Analyses of Nova Scotian Soils.—By Prof. L. C. Harlow, B. Sc., B. S. A., Provincial Normal College, Truro, N. S.

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"The soil is so complex in its relation to crops that it has been and still is one of Nature's greatest puzzles." What intricate actions, physical and chemical, are those which take place when the rain descends upon, or the salt tide water spreads over the marsh lands of our Province! Pages are written upon the action between two substances in a test tube; it is only natural then that much is afforded for investigation in one of Nature's great test tubes, the Bay of Fundy, where the fine residues carried by streams from the various geological formations are mechanically stirred by the ceaseless tide.

An analysis of the ebb tide water at the mouth of the Shubenacadie shows .622 grams of silt suspended in every 1000cc of water. Now this silt is the result of the breaking down, the weathering and transportation of the rocks of the Province. Of what is it composed mineralogically and chemically? A number of investigators as Delagé, Bonsteel and Ries, who have labored to determine the minerals in the soil have come to the conclusion that it has all the minerals unaltered which are present in the rocks. The commonest are quartz, limonite, hematite, kaolin, feldspar, micas, apatite, hornblendes, pyroxenes, chlorite, tourmaline, rutile, calcite, dolomite, selenite, zeolites.

Again the rocks as sandstone, shales, limestones, of one group, have the same mineral constituents as the granites, gneisses and schists of another group; but differ first, in the varying proportion of these minerals, and secondly in that the first group are water formed, the second heat formed.

Hence, a soil, whether artifically made by powdering a rock, or taken from a lately deposited marsh area, from a leached hillside or from a field worn out by cropping, will give the essential elements as shown by the analysis of the following:

	A. New tide deposit from Gaspereau River	B. A "worn out" hillside field from Upper Stewiacke, Col. Co.
Insoluble in acid of 1.11 sp. gr.	83.66	80.02
Potash	.72	.42
Soda (Na_2O)	.82	.09
Lime	.9	.55
Magnesia	1.39	.63
Sulphuric acid	.19	.11
Ferric oxide } Alumina }	7.7	3.25
		5.68
Phosphoric acid	.1	.12
Volatile at red heat	3.57	8.51
Water at 100°	1.1	1.28
Nitrogen	.06	1.8

Further analysis of the same ebb tide water shows in 1000cc 29.95gm. of dissolved solid made up as follows:—

Sodium chloride	24.24
Potassium chloride	.38
Magnesium chloride	2.47
Magnesium bromide	.036
Magnesium sulphate	1.63
Calcium sulphate	1.18

In addition to these, Ditmar gives about 30 other elements which are easily proven in salt water. That rock residue may become available to plants has been proven by Wöhler, who, in a classical experiment, found the zeolite apophyllite to be sufficiently physically soluble in pure water to be recrystallized from it. F. W. Clarke found muscovite, orthoclase, albite, and other micas, feldspars and zeolites to be soluble in pure water.

Again, Lemberg found that leucite, $KAlSi_2O_6$ in NaCs 10% solution gave $NaAlSi_2O_6$ and KCl; also that feldspar with ordinary soluble salts gave similar exchange of basic elements. These are the changes which must be taking place in our Bay of Fundy waters, and of which Cameron of the U. S. Bureau of Soils says "It is to be regretted that there are not more precise data available as to the stability of the various rock forming mineral species in contact with solutions of the more common and readily soluble salts at ordinary temperatures since such data would be of great value for geological, mineralogical and soil studies."

If the tide water with its dissolved matter acting on the newly brought down rock debris presents a wide range of possible new substances, how much more complex will be the action in a field, marsh or upland where we have organic matter, more or less decomposed; soil atmosphere, living plant organisms as bacteria, molds, ferments; animal forms as protozoa, in addition to the rock residues bathed in the soil moisture which is a solution of products yielded by many components and in equilibrium or nearly so with the solids or gases with which it is in contact.

Scientific Agriculture is the handling of this heterogeneous mixture so as to give, with a minimum of labor, the greatest crop return, and yet be able to pass it over to the next generation, not in an exhausted condition, but permanently improved. It is based on knowledge which is far from complete. Our marsh soils in some places are "run out," giving one half ton of hay per acre. Why is this? We usually say that the available plant food is used up; on the other hand the Bureau of Soils at Washington has, within the last ten years, advanced the Toxin theory which is, that plants in exhausted soils are like human beings in a room, the air of which is polluted by excreted substances, disagreeable and sickening; that the growing plant excretes poisons which, if allowed to accumulate in the soil, kill the plant;

that fertilizers by chemical action destroy these poisons, rendering the soil healthful for growing plants.

