional groundwater flow system drains beyond the area of Moose Mountain hills.

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APPENDICES

Appendix I

Chemical analyses of groundwater samples

Number on the map	Location			Groundwater flow system*	Depth ft.	pH	Spec. conductance micromhos at 25°C	Sum of constituents** ppm	Cations (epm)				Anions (epm)					Source of information****
	S	T	R						Ca^{2+}	Mg^{2+}	Na^{+}****	K^{+}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	NO_3^{-}	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	29	8	3	1		7.6	1100	579	4.790	5.596	0.339		0	5.899	4.685	0.141		F.a.
2	3	8	4	1	20	7.95		1495	6.25	7.40	2.83		0	6.89	8.13	1.01	0.26	S.R.C.
3	9	8	4	1	56	7.40		3905	16.25	22.20	15.22		0	10.66	42.50	1.41	0.21	S.R.C.
4	12	8	4	2	157	7.29		3335	16.50	13.16	14.57		0	6.97	35.94	0.90	0.23	S.R.C.
5	20	8	4	1	14	7.60		2335	11.50	13.98	7.17		0	4.84	25.10	0.79	0.73	S.R.C.
6	23	8	4	1	90	7.45		2290	15.75	9.88	7.04		0	7.30	25.73	0.59	0.01	S.R.C.
7	23	8	4	1	10	8.50		3010	11.00	26.32	4.35		1.23	4.59	35.63	0.51	-	S.R.C.
8	24	8	4	1	17	7.6	2300	1826	7.784	22.483	0.863		0	5.799	24.203	1.128		F.a.
9	26	8	4	1	20	7.70		945	5.25	6.17	0.61		0	5.49	6.15	0.31	0.21	S.R.C.
10	31	8	4	1	12	7.78		2115	10.75	12.34	1.65		0	6.56	10.52	3.80	3.71	S.R.C.
11	32	8	4	1	10	7.60		1450	9.35	8.14	1.57		0	5.67	9.13	2.20	2.66	S.R.C.
12	32	8	4	1	40	7.30		1875	17.20	8.14	1.57		0	7.30	19.17	0.20	0.18	S.R.C.
13	32	8	4	2	130	7.20		2340	11.60	6.50	17.61		0	10.26	24.11	1.01	0.15	S.R.C.
14	33	8	4	1	22	7.57		2125	9.25	13.16	1.00		0	7.71	9.79	2.20	4.03	S.R.C.
15	34	8	4	1	22	7.60		1060	9.00	8.22	0.78		0	5.98	9.90	0.42	0.81	S.R.C.
16	34	8	4	1	34	7.8	2000	1101	10.180	9.013	0.296		0	7.598	10.410	1.481		F.a.
17	5	8	5	1	12	8.01		555	4.50	3.95	0.22		0	5.74	0.52	0.90	1.45	S.R.C.
18	10	8	5	1	25	7.50		640	5.00	4.11	2.30		0	5.90	5.42	0.59	0.09	S.R.C.
19	12	8	5	1	18	7.63		2015	9.50	8.64	8.70		0	7.71	17.08	0.99	1.05	S.R.C.
20	16	8	5	1	16	7.50		1800	14.35	7.90	0.78		0	6.97	16.04	0.39	1.18	S.R.C.
21	18	8	5	1	10	7.70		280	3.25	1.48	0.65		0	4.10	0.75	0.39	0.39	S.R.C.
22	22	8	5	3	220	8.30		1315	0.35	0.82	19.57		0.33	10.46	Nil	10.28	Nil	S.R.C.
23	24	8	5	1	8	7.50		2635	11.75	18.92	6.96		0	6.15	29.79	0.51	0.05	S.R.C.
24	30	8	5	1	10	8.10		645	6.50	2.88	0.57		0	6.56	3.23	Nil	-	S.R.C.
25	34	8	5	1	15	7.80		605	4.35	3.78	2.48		0	3.28	6.50	0.20	0.34	S.R.C.
26	36	8	5	1	25	7.40		4375	21.75	24.26	16.09		0	9.02	51.25	1.07	1.19	S.R.C.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
27	16	8	6	1	65	8.00		1730	10.25	7.15	5.22		0	2.46	18.33	1.30	-	S.R.C.
28	23	8	6	3	167	8.90		1760	0.45	0.16	25.86		1.50	7.95	14.17	3.52	-	S.R.C.
29	36	8	6	3	132	7.52	700	1816	3.90	2.80	20.87		0	13.36	12.50	1.30	0.15	S.R.C.
30	30	9	2	1	14	7.65	1100	347	3.952	2.637	0.505	0.307	0	6.299	0.583	0.212		F.a.
31	30	9	2	1	6	7.45	3000	604	5.489	5.295	1.124		0	9.198	2.498	0.212	0.169	F.a.
32	12	9	3	1	60	7.8	1250	2406	20.559	16.119	3.088		0	7.966	29.528	0.917		W.R.B. Lab.
33	25	9	3	1	13	7.45	1500	658	6.986	4.996	0.707		0	9.198	3.279	0.212		F.a.
34	25	9	3	1	13	7.3		713	8.703	5.475	0.254		0	11.997	1.561	0.874		F.a.
35	3	9	4	1	spring	7.6	2200	1557	14.970	10.192	0.995		0	7.918	17.957	0.282		F.a.
36	10	9	4	1	8	7.49		1675	9.25	11.51	0.83		0	11.56	7.71	1.27	1.37	S.R.C.
37	16	9	4	1	16	7.75		725	6.30	5.59	0.35		0	7.54	4.83	0.20	0.03	S.R.C.
38	27	9	4	1	24	7.2	1800	1147	7.186	13.589	1.792		0	15.797	6.558	0.212		F.a.
39	2	9	5	1	spring	7.30		1330	18.50	10.86	4.87		0	6.77	26.46	0.39	0.02	S.R.C.
40	3	9	5	2	22	7.70		1410	10.60	7.90	1.57		0	6.49	13.54	0.20	0.48	S.R.C.
41	3	9	5	3	140	7.00		2230	9.95	3.13	18.04		0	8.85	22.92	0.59	0.24	S.R.C.
42	4	9	5	1	270	8.10		1855	0.60	0.25	29.13		0	18.03	11.15	1.41	0.15	S.R.C.
43	5	9	5	1	33	7.65		1480	8.60	7.81	2.78		0	5.90	10.21	1.24	2.26	S.R.C.
44	16	9	6	1	40	7.60		2320	16.75	9.87	0.91		0	7.30	17.50	0.82	1.37	S.R.C.
45	4	9	6	1	32	7.77		945	4.10	4.28	6.30		0	4.67	9.27	0.42	0.01	S.R.C.
46	16	9	6	1	25	8.50		905	2.30	7.40	1.52		1.13	3.85	3.96	0.79	1.58	S.R.C.
47	12	10	1	2	180	7.4	3000	1856	10.778	7.694	11.450	0.402	0	7.198	20.820	1.904		F.a.
48	13	10	1	2	140	7.6	2326	1751	6.287	3.923	16.175	0.381	0	5.589	20.237	0.733	0.015	W.R.B. Lab.
49	14	10	1	3	265	7.5	2520	1933	10.828	6.818	11.827		0	7.195	22.694	0.677	0.011	W.R.B. Lab.
50	14	10	1	3	285	7.75	3000	1751	7.585	6.195	14.389		0	7.598	18.738	1.833		F.a.
51	15	10	1	2	135	8.0	2750	1725	11.377	5.596	10.522		0	6.799	19.779	0.917		F.a.
52	16	10	1	1	27	7.65	1100	579	4.890	5.695	0.839	0.161	0	8.398	2.603	0.423		F.a.
53	18	10	1	1	14	8.3	1450	703	4.855	6.579	0.914		0	4.795	6.781	0.251	0.050	W.R.B. Lab.
54	18	10	1	1	16	7.55	2000	1643	7.784	9.692	10.082		0	8.998	16.656	1.904		F.a.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
55	14	10	2	1	6	7.5	4000	3516	9.431	36.702	5.655	1.337	0	3.596	49.010	0.454	0.215	W.R.B. Lab.
56	14	10	2	1	6	7.6	4000	3278	12.974	33.939	6.134	1.087	0	11.229	42.764	0.443	0.094	W.R.B. Lab.
57	14	10	2	1	6	7.5	3000	2418	9.631	24.754	4.070	1.220	0	6.150	32.687	0.186	0.090	W.R.P. Lab.
58	14	10	2	1	6	8.6	5180	4714	13.373	53.290	8.135	0.499	0.493	4.662	71.038	0.124	0.111	W.R.B. Lab.
59	14	10	2	1	6	7.2	800	470	2.580	4.276	0.827	0.100	0	1.926	5.559	0.051	0.110	W.R.B. Lab.
60	15	10	3	1	9	7.9	1200	454	4.591	3.397	1.376		0	8.798	0.354	0.212		F.a.
61	16	10	3	1	80	7.7	5500	4494	23.703	40.791	7.830	0.716	0	7.031	62.793	1.692	0.132	W.R.B. Lab.
62	24	10	4	1	60	7.3	1250	646	6.387	4.596	1.634		0	8.998	2.040	1.579		F.a.
63	3	10	5	1	4.7	7.9	1600	917	5.190	10.392	1.776		0	10.318	6.871	0.169		F.a.
64	5	10	5	1	25	8.0	3050	2602	12.924	24.014	4.698	0.320	0	5.130	34.561	1.044	0.968	W.R.B. Lab.
65	27	10	5	1	48	7.5	1980	1319	9.930	9.375	0.435	0.133	0	4.711	2.727	2.171	10.323	W.R.B. Lab.
66	28	10	5	1	11	8.2	29350	46807	18.760	595.911	137.832	8.186	0	14.866	727.659	5.358	0.003	W.R.B. Lab.
67	28	10	5	1	27	7.4	3860	3751	21.906	31.498	4.131	0.819	0	5.015	54.134	0.564	0.031	W.R.B. Lab.
68	28	10	5	1	24	8.6	28920	50175	19.511	710.060	71.307	10.795	2.840	16.079	801.570	2.397	0.008	W.R.B. Lab.
69	34	10	3	1	spring	7.6	1107	685	5.838	5.510	0.717	0.179	0	7.015	4.872	0.116	0.002	W.R.B. Lab.
70	23	11	3	1	90	7.4	3300	2065	17.665	16.487	1.089		0	9.678	22.954	2.609		F.a.
71	26	11	3	1	20	7.8	1100	574	3.892	6.895	0.183		0	6.349	4.268	0.353		F.a.
72	27	11	3	1	50	7.1	1500	811	8.982	5.995	0.352		0	10.198	4.919	0.212		F.a.
73	13	11	4	1	14	7.5	1600	962	7.684	11.291	0.050		0	13.400	5.413	0.212		F.a.
74	13	11	4	1	20	7.2	2600	1621	10.778	13.816	0.574	0.281	0	2.016	10.701	4.653	7.259	W.R.B. Lab.
75	14	11	4	1	40	7.8	1257	880	5.189	8.138	0.922	0.205	0	3.589	8.828	0.987	0.952	W.R.B. Lab.
76	14	11	4	1	15	8.3	864	472	5.040	3.454	1.000	0.284	0	5.769	1.374	0.902	0.071	W.R.B. Lab.
77	16	11	4	1	18	7.25	2000	1073	7.186	10.592	1.562		0	8.687	10.202	0.451		F.a.
78	19	11	4	1	30	7.7	1736	1248	4.486	13.899	3.087	0.130	0	8.638	12.908	0.161	-	W.R.B. Lab.
79	19	11	4	1	18	7.4	8400	7931	18.204	92.087	22.664		0	22.895	106.182	3.878		F.a.
80	20	11	4	1	45	7.9	824	513	2.480	6.472	0.717	0.128	0	4.589	3.831	0.395	0.074	W.R.B. Lab.
81	21	11	4	1	17	7.2	3400	2118	11.976	20.984	4.227		0	13.997	22.485	0.705		F.a.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
82	22	11	4	1	51	7.1	2877	2656	17.964	17.764	4.826	0.427	0	1.819	38.725	0.338	-	W.R.B. Lab.
83	26	11	4	1	12	7.35	1900	899	9.900	8.074	1.171		0	10.998	2.915	2.961	2.271	F.a.
84	30	11	4	1	60	7.25	2400	1505	13.972	10.492	1.492		0	9.918	15.615	0.423		F.a.
85	31	11	4	1	37	7.40		2800	16.00	19.33	3.65		0	9.02	30.63	0.37		S.R.C.
86	31	11	4	1	13	7.89		915	5.50	7.81	1.00		0	8.44	5.73	0.34		S.R.C.
87	31	11	4	1	50	8.19		485	4.00	3.29	0.35		0	6.03	1.77	0.20		S.R.C.
88	35	11	4	1	51	7.3	2300	1545	11.776	12.690	2.685		0	10.998	15.095	1.058		F.a.
89	35	11	4	1	9	7.65	1000	582	7.086	3.098	1.052		0	8.838	2.186	0.212		F.a.
90	15	11	5	1	14	7.6	800	555	4.880	3.808	0.748	0.038	0	3.852	5.309	0.116	0.006	W.R.B. Lab.
91	18	11	5	2 (?)	166	7.49		2010	12.75	10.69	5.44		0	8.69	20.83	0.42		S.R.C.
92	20	11	5	1	10	7.65		585	5.20	4.28	0.44		0	8.36	1.40	0.51		S.R.C.
93	20	11	5	1	110	7.92		1840	10.90	9.05	5.00		0	3.46	21.67	0.39		S.R.C.
94	21	11	5	1	80	7.2	2700	1797	15.569	9.592	4.655		0	9.198	20.195	0.423		F.a.
95	22	11	5	1	14	7.45	700	276	4.291	1.100	0.114		0	4.699	0.355	0.451		F.a.
96	26	11	5	1	15	7.9	2331	1922	8.932	18.340	3.957	0.102	0	6.572	25.317	0.054	0.001	W.R.B. Lab.
97	7	12	5	1	117	7.60		4490	24.00	28.78	8.91		0	9.18	50.63	1.10		S.R.C.
98	11	12	4	2	150	7.6	3500	2385	20.559	15.388	3.713		0	10.918	28.107	0.635		F.a.
99	15	12	4	2	200	7.2		3020	18.30	16.94	7.17		0	6.87	36.25	0.54		S.R.C.
100	17	12	4	1	104	7.49		1520	7.46	13.33	1.10		0	12.25	6.50	3.13		S.R.C.
101	20	12	4	1	48	7.75		1500	7.50	12.99	1.22		0	10.57	13.13	1.30		S.R.C.
102	28	12	4	1	126	7.40		2145	10.80	12.17	7.13		0	4.90	26.56	0.59		S.R.C.
103	33	12	4	1	78	7.55		1970	11.90	10.03	6.26		0	5.67	21.88	0.34		S.R.C.
104	34	12	4	1	120	7.50		2450	14.25	14.39	4.78		0	5.49	27.92	0.90		S.R.C.
105	35	12	5	1	85	7.85		665	3.30	5.02	1.57		0	4.20	4.79	0.42	0.12	S.R.C.
106	9	12	5	1	50	7.45		2900	21.90	15.63	2.74		0	5.41	36.25	0.31		S.R.C.
107	17	12	5	1	12	7.55		2125	11.40	16.45	1.78		0	12.30	11.73	4.34		S.R.C.
108	17	12	5	1	50	7.50		2550	18.10	14.14	3.74		0	4.98	27.71	2.39		S.R.C.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
109	28	12	5	1	83	7.71		1560	11.75	7.81	2.61		0	6.03	15.00	0.28		S.R.C.
110	29	12	5	1	18	7.85		1070	6.40	7.89	4.87		0	8.36	8.33	0.37		S.R.C.
111	30	12	5	1	70	7.70		2095	6.85	8.72	10.00		0	2.87	22.92	0.85		S.R.C.
112	32	12	5	1	72	7.50		2665	15.45	12.91	9.35		0	6.90	30.31	1.41		S.R.C.
113	10	13	4	1	80	7.60		1720	7.40	9.13	6.74		0	4.07	20.31	0.59		S.R.C.
114	14	13	4	2	127	7.82		1290	4.95	7.32	5.39		0	3.51	13.33	0.62		S.R.C.
115	16	13	4	1	70	7.00		1400	6.90	8.88	3.83		0	1.93	13.54	2.20		S.R.C.
116	22	13	4	2	130	8.00		5400	15.25	44.00	13.91		0	7.05	66.67	0.90		S.R.C.
117	23	13	4	1	90	7.61		1450	7.15	7.15	7.17		0	7.56	13.75	0.98		S.R.C.
118	26	13	4	1	50	7.45		2370	12.90	13.32	7.26		0	5.87	24.17	2.39	2.13	S.R.C.
119	3	13	5	1	60	7.40		1950	13.05	11.18	3.61		0	7.44	20.13	0.42		S.R.C.
120	5	13	5	2	134	7.60		1455	8.60	6.25	4.87		0	4.53	14.90	0.90		S.R.C.
121	7	13	5	1	72	7.43		2370	10.55	12.50	10.87		0	8.61	25.63	0.99		S.R.C.
122	8	13	5	1	35	7.40		1750	12.10	9.38	1.04		0	7.30	13.33	1.49		S.R.C.
123	8	13	5	1	40	7.80		3080	15.75	20.56	6.09		0	5.16	36.46	2.00		S.R.C.
124	9	13	5	2	174	7.40		2400	12.65	10.53	10.13		0	7.43	23.75	1.66		S.R.C.
125	16	13	5	1	60	7.65		2500	15.75	10.28	9.57		0	10.25	25.83	0.99		S.R.C.
126	17	13	5	1	40	8.42		2225	8.25	17.43	3.65		1.67	4.25	20.10	2.11		S.R.C.
127	17	13	5	1	50	7.81		1515	5.95	11.60	1.74		0	6.15	9.79	1.38		S.R.C.
128	21	13	5	1	35	7.92		1960	10.20	12.91	1.74		0	3.31	17.71	2.28		S.R.C.
129	27	13	5	1	90	7.80		3130	14.75	23.85	5.22		0	7.54	35.10	1.69		S.R.C.
130	30	13	5	2 (?)	140	8.25		2050	10.25	11.92	4.78		0	4.10	22.29	0.90		S.R.C.
131	33	13	5	1	50	7.48		3170	22.15	17.85	6.04		0	6.39	36.04	1.61		S.R.C.
132	35	13	5	2	120	7.85		1835	7.05	9.95	8.17		0	3.69	18.23	1.13		S.R.C.

