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IV. TROCKENLEGUNG DER ZUIDER ZEE.

II. THE RECLAMATION OF A PART OF THE ZUYDER ZEE

by

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1. *Kwelders and Polders.*

Most of Holland consists of deposits of the rivers and the sea, and, lying below high sea and river level, it is protected from the sea and the rivers by dunes and dikes. In this paper I will confine myself to the sea-deposits.

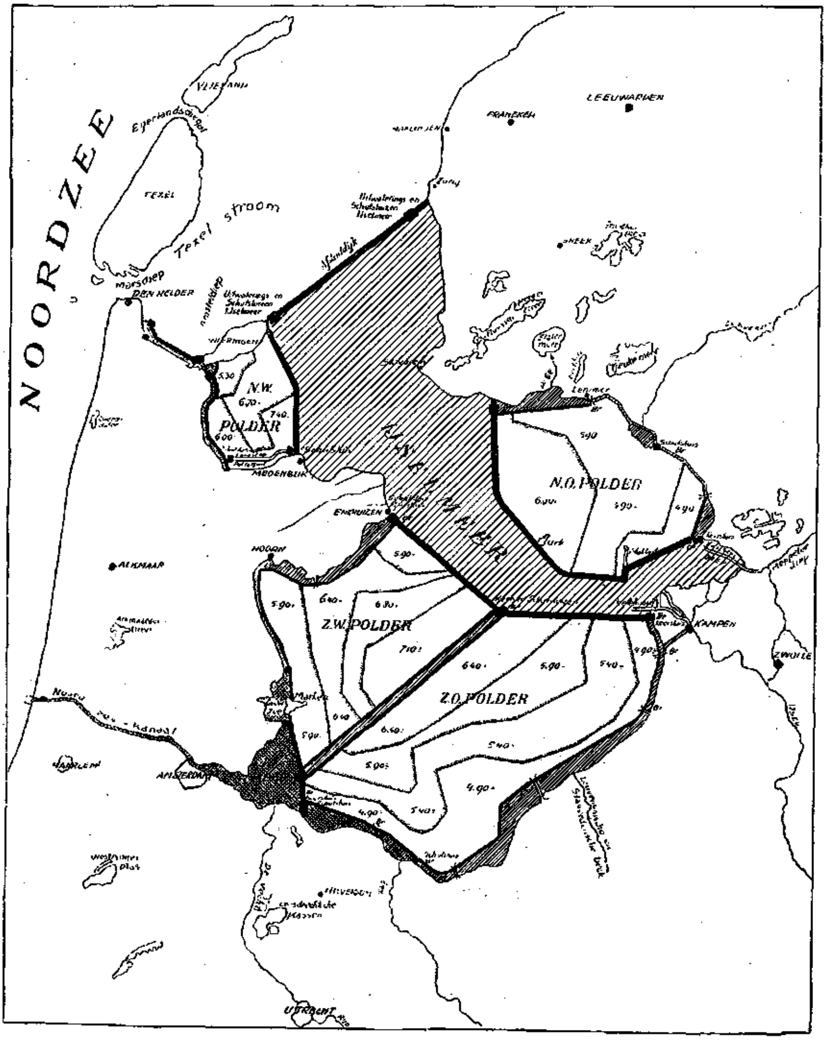
The sea-deposits, partly sandy, partly clayey, are brought by the recurrent tides against our sea-dikes, until they are so high as not to be covered by the normal summer tides. The salts of the sea-water are then, at least for the greater part, washed out of the upper layer by the rain-water, so that a grass-flora makes its appearance. These grass-grown deposits are called "kwelders" (German: Groden); they are covered only by the high tides, especially in winter. When the kwelder is high enough, a dike is built to keep out the sea-water; the kwelder is now transformed into a young sea-polder.

In the same manner the river-polders are formed by the river-deposits.

It is obvious that the oldest maps of Holland differ much from the present map.