Some of these toxins, as picoline carboxylic acid, dihydroxystearic acid and agroceric acid, have been isolated from the soil and their deleterious effects shown on seedlings. These two views have led to a long discussion between the soil men at Washington and another group represented by Hall, of England, and Hopkins, of Illinois. One writer says "The practice of Agriculture has suffered and is suffering today from an insufficient accumulation of facts and data and from an overproduction of theories and conclusions"

It is the purpose of this work to provide some data regarding the *ultimate* composition of the rock debris found in the soils of this Province. To this end 125 samples of soil have been collected, 86 of which have been studied with particular emphasis on the chemical analyses and the relationship of the soil to the surrounding rock, both native and drift. This work has been my pastime during vacation seasons since 1908.

Samples were taken as follows:—

24 Marsh soils from various points between Kingsport and Windsor, along the Cobequid Bay and from the Amherst areas.

25 at various places along a line extending across the county from Tatamagouche to Middle Musquodoboit.

12 from the central part of Lunenburg county.
8 from the Annapolis valley.
10 from the Wentworth valley.
2 from the Government farm, Truro.
2 near Antigonish town.
1 from Guysboro county.
1 from Digby county.
1 from Clifton, Colchester county.

This article will present results of the analyses with tentative deductions therefrom. It is expected that this work will be continued so as to include soils from all parts of the Province and special study of certain problems which at present can only be suggested.

While *good* soils differ in the amounts of the essential elements, yet the following standard from Professor Snyder, Minnesota Exp. Station might be taken for comparison:—

Potash soluble in acid	Phosphoric acid	Lime	Nitrogen
Good soil........ .3-.6%	.15% if neutral or alkaline.	.3 to .5% if partly limestone	.2%
Poor soil......... ·1%	.05%		.07%

The following table gives the composition of typical soils from various geological areas of the Province.

TABLE I.

Constituent		Ign.	Sil.	Permian.		Carboniferous					Triassic			Cambrian	
	A	5	6	1	2	3	4	5a	7	8	9	10	11	13	12
Insoluble........	79 95	76.14	76 48	85.92	87.44	86.31	89.00	82.78	72.93	78.04	87.18	81.64	81.45	76.73	73.78
Potash..........	.29	.12	.36	.15	.11	.12	.13	.3	.5	39	.26	.31	.41	.15	.3
Soda	25	.03	.06	05	.09	.11	.08	.05	.04	.1	.4	.06	.01	.16	.3
Lime	2.16	.38	.3	.3	.3	.29	.4	.17	.5	.27	.25	.3	.2	.3	.35
Magnesia	.55	.23	.42	.41	.72	.29	.52	.92	.49	.23	.28	.7	.83	.74	.38
Sulphuric acid ..	.03	.18	.05	.08	.07	.07	.05	.11	.09	.08	.14	.07	.04	.08	
Iron oxide	2.68	3.15	3.28	2 65	2.80	3.10	3.40	3.63	3.05	3 45	2.74	3.40	2.90	9.1	2.5
Alumina........	5.20	3.74	4.14	2.72	2.72	2.80	2.75	3.89	5.88	5.73	2.22	4.33	3.28		3.75
Phos. acid	.23	.11	.08	.08	.09	.15	.05	.18	.29	.19	.09	.22	.12	.002	.27
Volatile or organic	7.00	12 36	11.88	7.26	4.65	5.01	2.88	7.61	11 66	9.58	5.35	10.28	6.22	11.12	10.85
Moisture........		3.49	2.76	1.17	1.13	1.51	.76	.94	4.46	2.06	1.2		3.98	2.37	6.65
Nitrogen........	.29	.34	.18	.15	.08	.1	.02	.18	24	.23	.14	.17	.1	.21	.34

EXPLANATION OF TABLE I.

A.—Average of 200 United States fertile surface soils. Snyder, Minnesota Exp. station.

No. 5—From the head of Wentworth valley, Cumberland county, would be made up of debris from the igneous rock of the Cobequids; organic matter is due to the field being used as pasture for a long time.

No. 5—The Silurian rock area in Nova Scotia is small; this sample from near Wentworth Station is a mixture of decayed igneous rock, Silurian sandstone and Drift.