* Groundwater flow system 1 - local and intermediate (1-st hydrogeological complex)
                            2 - regional (2-nd hydrogeological complex)
                            3 - regional (3-rd hydrogeological complex)

** The value of total dissolved solids (110°C) is given in this column for analyses obtained from Saskatchewan Research Council

*** The values of the Na⁺ and K⁺ constituents for field analyses (F.a.) are calculated

**** F.a. - analysis made in field with a HACH chemical kit
      S.R.C. - analysis obtained from Saskatchewan Research Council
      W.R.B. Lab. - analysis made in the Inland Waters Branch Laboratorium in Ottawa

Appendix II

The interrelation of ions and chemical classification of ground water

Number on the map	Chemistry of water according to Kurlov formula	Type of water accto Priklonski formula	Ratios*					
			$\dfrac{SO_4^{2-}}{HCO_3^- + CO_3^{2-}}$	$\dfrac{Mg^{2+}}{Ca^{2+}}$	$\dfrac{Na^+}{Mg^{2+}}$	$\dfrac{Na^+}{Ca^{2+}}$	$\dfrac{Na^+}{Cl^-}$	$\dfrac{Na^+ - Cl^-}{SO_4^{2-}}$
1	2	3	4	5	6	7	8	9
1	$M_{0.6} \dfrac{HCO_3\ 27.50\ \ SO_4\ 21.84\ \ Cl\ 0.66}{Mg\ 26.09\ \ Ca\ 22.33\ \ Na\ 1.58}$	$HCO_3-(SO_4)-Mg-(Ca)$	0.794	1.168	0.061	0.071	2.404	0.042
2	$M_{1.5} \dfrac{SO_4\ 24.95\ \ HCO_3\ 21.15\ \ Cl\ 3.10\ \ NO_3\ 0.80}{Mg\ 22.45\ \ Ca\ 18.96\ \ Na\ 8.59}$	$SO_4-(HCO_3)-Mg-Ca$	1.180	1.184	0.382	0.453	2.802	0.224
3	$M_{3.9} \dfrac{SO_4\ 38.79\ \ HCO_3\ 9.73\ \ Cl\ 1.29\ \ NO_3\ 0.19}{Mg\ 20.68\ \ Ca\ 15.14\ \ Na\ 14.18}$	$SO_4-Mg-Ca-Na$	3.987	1.366	0.685	0.937	10.794	0.325
4	$M_{3.3} \dfrac{SO_4\ 40.81\ \ HCO_3\ 7.91\ \ Cl\ 1.02\ \ NO_3\ 0.26}{Ca\ 18.65\ \ Na\ 16.47\ \ Mg\ 14.88}$	$SO_4-Ca-Na-Mg$	5.156	0.798	1.107	0.883	16.188	0.380
5	$M_{2.3} \dfrac{SO_4\ 39.89\ \ HCO_3\ 7.70\ \ Cl\ 1.26\ \ NO_3\ 1.15}{Mg\ 21.41\ \ Ca\ 17.61\ \ Na\ 10.98}$	$SO_4-Mg-Ca$	5.186	1.216	0.513	0.623	9.076	0.254
6	$M_{2.3} \dfrac{SO_4\ 38.25\ \ HCO_3\ 10.85\ \ Cl\ 0.88\ \ NO_3\ 0.02}{Ca\ 24.10\ \ Mg\ 15.12\ \ Na\ 10.78}$	$SO_4-Ca-Mg$	3.525	0.627	0.713	0.447	11.932	0.251

1	2	3	4	5	6	7	8	9
7	$M_{3.0} \dfrac{SO_4\ 42.46\quad HCO_3\ 5.47\quad CO_3\ 1.46\quad Cl\ 0.61}{Mg\ 31.58\quad Ca\ 13.20\quad Na\ 5.22}$	$SO_4-Mg-(Ca)$	6.122	2.393	0.165	0.395	8.529	0.108
8	$M_{1.8} \dfrac{SO_4\ 38.88\quad HCO_3\ 9.31\quad Cl\ 1.81}{Mg\ 36.11\quad Ca\ 12.50\quad Na\ 1.39}$	$SO_4-Mg-(Ca)$	4.174	2.888	0.038	0.111	0.765	-0.011
9	$M_{0.9} \dfrac{SO_4\ 25.29\quad HCO_3\ 22.58\quad Cl\ 1.27\quad NO_3\ 0.86}{Mg\ 25.64\quad Ca\ 21.82\quad Na\ 2.54}$	$SO_4-(HCO_3)-Mg-(Ca)$	1.120	1.175	0.099	0.116	1.968	0.049
10	$M_{2.1} \dfrac{SO_4\ 21.39\quad HCO_3\ 13.34\quad Cl\ 7.73\quad NO_3\ 7.54}{Mg\ 24.94\quad Ca\ 21.73\quad Na\ 3.33}$	$SO_4-HCO_3-Mg-Ca$	1.604	1.148	0.134	0.153	0.434	-0.204
11	$M_{1.5} \dfrac{SO_4\ 23.22\quad HCO_3\ 14.42\quad NO_3\ 6.77\quad Cl\ 5.59}{Ca\ 24.53\quad Mg\ 21.35\quad Na\ 4.12}$	$SO_4-HCO_3-Ca-Mg$	1.610	0.871	0.193	0.168	0.713	-0.069
12	$M_{1.9} \dfrac{SO_4\ 35.70\quad HCO_3\ 13.59\quad Cl\ 0.37\quad NO_3\ 0.34}{Ca\ 31.96\quad Mg\ 15.12\quad Na\ 2.92}$	$SO_4-(HCO_3)-Ca-(Mg)$	2.626	0.473	0.193	0.091	7.850	0.071
13	$M_{2.3} \dfrac{SO_4\ 33.96\quad HCO_3\ 14.41\quad Cl\ 1.42\quad NO_3\ 0.21}{Na\ 24.66\quad Ca\ 16.24\quad Mg\ 9.10}$	$SO_4-(HCO_3)-Na-Ca$	2.356	0.560	2.709	1.518	17.436	0.687

1	2	3	4	5	6	7	8	9
14	$M_{2.1}\ \dfrac{SO_4\ 20.63\quad HCO_3\ 16.24\quad NO_3\ 8.49\quad Cl\ 4.64}{Mg\ 28.11\quad Ca\ 19.76\quad Na\ 2.13}$	$SO_4\text{-}HCO_3\text{-}Mg\text{-}(Ca)$	1.270	1.423	0.076	0.108	0.454	-0.123
15	$M_{1.1}\ \dfrac{SO_4\ 28.93\quad HCO_3\ 17.47\quad NO_3\ 2.37\quad Cl\ 1.23}{Ca\ 25.00\quad Mg\ 22.83\quad Na\ 2.17}$	$SO_4\text{-}(HCO_3)\text{-}Ca\text{-}(Mg)$	1.656	0.913	0.095	0.087	1.857	0.036
16	$M_{1.1}\ \dfrac{SO_4\ 26.71\quad HCO_3\ 19.49\quad Cl\ 3.80}{Ca\ 26.12\quad Mg\ 23.12\quad Na\ 0.76}$	$SO_4\text{-}(HCO_3)\text{-}Ca\text{-}(Mg)$	1.370	0.885	0.033	0.029	0.200	-0.114
17	$M_{0.6}\ \dfrac{HCO_3\ 33.33\quad NO_3\ 8.42\quad Cl\ 5.23\quad SO_4\ 3.02}{Ca\ 25.95\quad Mg\ 22.78\quad Na\ 1.27}$	$HCO_3\text{-}Ca\text{-}(Mg)$	0.091	0.878	0.056	0.049	0.244	-1.097
18	$M_{0.6}\ \dfrac{HCO_3\ 24.58\quad SO_4\ 22.58\quad Cl\ 2.46\quad NO_3\ 0.38}{Ca\ 21.91\quad Mg\ 18.01\quad Na\ 10.08}$	$HCO_3\text{-}SO_4\text{-}Ca\text{-}Ng$	0.919	0.822	0.560	0.460	3.898	0.315
19	$M_{2.0}\ \dfrac{SO_4\ 31.83\quad HCO_3\ 14.37\quad NO_3\ 1.96\quad Cl\ 1.84}{Ca\ 17.69\quad Na\ 16.22\quad Mg\ 16.09}$	$SO_4\text{-}(HCO_3)\text{-}Ca\text{-}Na\text{-}Mg$	2.215	0.909	1.007	0.916	8.788	0.451
20	$M_{1.8}\ \dfrac{SO_4\ 32.63\quad HCO_3\ 14.18\quad NO_3\ 2.40\quad Cl\ 0.79}{Ca\ 31.16\quad Mg\ 17.15\quad Na\ 1.69}$	$SO_4\text{-}(HCO_3)\text{-}Ca\text{-}(Mg)$	2.301	0.551	0.099	0.054	2.000	0.024

1	2	3	4	5	6	7	8	9
21	$M_{0.3} \dfrac{HCO_3\ 36.42\ \ SO_4\ 6.66\ \ Cl\ 3.46\ \ NO_3\ 3.46}{Ca\ 30.20\ \ Mg\ 13.76\ \ Na\ 6.04}$	$HCO_3-Ca-(Mg)$	0.183	0.455	0.439	0.200	1.667	0.347
22	$M_{1.3} \dfrac{HCO_3\ 24.82\ \ Cl\ 24.40\ \ CO_3\ 0.78}{Na\ 47.18\ \ Mg\ 1.98\ \ Ca\ 0.84}$	$HCO_3-Cl-Na$	0	2.343	23.866	55.914	1.904	
23	$M_{2.6} \dfrac{SO_4\ 40.81\ \ HCO_3\ 8.42\ \ Cl\ 0.70\ \ NO_3\ 0.07}{Mg\ 25.14\ \ Ca\ 15.61\ \ Na\ 9.25}$	$SO_4-Mg-(Ca)$	4.844	1.610	0.368	0.592	13.647	0.217
24	$M_{0.6} \dfrac{HCO_3\ 33.50\ \ SO_4\ 16.50}{Ca\ 32.66\ \ Mg\ 14.47\ \ Na\ 2.87}$	$HCO_3-(SO_4)-Ca-(Mg)$	0.492	0.443	0.198	0.088		0.176
25	$M_{0.6} \dfrac{SO_4\ 31.49\ \ HCO_3\ 15.89\ \ NO_3\ 1.65\ \ Cl\ 0.97}{Ca\ 20.50\ \ Mg\ 17.81\ \ Na\ 11.69}$	$SO_4-(HCO_3)-Ca-Mg$	1.982	0.869	0.656	0.570	12.400	0.351
26	$M_{4.4} \dfrac{SO_4\ 40.98\ \ HCO_3\ 7.21\ \ NO_3\ 0.95\ \ Cl\ 0.86}{Mg\ 19.52\ \ Ca\ 17.52\ \ Na\ 12.96}$	$SO_4-Mg-Ca-Na$	5.682	1.115	0.663	0.740	15.037	0.293
27	$M_{1.7} \dfrac{SO_4\ 41.49\ \ HCO_3\ 5.57\ \ Cl\ 2.94}{Ca\ 22.66\ \ Mg\ 15.80\ \ Na\ 11.54}$	$SO_4-Ca-Mg$	7.451	0.698	0.730	0.509	4.015	0.214