The soil of a young sea-polder, especially if it contains a large amount of clay, is extremely fertile. In consequence of the formation of the kwelder soil in salty water (which flocculates the clay particles) and of the grass-crop (whose roots penetrate the upper soil layer), the kwelder soil, and later the young polder soil, is extremely permeable to water. This causes the salts of the sea-water to be washed out by the rains, as early as the first winter after endikening, to an appreciable depth, so that the young polder is immediately ready for cultivation. The clay-sea-polders especially yield very good crops, without any fertilizing, within as little as

12 months after their endikening and during a long period of years. It should further be noted that young sea-polder soils possess a good structure and are easy to plough. The principal precaution that must be taken is to plough the soil to a very



Plan of the enclosure and partial endikening of the Zuyder Zee; dam and four polders.

The N.W. polder is the so-called Wieringermeerpolder. The dam (Dutch: afsluitdijk) runs from the island of Wieringen to the coast of Friesland.

slight depth, at first only a few centimetres, gradually to plough deeper, and especially not to plough the wet soil. All these measures are intended to preserve the good soil structure, and especially the high permeability of the soil, as long as possible, not only till the salts are washed out, but long enough for the sodium clay to be transformed into calcium clay soil.

Holland is a small country with a big population, so that the idea of reclaiming a part of the Zuyder Zee was mooted 80 years ago. This is now being done. The work consists of two different operations:

1. the enclosure of the Zuyder Zee,
2. the work of reclaiming part of this sea.

2. *The Enclosure of the Zuyder Zee.*

A dam, 30 kilometres long, is being built from the coast of the province of Noord-Holland, by way of the island of Wieringen, to the coast of the province of Friesland; we hope this work will be completed by 1932.

3. *The Reclamation of part of the Zuyder Zee.*

The dam, having been made, the Zuyder Zee is being transformed into an inland sea, a lake, the plan being to endiken in this lake four polders, of respectively 20 000; 55 000; 95 000 and 55 000 hectares, total 225 000 hectares, an area, that is, equal to 7 % of the total area of Holland, and to 10 % of the area now available for cultivation.

Owing to the increase in the population and the resultant need for new arable land, and partly, perhaps, to the increasing amount of unemployment, it was decided in 1925 to endiken the Wieringermeer at once. This work was completed by the end of 1929, and since January, 1930, two gigantic stations, at Medemblik and Den Oever (on the island of Wieringen), have been pumping out the water, so that in September, October, 1930, the 20 000 hectares of the new Wieringermeer Polder were above water.

4. *Experimental Polder near Andijk.*

The soil of the new Zuyder Zee polders consists of more or less sandy or clayey deposits, from nearly pure sand to very heavy clay. The land emerging from the water is of course not covered with any vegetation. At first the clay soils form a mass with little or no structure, and consequently with small permeability or none at all. The reclamation of the young Zuyder Zee polders is therefore quite a different matter from that of the young polders which were previously grass-grown kwelders, and whose soil possessed, as stated above, a very good permeability for water, and but little salt in the upper layer.

According to the report of the Commission presided over by Dr. LOVINK, published in 1924, the Government of the Netherlands undertook the endikening, in 1926, of a small part of the Zuyder Zee, near the village of Andijk. The object with which the creation of this experimental polder of about 40 hectares was decided upon, was to study the cultivation of the soils of the Zuyder Zee, which are entirely devoid of any grass-growth and have, on becoming exposed, a not very favourable structure or none at all. In 1927 the water was pumped off this polder. The Government then called into being a Commission under the presidency of Dr. LOVINK, for the purpose of studying the technical and scientific problems which presented themselves during the cultivation of this experimental polder. The study of the soil was entrusted to the present writer. The results of these researches have been published in the proceedings of the Lovink Commission (Blue Book No. I), which contains a report on "The Constitution of the Soil of the Experimental Polder near Andijk in 1927/1928". The following resumé is partly taken from this report.

The upper part of the soil of the greater part of this experimental polder was a very wet, very clayey mass, averaging about 55 cm in thickness. This muddy upper layer contained, in 1927, per cent of dry matter 12,2 % $CaCO_3$—3,6 % humus—61,6 % clay (fractions I and II) — 19,7 % sand, and 2,86 % NaCl.