Nos. 1 and 2—are typical of the large Permian areas north of the Cobequids. No. 1 is a very productive hay field. No. 2 is virgin soil.

No. 3—is a fairly productive soil from Wentworth Center, Millstone Grit area.

No. 4—is a subsoil from a model orchard at Aspen, Guysboro county.

No. 5a—is an average of 5 soils from the Limestone areas Stewiacke and Musquodobit valleys.

No. 7—is a well cultivated and productive field at Antigonish on the Carboniferous limestone.

No. 8—is from the same geological formation at Wentworth, Cumberland county.

No. 9 is a surface virgin soil from Government farm, Truro.

No. 10—is an upland soil on the Midland railway about eight miles from Truro.

No. 11—From Atlanta, Kings county; an orchard soil.

No. 12—A surface, virgin soil from central Lunenburg.

No. 13—A soil from Hectanooga, Digby county, farm of Father Broque.

TABLE 2—MARSH SOILS.

	1	2	4	q	u	A	G	C	E	F	M	14	H	S	t	13
Insoluble..	84.91	76.77	84.76	82.70	83.66	83.02	77.04	74.92	78.44	78.07	76.24	83.04	75.6	77.23	78.33	75.31
Potash....	.58	.98	.61	.79	.72	.64	.61	1.22	.84	.63	.48	.27	.75	.62	.99	03
Soda.....	.48	.53	.78	.64	.82	1.49	1.43	1.24	1.46	.76	88	.57	1.14	1.08	.36	02
Lime	1.05	.7	1.15	.65	.9	1.05	.83	.67	.4	.6	.6	.6	.3	.3	.65	.4
Magnesia	1.40	2.04	.97	1.23	1.39	1.13	.65	.85	.58	.86	78	.13	.4	1.65	1.58	1.17
Sulphuric acid....	.14	.25	.28	.12	.19	.31	.75	.55	.85	.79	.96	.17	.8	.11	.09	.61
Iron oxide	7.3	12.2	7.5	9.2	7.7	3.54	5.63	5.45	6.35	8.0	4.5	2.90	5.3	13.1	11.2	4.1
Alumina						3.74	5.45	6.09	4.35	3.44	6.9	4.54	5 4			5.5
Phosphoric acid....	.13	0.18	.05	18.	.1	.18	.27	.34	.21	.21	.19	.21	.25	.16	.16	.19
Volatile or organic	4.22	5.02	3.32	4.29	3.57	3.00	5.00	6.92	4.77	6 01	5.75	4.89	8.12	3.98	5.75	10.43
Moisture	.27	1.82	.82	1.24	1.1	.71	2.1	.43	1.55	1.5	2 62	1.89	2 12	1.6	1.43	1.86
Nitrogen..	.05	.15	.06	.08	.06	.14	36	.27	.26	.29	.24	.13	.35	.05	.14	.26

EXPLANATION OF TABLE II.

New Deposits of Marsh Mud.

No. 1—from Mr. Carl Church's property, Falmouth.

No. 2—from Mr. C. H. Black's property, Amherst.

No. 4—from Cornwallis River, near Wolfville.

No. q—from Mr. Taggart's farm, Masstown, Colchester county.

No. u—from Gaspereau River, Mr. Patterson's land.

No. A—from Mr. A. C. Layton's property, Great Village.

No. G—from Folly River, Colchester county.

No. C—from Mr. Urquhart's property, Folly; dyked 3 years before and salt marsh grasses being crowded out by timothy, etc.

No. S—taken at depth of 27-36 inches from A. C. Layton's new marsh, Great Village.

Good Dyked Soil.

No. H—Great Village; cropped for ten years with no treatment; at the time of sampling gave 2½ tons hay per acre.

No. t—from same property, ploughed two years before and gave in 1907, four tons hay per acre.

Run out Marsh.

No. E—Old marsh of Mr. Morrison, Folly, Colchester county.

No. F—Old marsh of Mr. Urquhart, Folly, Colchester county, full of weeds.

No. M—Very sour soil: full of weeds: no drainage: Mr. C. T. Smith, Folly.

No. 13—Mr. Patterson's, Horton, Kings county.

No. 14—Mr. C. Logan, Amherst Point: ½ ton hay to the acre.

TABLE 3—SOILS FROM TATAMAGOUCHE AND STEWIACKE.

