HALOMORPHISM IN MANITOBA SOILS

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I. INTRODUCTION:

The occurrence of areas in Manitoba where the productivity of soil is impaired by the presence of excessive amounts of soluble salts has been known since the time of the early settlers. The distribution and extent of these areas has been determined over most of the agricultural portion of the province through the operations of the Manitoba Soil Survey. The mapping of saline soils by this survey has been based on morphological features expressed in the soil profiles, such as pseudo-mycelium and crystalline gypsum, together with observations of native vegetation or crop growth. Investigations to determine the amount and composition of the soluble salts have been limited mainly to areas of special interest and to soil samples submitted to the Soils Laboratories of The University of Manitoba by farm operators.

In order to gain a more comprehensive understanding of halomorphism in Manitoba soils, the investigations herein recorded were undertaken to ascertain the nature of the salts in different parts of the province and the concentrations at which they occur. Arising from these studies, some theories are advanced concerning the possible origin of these salts based on a consideration of their composition and of the geology of the areas.

II. REVIEW OF LITERATURE:

A. Nature, Origin and Classification of Saline Soils

It has long been known that the ability of some soils to support the growth of useful vegetation was appreciably lowered by the presence of excessive amounts of soluble substances. However, a clear understanding of the origin and nature of soluble salts in soils was not attained until recent years. One of the first acceptable scientific theories for the formation of saline soils was advanced in 1912 by Hilgard (14). He separated the continental alkali lands from those in which the salts were clearly derived from past or periodic flooding by sea water, and attributed the salinization of these to the dry climate in which they exist. He contended that the accumulation of salts in the upper horizons of the soil was due largely to the downward movement of water being insufficient to leach out those salts which were continually being formed through the weathering of the soil minerals.

De Sigmond (6), of Hungary, recognized the importance of Hilgard's work but found that under the climatical conditions prevailing in the region of the Hungarian Plain, an impervious subsoil was a necessary supplement to the dry climate for the formation of saline soils. He considered that three factors took part in the evolution of szek (saline) soils; (i) the arid climate, (ii) the impermeable subsoil, and (iii) meteorological conditions which bring the soil periodically under the influence of excessive moisture. He states, "Wherever such conditions

have existed or now exist there were and will be formed sooner or later szek soil."

In their recent publication on saline and alkali soils, the staff members of the California Salinity Laboratory (15) substantially agree with de'Sigmond's conclusions. They attribute the salinization of soils to one or a combination of three principal factors--arid climate, poor drainage, and irrigation. They state that poor drainage conditions are an essential prerequisite to this process and that restricted drainage of soils may be due to the presence of a high water table, to low permeability of the soil, or to a combination of both factors.

The classification of alkali soils has developed along somewhat different lines in different parts of the world. Hilgard differentiated continental saline soils into two groups on the basis of the chemical composition of the salts and the surface appearance of the soil. Soils containing appreciable amounts of sodium carbonate were named "black alkali soils", because of the brown or black crust on their surface formed through the dissolving action of carbonate of soda on the soil humus. Opposed to these were "white alkali soils", so called because of the white efflorescence of salts which appeared when the surface of the soil dried.

In Hungary and Russia, the division of alkali soils has been based on their chemical and morphological nature. De Sigmond (6) separated the alkali soils of the Hungarian Plain into two

chief groups: (i) Szek soils; (ii) Szik soils. This classification is very similar to that set up by the Russian scientists Sibirtsev and Glinka. The Solonchak soils of Russia and Szek soils of Hungary are soils containing appreciable amounts of soluble salts, particularly the carbonate and chloride of soda, and having no characteristic morphology, other than the common occurrence of salt efflorescences on the surface. They are formed simply by the accumulation of soluble salts in the upper horizons of poorly drained soils. The Szik soils of de'Sigmond and the Solonetz soils of Glinka are characterized by a high content of exchangeable sodium and a particular type of profile, in which a leached "A" horizon of 0.1-20.0 cm or more is underlain by a heavy textured, dark colored, columnar "B" horizon.