The original soil was of a dark colour owing to the presence of ferrosulphide (FeS), and further very wet, containing an average of 172 g water per 100 g dry matter; 1 litre soil water therefore contained 16 g NaCl (1000 × 2,86 : 172 = approximately 16).

This muddy, very watery soil, to be converted into normal soil, has first to dry. Very fortunately, the summers of the years 1928 and 1929 were very hot and dry, whilst in the two severe winter periods not much rain fell. As a result, the soil dried rapidly, large fissures and non-capillary pores, which later on crumbled, appearing, and the originally structure-less soil consequently acquired a very good structure, and became permeable to water.

In our humid climate a permeable soil rapidly loses its salts, as may be seen from the following figures (*see Table A*). The muddy mass of 1927, averaging about 55 cm in thickness, and coloured black with ferrosulphide (FeS), with 172 g water and 2,86 g NaCl per 100 g dried matter, had changed in 2 years, that is from 1927 to 1929, to a grey, fairly dry upper layer, 20 cm thick, with 66 g water and only 0,2 g NaCl, 1 litre soil water containing about 3 g NaCl, and a sub-layer, about 23 cm thick (from 20 to 43), still in parts black and fairly wet, with 116 g water and 1,3 % NaCl, 1 litre soil water still containing about 11 g NaCl (*see Table A*).

TABLE A.

Average figures of the muddy soils of the Experimental Polder near Andijk.
(very heavy clay soil: 12,2 % $CaCO_3$—3,6 % humus—61,6 % clay (fractions I + II)—19,7 % sand—2,86 % NaCl).

Water and NaCl content in 1927, 1929, 1930	g water per 100 g dry soil (a)			g NaCl per 100 g dry soil (b)			g NaCl per 100 litre water ($c = 1000\, b : a$)		
	1927	Summer 1929	March 1930	1927	Summer 1929	March 1930	1927	Summer 1929	March 1930
Upper layer, 0—20 cm, grey, fairly dry		66	66		0,2	0,04		3	0,6
Total muddy mass, 55 cm, coloured black (FeS)	172			2,8			16		
Sub-layer, 20—43 cm, in parts black (FeS)		116	110		1,3	0,42		11	3,8

TABLE B.

Some physical values of the muddy layer of the Experimental Polder near Andijk, in the middle of July, 1930.
(Clay content; water and NaCl content; volume weight; permeability (D-value) for water, according to Kopecky).

Depth in cm	Colour and degree of moisture	Clay % (I + II)	a = g H_2O / b = g NaCl per 100 g dry soil; c = 1000b : a = g NaCl per Litre soil water			Volume weight	per 100 cm³ soil under natural conditions, cm³			D = permeability in metres per 24 hours (Kopecky)
			a	b	c		soil	water	air	
0— 7	grey, dry	66,5	31,9	0,05	1,6	0,829	33,0	30,4	36,6	34
10—17	grey, rather dry	74,3	73,7	0,26	3,5	0,834	32,3	42,7	24,0	> 115
20—27	grey, rather dry	72,2	80,2	0,26	3,2	0,673	26,0	68,0	6,0	> 115
40—47	dark, wet	60,4	124	0,62	5,0	0,740	22,5	76,2	1,3	1,9

The tests made in March, 1930, showed that little change had taken place in the water-content of the layers of 20 cm and of about 20—40 cm; the percentages of NaCl had, however, fallen to 0,04 % and 0,42 % respectively, 1 litre soil water containing 0,6 and 3,8 g NaCl respectively (*see Table A*).

Some physical values of the successive layers were also determined at two spots in the summer of 1930 (*see Table B*), to wit: the permeability of the soil for water, according to KOPECKY's method, and the volume-weight. Together with the specific gravity and the water content of the soil, this latter figure gives us the amount of cm^3 soil, water and air per 100 cm^3 (*see Table B*).