1	2	3	4	5	6	7	8	9
28	$M_{1.8}$ $\dfrac{SO_4\ 26.11\quad HCO_3\ 14.65\quad Cl\ 6.48\quad CO_3\ 2.76}{Na\ 48.85\quad Ca\ 0.85\quad Mg\ 0.30}$	$SO_4-(HCO_3)-Na$	1.499	0.356	161.625	57.467	7.347	1.577
29	$M_{1.8}$ $\dfrac{HCO_3\ 24.46\quad SO_4\ 22.88\quad Cl\ 2.38\quad NO_3\ 0.28}{Na\ 37.85\quad Ca\ 7.07\quad Mg\ 5.08}$	HCO_3-SO_4-Na	0.936	0.718	7.454	5.351	16.054	1.566
30	$M_{0.3}$ $\dfrac{HCO_3\ 44.40\quad SO_4\ 4.11\quad Cl\ 1.49}{Ca\ 27.85\quad Mg\ 18.59\quad Na\ 3.56}$	$HCO_3-Ca-(Mg)$	0.093	0.667	0.192	0.128	2.382	0.503
31	$M_{0.6}$ $\dfrac{HCO_3\ 38.62\quad SO_4\ 10.49\quad Cl\ 0.89}{Ca\ 23.05\quad Mg\ 22.23\quad Na\ 4.72}$	$HCO_3-Ca-Mg$	0.272	0.965	0.212	0.205	5.302	0.365
32	$M_{2.4}$ $\dfrac{SO_4\ 38.27\quad HCO_3\ 10.32\quad Cl\ 1.19\quad NO_3\ 0.22}{Ca\ 25.65\quad Mg\ 20.12\quad Na\ 3.85\quad K\ 0.38}$	$SO_4-Ca-(Mg)$	3.707	0.785	0.191	0.150	3.371	0.074
33	$M_{0.7}$ $\dfrac{HCO_3\ 36.24\quad SO_4\ 12.92\quad Cl\ 0.84}{Ca\ 27.53\quad Na\ 19.69\quad Mg\ 2.78}$	$HCO_3-(SO_4)-Ca-(Mg)$	0.356	0.715	0.142	0.101	3.335	0.151
34	$M_{0.7}$ $\dfrac{HCO_3\ 41.56\quad SO_4\ 5.41\quad Cl\ 3.03}{Ca\ 30.15\quad Na\ 18.97\quad Mg\ 0.88}$	$HCO_3-Ca-(Mg)$	0.130	0.629	0.046	0.029	0.291	-0.397

1	2	3	4	5	6	7	8	9
35	$M_{1.6}\ \dfrac{SO_4\ 34.32\ \ HCO_3\ 15.14\ \ Cl\ 0.54}{Ca\ 28.62\ \ Mg\ 19.48\ \ Na\ 1.90}$	$SO_4-(HCO_3)-Ca-(Mg)$	2.268	0.681	0.098	0.066	3.528	0.040
36	$M_{1.7}\ \dfrac{HCO_3\ 26.38\ \ SO_4\ 17.59\ \ NO_3\ 3.13\ \ Cl\ 2.90}{Mg\ 26.66\ \ Ca\ 21.42\ \ Na\ 1.92}$	$HCO_3-(SO_4)-Mg-(Ca)$	0.667	1.244	0.072	0.090	0.654	-0.057
37	$M_{0.7}\ \dfrac{HCO_3\ 29.92\ \ SO_4\ 19.17\ \ Cl\ 0.79\ \ NO_3\ 0.12}{Ca\ 25.73\ \ Mg\ 22.84\ \ Na\ 1.43}$	$HCO_3-(SO_4)-Ca-(Mg)$	0.641	0.887	0.063	0.056	1.750	0.031
38	$M_{1.1}\ \dfrac{HCO_3\ 35.00\ \ SO_4\ 14.53\ \ Cl\ 0.47}{Mg\ 30.11\ \ Ca\ 15.92\ \ Na\ 3.97}$	$HCO_3-(SO_4)-Mg-(Ca)$	0.415	1.891	0.132	0.249	8.453	0.241
39	$M_{1.3}\ \dfrac{SO_4\ 39.33\ \ HCO_3\ 10.06\ \ Cl\ 0.58\ \ NO_3\ 0.03}{Ca\ 27.02\ \ Mg\ 15.86\ \ Na\ 7.12}$	$SO_4-Ca-(Mg)$	3.908	0.587	0.448	0.263	12.487	0.169
40	$M_{1.4}\ \dfrac{SO_4\ 32.69\ \ HCO_3\ 15.67\ \ NO_3\ 1.16\ \ Cl\ 0.48}{Ca\ 26.41\ \ Mg\ 19.68\ \ Na\ 3.91}$	$SO_4-(HCO_3)-Ca-(Mg)$	2.086	0.745	0.199	0.148	7.850	0.101
41	$M_{2.2}\ \dfrac{SO_4\ 35.15\ \ HCO_3\ 13.57\ \ Cl\ 0.90\ \ NO_3\ 0.38}{Na\ 28.98\ \ Ca\ 15.99\ \ Mg\ 5.03}$	$SO_4-(HCO_3)-Na-(Ca)$	2.590	0.313	5.764	1.813	30.576	0.761

1	2	3	4	5	6	7	8	9
42	$M_{1.9} \dfrac{HCO_3\ 29.33\quad SO_4\ 18.14\quad Cl\ 2.29\quad NO_3\ 0.24}{Na\ 48.58\quad Ca\ 1.00\quad Mg\ 0.42}$	$HCO_3-(SO_4)-Na$	0.618	0.417	116.520	48.550	20.660	2.486
43	$M_{1.5} \dfrac{SO_4\ 26.04\quad HCO_3\ 15.04\quad NO_3\ 5.76\quad Cl\ 3.16}{Ca\ 22.41\quad Mg\ 20.35\quad Na\ 7.24}$	$SO_4-(HCO_3)-Ca-Mg$	1.731	0.908	0.356	0.323	2.242	0.151
44	$M_{2.3} \dfrac{SO_4\ 32.42\quad HCO_3\ 13.52\quad NO_3\ 2.54\quad Cl\ 1.52}{Ca\ 30.42\quad Mg\ 17.93\quad Na\ 1.65}$	$SO_4-(HCO_3)-Ca-(Mg)$	2.397	0.589	0.092	0.054	1.110	0.005
45	$M_{0.9} \dfrac{SO_4\ 32.26\quad HCO_3\ 16.25\quad Cl\ 1.46\quad NO_3\ 0.03}{Na\ 21.46\quad Ca\ 14.58\quad Mg\ 13.96}$	$SO_4-(HCO_3)-Na-Mg$	1.985	1.044	1.472	1.537	15.000	0.634
46	$M_{0.9} \dfrac{SO_4\ 17.51\quad HCO_3\ 17.02\quad NO_3\ 6.98\quad CO_3\ 5.00\quad Cl\ 3.49}{Mg\ 32.98\quad Ca\ 10.25\quad Na\ 6.77}$	SO_4-HCO_3-Mg	0.795	3.217	0.205	0.661	1.924	0.184
47	$M_{1.9} \dfrac{SO_4\ 34.79\quad HCO_3\ 12.03\quad Cl\ 3.18}{Na\ 19.13\quad Ca\ 18.01\quad Mg\ 12.86}$	$SO_4-Na-Ca-Mg$	2.892	0.714	1.488	1.062	6.014	0.459
48	$M_{1.8} \dfrac{SO_4\ 38.08\quad HCO_3\ 10.52\quad Cl\ 1.38\quad NO_3\ 0.02}{Na\ 30.19\quad Ca\ 11.74\quad Mg\ 7.32\quad K\ 0.75}$	SO_4-Na	3.621	0.624	4.123	2.573	22.067	0.763

1	2	3	4	5	6	7	8	9
49	$M_{1.9}\dfrac{SO_4\ 37.11\quad HCO_3\ 11.77\quad Cl\ 1.11\quad NO_3\ 0.01}{Na\ 19.81\quad Ca\ 18.13\quad Mg\ 11.42\quad K\ 0.64}$	SO$_4$-Na-Ca	3.154	0.630	1.735	1.092	17.470	0.491
50	$M_{1.8}\dfrac{SO_4\ 33.26\quad HCO_3\ 13.49\quad Cl\ 3.25}{Na\ 25.54\quad Ca\ 13.46\quad Mg\ 11.00}$	SO$_4$-(HCO$_3$)-Na-(Ca)	2.466	0.817	2.323	1.897	7.850	0.670
51	$M_{1.7}\dfrac{SO_4\ 35.97\quad HCO_3\ 12.36\quad Cl\ 1.67}{Ca\ 20.69\quad Na\ 19.13\quad Mg\ 10.18}$	SO$_4$-(HCO$_3$)-Ca-Na	2.909	0.492	1.880	0.925	11.474	0.486
52	$M_{0.6}\dfrac{HCO_3\ 36.76\quad SO_4\ 11.39\quad Cl\ 1.85}{Mg\ 24.93\quad Ca\ 21.40\quad Na\ 3.67}$	HCO$_3$-Mg-Ca	0.310	1.165	0.147	0.172	1.983	0.160
53	$M_{0.7}\dfrac{SO_4\ 28.54\quad HCO_3\ 20.19\quad Cl\ 1.06\quad NO_3\ 0.21}{Mg\ 26.30\quad Ca\ 19.41\quad Na\ 3.65\quad K\ 0.64}$	SO$_4$-(HCO$_3$)-Mg-(Ca)	1.414	1.355	0.139	0.188	3.657	0.098
54	$M_{1.6}\dfrac{SO_4\ 30.22\quad HCO_3\ 16.33\quad Cl\ 3.45}{Na\ 18.29\quad Mg\ 17.59\quad Ca\ 14.12}$	SO$_4$-(HCO$_3$)-Na-Mg	1.851	1.245	1.040	1.295	5.295	0.491
55	$M_{3.5}\dfrac{SO_4\ 46.00\quad HCO_3\ 3.37\quad Cl\ 0.43\quad NO_3\ 0.20}{Mg\ 34.54\quad Ca\ 8.88\quad Na\ 5.32\quad K\ 1.26}$	SO$_4$-Mg	13.629	3.890	0.154	0.600	12.456	0.106

1	2	3	4	5	6	7	8	9
56	$M_{3.3} \dfrac{SO_4\ 39.21\ HCO_3\ 10.30\ Cl\ 0.41\ NO_3\ 0.08}{Mg\ 31.35\ Ca\ 11.98\ Na\ 5.67\ K\ 1.00}$	SO_4-Mg	3.808	2.615	0.181	0.473	13.846	0.133
57	$M_{2.4} \dfrac{SO_4\ 41.79\ HCO_3\ 7.86\ Cl\ 0.24\ NO_3\ 0.11}{Mg\ 31.19\ Ca\ 12.14\ Na\ 5.13\ K\ 1.54}$	SO_4-Mg	3.469	2.570	0.164	0.423	21.596	0.117
58	$M_{4.7} \dfrac{SO_4\ 46.48\ HCO_3\ 3.05\ CO_3\ 0.32\ Cl\ 0.08\ NO_3\ 0.07}{Mg\ 35.39\ Ca\ 8.88\ Na\ 5.40\ K\ 0.33}$	SO_4-Mg	13.780	3.984	0.153	0.608	65.605	0.113
59	$M_{0.5} \dfrac{SO_4\ 36.35\ HCO_3\ 12.59\ NO_3\ 0.73\ Cl\ 0.33}{Mg\ 27.47\ Ca\ 16.57\ Na\ 5.32\ K\ 0.64}$	$SO_4-(HCO_3)-Mg-(Ca)$	2.886	1.656	0.193	0.321	16.215	0.139
60	$M_{0.5} \dfrac{HCO_3\ 46.98\ SO_4\ 1.89\ Cl\ 1.13}{Ca\ 24.51\ Mg\ 18.14\ Na\ 7.35}$	$HCO_3-Ca-Mg$	0.040	0.740	0.405	0.300	6.491	3.288
61	$M_{4.5} \dfrac{SO_4\ 43.82\ HCO_3\ 4.91\ Cl\ 1.18\ NO_3\ 0.09}{Mg\ 27.92\ Ca\ 16.23\ Na\ 5.36\ K\ 0.49}$	$SO_4-Mg-(Ca)$	8.931	1.720	0.192	0.330	4.627	0.098
62	$M_{0.6} \dfrac{HCO_3\ 35.66\ SO_4\ 8.08\ Cl\ 6.26}{Ca\ 25.31\ Mg\ 18.21\ Na\ 6.48}$	$HCO_3-Ca-(Mg)$	0.227	0.720	0.356	0.256	1.035	0.027

1	2	3	4	5	6	7	8	9
63	$M_{0.9} \dfrac{HCO_3\ 29.72\quad SO_4\ 19.79\quad Cl\ 0.49}{Mg\ 29.93\quad Ca\ 14.95\quad Na\ 5.12}$	$HCO_3-(SO_4)-Mg-(Ca)$	0.666	2.002	0.171	0.342	10.509	0.234
64	$M_{2.6} \dfrac{SO_4\ 41.44\quad HCO_3\ 6.15\quad Cl\ 1.25\quad NO_3\ 1.16}{Mg\ 28.62\quad Ca\ 15.40\quad Na\ 5.60\quad K\ 0.38}$	$SO_4-Mg-(Ca)$	6.737	1.855	0.196	0.364	4.504	0.106
65	$M_{1.3} \dfrac{NO_3\ 25.89\quad HCO_3\ 11.82\quad SO_4\ 6.84\quad Cl\ 5.45}{Ca\ 24.98\quad Mg\ 23.59\quad Na\ 1.09\quad K\ 0.34}$	$NO_3-Ca-Mg$	0.580	0.944	0.046	0.044	0.200	-0.637
66	$M_{46.8} \dfrac{SO_4\ 48.65\quad Cl\ 0.99\quad NO_3\ 0.36}{Mg\ 39.17\quad Na\ 9.06\quad Ca\ 1.23\quad K\ 0.54}$	SO_4-Mg	48.948	31.765	0.231	7.347	25.725	0.182
67	$M_{3.8} \dfrac{SO_4\ 45.31\quad HCO_3\ 4.20\quad Cl\ 0.47\quad NO_3\ 0.02}{Mg\ 26.99\quad Ca\ 18.77\quad Na\ 3.54\quad K\ 0.70}$	$SO_4-Mg-(Ca)$	10.794	1.438	0.131	0.189	7.324	0.066
68	$M_{50.2} \dfrac{SO_4\ 48.70\quad HCO_3\ 0.98\quad CO_3\ 0.17\quad Cl\ 0.15}{Mg\ 43.74\quad Na\ 4.39\quad Ca\ 1.20\quad K\ 0.67}$	SO_4-Mg	42.369	36.393	0.100	3.655	29.748	0.086
69	$M_{0.7} \dfrac{HCO_3\ 29.22\quad SO_4\ 20.29\quad Cl\ 0.48\quad NO_3\ 0.01}{Ca\ 23.84\quad Mg\ 22.50\quad Na\ 2.93\quad K\ 0.73}$	$HCO_3-(SO_4)-Ca-Mg$	0.695	0.944	0.130	0.123	6.181	0.123