	22s	16s	6s	11s	17s	7n	13n	2n	12n	9n
Insoluble	85.59	79.56	83.19	80.02	79.33	91.13	85.12	72 15	86.08	65.14
Potash	.28	32	.36	.42	.4	.19	.21	.39	.29	.55
Soda	.05	.05	.15	09	.08	.06	.13	.27	.15	.48
Lime	.20	.12	.20	.55	.33	.10	.39	.35	.42	.55
Magnesia	1.21	.71	.73	.63	1.0	.37	.66	1 15	.52	.57
Sulphuric Acid	.09	.12	.11	.11	.07	.16	.10	.13	.10	4 32
Iron oxide	2.54	4.61	3.74	3.25	4.15	1.30	2.25	4.45	2.22	8.32
Alumina	3.92	4.85	2.91	5.68	6.66	2.11	2.27	7.64	2.94	.16
Phosphoric acid	.14	.19	.20	.12	.14	.09	.18	.31	.14	.15
Organic	6.54	8.3	8.19	8.51	8.12	4.08	7.96	11.3	6.54	15.6
Moisture	.44	1.24	1.25	1.28	1.74	.71	1.21	2.16	1.41	3.35
Nitrogen	.13	.21	.22	.18	.17	.07	.23	.3	.15	.83
Humus	1 30	2.55	2.75	2.7	2.56	1.65	2.70	3.30	1.85	....

EXPLANATION OF TABLE III.

No. 22s—From worn out hillside, Campbell Brothers, Stewiacke.

No. 16s—Mr. D. W. Reid, Middle Musquodobit; model orchard giving good returns for 25 years; mostly barn manure.

No. 6s—Property of Dr. Reynolds, Otter brook, Stewiacke; old field near river intervale.

No. 11s—Worn out hillside at Mr. E. Hamilton's, Springside, Colchester county.

No. 17s—Middle Musquodobit; the Layton farm, giving fair hay crop with no cultivation.

No. 7n—Pasture, newly broken up and given little bone meal. Mr. J. Cunningham, Bayhead, Colchester county.

No. 13n—Turnip field giving good yield; previously in hay for several years; 40 tons barn manure per acre. Mr. A. P Semple, Brule.

No. 12n—Mr. Jas. Kennedy, Brule; upland not ploughed for 8 years; top dressed once with barn yard manure; yield 2 tons per acre.

No. 2n—McCallum's Settlement; old field.

No. 9n—Run out upland; farm of Wm. Charlton, Stake Road, Cumberland county.

Averaging up these analyses we have:—

TABLE IV.

	Acid Sol. Potash	P_2O_5	Lime	Org.	Nitrogen
16 Marsh soils...........	.75	.15	.75	6.7	.18
10 Upland...............	.34	.16	.3	10.	.25
14 of Table I............	.2	.14	.25	10.3	.17
Average of 200 fertile surface American soils—*Snyder*...............	.29	.24	2.16	7.	.29

What is the availability of the plant food in Nova Scotia soils? Four samples collected by the writer and analyzed at Ottawa under the direction of Professor Shutt gave as follows:

	Lime		Potash		Phosphoric acid	
	Acid soluble	Available	Acid soluble	Available	Acid soluble	Available
1—Good soil	1.64	.99	.27	.048	.23	.087
2—Virgin soil	.04	0	.145	.105	.026	.011
3— "	.36	.15	.37	.019	.11	.023
4— "	.11	.02	.42	.018	064	.023

Of the important plant foods nitrogen, lime, phosphoric acid, and potash, consider first potash. We regard it as existing in the soil in the easily soluble or available form; the more difficult soluble or acid soluble and the insoluble part; for example a soil analyzed:

POTASH

Insoluble in acid................ .737% }
Acid soluble.................... .149% } .886 % unavailable
Available...................... .02 %

That is, there are 45 times as much insoluble potash as available.

Dyer, in Proc. Royal Society, 1901, says that less than .01 to .03 per cent of available phosphoric acid in a soil indicates the need of phosphate manures and that soils with .01 per cent of available potash probably require no application of potash manures.

Hence, from Dyer's statement and the analyses in Tables 1-5 we can say that our soils have a good supply of potash but available to a limited extent. Comparing soil No. 1, which has a good supply of lime and organic matter, with Nos. 2, 3, and 4, low in these components, one may account for the greater proportion of available potash in No. 1.

Phosphoric Acid.