The upper 30 cm was already quite grey in colour, fairly dry (a = from 31,9 too 80,2), and extraordinarily permeable for water (D-values, in m per diem 34 and 115); the layer of 40—50 cm was still partly black, rather wet (*a* = 124), and still only very slightly permeable (D = 1,9). The air-content of the upper 20 cm was very high (36,6 % and 24,0 %), as a result of which the water-containing capacity of the layer of 0—20 cm amounted to no less than 36,6 + 24,0 = 60,6 mm. It should be noted that this is not the whole water-containing capacity (this is much greater, viz. 67 + 66,7 = 133,7 mm water), but the temporary water-containing capacity. This means, therefore, that a further rainfall of 66 mm, after the middle of July, 1930, when samples were taken, could be entirely contained in the upper 20 cm. This fact, plus the great permeability of the upper layers, accounts for the soil not being overburdened with water notwithstanding the heavy rains after the middle of July, 1930.

In addition to the drying and de-salting processes, the soil has to undergo still another change; the original sodium clay soil, or rather, the sodium magnesium clay soil, has to be changed into a calcium clay soil. Whereas the clay substance of normal Dutch polder soils contains an average of 79 Ca, 13 Mg, 2 K, and 6 Na per 100 milligram-equivalents of exchangeable bases, the original muddy mass of the Andijk Experimental Polder contained in 1927 about 24 Ca, 49 Mg, 8 K, and 19 Na per 100 mg equivalents. The transformation of this sodium clay into calcium clay must take take place under the influence of the Ca of the calcium carbonate of the soil, which must first be brought into solution by means of the carbon dioxide as calcium bicarbonate. Sodium clay and calcium- bi-carbonate then give further calcium clay and sodium bi-carbonate.

As this process is reversible, it is in the first place necessary that the sodium bi-carbonate formed should be led off, which takes place if the soil is well permeable for water and the rain-water is rapidly led off by a system of drains or ditches.

In the second place an abundant production of carbon dioxide in the soil, or in any case a good penetration of the CO_2 of the air into the soil, is important. It is obvious that in this regard also a high permeability of the soil is of the greatest importance.

Finally, a good aeration of the soil (presence of O_2) promotes the conversion of iron sulphide (FeS) into iron sulphate ($FeSO_4$), which latter product, with calcium carbonate, gives gypsum, which is soluble in water. This gypsum promotes in turn the conversion of the sodium clay substance into calcium clay.

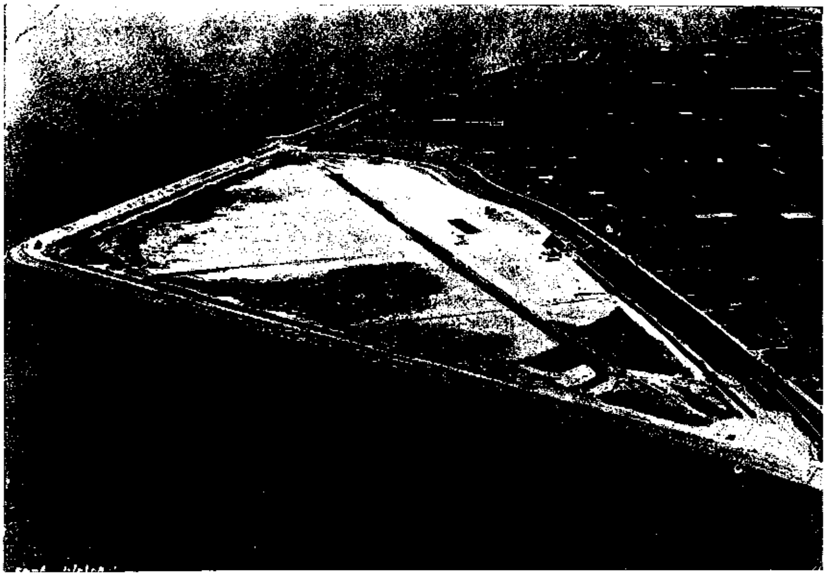
Mainly owing to the drying up of the soil and the consequent good permeability of the soil for water and air (presence of CO_2 and O_2), the conversion of the sodium clay had already proceeded satisfactorily, simply as a result of the calcium carbonate present in the soil, from 1927 to 1930. Fertilizing tests have shown that extra fertilizing even with $CaSO_4$ and sulphur (S) has not had the slightest effect.