1	2	3	4	5	6	7	8	9
70 M_2.1	$\dfrac{SO_4\ 32.57\ \ HCO_3\ 13.73\ \ Cl\ 3.70}{Ca\ 25.06\ \ Mg\ 23.39\ \ Na\ 1.55}$	$SO_4-(HCO_3)-Ca-(Mg)$	2.372	0.933	0.066	0.062	0.417	-0.066
71 M_0.6	$\dfrac{HCO_3\ 28.94\ \ SO_4\ 19.45\ \ Cl\ 1.61}{Mg\ 31.43\ \ Ca\ 17.74\ \ Na\ 0.83}$	$HCO_3-(SO_4)-Mg-(Ca)$	0.672	1.772	0.027	0.047	0.518	-0.040
72 M_0.8	$\dfrac{HCO_3\ 33.23\ \ SO_4\ 16.05\ \ Cl\ 0.69}{Ca\ 29.30\ \ Mg\ 19.55\ \ Na\ 1.15}$	$HCO_3-(SO_4)-Ca-(Mg)$	0.482	0.667	0.059	0.039	1.660	0.028
73 M_1.0	$\dfrac{HCO_3\ 35.22\ \ SO_4\ 14.22\ \ Cl\ 0.56}{Mg\ 29.68\ \ Ca\ 20.19\ \ Na\ 0.13}$	$HCO_3-(SO_4)-Mg-(Ca)$	0.404	1.469	0.004	0.007	0.236	-0.030
74 M_1.6	$\dfrac{SO_4\ 21.72\ \ NO_3\ 14.74\ \ Cl\ 9.45\ \ HCO_3\ 4.09}{Mg\ 27.14\ \ Ca\ 21.18\ \ Na\ 1.13\ \ K\ 0.55}$	$SO_4-(NO_3)-Mg-(Ca)$	5.308	1.282	0.042	0.053	0.123	-0.381
75 M_0.9	$\dfrac{SO_4\ 30.75\ \ HCO_3\ 12.50\ \ Cl\ 3.44\ \ NO_3\ 3.31}{Mg\ 28.15\ \ Na\ 17.95\ \ Ca\ 3.19\ \ K\ 0.71}$	$SO_4-(HCO_3)-Mg-(Ca)$	2.459	1.568	0.113	0.178	0.934	-0.007
76 M_0.5	$\dfrac{HCO_3\ 35.54\ \ SO_4\ 8.46\ \ Cl\ 5.56\ \ NO_3\ 0.44}{Ca\ 25.77\ \ Mg\ 17.66\ \ Na\ 5.11\ \ K\ 1.46}$	$HCO_3-Ca-(Mg)$	0.238	0.685	0.290	0.198	1.109	0.071

1	2	3	4	5	6	7	8	9
77	$M_{1.1}$ $\dfrac{SO_4\ 26.38\quad HCO_3\ 22.46\quad Cl\ 1.16}{Mg\ 27.38\quad Ca\ 18.58\quad Na\ 4.04}$	$SO_4-(HCO_3)-Mg-(Ca)$	1.174	1.473	0.147	0.217	3.463	0.109
78	$M_{1.2}$ $\dfrac{SO_4\ 29.73\quad HCO_3\ 19.90\quad Cl\ 0.37}{Mg\ 32.17\quad Ca\ 10.38\quad Na\ 7.15\quad K\ 0.30}$	$SO_4-(HCO_3)-Mg$	1.494	3.098	0.222	0.688	19.174	0.227
79	$M_{7.9}$ $\dfrac{SO_4\ 39.93\quad HCO_3\ 8.61\quad Cl\ 1.46}{Mg\ 34.63\quad Na\ 8.52\quad Ca\ 6.85}$	SO_4-Mg	4.638	5.059	0.246	1.245	5.844	0.177
80	$M_{0.5}$ $\dfrac{HCO_3\ 25.81\quad SO_4\ 21.55\quad Cl\ 2.22\quad NO_3\ 0.42}{Mg\ 33.03\quad Ca\ 12.66\quad Na\ 3.66\quad K\ 0.65}$	$HCO_3-(SO_4)-Mg-(Ca)$	0.835	2.610	0.111	0.289	1.815	0.084
81	$M_{2.1}$ $\dfrac{SO_4\ 30.23\quad HCO_3\ 18.82\quad Cl\ 0.95}{Mg\ 28.21\quad Ca\ 16.11\quad Na\ 5.68}$	$SO_4-(HCO_3)-Mg-(Ca)$	1.606	1.752	0.201	0.353	5.996	0.157
82	$M_{2.7}$ $\dfrac{SO_4\ 47.36\quad HCO_3\ 2.23\quad Cl\ 0.41}{Ca\ 21.92\quad Mg\ 21.67\quad Na\ 5.89\quad K\ 0.52}$	$SO_4-Ca-Mg$	21.289	0.989	0.272	0.269	14.278	0.118
83	$M_{0.9}$ $\dfrac{HCO_3\ 28.73\quad Cl\ 7.73\quad SO_4\ 7.61\quad NO_3\ 5.93}{Ca\ 25.85\quad Mg\ 21.09\quad Na\ 3.06}$	$HCO_3-Ca-(Mg)$	0.265	0.816	0.145	0.118	0.395	-0.614

1	2	3	4	5	6	7	8	9
84 $M_{1.5}$	$\dfrac{SO_4\ 30.08\quad HCO_3\ 19.11\quad Cl\ 0.81}{Ca\ 26.91\quad Mg\ 20.21\quad Na\ 2.88}$	$SO_4-(HCO_3)-Ca-(Mg)$	1.574	0.751	0.142	0.107	3.527	0.068
85 $M_{2.8}$	$\dfrac{SO_4\ 38.27\quad HCO_3\ 11.27\quad Cl\ 0.46}{Mg\ 24.80\quad Ca\ 20.52\quad Na\ 4.68}$	$SO_4-Mg-Ca$	3.396	1.208	0.189	0.228	9.865	0.107
86 $M_{0.9}$	$\dfrac{HCO_3\ 29.08\quad SO_4\ 19.75\quad Cl\ 1.17}{Mg\ 27.29\quad Ca\ 19.22\quad Na\ 3.49}$	$HCO_3-(SO_4)-Mg-(Ca)$	0.679	1.420	0.128	0.182	2.941	0.115
87 $M_{0.5}$	$\dfrac{HCO_3\ 37.69\quad SO_4\ 11.06\quad Cl\ 1.25}{Ca\ 26.18\quad Mg\ 21.53\quad Na\ 2.29}$	$HCO_3-Ca-(Mg)$	0.294	0.823	0.106	0.088	1.750	0.085
88 $M_{1.5}$	$\dfrac{SO_4\ 27.80\quad HCO_3\ 20.25\quad Cl\ 1.95}{Mg\ 23.37\quad Ca\ 21.69\quad Na\ 4.94}$	$SO_4-(HCO_3)-Mg-Ca$	1.373	1.078	0.212	0.228	2.538	0.108
89 $M_{0.6}$	$\dfrac{HCO_3\ 39.33\quad SO_4\ 9.73\quad Cl\ 0.94}{Ca\ 31.53\quad Mg\ 13.79\quad Na\ 4.68}$	$HCO_3-Ca-(Mg)$	0.247	0.437	0.340	0.148	4.962	0.384
90 $M_{0.6}$	$\dfrac{SO_4\ 28.60\quad HCO_3\ 20.75\quad Cl\ 0.62\quad NO_3\ 0.03}{Ca\ 25.75\quad Mg\ 20.10\quad Na\ 3.95\quad K\ 0.20}$	$SO_4-(HCO_3)-Ca-(Mg)$	1.378	0.780	0.196	0.153	6.448	0.119

1	2	3	4	5	6	7	8	9
91	$M_{2.0} \dfrac{SO_4\ 34.79\ HCO_3\ 14.51\ Cl\ 0.70}{Ca\ 22.07\ Mg\ 18.51\ Na\ 9.42}$	$SO_4-(HCO_3)-Ca-Mg$	2.397	0.838	0.509	0.427	12.952	0.241
92	$M_{0.6} \dfrac{HCO_3\ 40.70\ SO_4\ 6.82\ Cl\ 2.48}{Ca\ 26.21\ Mg\ 21.57\ Na\ 2.22}$	$HCO_3-Ca-(Mg)$	0.167	0.823	0.103	0.085	0.863	-0.041
93	$M_{1.8} \dfrac{SO_4\ 42.46\ HCO_3\ 6.78\ Cl\ 0.76}{Ca\ 21.84\ Mg\ 18.14\ Na\ 10.02}$	$SO_4-Ca-Mg$	6.263	0.830	0.552	0.459	12.821	0.213
94	$M_{1.8} \dfrac{SO_4\ 33.87\ HCO_3\ 15.42\ Cl\ 0.71}{Ca\ 26.11\ Mg\ 16.09\ Na\ 7.80}$	$SO_4-(HCO_3)-Ca-(Mg)$	2.196	0.616	0.485	0.299	11.005	0.210
95	$M_{0.3} \dfrac{HCO_3\ 42.68\ Cl\ 4.10\ SO_4\ 3.22}{Ca\ 38.97\ Mg\ 9.99\ Na\ 1.04}$	HCO_3-Ca	0.076	0.256	0.104	0.027	0.253	-0.949
96	$M_{1.9} \dfrac{SO_4\ 39.63\ HCO_3\ 10.29\ Cl\ 0.08\ K\ 0.16}{Mg\ 29.27\ Ca\ 14.26\ Na\ 6.31}$	$SO_4-Mg-(Ca)$	3.852	2.053	0.216	0.443	73.278	0.154
97	$M_{4.5} \dfrac{SO_4\ 41.56\ HCO_3\ 7.54\ Cl\ 0.90}{Mg\ 23.33\ Ca\ 19.45\ Na\ 7.22}$	$SO_4-Mg-Ca$	5.515	1.199	0.310	0.371	8.100	0.154

1	2	3	4	5	6	7	8	9
98	$M_{2.4}$ $\dfrac{SO_4\ 35.44\ HCO_3\ 13.76\ Cl\ 0.80}{Ca\ 25.92\ Mg\ 19.40\ Na\ 4.68}$	$SO_4-(HCO_3)-Ca-(Mg)$	2.574	0.748	0.241	0.181	5.847	0.110
99	$M_{3.0}$ $\dfrac{SO_4\ 41.51\ HCO_3\ 7.87\ Cl\ 0.62}{Ca\ 21.58\ Mg\ 19.97\ Na\ 8.45}$	$SO_4-Ca-Mg$	5.277	0.926	0.423	0.392	13.278	0.183
100	$M_{1.5}$ $\dfrac{HCO_3\ 27.99\ SO_4\ 14.86\ Cl\ 7.15}{Mg\ 30.45\ Ca\ 17.04\ Na\ 2.51}$	$HCO_3-(SO_4)-Mg-(Ca)$	0.531	1.787	0.083	0.147	0.351	-0.312
101	$M_{1.5}$ $\dfrac{SO_4\ 26.26\ HCO_3\ 21.14\ Cl\ 2.60}{Mg\ 29.92\ Ca\ 17.27\ Na\ 2.81}$	$SO_4-(HCO_3)-Mg-(Ca)$	1.242	1.732	0.094	0.163	0.938	-0.006
102	$M_{2.1}$ $\dfrac{SO_4\ 41.44\ HCO_3\ 7.64\ Cl\ 0.92}{Mg\ 20.22\ Ca\ 17.94\ Na\ 11.84}$	$SO_4-Mg-Ca$	5.420	1.127	0.586	0.660	12.085	0.246
103	$M_{2.0}$ $\dfrac{SO_4\ 39.23\ HCO_3\ 10.16\ Cl\ 0.61}{Ca\ 21.11\ Mg\ 17.79\ Na\ 11.10}$	$SO_4-Ca-Mg$	3.859	0.843	0.624	0.526	18.412	0.271
104	$M_{2.5}$ $\dfrac{SO_4\ 40.69\ HCO_3\ 8.00\ Cl\ 1.31}{Mg\ 21.53\ Ca\ 21.32\ Na\ 7.15}$	$SO_4-Mg-Ca$	5.086	1.010	0.332	0.335	5.311	0.139

1	2	3	4	5	6	7	8	9
105	$M_{0.7} \dfrac{SO_4\ 25.45\quad HCO_3\ 22.32\quad Cl\ 2.23}{Mg\ 25.38\quad Ca\ 16.68\quad Na\ 7.94}$	$SO_4-(HCO_3)-Mg-(Ca)$	1.140	1.521	0.313	0.476	3.738	0.240
106	$M_{2.9} \dfrac{SO_4\ 43.06\quad HCO_3\ 6.43\quad Cl\ 0.37\quad NO_3\ 0.14}{Ca\ 27.19\quad Mg\ 19.41\quad Na\ 3.40}$	$SO_4-Ca-(Mg)$	6.701	0.714	0.175	0.125	8.839	0.067
107	$M_{2.1} \dfrac{HCO_3\ 21.67\quad SO_4\ 20.68\quad Cl\ 7.65}{Mg\ 27.76\quad Ca\ 19.24\quad Na\ 3.00}$	$HCO_3-SO_4-Mg-(Ca)$	0.954	1.443	0.108	0.156	0.410	-0.218
108	$M_{2.6} \dfrac{SO_4\ 39.50\quad HCO_3\ 7.10\quad Cl\ 3.40}{Ca\ 25.15\quad Mg\ 19.65\quad Na\ 5.20}$	$SO_4-Ca-(Mg)$	5.564	0.781	0.264	0.207	1.565	0.049
109	$M_{1.6} \dfrac{SO_4\ 35.19\quad HCO_3\ 14.15\quad Cl\ 0.66}{Ca\ 26.50\quad Mg\ 17.61\quad Na\ 5.89}$	$SO_4-(HCO_3)-Ca-(Mg)$	2.488	0.665	0.334	0.222	9.321	0.155
110	$M_{1.1} \dfrac{HCO_3\ 24.50\quad SO_4\ 24.41\quad Cl\ 1.09}{Mg\ 20.59\quad Ca\ 16.70\quad Na\ 12.71}$	$HCO_3-SO_4-Mg-Ca-Na$	0.996	1.233	0.618	0.761	13.162	0.540
111	$M_{2.1} \dfrac{SO_4\ 43.02\quad HCO_3\ 5.39\quad Cl\ 1.59}{Na\ 19.56\quad Mg\ 17.05\quad Ca\ 13.39}$	$SO_4-Na-Mg-Ca$	7.986	1.273	1.147	1.460	11.765	0.399