These two systems of classification result in some instances in similar divisions, but there are distinct differences. Kelley of the University of California (17) compared the methods by stating, "black alkali denotes soil which contains Na_2CO_3 while solonetz has a twofold significance: namely, morphological and chemical; that is, it refers to certain morphological features of the soil profile and to the presence of absorbed sodium. Since soils which contain Na_2CO_3 probably always contain more or less absorbed (replaceable) sodium, black alkali is equivalent to solonetz in a chemical sense but not necessarily so in a physical sense. Solonchak denotes structureless alkali soil containing a high concentration of soluble salts. White alkali (saline) soils are usually classified as solonchak but solonchaks sometimes

contain Na_2CO_3 as well as neutral salts".

In recent years a system of classification has been developed in the United States (15, 22) based on the concentration of soluble salts in the soil, as determined by conductivity measurements on their saturation extracts, and the percentage of sodium on the exchange complex of the soil. In this system, salinized and alkalinized soils are grouped under three headings: (i) Saline soils; (ii) Saline--alkali soils; (iii) Nonsaline--alkali soils.

The term saline soils is used to denote soils for which the conductivity of the saturation extract is more than 4 millimho/cm* and the exchangeable - sodium - percentage is less than 15. Ordinarily the pH is less than 8.5. These soils correspond to Hilgard's "white alkali" and to the "solonchaks" of the Russians. They are often identified by the presence of white crusts of salt on the surface or by streaks of salt within the soil. They may develop from normal soils having distinctly developed profile characteristics or on undifferentiated soil material such as alluvium, in which case soil horizon and profile characteristics may be only feebly developed.

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* Millimho/cm. is the common way in which electrical conductivity is expressed. It is equivalent to mho/cm.$X10^3$ where mho/cm. is the reciprocal of the resistence measure ohm/cm.

Saline - alkali soils are soils for which the conductivity of their saturation extract is greater than 4 millimho/cm. and the exchangeable - sodium - percentage is greater than 15. As long as excess salts are present the soil's appearance and properties are generally similar to those of saline soils, but if these are leached downward, the properties of these soils may change markedly and become similar to those of nonsaline - alkali soils.

The term nonsaline - alkali soils is applied to soils for which the exchangeable - sodium - percentage is greater than 15 and the conductivity of the saturation extract is less than 4 millimho/cm. The pH values generally range between 8.5 and 10. The soils correspond to Hilgard's "black alkali" soils and in some cases to the solonetz soils of the Russians. They are formed directly from saline-alkali soils through drainage and leaching in the absence of gypsum or other sources of soluble calcium.

The investigations reported in this thesis were conducted on soils containing soluble salts and hence on those which belong to the first two categories of this classification; namely saline and saline - alkali soils.

B. Review of Information on Salinity in Manitoba Soils

The principal source of information on the distribution of saline soils in Manitoba is the maps of the Manitoba Soil Survey. These maps were made during a reconnaissance survey of the soils and cover a large portion of the agricultural area of

the province. Wherever saline soils were observed in the field in the course of this survey their occurrence was recorded on the field maps and the extent of the larger areas shown by boundaries. At the time the soils were mapped in the field the degree of salinity was estimated through observations on the species and vigor of native plants and growing crops within the areas, and the results were shown by the use of symbols denoting slightly saline, saline and strongly saline soils. These maps were studied and used in the selecting of sample areas for the investigation reported in this thesis.

Quantitative analyses to determine the kind of salts present in the saline soils of the province have been few in number. Those that have been conducted have indicated that the sulphates of calcium, magnesium and to a lesser extent sodium are the chief constituents of the soluble salts in most areas, but that high concentrations of chlorides occur in some regions. This has been supported by the qualitative tests made on a large number of samples of saline soil which farmers have sent to the Soils Department of The University of Manitoba over a period of twenty-five years.

The absence of appreciable amounts of soluble carbonates in nearly all of the saline soils that have been tested and the lack of significant amounts of exchangeable sodium in the solonetzic soils of the Red River Valley, as determined by Ellis and Caldwell (8), has lead to the general conclusion that high concentrations of sodium carbonate are not common in Manitoba. This

has been supported by the field observations of the Manitoba Soil Survey. In their report on the solonetzic soils of the Red River Valley, Ellis and Caldwell (8) suggested that the structure of these soils, which closely resembles the solonetz soils described by Glinka and de'Sigmond (6), has been formed through the action of magnesium rather than sodium and they suggested that solonetz soils be considered as a group which should be subdivided into sodium-solonetz and magnesium-solonetz. This is in accordance with the views subsequently expressed by other soil scientists and would explain the occurrence of large areas of soils exhibiting the characteristic structural profile of Glinka's so-called "sodium solonetz soils" but containing no appreciable amount of absorbed sodium on their exchange complex.