It follows from what has thus far been said that all endeavours must be directed to promoting as far as possible a good permeability of the soil for water and air, and, where this already exists, to doing everything to retain it and nothing to mar it. More especially the leading-off of the surplus water by means of a good system of drainage, and further a judicious cultivation of the ground, superficial ploughing, and certainly no ploughing in the wet soil, are amongst the measures most to be recommended.

The reclamation of the young soil of the Andijk Experimental Polder was therefore, in any case in the beginning, in the main a question of a physical nature. I may add that the Andijk clay soil had no very great need of fertilizers.

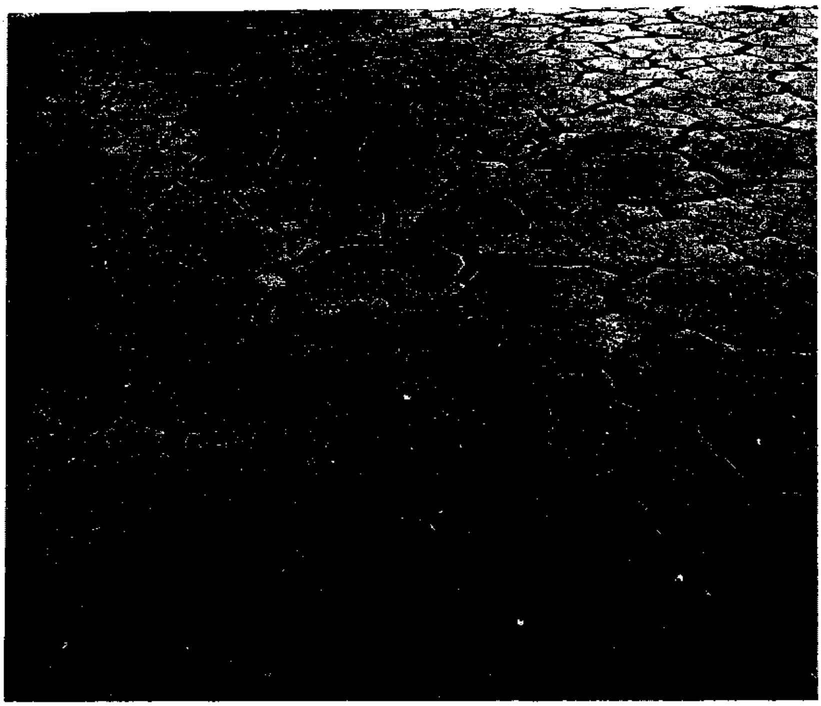
The Andijk clay soil contained an average of only 3,3 % organic matter and 0,3 % nitrogen (N). The nitrogen content of the organic matter was therefore 9 %, a fairly high figure, which points to the good state of decomposition of the organic substance and to a high assimilability of the organic nitrogen. On the other hand, the content of only 0,3 % nitrogen is not high. Fertilizing experiments have shown that only those crops requiring a great deal of nitrogen, such as sugar-beets, showed a slight reaction to nitrogen fertilizers. The content of potassium of the Andijk clay soil was not determined, but in all probability this young sea-clay soil did not require any potassium fertilizing, with which supposition the results of fertilizing experiments were in full agreement.

Finally, the Andijk clay soil contained an average of 0,232 % of phosphoric pentoxide (P_2O_5) soluble in nitric acid and of 0,105 % P_2O_5 soluble in 1 % citric acid; the relative solubility of the phos-