1	2	3	4	5	6	7	8	9
112 $M_{2.7}$	$\dfrac{SO_4\ 39.24\quad HCO_3\ 8.93\quad Cl\ 1.83}{Ca\ 20.48\quad Mg\ 17.12\quad Na\ 12.40}$	$SO_4-Ca-Mg$	4.393	0.836	0.724	0.605	6.631	0.262
113 $M_{1.7}$	$\dfrac{SO_4\ 40.67\quad HCO_3\ 8.15\quad Cl\ 1.18}{Mg\ 19.62\quad Ca\ 15.90\quad Na\ 14.48}$	$SO_4-Mg-Ca-Na$	4.990	1.234	0.738	0.911	11.424	0.303
114 $M_{1.3}$	$\dfrac{SO_4\ 38.17\quad HCO_3\ 10.05\quad Cl\ 1.78}{Mg\ 20.73\quad Na\ 15.26\quad Ca\ 14.01}$	$SO_4-Mg-Na-Ca$	3.798	1.479	0.746	1.089	8.694	0.358
115 $M_{1.4}$	$\dfrac{SO_4\ 38.31\quad Cl\ 6.23\quad HCO_3\ 5.46}{Mg\ 22.64\quad Ca\ 17.59\quad Na\ 9.77}$	$SO_4-Mg-Ca$	7.016	1.287	0.431	0.555	1.741	0.120
116 $M_{5.4}$	$\dfrac{SO_4\ 44.67\quad Cl\ 4.72\quad HCO_3\ 0.61}{Mg\ 30.07\quad Ca\ 10.42\quad Na\ 9.51}$	SO_4-Mg	9.457	2.885	0.316	0.912	15.456	0.195
117 $M_{1.5}$	$\dfrac{SO_4\ 30.84\quad HCO_3\ 16.96\quad Cl\ 2.20}{Na\ 16.70\quad Mg\ 16.65\quad Ca\ 16.65}$	$SO_4-(HCO_3)-Na-Mg-Ca$	1.819	1.000	1.003	1.003	7.316	0.450
118 $M_{2.4}$	$\dfrac{SO_4\ 34.97\quad HCO_3\ 8.49\quad Cl\ 3.46\quad NO_3\ 3.08}{Mg\ 19.89\quad Ca\ 19.27\quad Na\ 10.84}$	$SO_4-Mg-Ca$	4.118	1.033	0.545	0.563	3.038	0.201

1	2	3	4	5	6	7	8	9
119	$M_{2.0}\ \dfrac{SO_4\ 35.96\ \ HCO_3\ 13.29\ \ Cl\ 0.75}{Ca\ 23.44\ \ Mg\ 20.08\ \ Na\ 6.48}$	$SO_4-(HCO_3)-Ca-Mg$	2.706	0.857	0.323	0.277	8.595	0.158
120	$M_{1.5}\ \dfrac{SO_4\ 36.65\ \ HCO_3\ 11.14\ \ Cl\ 2.21}{Ca\ 21.80\ \ Mg\ 15.85\ \ Na\ 12.35}$	$SO_4-Ca-Mg$	3.289	0.727	0.779	0.566	5.411	0.266
121	$M_{2.4}\ \dfrac{SO_4\ 36.38\ \ HCO_3\ 12.22\ \ Cl\ 1.40}{Mg\ 18.43\ \ Na\ 16.02\ \ Ca\ 15.55}$	$SO_4-Mg-Na-Ca$	2.977	1.185	0.870	1.030	10.980	0.385
122	$M_{1.8}\ \dfrac{SO_4\ 30.13\ \ HCO_3\ 16.50\ \ Cl\ 3.37}{Ca\ 26.87\ \ Mg\ 20.83\ \ Na\ 2.30}$	$SO_4-(HCO_3)-Ca-(Mg)$	1.826	0.775	0.111	0.086	0.698	-0.034
123	$M_{3.1}\ \dfrac{SO_4\ 41.79\ \ HCO_3\ 5.92\ \ Cl\ 2.29}{Mg\ 24.25\ \ Ca\ 18.57\ \ Na\ 7.18}$	$SO_4-Mg-Ca$	7.066	1.305	0.296	0.387	3.045	0.112
124	$M_{2.4}\ \dfrac{SO_4\ 36.16\ \ HCO_3\ 11.31\ \ Cl\ 2.53}{Ca\ 18.99\ \ Mg\ 15.81\ \ Na\ 15.20}$	$SO_4-Ca-Mg-Na$	3.197	0.832	0.962	0.801	6.102	0.357
125	$M_{2.5}\ \dfrac{SO_4\ 34.84\ \ HCO_3\ 13.83\ \ Cl\ 1.33}{Ca\ 22.12\ \ Mg\ 14.44\ \ Na\ 13.44}$	$SO_4-(HCO_3)-Ca-Mg-Na$	2.520	0.653	0.931	0.608	9.667	0.332

1	2	3	4	5	6	7	8	9
126	$M_{2.2}$ $\dfrac{SO_4\ 35.73\quad HCO_3\ 7.55\quad Cl\ 3.75\quad CO_3\ 2.97}{Mg\ 29.72\quad Ca\ 14.06\quad Na\ 6.22}$	$SO_4-Mg-(Ca)$	3.395	2.113	0.209	0.442	1.730	0.077
127	$M_{1.5}$ $\dfrac{SO_4\ 28.26\quad HCO_3\ 17.75\quad Cl\ 3.99}{Mg\ 30.07\quad Ca\ 15.42\quad Na\ 4.51}$	$SO_4-(HCO_3)-Mg-(Ca)$	1.592	1.950	0.150	0.292	1.261	0.037
128	$M_{2.0}$ $\dfrac{SO_4\ 38.01\quad HCO_3\ 7.10\quad Cl\ 4.89}{Mg\ 25.98\quad Ca\ 20.52\quad Na\ 3.50}$	$SO_4-Mg-(Ca)$	5.350	1.266	0.135	0.171	0.763	-0.030
129	$M_{3.1}$ $\dfrac{SO_4\ 39.59\quad HCO_3\ 8.50\quad Cl\ 1.91}{Mg\ 27.21\quad Ca\ 16.83\quad Na\ 5.96}$	$SO_4-Mg-(Ca)$	4.655	1.617	0.219	0.354	3.089	0.101
130	$M_{2.1}$ $\dfrac{SO_4\ 40.84\quad HCO_3\ 7.51\quad Cl\ 1.65}{Mg\ 22.11\quad Ca\ 19.02\quad Na\ 8.87}$	$SO_4-Mg-Ca$	5.437	1.163	0.401	0.466	5.311	0.174
131	$M_{3.2}$ $\dfrac{SO_4\ 40.92\quad HCO_3\ 7.25\quad Cl\ 1.83}{Ca\ 24.06\quad Mg\ 19.38\quad Na\ 6.56}$	$SO_4-Ca-Mg$	5.640	0.806	0.338	0.273	3.752	0.123
132	$M_{1.8}$ $\dfrac{SO_4\ 39.55\quad HCO_3\ 8.00\quad Cl\ 2.45}{Mg\ 19.77\quad Na\ 16.23\quad Ca\ 14.00}$	$SO_4-Mg-Na-Ca$	4.940	1.411	0.821	1.159	7.230	0.386

* For the calculations of ratios an ion concentration in epm was used.