The total phosphoric acid of the soil exists in a much more easily soluble form than the total potash; the acid soluble phosphoric acid is the total and is found in our soils as shown in the summary, Table 4. The phosphoric acid is, as shown in Table 5, about one-fourth available and therefore soon used either by the plant, or washed away as a sediment.

Lime and Acid Soils.

Comparing the percentage of the important constituents with standards given, one notices the deficiency of lime. The lime, CaO, shown in the hydrochloric acid extract may come from dissolving the limestone or the lime silicates; since limestone cannot exist in the presence of acids we are led to test soils for acidity.

Acid Soils.

A simple test for an acid soil is: Place a lump of damp soil on a piece of moistened blue litmus; a reddening shows the presence of acid. Out of sixty-eight soils from upland, intervale, and marsh so tested, only ten showed no acid reaction and of these, six were new marsh deposits; the four only, cultivated soils showing no acid reaction were from areas giving good crops, in one case four tons of hay per acre. Many of the acid soils were from unused fields and some from geological areas showing much limestone rock. Now lime and limestone are the substances which will correct the acidity so we are, from this test, led to infer that our soils need additions of lime. The action of this substance in the soil is very complex and but imperfectly understood.

Since Nova Scotia has many limestone areas, one might expect the soil to be well provided with lime, but such is not the case; it being a land of hills and valleys, of brooks and rivers, the limestone is carried away especially from the light soils of the limestone areas. From the limestone soils of

England, 1429 pounds per acre to the depth of nine inches were carried away in the drainage water per year, or in the forty years of the experiment, about 28 tons per acre.

Limestone has the following uses in the soil:—

(1) To supply calcium, a necessary element of plant food; 4 tons of clover per crop, for 30 crops would require 3,510 pounds of Calcium.

(2) To neutralize the acids resulting from the decay of organic material or the decomposition of such fertilizers as ammonium sulphate. Very often the soils with the least organic matter show the least lime and vice versa; e. g., a muck soil at Truro shows at the surface:—

	Inorganic matter.	Volatile matter.	Lime
At surface...........	7%	85.90%	3.20%
1st ft. of subsoil......	79%	15.73%	1.40%

(3) To effect a chemical dissolving of potash silicates and to set free phosphoric acid from iron and aluminum phosphates.
(4) For its flocculating effect on the clay soils.

Caustic Lime, CaO, has an antiseptic effect on the soil. Hutchinson of Rothamsted Exp. station, England, in June, 1913, says: "Caustic lime is a valuable antiseptic and when applied to the soil, even in the presence of large quantities of carbonate of lime, disturbs or destroys the state of equilibrium existing between the micro-flora and micro-fauna of the soil; it kills many bacteria and destroys the larger protozoa which exert a depressing effect on bacterial growth; the inhibitory action of caustic lime on soil bacteria persists until all the oxide is changed to the carbonate; this is followed by a period of active bacterial growth.

Organic Matter and Nitrogen.

Table 4 gives averages of the organic matter and nitrogen in the three groups of soil studied: these indicate organic matter deficient in nitrogen, just as we have in the peat soils much organic matter with little nitrogen; we must say then, that while the organic matter averages fairly well, the nitrogen content is low, there being too much cropping for the amount of nitrogen returned.

Again, these soils are, as a rule, acid; consequently, the bacteria, which break up the organic matter and form nitrates and which cannot work in the presence of acids, are rendered inactive; this brings into question the availability of the nitrogen and suggests the use of a base like lime.

The great problem in Nova Scotia seems to be to increase and maintain the amount of available nitrogen.

The analyses thus far show:—

(1) That our soils have a good supply of potash but that it is only slightly available.

(2) That phosphoric acid in many soils is in small amounts, is about one third available and hence soon used.

(3) That, while volatile matter is quite high, it is deficient in nitrogen.

(4) That lime is *very deficient* in many soils.

Hopkins of Illinois, in speaking of the average soils of the United States says "Phosphorus is the key to permanent agriculture on these lands."

The recommendation from this study is, if the soil is in fair condition, supply (1) limestone in the powdered form, 2 tons per acre every four years; (2) a mineral phosphate as basic slag, or if obtainable, ground rock phosphate, 600 lbs. per acre every three or four years; this will put the land in condition for growing legumes which, if ploughed under or fed and the manure returned to the land, will increase the store of nitrogen and organic matter. This organic matter will help to dissolve the potash which is present, locked up in the soil.