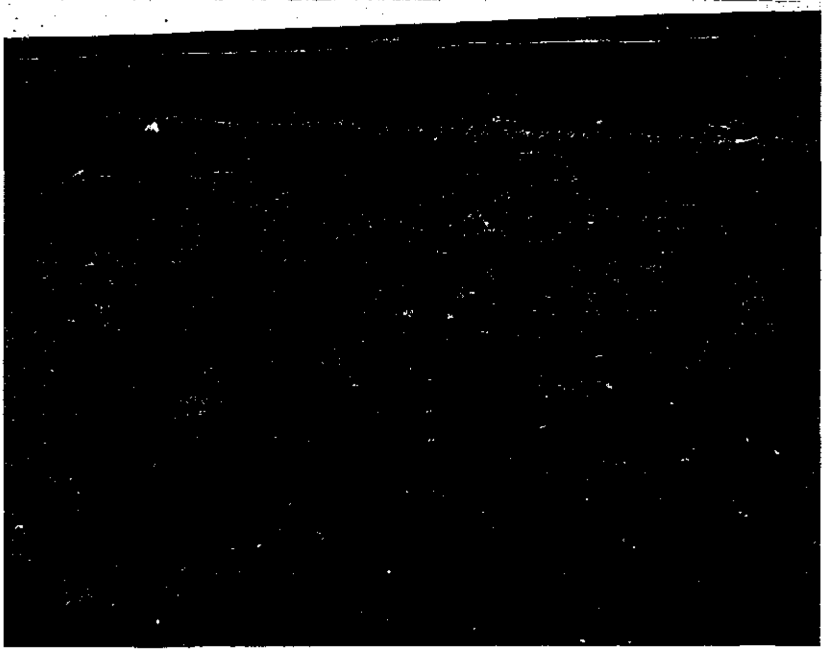


Experimental Polder, near Andijk; situated on the coast of the Province of Noord-Holland, to the east of the town of Medemblik.

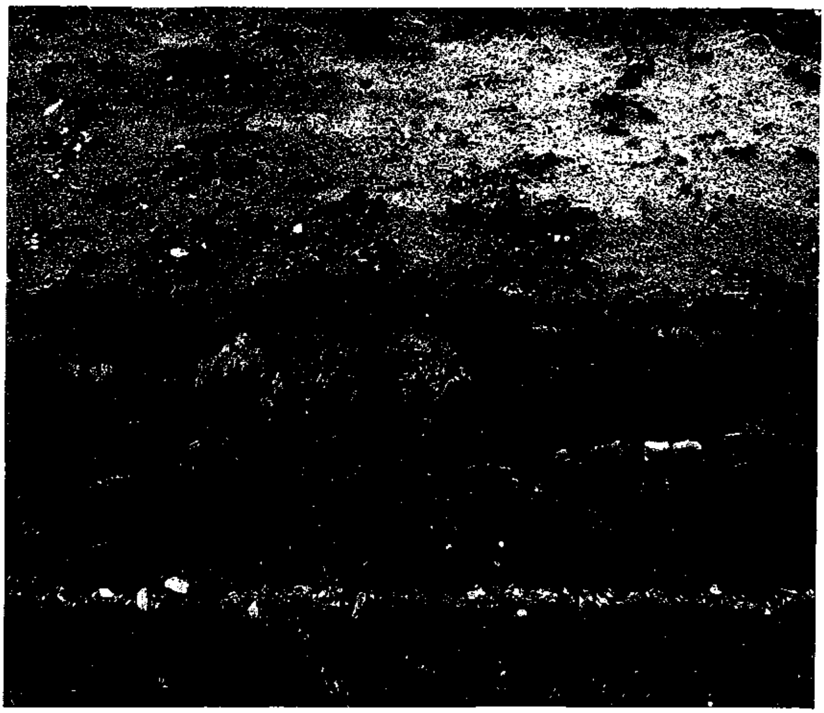
The drainage canal, running parallel to the old coast, is clearly seen on the photo. To the left of this canal can be seen the wet and dry patches of the muddy soil, depending on the more or less favourable situation with regard to the drying process of the soil. The photo was taken in 1928, about a year after endikening.



Photos 2 and 3 are two of a series of photos of the Andijk Experimental Polder, all taken on the same day (November 1928), but from several points, each more favourable than the preceding one from the point of view of the drying process of the soil. Photo No. 3 is the least favourable (Parcel V, northern part); the muddy mass shows wide fissures, but is not yet crumbled.