Appendix III

Selected chemical analyses of slough and lake waters

No	Slough No.	Location S	T	R	Date of sample collecting	pH	Spec. conductance micromhos at 25°C	Sum of constituents ppm	Cations (epm) Ca*	Mg*	Na*	K*	CO₃⁼	Anions (epm) HCO₃⁻	SO₄⁼	Cl⁻	NO₃⁻	F⁻	Silica SiO₂ ppm	Sources of information **
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	26	14	9	2	9/8/65	9.0	3950	3179	2.001	44.656	6.351	0.921	1.317	3.704	46.220	0.761	0.050	0.051	13	W.R.B. Lab.
2	36	17	9	2	9/8/65	7.1	4000	3502	7.136	39.475	8.439	1.432	0	1.837	52.633	0.960	0.065	0.053	8.6	W.R.B. Lab.
3	38	30	9	2	23/7/65	9.0	2000	1591	1.397	23.218	2.871	1.344	2.114	8.310	17.014	0.558	0.034	0.033	9.8	W.R.B. Lab.
4	41	1	9	3	9/8/65	7.1	1200	767	3.583	6.883	1.309	0.655	0	4.016	8.120	0.338	0.066	0.025	28	W.R.B. Lab.
5	49	7	9	3	9/8/65	8.8	5900	5653	2.460	77.881	11.310	3.070	1.213	7.277	81.614	2.369	0.077	0.063	12	W.R.B. Lab.
6	65	12	9	3	13/8/65	8.5	7700	7523	6.886	93.342	19.575	2.301	0.307	4.524	113.469	2.961	0.09	0.072	4	W.R.B. Lab.
7	67	12	9	3	9/8/65	8.7	5000	4330	3.468	59.459	9.744	2.149	0.923	6.949	60.211	2.284	0.081	0.056	15	W.R.B. Lab.
8	72	21	9	3	13/8/65	7.2	400	218	1.727	1.332	0.126	0.396	0	2.655	0.629	0.166	0.123	0.021	25	W.R.B. Lab.
9	73	21	9	3	13/8/65	7.4	1500	1253	4.276	15.132	0.883	0.716	0	4.098	15.303	0.987	0.355	0.037	19	W.R.B. Lab.
10	80	10	9	4	25/5/66	8.8	3450	2589	5.00	39.02	1.24		2.00	7.50	34.35	1.41				F.a.
11	82	11	9	4	25/5/66	7.9	1100	717	4.00	7.60	1.28		0	5.50	7.03	0.35				F.a.
12	94	27	9	4	8/8/66	8.8	1184	779	0.833	12.994	0.870	1.207	1.900	7.736	5.580	0.395	0.032	0.006	20	W.R.B. Lab.
13	115	33	9	6	11/8/66	8.9	546670	129244	48.802	1427.851	500.020	41.184	13.165	22.749	1990.392	39.480	0.015	0.004	10	W.R.B. Lab.
14	118	8	10	1	24/5/66	8.3	400	234	2.00	0.50	1.81		0	3.20	0.83	0.28				F.a.
15	120	10	10	1	24/5/66	8.2	1400	808	6.79	5.70	1.66		0	5.90	7.55	0.70				F.a.
16	122	13	10	1	24/5/66	8.3	1600	1172	7.29	10.21	3.00		0	7.60	11.71	1.19				F.a.
17	131	1	10	2	9/8/65	8.6	500		1.467	4.605			0.342	4.379						W.R.B. Lab.
18	144	12	10	2	27/7/65	8.6	1300	965	4.775	10.773	1.157	0.499	0.583	5.589	9.797	0.231	0.108	0.031	21	W.R.B. Lab.
19	146	12	10	2	7/8/65	9.1	7000	6740	1.981	92.849	16.182	1.790	2.960	6.638	97.958	3.158	0.076	0.067	19	W.R.B. Lab.
20	148	13	10	2	27/7/65	9.2	6500	5741	3.169	75.990	14.877	1.417	4.163	5.638	82.160	2.482	0.056	0.064	21	W.R.B. Lab.
21	152	14	10	2	20/6/66	8.9	4700	4004	4.990	56.556	5.834		2.000	5.279	58.296	1.805				F.a.
22	153	14	10	2	23/7/65	8.4	2500	2063	6.038	23.273	4.211	0.785	0.267	5.128	27.982	0.372	0.076		7.4	W.R.B. Lab.
23	154	14	10	2	23/7/65	9.2	4150	3724	2.984	48.185	10.000	1.406	3.066	6.327	50.905	1.159	0.018		5.7	W.R.B. Lab.
24	156	14	10	2	7/8/65	8.9	6250	5932	2.375	84.707	11.658	1.791	2.611	7.260	86.112	2.087	0.034	0.065	4.8	W.R.B. Lab.
25	160	14	10	2	7/8/65	8.6	3000	2305	3.568	31.498	3.915	0.921	0.720	8.539	29.328	0.677	0.042	0.044	9.3	W.R.B. Lab.
26	161	14	10	2	23/7/65	7.2	300	169	1.487	1.210	0.144	0.235	0	2.438	0.433	0.045	0.108	0.016	9.2	W.R.B. Lab.
27	163	14	10	2	23/7/65	8.7	900	537	2.041	6.070	0.522	0.435	0.177	2.281	6.475	0.034	0.068	0.026	2.6	W.R.B. Lab.
28	164	14	10	2	23/7/65	7.7	2100	1562	5.389	17.168	2.349	0.596	0	3.896	21.174	0.243	0.079		20.0	W.R.B. Lab.
29	165	14	10	2	23/7/65	7.8	2000	1380	8.782	11.498	1.762	0.563	0	4.875	17.093	0.212	0.082		21	W.R.B. Lab.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
30	166	14	10	2	23/7/65	7.6	1450	1017	5.938	9.467	0.683	0.486	0	2.178	14.012	0.099	0.045		3.1	W.R.B. Lab.
31	167	15	10	2	23/7/65	9.1	950	534	1.297	7.714	1.240	0.596	2.313	7.178	0.802	0.375	0.134	0.024	17.0	W.R.B. Lab.
32	168	15	10	2	23/7/65	8.3	950	583	4.356	4.638	0.487	0.384	0	3.756	5.871	0.155	0.094	0.027	6.2	W.R.B. Lab.
33	169	15	10	2	23/7/65	7.5	200	120	1.307	0.513	0.052	0.233	0	1.704	0.142	0.071	0.061	0.015	13	W.R.B. Lab.
34	170	15	10	2	23/7/65	8.7	2300	1762	2.834	23.521	2.784	0.909	0.800	5.838	22.797	0.522	0.058		2.3	W.R.B. Lab.
35	171	15	10	2	23/7/65	8.7	2000	1569	3.463	19.820	2.175	0.722	0.266	4.313	21.278	0.282	0.045	0.03	7.5	W.R.B. Lab.
36	172	15	10	2	23/7/65	8.0	900	502	3.728	3.964	0.396	0.256	0	3.116	4.950	0.121	0.077	0.022	19.0	W.R.B. Lab.
37	173	15	10	2	23/7/65	8.0	500	218	2.355	1.620	0.078	0.143	0	3.674	0.333	0.054	0.058	0.016	11.0	W.R.B. Lab.
38	174	15	10	2	23/7/65	7.1	200	149	1.712	0.863	0.061	0.159	0	2.296	0.270	0.039	0.071	0.015	9.0	W.R.B. Lab.
39	175	15	10	2	23/7/65	7.7	200	138	1.697	0.543	0.043	0.218	0	2.181	0.083	0.054	0.082	0.014	11.0	W.R.B. Lab.
40	176	15	10	2	13/8/66	8.0	650	392	1.996	4.397	1.335	0.512	0	5.559	1.915	0.254	0.100	0.020	3.8	F.a.
41	178	19	10	2	7/8/65	8.1	900	387	2.061	4.293	0.291			4.507	2.457	0.076				W.R.B. Lab.
42	185	22	10	3	13/8/66	9.2	1150	682	0.898	8.094	4.721		3.600	6.799	2.186	1.128				F.a.
43	194	4	10	3	7/8/65	9.0	1800	1075	0.354	16.040	3.785	1.151	3.023	11.227	5.496	1.043	0.073	0.026	7.0	W.R.B. Lab.
44	201	16	10	3	13/8/65	8.8	1050	685	5.539	5.072	0.283	0.327	0.733	5.982	4.830	0.132	0.355	0.031	23.0	W.R.B. Lab.
45	206	18	10	4	13/8/65	7.6	1600	1211	1.692	16.119	1.718	0.972	0	6.474	13.762	0.299	0.242	0.032	23	W.R.B. Lab.
46	211	24	10	4	25/5/66	8.3	4000	3553	2.00	59.23	0.22		0	8.30	52.05	1.10				F.a.
47	215	3	10	4	23/7/65	8.7	2000	1368	2.171	18.668	2.131	1.114	0.495	7.228	15.558	0.395	0.069	0.033	6.9	F.a.
48	228	11	10	4	25/5/66	8.3	600	449	2.20	5.80	0.60		0	5.00	3.43	0.17				F.a.
49	244	13	10	4	14/8/65	7.4	1000	600	3.423	5.411	0.335	0.839	0	2.721	6.933	0.087	0.048	0.024	3.9	W.R.B. Lab.
50	245	14	10	4	22/5/66	7.4	1000	619	5.00	6.00	0.26		0	5.50	5.62	0.14				F.a.
51	246	23	10	4	22/5/66	7.8	1200	860	6.49	8.30	0.29		0	5.50	9.37	0.21				F.a.
52	252	23	10	4	22/5/66	8.1	1500	1025	5.00	12.21	0.55		0	4.80	12.75	0.21				F.a.
53	253	23	10	4	14/8/65	7.6	2500	1914	7.834	21.136	1.644	1.074	0	5.196	25.557	0.259	0.169	0.044	16.0	W.R.B. Lab.
54	254	24	10	4	22/5/66	8.3	1500	1084	3.20	16.01	0.22		0.88	6.00	13.01	0.42				F.a.
55	255	26	10	4	9/6/66	8.7	1500	1119	2.00	15.99	2.04	1.279	1.853	5.72	13.01	0.42	0.113	0.049	14	F.a.
56	259	36	10	4	14/8/65	9.2	3100	2640	2.160	34.705	5.351		0	4.622	36.643	0.747				W.R.B. Lab.
57	261	36	10	4	22/5/66	8.2	2000	1466	4.00	20.01	1.55		4.233	6.40	18.74	0.42				F.a.
58	262	4	10	5	14/8/65	9.3	4600	4245	1.287	60.446	9.396	1.739	4.966	8.670	56.964	1.805	0.105	0.056	5.5	W.R.B. Lab.
59	263	4	10	5	16/8/65	9.2	6100	5952	0.419	86.269	8.439	4.603	0	8.703	83.328	2.566	0.092	0.063	8.8	W.R.B. Lab.
60	264		10		16/8/65	8.2	13000	11515	14.621	166.947	23.490	10.232		14.390	194.875	8.601	0.581		26	W.R.B. Lab.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
61	267	8	10	5	16/8/65	8.3	4700	4345	3.742	57.650	7.569	3.274	0	7.359	61.544	1.551	0.218	0.058	21	W.R.B. Lab.
62	268	9	10	5	16/8/65	9.3	4600	4092	1.771	57.403	5.829	2.967	2.980	3.393	59.295	1.269	0.065	0.058	20	W.R.B. Lab.
63	269	9	10	5	16/8/65	8.6	8100	8156	9.181	102.882	13.790	6.650	1.213	14.227	113.854	4.596	0.371	0.080	24	W.R.B. Lab.
64	271	11	10	5	16/8/65	8.7	3100	2687	1.597	36.843	4.350	3.223	0.823	9.752	32.896	1.410	0.371	0.049	10	W.R.B. Lab.
65	272	12	10	5	8/8/65	8.9	2200	1436	1.796	23.382	1.427		2.400	7.998	15.615	0.592	0.061	0.080	10	F.a.
66	276	17	10	5	16/8/65	9.4	9000	9395	2.220	127.718	19.488	6.344	8.233	10.981	131.915	4.935	0.003	0.005	5	W.R.B. Lab.
67	282	22	10	5	8/8/66	9.0	13670	17262	2.710	233.233	39.567	10.769	5.999	13.145	255.253	5.640	0.039	0.001	10	W.R.B. Lab.
68	293	28	10	5	8/8/66	9.0	30110	50031	15.619	653.808	116.092	21.027	4.366	5.573	786.996	4.653	0.002	0.002	12	W.R.B. Lab.
69	294	28	10	5	8/8/66	8.8	29910	48149	29.946	608.165	126.092	18.622	1.357	2.934	755.766	5.217	0.363	0.053	22	W.R.B. Lab.
70	344	1	10	6	16/8/65	9.0	3950	3119	4.790	40.873	4.080	3.070	1.953	8.703	39.725	1.099	0.007	0.005	5	W.R.B. Lab.
71	346	4	10	6	11/8/66	8.9	32645	52462	29.291	597.556	182.181	20.464	3.933	7.130	818.226	2.820				
72	355	11	10	6	2/7/66	8.1	4500	3932	14.970	50.661	1.612		0	13.447	53.091	0.705				F.a.
73	357	15	10	6	2/7/66	8.15	1000	430	2.196	5.396	1.513		0	8.198	0.625	0.282				F.a.
74	361	19	10	6	27/6/66	8.3	9250	7931	25.150	100.721	4.878		0	6.999	118.674	5.076				F.a.
75	365	20	10	6	27/6/66	8.8	4100	3353	5.389	44.365	4.776		2.000	9.198	41.640	1.692				F.a.
76	370	22	10	6	16/8/65	8.9	600	331	3.019	2.632	0.122	0.384	1.337	4.081	0.502	0.065	0.132	0.021	23	W.R.B. Lab.
77	416	7	11	3	14/8/65	7.6	500	280	1.586	1.751	0.196	1.151	0	3.671	0.320	0.386	0.150	0.017	28	W.R.B. Lab.
78	431	18	11	3	14/8/65	9.4	5300	4780	1.781	61.680	13.050	2.864	2.836	6.441	66.624	2.200	0.290	0.061	7.0	W.R.B. Lab.
79	454	29	11	4	14/6/66	8.8	3000	2502	11.257	28.298	3.380		1.600	9.398	31.230	0.707				F.a.
80	459	36	11	4	14/6/66	8.3	3400	2485	8.084	29.317	4.770		0	8.798	32.531	0.846				F.a.
81	461	1	11	4	22/5/66	8.0	1700	1215	2.70	18.51	1.16		0	8.80	13.01	0.56				F.a.
82	462	1	11	4	22/5/66	8.1	2100	1630	6.79	20.41	0.77		0	6.00	21.34	0.63				F.a.
83	469	13	11	4	14/8/65	8.5	9200	9666	9.481	117.685	24.273	4.093	0.247	6.343	104.907	4.089	0.169	0.080	13	W.R.B. Lab.
84	473	15	11	4	14/8/65		15500	16520	4.741	191.372	60.030	6.906	0.373	13.391	241.512	11.844	0.105		7.0	W.R.B. Lab.
85	476	19	11	4	8/8/66	9.0	10030	11325	2.495	134.133	41.741	4.170	4.466	8.670	167.809	5.358	0.106	0.004	4.0	W.R.B. Lab.
86	477	19	11	4	13/7/66	9.0	5000	3871	2.994	50.960	12.570		4.799	9.598	49.448	2.679				F.a.
87	488	23	11	4	30/6/66	8.1	5000	4308	6.986	54.957	10.171		0	9.198	60.378	2.538				F.a.
88	498	26	11	4	14/8/65	9.0	5100		1.586	58.134	14.877	2.455	1.543	7.687	63.626	2.256	0.126	0.059	9.6	W.R.B. Lab.
89	523	35	11	4	8/8/66	8.0	308	180	1.831	1.069	0.109	0.460	0	2.770	0.264	0.121	0.026	0.003	6.2	W.R.B. Lab.
90	524	35	11	4	22/5/66	8.2	2500	1806	7.49	19.51	3.96		0	8.40	21.86	0.70				F.a.
91	538	9	11	5	15/6/66	8.4	3500	2948	7.485	41.068	2.008		0.400	8.998	40.599	0.564				F.a.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
92	591	34	11	5	18/6/66	8.5	2400	1710	5.689	20.684	3.648		0.800	9.398	19.259	0.564				F.a.
93	596	2	11	6	16/8/65	9.3	1600		0.888	12.090	3.132	2.609	2.260	6.769	8.599	0.987	0.124	0.034	28	W.R.B. Lab.
94	613	12	11	6	24/6/66	9.5	22000	24427	7.265	356.440	40.999		7.999	4.999	375.801	15.905				F.a.
95	642	2	12	4	22/5/66	8.1	1500	1088	5.70	12.31	1.14		0	6.50	12.23	0.42				F.a.
96	698	15	12	5	18/6/66	8.4	2550	1988	7.784	25.780	1.441		0.800	9.698	23.943	0.564				F.a.
97	13N	32	12	5	12/8/66	9.45	2000	1351	5.230	12.250	4.697		1.520	1.480	18.218	0.959				F.a.

* the calculated value $Na^+ + K^+$ is given in this column for field-analyses (F.a.)

** F.a. - analyses made in the field with a HACH-chemical kit
W.R.B. Lab. - analyses made by Inland Waters Branch Laboratory in Ottawa

Appendix IV

The interrelation of ions and chemical classification of

slough and lake waters

No.	Slough No.	Chemistry of water according to Kurlov formula	Type of water according to Priklonski formula	Ratios*				
				$\dfrac{SO_4^{2-}}{HCO_3^-+CO_3^{2-}}$	$\dfrac{Cl^--Na^+}{Cl^-}$	$\dfrac{Mg^{2+}}{Ca^{2+}}$	$\dfrac{Na^+}{Ca^{2+}+Mg^{2+}}$	$\dfrac{Na^+}{Ca^{2+}}$
1	2	3	4	5	6	7	8	9
1	26	$SO_4\ 44.35\ HCO_3\ 3.56\ CO_3\ 1.26\ Cl\ 0.73\ NO_3\ 0.05\ F\ 0.05 / Mg\ 41.40\ Na\ 5.89\ Ca\ 1.86\ K\ 0.85$ $M_{3.2}$	SO_4-Mg	9.205	-7.346	22.317	0.136	3.174
2	36	$SO_4\ 47.38\ HCO_3\ 1.65\ Cl\ 0.86\ NO_3\ 0.06\ F\ 0.05 / Mg\ 34.94\ Na\ 7.47\ Ca\ 6.32\ K\ 1.27$ $M_{3.5}$	SO_4-Mg	28.652	-7.791	6.089	0.167	1.182
3	Carlyle Lake 38	$SO_4\ 30.31\ HCO_3\ 14.81\ CO_3\ 3.77\ Cl\ 0.99\ NO_3\ 0.06\ F\ 0.06 / Mg\ 40.26\ Na\ 4.98\ Ca\ 2.43\ K\ 2.33$ $M_{1.6}$	$SO_4-(HCO_3)-Mg$	1.632	-4.145	16.620	0.117	2.055
4	41	$SO_4\ 32.31\ Cl\ 15.98\ NO_3\ 1.35\ 0.26\ F\ 0.10 / Mg\ 27.69\ Ca\ 44.42\ Na\ 5.26\ K\ 2.63$ $M_{0.8}$	$SO_4-(HCO_3)-Mg-(Ca)$	2.022	-2.873	1.922	0.125	0.363
5	49	$SO_4\ 44.06\ Cl\ 3.93\ CO_3\ 1.28\ NO_3\ 0.66\ 0.04\ F\ 0.03 / Mg\ 41.11\ Na\ 5.97\ K\ 1.62\ Ca\ 1.30$ $M_{5.7}$	SO_4-Mg	9.613	-3.774	31.659	0.140	4.6
6	65	$SO_4\ 46.72\ HCO_3\ 1.86\ Cl\ 1.22\ CO_3\ 0.13\ NO_3\ 0.04\ F\ 0.03 / Mg\ 38.22\ Na\ 8.02\ Ca\ 2.82\ K\ 0.94$ $M_{7.5}$	SO_4-Mg	23.488	-5.611	13.551	0.195	2.843

1	2	3	4	5	6	7	8	9
7	67	$M_{4.3} \dfrac{SO_4 42.70 \ HCO_3 4.93 \ Cl 1.62 \ CO_3 0.65 \ NO_3 0.06 \ F 0.04}{Mg_{39.73} Na_{6.51} Ca_{2.32} K_{1.44}}$	SO_4-Mg	7.649	-3.266	17.14	0.155	2.809
8	72	$M_{0.2} \dfrac{HCO_3 36.94 \ SO_4 48.75 \ NO_3 2.31 \ Cl 1.71 \ F 0.29}{Ca_{24.11} Mg_{18.60} K_{5.53} Na_{1.76}}$	HCO_3-Ca-Mg	0.237	+0.241	0.775	0.041	0.073
9	73	$M_{1.3} \dfrac{SO_4 36.82 \ HCO_3 39.86 \ NO_3 2.38 \ Cl 0.85 \ F 0.09}{Mg_{36.02} Ca_{10.18} Na_{2.10} K_{1.70}}$	SO_4-Mg	3.734	+0.105	3.546	0.082	0.206
10	80	$M_{2.6} \dfrac{SO_4 37.95 \ HCO_3 8.28 \ CO_3 3.21 \ Cl 2.21 \ 1.56}{Mg_{43.11} Ca_{5.52} Na+K_{1.37}}$	SO_4-Mg	3.616	–	7.804	0.028	0.248
11	82	$M_{0.7} \dfrac{SO_4 27.29 \ HCO_3 21.35 \ Cl 1.36}{Mg_{29.50} Ca_{15.53} Na+K_{4.97}}$	SO_4-(HCO_3)-Mg-(Ca)	1.278	–	1.900	0.110	0.320
12	94	$M_{0.8} \dfrac{SO_4 24.72 \ SO_4 17.83 \ CO_3 36.07 \ Cl 1.26 \ NO_3 0.10 \ F 0.02}{Mg_{40.85} K_{3.79} Na_{2.74} Ca_{2.62}}$	HCO_3-(SO_4)-Mg	0.579	-1.203	15.599	0.063	1.044
13	115	$M_{129.1} \dfrac{SO_4 48.17 \ Cl 0.96 \ HCO_3 0.55 \ CO_3 0.32}{Mg_{35.38} Na_{12.39} Ca_{1.21} K_{1.02}}$	SO_4-Mg	55.421	-11.665	29.258	0.339	10.246
14	118	$M_{0.2} \dfrac{HCO_3 37.12 \ SO_4 49.63 \ Cl 3.25}{Ca_{23.20} Na+K_{21.00} Mg_{5.80}}$	HCO_3-Ca-Na	0.259	–	0.250	0.724	0.905