C. Salt Deposits and Saline Ground Waters of Manitoba

The soluble salts in the soils of Manitoba appear to have been derived mainly from the decomposition of minerals on which the soils are developed. These minerals originally came from the rock formations, which now underlie the surface deposits, and were transported to their present sites by glacial and glacio-fluvial action. Therefore a review of the evidence of salt deposits and saline waters in these rock formations is pertinent to a study of soil salinity.

Manufacture of salt by evaporation of brines issuing as springs in the area of Dawson Bay on Lake Winnipegosis, was begun around 1820 by James Monkman. These operations were visited in 1889 by J.B. Tyrrell, whose descriptions and analytical

data on saline springs found scattered along the west shore of Lake Winnipegosis were published by Cole (4). Tyrrell thought that these springs arise in the porous dolomites of late Silurian or early Devonian age and that the salts originate through the leaching of numerous salt crystals which were observed to occur in these formations. Cole also reported the occurrence of saline wells in the Westbourne and Winnipeg areas and that strong flows of brine were encountered at depths of 1,225 and 1,455 feet in a deep government well drilled at Neepawa for the purpose of obtaining gas.

Wallace (27) examined some 80 saline springs in Manitoba and collected data on numerous saline wells. On the basis of this information he described the brine-containing area as being about 50 miles wide (from the Manitoba escarpment to the West shore of Lake Winnipeg) and 400 miles long (from the north end of Lake Winnipegosis to Grand Forks in North Dakota). Concerning the origin of these brines he stated (28), "The evidence points to their originating by the leaching of isolated salt crystals in the Paleozoic strata", and also that, "whenever the Dakota sandstone (Swan River formation) is tapped at any considerable depth in Manitoba a strong flow of brine is obtained". He advanced the theory that the volume of flow of saline waters originates in the Dakota sandstone but, due to the impervious shales capping this sandstone, the water which enters by the lateral seepage penetrates downward into the Devonian limestone, travels laterally through the fissures and openings which

characterize these formations and reaches the surface wherever outcrops occur.

Wallace concluded that there are four salt water horizons in Manitoba: (i) in the Winnipeg sandstone; (ii) in the Upper Mottled limestone (approximately); (iii) in the gypsum zone of the Silurian (approximately); and (iv) in the Devonian strata. He believed that there is no genetic relationship between these salt brines and the gypsum deposits which occur in the rock formations. He based this assumption on the presence of a fresh water horizon between the gypsum beds and the brines and the absence of other salts in the sulphate waters of the gypsum zone.

At the Neepawa Salt Plant, now being operated by the Canadian Industries Limited, brine is being pumped out of two wells from the Silurian limestones from a depth of about 1,400 feet. This source of brine has been continuously tapped since 1933 and no appreciable change has occurred in its composition. The percentage of sodium chloride in the brine averages around 15.4 and smaller amounts of calcium chloride, sulphate and bicarbonate; magnesium, potassium and lithium chloride; and sodium bromide are also present (23).

Gypsum deposits in the rock formations of Manitoba have been reported on by Wallace (27, 28) and by Cole (5). Wallace noted that the important deposits lying at or near the surface occur in three areas: Gypsumville area; Leifur district; Dominion City, Arnaud, St. Pierre district. He advanced the theory that these gypsum deposits represent precipitation of

successive layers of gypsum and anhydrite in closed or partially closed inland seas during Silurian times. Cole described the surface deposits at Gypsumville, where the rock has been quarried since 1901, as comprising an area of about 56 square miles. Gypsum layers also have been encountered in rock formations of Jurassic and Devonian age in deep wells in the western part of the province.

Examination of any data on well water analysis reveals that the ground waters over a large portion of Manitoba contain high concentrations of soluble salts (24, 16, 12). This is particularly the case in the western portion of the Red River Valley, the Westbourne-Gladstone area and the Whitewater Lake area of south-western Manitoba. The composition of these saline waters varies somewhat in different areas and at different depths within the same areas. This will be discussed in more detail in another portion of this thesis.