1	2	3	4	5	6	7	8	9
15	120	$M_{0.8} \ \dfrac{SO_4 26.68 \ HCO_3 20.85 \ Cl 2.47}{Ca_{23.99} Mg_{20.15} Na+K_{5.86}}$	$SO_4-(HCO_3)-Ca-Mg$	1.280	–	0.839	0.133	0.244
16	122	$M_{1.2} \ \dfrac{SO_4 28.56 \ HCO_3 18.54 \ Cl 2.90}{Mg_{24.90} Ca_{17.78} Na+K_{7.32}}$	$SO_4-(HCO_3)-Mg-Ca$	1.541	–	1.401	0.171	0.412
17	131	–	–	–	–	3.139	–	–
18	144	$M_{1.0} \ \dfrac{SO_4 29.98 \ HCO_3 17.10 \ CO_3 1.78 \ Cl 0.71 \ NO_3 0.33 \ F 0.10}{Mg_{31.31} Ca_{13.88} Na_{3.36} K_{1.45}}$	$SO_4-(HCO_3)-Mg-(Ca)$	1.587	-4.009	2.256	0.065	0.251
19	146	$M_{6.7} \ \dfrac{SO_4 44.18 \ HCO_3 2.99 \ Cl 1.42 \ CO_3 1.34 \ NO_3 0.04 \ F 0.03}{Mg_{41.16} Na_{7.17} Ca_{0.88} K_{0.79}}$	SO_4-Mg	10.206	-4.156	46.877	0.170	8.169
20	148	$M_{5.7} \ \dfrac{SO_4 43.44 \ HCO_3 2.98 \ CO_3 2.20 \ Cl 1.31 \ F 0.04 \ NO_3 0.03}{Mg_{39.81} Na_{7.79} Ca_{1.66} K_{0.74}}$	SO_4-Mg	8.384	-4.994	23.980	0.188	4.694
21	152	$M_{4.0} \ \dfrac{SO_4 43.26 \ HCO_3 3.92 \ CO_3 1.48 \ Cl 1.34}{Mg_{41.97} Na+K_{4.33} Ca_{3.70}}$	SO_4-Mg	8.009	–	11.334	0.095	1.169
22	153	$M_{2.1} \ \dfrac{SO_4 41.36 \ HCO_3 7.58 \ Cl 0.55 \ CO_3 0.39 \ NO_3 0.12}{Mg_{33.92} Ca_{8.80} Na_{6.14} K_{1.14}}$	SO_4-Mg	5.182	-10.320	3.854	0.144	0.69

1	2	3	4	5	6	7	8	9
23	154	$M_{3.7}\ \dfrac{SO_4 41.00\ HCO_3 5.10\ CO_3 2.95\ Cl 0.93\ NO_3 0.02}{Mg_{38.50}\ Na_{7.99}\ Ca_{2.39}\ K_{1.12}}$	$SO_4\text{-}Mg$	5.419	-7.632	16.148	0.195	3.353
24	156	$M_{5.9}\ \dfrac{SO_4 43.86\ HCO_3 3.70\ CO_3 1.33\ Cl 1.06\ F 0.03\ NO_3 0.02}{Mg_{42.13}\ Na_{5.80}\ Ca_{1.18}\ K_{0.89}}$	$SO_4\text{-}Mg$	8.723	-4.586	35.670	0.134	4.908
25	160	$M_{2.3}\ \dfrac{SO_4 37.27\ HCO_3 10.85\ CO_3 0.92\ Cl 0.86\ NO_3 0.05\ F 0.05}{Mg_{39.47}\ Na_{4.91}\ Ca_{4.47}\ K_{1.15}}$	$SO_4\text{-}Mg$	3.167	-4.783	8.828	0.111	1.881
26	161	$M_{0.2}\ \dfrac{HCO_3 40.10\ SO_4 7.12\ NO_3 1.78\ Cl 0.74\ F 0.26}{Ca_{24.17}\ Mg_{19.67}\ K_{3.82}\ Na_{2.34}}$	$HCO_3\text{-}Ca\text{-}Mg$	0.176	-2.200	0.814	0.055	0.097
27	163	$M_{0.5}\ \dfrac{SO_4 35.73\ HCO_3 12.59\ CO_3 0.98\ NO_3 0.37\ Cl 0.19\ F 0.14}{Mg_{33.47}\ Ca_{11.25}\ Na_{2.88}\ K_{2.40}}$	$SO_4\text{-}(HCO_3)\text{-}Mg$	2.632	-14.353	2.974	0.064	0.256
28	164	$M_{1.6}\ \dfrac{SO_4 41.69\ HCO_3 7.67\ Cl 0.48\ NO_3 0.16}{Mg_{33.66}\ Ca_{10.57}\ Na_{4.60}\ K_{1.17}}$	$SO_4\text{-}Mg$	5.435	-8.667	3.186	0.104	0.436
29	165	$M_{1.4}\ \dfrac{SO_4 38.39\ HCO_3 10.95\ Cl 0.48\ NO_3 0.18}{Mg_{25.43}\ Ca_{19.43}\ Na_{3.90}\ K_{1.24}}$	$SO_4\text{-}Mg\text{-}(Ca)$	3.506	-7.311	1.309	0.087	0.201
30	166	$M_{1.0}\ \dfrac{SO_4 42.89\ HCO_3 6.67\ Cl 0.30\ NO_3 0.14}{Mg_{28.55}\ Ca_{17.92}\ Na_{2.06}\ K_{1.47}}$	$SO_4\text{-}Mg\text{-}(Ca)$	6.433	-5.899	1.593	0.044	0.115

1	2	3	4	5	6	7	8	9
31	167	$M_{0.5}$ $\dfrac{HCO_3\,33.15\ CO_3\,10.68\ SO_4\,4.71\ Cl\,1.73\ NO_3\,30.62\ F\,0.11}{Mg_{35.56}Ca_{5.98}Na_{5.72}K_{2.74}}$	HCO_3-Mg	0.084	-2.307	5.947	0.137	0.956
32	168	$M_{0.6}$ $\dfrac{SO_4\,29.64\ HCO_3\,18.96\ Cl\,0.78\ NO_3\,0.48\ F\,0.14}{Mg_{23.50}Ca_{22.09}Na_{2.47}K_{1.94}}$	$SO_4-(HCO_3)-Mg-Ca$	1.563	-2.142	1.064	0.054	0.112
33	169	$M_{0.1}$ $\dfrac{HCO_3\,42.75\ SO_4\,3.56\ Cl\,1.77\ NO_3\,1.55\ F\,0.37}{Ca_{31.09}Mg_{12.13}K_{5.54}Na_{1.24}}$	HCO_3-Ca	0.083	+0.268	0.443	0.026	0.037
34	170	$M_{1.8}$ $\dfrac{SO_4\,37.98\ HCO_3\,9.72\ CO_3\,1.33\ Cl\,0.87\ NO_3\,0.10}{Mg_{39.14}Ca_{4.72}Na_{4.63}K_{1.51}}$	SO_4-Mg	3.434	-4.333	8.306	0.105	0.982
35	171	$M_{1.6}$ $\dfrac{SO_4\,40.58\ HCO_3\,8.23\ CO_3\,0.54\ Cl\,0.50\ NO_3\,0.09\ F\,0.06}{Mg_{37.85}Ca_{6.62}Na_{4.15}K_{1.38}}$	SO_4-Mg	4.645	-6.713	5.715	0.093	0.627
36	172	$M_{0.5}$ $\dfrac{SO_4\,29.87\ HCO_3\,18.80\ Cl\,0.73\ NO_3\,0.47\ F\,0.13}{Mg_{23.75}Ca_{22.34}Na_{2.37}K_{1.54}}$	$SO_4-(HCO_3)-Mg-Ca$	1.589	-2.273	1.063	0.051	0.106
37	173	$M_{0.2}$ $\dfrac{HCO_3\,44.43\ SO_4\,4.03\ NO_3\,0.70\ Cl\,0.65\ F\,0.19}{Ca_{28.06}Mg_{19.30}K_{1.71}Na_{0.93}}$	$HCO_3-Ca-(Mg)$	0.091	-0.444	0.688	0.019	0.033
38	174	$M_{0.1}$ $\dfrac{HCO_3\,42.66\ SO_4\,5.02\ NO_3\,1.32\ Cl\,0.72\ F\,0.28}{Ca_{30.63}Mg_{15.44}K_{2.84}Na_{1.09}}$	$HCO_3-Ca-(Mg)$	0.118	-0.564	0.483	0.023	0.034

1	2	3	4	5	6	7	8	9
39	175	$M_{0.1}\ \dfrac{HCO_3\ 45.17\ SO_4\ 1.72\ NO_3\ 1.70\ Cl\ 1.12\ F\ 0.29}{Ca\ 33.93\ Mg\ 10.85\ K\ 4.36\ Na\ 0.86}$	HCO_3-Ca	0.038	+0.204	0.319	0.019	0.025
40	176	$M_{0.4}\ \dfrac{HCO_3\ 35.97\ SO_4\ 12.39\ Cl\ 1.64}{Mg\ 28.45\ Ca\ 12.91\ Na+K\ 8.64}$	$HCO_3-Mg-(Ca)$	0.344	-	2.203	0.209	0.669
41	178	$M_{0.4}\ \dfrac{HCO_3\ 31.47\ SO_4\ 17.16\ NO_3\ 0.70\ Cl\ 0.53\ F\ 0.14}{Mg\ 29.99\ Ca\ 14.40\ K\ 3.58\ Na\ 2.03}$	$HCO_3-(SO_4)-Mg-(Ca)$	0.545	-2.829	2.083	0.046	0.141
42	185	$M_{0.7}\ \dfrac{HCO_3\ 24.79\ CO_3\ 13.13\ SO_4\ 4.97\ Cl\ 4.11}{Mg\ 29.51\ Na+K\ 17.21\ Ca\ 3.28}$	$HCO_3-Mg-(Na)$	0.210	-	9.013	0.525	5.257
43	194	$M_{1.1}\ \dfrac{HCO_3\ 26.87\ SO_4\ 13.16\ CO_3\ 7.24\ Cl\ 2.50\ NO_3\ 0.17\ F\ 0.06}{Mg\ 37.60\ Na\ 8.87\ K\ 2.70\ Ca\ 0.83}$	$HCO_3-(SO_4)-Mg$	0.594	-2.629	45.311	0.231	9.951
44	201	$M_{0.7}\ \dfrac{HCO_3\ 24.79\ SO_4\ 20.02\ CO_3\ 3.04\ NO_3\ 1.47\ Cl\ 0.55\ F\ 0.13}{Mg\ 24.42\ Ca\ 23.04\ K\ 1.36\ Na\ 1.18}$	$HCO_3-(SO_4)-Mg-Ca$	0.719	-1.144	1.060	0.025	0.051
45	206	$M_{1.2}\ \dfrac{SO_4\ 33.07\ HCO_3\ 15.55\ Cl\ 0.72\ NO_3\ 0.58\ F\ 0.08}{Mg\ 39.31\ Na\ 4.19\ Ca\ 4.13\ K\ 2.37}$	$SO_4-(HCO_3)-Mg$	2.126	-4.746	9.58	0.09	1.285
46	211	$M_{3.6}\ \dfrac{SO_4\ 42.35\ HCO_3\ 6.75\ Cl\ 0.90}{Mg\ 48.19\ Ca\ 1.63\ Na+K\ 0.18}$	SO_4-Mg	6.271	-	29.615	0.004	0.110

1	2	3	4	5	6	7	8	9
47	Kenosee Lake 215	$M_{1.4}$ $\dfrac{SO_4 32.71\ HCO_3 15.20\ CO_3 1.04\ Cl 0.83\ NO_3 0.15\ F 0.07}{Mg_{38.76}Ca_{4.51}Na_{4.42}K_{2.31}}$	$SO_4-(HCO_3)-Mg$	2.013	-4.395	8.608	0.102	0.981
48	228	$M_{0.4}$ $\dfrac{HCO_3 29.07\ SO_4 19.94\ Cl 0.92}{Mg_{33.72}Ca_{12.79}Na+K_{3.49}}$	$HCO_3-(SO_4)-Mg-(Ca)$	0.686	–	2.636	0.075	0.273
49	244	$M_{0.6}$ $\dfrac{SO_4 35.33\ HCO_3 13.86\ Cl 0.44\ NO_3 0.25\ F 0.12}{Mg_{27.04}Ca_{17.10}K_{4.19}Na_{1.67}}$	$SO_4-(HCO_3)-Mg-(Ca)$	2.549	-2.851	1.580	0.038	0.097
50	245	$M_{0.6}$ $\dfrac{SO_4 24.96\ HCO_3 24.42\ Cl 0.62}{Mg_{26.64}Ca_{22.20}Na+K_{1.16}}$	$SO_4-HCO_3-Mg-(Ca)$	1.022	–	1.200	0.024	0.052
51	246	$M_{0.9}$ $\dfrac{SO_4 31.07\ HCO_3 18.23\ Cl 0.70}{Mg_{27.52}Ca_{21.52}Na+K_{0.96}}$	$SO_4-(HCO_3)-Mg-(Ca)$	1.704	–	1.279	0.020	0.045
52	252	$M_{1.0}$ $\dfrac{SO_4 35.90\ HCO_3 13.51\ Cl 0.59}{Mg_{34.37}Ca_{14.08}Na+K_{1.55}}$	$SO_4-(HCO_3)-Mg-(Ca)$	2.656	–	2.442	0.032	0.110
53	253	$M_{1.9}$ $\dfrac{SO_4 40.93\ HCO_3 8.32\ Cl 0.41\ NO_3 0.27\ F 0.07}{Mg_{33.35}Ca_{12.36}Na_{2.59}K_{1.70}}$	SO_4-Mg	4.920	-5.347	2.899	0.094	0.210

1	2	3	4	5	6	7	8	9
54	254	$M_{1.1}\ \dfrac{SO_4\,33.48\ HCO_3\,15.44\ Cl\,1.08}{Mg_{41.20}Ca_{8.23}Na+K_{0.57}}$	$SO_4-(HCO_3)-Mg$	2.168	–	5.003	0.011	0.069
55	255	$M_{1.1}\ \dfrac{SO_4\,32.48\ HCO_3\,14.27\ CO_3\,2.20\ Cl\,1.05}{Mg_{39.92}Ca_{4.99}Na+K_{5.09}}$	$SO_4-(HCO_3)-Mg$	1.971	–	7.995	0.113	1.020
56	259	$M_{2.6}\ \dfrac{SO_4\,41.61\ HCO_3\,5.25\ CO_3\,2.10\ Cl\,0.85\ NO_3\,0.13\ F\,0.06}{Mg_{39.90}Na_{6.15}Ca_{2.48}K_{1.47}}$	SO_4-Mg	5.659	-6.163	17.370	0.145	2.477
57	261	$M_{1.5}\ \dfrac{SO_4\,36.66\ HCO_3\,12.52\ Cl\,0.82}{Mg_{39.15}Ca_{7.82}Na+K_{3.03}}$	$SO_4-(HCO_3)-Mg$	2.928	–	5.003	0.065	0.387
58	262	$M_{4.2}\ \dfrac{SO_4\,39.65\ HCO_3\,6.03\ CO_3\,2.95\ Cl\,1.26\ NO_3\,0.07\ F\,0.04}{Mg_{41.48}Na_{6.45}K_{1.19}Ca_{0.88}}$	SO_4-Mg	4.415	-4.206	46.939	0.152	7.301
59	263	$M_{6.0}\ \dfrac{SO_4\,41.79\ HCO_3\,4.36\ CO_3\,2.49\ Cl\,1.29\ NO_3\,0.04\ F\,0.03}{Mg_{43.25}Na_{4.23}K_{2.31}Ca_{0.21}}$	SO_4-Mg	6.100	-2.289	205.894	0.097	20.141
60	264	$M_{11.5}\ \dfrac{SO_4\,44.61\ HCO_3\,3.29\ Cl\,1.97\ NO_3\,0.13}{Mg_{38.77}Na_{5.46}K_{2.37}Ca_{3.40}}$	SO_4-Mg	13.542	-1.731	11.416	0.129	1.606
61	267	$M_{4.3}\ \dfrac{SO_4\,43.51\ HCO_3\,5.20\ Cl\,1.10\ NO_3\,0.15\ F\,0.04}{Mg_{39.90}Na_{5.24}Ca_{2.59}K_{2.27}}$	SO_4-Mg	8.363	-3.880	15.406	0.123	2.023

1	2	3	4	5	6	7	8	9
62	268	$M_{4.1}$ $SO_{4\,44.24}\,HCO_{3\,2.53}\,CO_{3\,2.19}\,Cl_{0.95}\,NO_{3\,0.05}\,F_{0.04}$ / $Mg_{42.23}\,Na_{4.29}\,K_{2.18}\,Ca_{1.30}$	SO_4-Mg	9.304	-3.593	32.608	0.098	3.291
63	269	$M_{8.2}$ $SO_{4\,42.37}\,HCO_{3\,5.20}\,Cl_{1.71}\,CO_{3\,0.45}\,NO_{3\,0.14}\,F_{0.03}$ / $Mg_{38.82}\,Na_{5.20}\,Ca_{3.47}\,K_{2.51}$	SO_4-Mg	7.374	-2.000	11.208	0.123	1.502
64	271	$M_{2.7}$ $SO_{4\,36.31}\,HCO_{3\,10.76}\,Cl_{1.56}\,CO_{3\,0.91}\,NO_{3\,0.41}\,F_{0.05}$ / $Mg_{40.03}\,Na_{4.73}\,K_{3.50}\,Ca_{1.74}$	SO_4-Mg	3.111	-2.085	22.961	0.113	2.724
65	272	$M_{1.4}$ $SO_{4\,29.35}\,HCO_{3\,15.03}\,CO_{3\,4.51}\,Cl_{1.11}$ / $Mg_{43.94}\,Ca_{3.38}\,Na+K_{2.68}$	SO_4-(HCO_3)-Mg	1.502	-	13.019	0.057	0.795
66	276	$M_{9.4}$ $SO_{4\,42.22}\,HCO_{3\,3.51}\,CO_{3\,2.64}\,Cl_{1.58}\,F_{0.03}\,NO_{3\,0.02}$ / $Mg_{41.00}\,K_{6.26}\,Ca_{2.03}\,Na_{0.71}$	SO_4-Mg	6.865	-2.949	57.530	0.150	8.778
67	282	$M_{17.3}$ $SO_{4\,45.57}\,HCO_{3\,2.35}\,CO_{3\,1.07}\,Cl_{1.01}$ / $Mg_{40.74}\,Na_{6.91}\,K_{1.88}\,Ca_{0.47}$	SO_4-Mg	13.333	-6.015	86.064	0.168	14.600
68	293	$M_{50.0}$ $SO_{4\,49.09}\,HCO_{3\,0.35}\,Cl_{0.29}\,CO_{3\,0.27}$ / $Mg_{40.53}\,Na_{7.20}\,K_{1.30}\,Ca_{0.97}$	SO_4-Mg	79.183	-23.950	41.860	0.173	7.433
69	294	$M_{48.1}$ $SO_{4\,49.38}\,Cl_{0.34}\,HCO_{3\,0.19}\,CO_{3\,0.09}$ / $Mg_{38.84}\,Na_{8.06}\,Ca_{1.91}\,K_{1.19}$	SO_4-Mg	176.128	-23.169	20.309	0.198	4.211

1	2	3	4	5	6	7	8	9
70	344	$M_{3.1}$ $\dfrac{SO_4 38.27\ HCO_3 38.39\ CO_3 1.88\ Cl 1.06\ NO_3 0.35\ F 0.05}{Mg_{38.70} Ca_{4.53} Na_{3.86} K_{2.91}}$	SO_4-Mg	3.728	-2.712	8.517	0.089	0.852
71	346	$M_{52.5}$ $\dfrac{SO_4 49.16\ HCO_3 0.43\ CO_3 0.24\ Cl 0.17}{Mg_{36.02} Na_{10.98} Ca_{1.77} K_{1.23}}$	SO_4-Mg	73.961	-63.603	20.401	0.291	6.220
72	355	$M_{3.9}$ $\dfrac{SO_4 39.48\ HCO_3 10.00\ Cl 0.52}{Mg_{37.67} Ca_{11.13} Na+K_{1.20}}$	SO_4-Mg	3.948	-	3.384	0.025	0.108
73	357	$M_{0.4}$ $\dfrac{HCO_3 45.02\ SO_4 3.43\ Cl 1.55}{Mg_{29.63} Ca_{12.06} Na_{8.31}}$	HCO_3-Mg	0.076	-	2.457	0.199	0.689
74	361	$M_{7.9}$ $\dfrac{SO_4 45.38\ HCO_3 2.68\ Cl 1.94}{Mg_{38.52} Ca_{9.62} Na+K_{1.86}}$	SO_4-Mg	16.956	-	4.005	0.039	0.194
75	365	$M_{3.2}$ $\dfrac{SO_4 38.18\ HCO_3 3.44\ Cl 1.83\ NO_3 1.55}{Mg_{40.68} Ca_{4.94} Na+K_{4.38}}$	SO_4-Mg	3.719	-	8.233	0.096	0.886
76	370	$M_{0.3}$ $\dfrac{HCO_3 33.24\ CO_3 10.89\ SO_4 4.09\ NO_3 1.08\ Cl 0.53\ F 0.17}{Ca_{24.52} Mg_{21.37} K_{3.12} Na_{0.99}}$	$HCO_3-Ca-Mg$	0.093	-0.877	0.872	0.022	0.040
77	416	$M_{0.3}$ $\dfrac{HCO_3 40.39\ Cl 4.25\ SO_4 3.52\ NO_3 1.65\ F 0.19}{Mg_{18.69} Ca_{16.93} K_{12.29} Na_{2.09}}$	$HCO_3-Mg-Ca$	0.087	+0.492	1.104	0.059	0.124

1	2	3	4	5	6	7	8	9
78	431	$M_{4.8}\ \dfrac{SO_4\,42.46\ HCO_3\,4.10\ CO_3\,1.81\ Cl\,1.40\ NO_3\,0.19\ F\,0.04}{Mg\,38.85\ Na\,8.22\ K\,1.81\ Ca\,1.12}$	$SO_4\text{-}Mg$	7.182	-4.932	34.652	0.206	7.327
79	454	$M_{2.5}\ \dfrac{SO_4\,36.37\ HCO_3\,10.95\ Cl\,1.86\ \ 0.82}{Mg\,32.95\ Ca\,13.11\ Na+K\,3.94}$	$SO_4\text{-}(HCO_3)\text{-}Mg\text{-}(Ca)$	2.840	–	2.514	0.085	0.300
80	459	$M_{2.5}\ \dfrac{SO_4\,38.57\ HCO_3\,10.43\ Cl\,1.00}{Mg\,34.76\ Ca\,9.58\ Na+K\,5.66}$	$SO_4\text{-}Mg$	3.698	–	3.627	0.128	0.591
81	461	$M_{1.2}\ \dfrac{SO_4\,29.08\ HCO_3\,19.67\ Cl\,1.25}{Mg\,41.37\ Ca\,6.03\ Na+K\,2.60}$	$SO_4\text{-}(HCO_3)\text{-}Mg$	1.478	–	6.856	0.055	0.430
82	462	$M_{1.6}\ \dfrac{SO_4\,38.15\ HCO_3\,10.72\ Cl\,1.13}{Mg\,36.49\ Ca\,12.14\ Na+K\,1.37}$	$SO_4\text{-}Mg$	3.557	–	3.006	0.028	0.113
83	469	$M_{9.7}\ \dfrac{SO_4\,46.49\ HCO_3\,2.04\ Cl\,1.31\ CO_3\,0.08\ NO_3\,0.05\ F\,0.03}{Mg\,37.83\ Na\,7.80\ Ca\,3.05\ K\,1.32}$	$SO_4\text{-}Mg$	21.989	-4.936	12.413	0.191	2.560
84	473	$M_{16.5}\ \dfrac{SO_4\,45.19\ HCO_3\,2.50\ Cl\,2.22\ CO_3\,0.07\ NO_3\,0.02}{Mg\,36.34\ Na\,11.45\ K\,1.31\ Ca\,0.90}$	$SO_4\text{-}Mg$	17.551	-4.068	40.431	0.307	12.662
85	476	$M_{11.3}\ \dfrac{SO_4\,45.01\ HCO_3\,2.32\ Cl\,1.44\ CO_3\,1.20\ NO_3\,0.03}{Mg\,36.75\ Na\,11.43\ K\,1.14\ Ca\,0.68}$	$SO_4\text{-}Mg$	12.776	-6.790	53.761	0.306	16.730

1	2	3	4	5	6	7	8	9
86	477	$M_{3.9} \dfrac{SO_4\,37.17\ HCO_3\,7.21\ CO_3\,3.61\ Cl\,2.01}{Mg_{38.30}Na+K_{9.45}Ca_{2.25}}$	SO_4-Mg	3.435	–	17.021	0.233	4.198
87	488	$M_{4.3} \dfrac{SO_4\,41.86\ HCO_3\,6.38\ Cl\,1.76}{Mg_{33.11}Na+K_{7.05}Ca_{4.84}}$	SO_4-Mg	6.564	–	7.867	0.164	1.456
88	498	$M_{4.6} \dfrac{SO_4\,42.25\ HCO_3\,5.11\ Cl\,1.50\ CO_3\,1.02\ NO_3\,0.08\ F\,0.04}{Mg_{37.73}Na_{9.65}K_{1.59}Ca_{1.03}}$	SO_4-Mg	6.893	-5.594	36.654	0.249	9.380
89	523	$M_{0.2} \dfrac{HCO_3\,43.50\ SO_4\,4.15\ Cl\,1.90\ NO_3\,0.41\ F\,0.04}{Ca_{26.39}Mg_{15.41}K_{6.63}Na_{1.57}}$	$HCO_3-Ca-(Mg)$	0.095	+0.099	0.584	0.038	0.060
90	524	$M_{1.8} \dfrac{SO_4\,35.30\ HCO_3\,13.57\ Cl\,1.13}{Mg_{31.51}Ca_{12.10}Na+K_{6.39}}$	$SO_4-(HCO_3)-Mg$	2.602	–	2.605	0.147	0.525
91	538	$M_{2.9} \dfrac{SO_4\,40.15\ HCO_3\,8.90\ Cl\,0.56\ CO_3\,0.39}{Mg_{40.61}Ca_{7.40}Na+K_{1.99}}$	SO_4-Mg	4.320	–	5.487	0.041	0.268
92	591	$M_{1.7} \dfrac{SO_4\,32.08\ HCO_3\,15.65\ CO_3\,1.33\ Cl\,0.94}{Mg_{34.45}Ca_{9.48}Na+K_{6.07}}$	$SO_4-(HCO_3)-Mg$	1.889	–	3.636	0.138	0.641
93	596	$M_{1.1} \dfrac{SO_4\,22.90\ HCO_3\,18.03\ CO_3\,6.02\ Cl\,2.63\ NO_3\,0.33\ F\,0.09}{Mg_{32.29}Na_{8.37}Ca_{6.97}Ca_{2.37}}$	SO_4-HCO_3-Mg	0.952	-2.173	13.6	0.241	3.527

1	2	3	4	5	6	7	8	9
94	613	$M_{24.4}$ $\dfrac{SO_4{46.43}\ Cl_{1.96}\ CO_3{0.99}\ HCO_3{0.62}}{Mg_{44.04}\ Na+K_{5.06}\ Ca_{0.90}}$	SO_4-Mg	28.912	–	49.063	0.113	5.643
95	642	$M_{1.5}$ $\dfrac{SO_4{31.93}\ HCO_3{16.97}\ Cl_{1.10}}{Mg_{32.14}\ Ca_{14.88}\ Na+K_{2.98}}$	$SO_4-(HCO_3)-Mg-(Ca)$	1.882	–	2.160	0.063	0.200
96	698	$M_{2.0}$ $\dfrac{SO_4{34.20}\ HCO_3{13.85}\ CO_3{1.14}\ Cl_{0.81}}{Mg_{36.82}\ Ca_{11.12}\ Na+K_{2.06}}$	$SO_4-(HCO_3)-Mg$	2.281	–	3.312	0.043	0.185
97	13N	$M_{1.4}$ $\dfrac{SO_4{41.07}\ CO_3{3.43}\ HCO_3{3.34}\ Cl_{2.16}}{Mg_{27.62}\ Ca_{11.79}\ Na+K_{10.59}}$	SO_4-Mg	6.073	–	2.342	0.269	0.899

* For the calculation of the ratios ion concentrations in epm were used.