This photo (no. 3) is of the part that, since the endikening in August 1927, has been most favourably situated with respect to the drying process of the soil (Parcel III, section 1*a*). The fissures are being filled up by loose soil. Increased vegetation, for the moment (November 1928) only saline plants.



This is a profile of the muddy mass, dried up at the surface, but with wide fissures underneath. Under this layer with fissures is seen a thin layer of shells, below which the muddy mass shows no fissures. The photo illustrates fairly well the profile mentioned in Table B (p. 182), the layer under the shells being the dark, wet layer at a depth of 40—47 cm. It is further seen that there are no fissures in this latter, very watery layer, but only in the drier soil above the shells.

phoric acid according to LEMMERMANN was therefore no less than 45,3 %, a very high value indeed. In full agreement with this, the Andijk clay soil did not react to phosphoric acid (P_2O_5) fertilizing.

5. *The Wieringermeer Polder.*

The big work now ahead of us is the problem of the reclamation of the soils of the young Wieringermeer Polder to an area of about 20 000 hectares of land.

The dike from Medemblik to Wieringen was completed about January, 1930; the water was pumped out by about September, 1930. The chart (page 178) shows the canals and the plan of the parcels, each of which is about 30 hectares in extent.

The mapping of this young polder, provisionally carried out by VAN BEMMELEN as early as 1880, was resumed, also provisionally, in 1927 by the present writer. These two series of mapping operations were carried out at a time when the land was still under the sea. The report mentioned above (Blue Book No. I) contains a Report of VAN BEMMELEN'S Researches in the year 1880, with a soil map of the bottom of the Wieringen Lake; further the present writer's report entitled "The constitution of the soil of the future Wieringermeer Polder according to the borings made in 1927".

When the surface was exposed, a new and more detailed mapping was undertaken, in 1930 and 1931, under the direction of the writer by Engineer A. ZUUR, head of the Pedological Laboratory, at Medemblik. This work is nearly completed for the four sections (see chart) of the new polder, whilst the detailed analysis of a large collection of samples has been carried out at the Institute of Soil Science at Groningen. The results of this operation and of these analyses show that the soil of the first section of the Wieringermeer Polder is largely composed, at the surface, of a layer of sand of varying thickness, below which clay is found at several places; there is further a slight percentage of clay and light clay and an inconsiderable quantity of peat. The second section, on the contrary, is principally composed of clayey soils. In the other sections soils are found varying from rather heavy clay soils to more sandy soils. Owing to the fact that some parts of the Wieringermeer Polder have been exposed for about 6 to 7 centuries, soils are found there which are already absolutely free from calcium and frequently very acid (pH as high as 1 and even 0,6). Fortunately these parts are only of slight extent, whilst the $CaCO_3$ of the new deposits of the sea are present nearly everywhere in large quantities.

The various types of soil each present their own peculiar difficulties with regard to cultivation, more especially as regards the drying and de-salting of the soil. In this respect two types may be more particularly distinguished, namely sandy soils and clayey soils. All over the Wieringermeer Polder it is necessary to dig ditches or to make a drainage system, but there are differences between the rates of drying and de-salting of these two types.

As a result of a good system of drainage the sandy soils lose their surplus water and their salts fairly rapidly. The analysis of soil samples taken in October, 1930, from the sandy area S.E. of De Haukes (island of Wieringen) demonstrated that in the parcels first ditched the leaching out of the salt was satisfactory, so that it was possible to sow some 200 hectares of these sandy soils with rye and grass and clover as early as the autumn of 1930; this area bore a fine crop in the summer of 1931. On this type of soil the provision of water will probably cause trouble in the future; the possibility of infiltrating these soils with fresh water is now being studied.

The drying and de-salting process of the heavy clay soils proceeds more slowly, even if ditches have been dug or drains laid down. Especially in this area the problem of the intensity with which the soil has to be drained constitutes a point of extensive research. An experimental field, 30 hectares in extent, was therefore laid out in the year 1930, near Kolhorn, to permit of a study of the drying and de-salting processes on the clayey soils, and also of the conversion of the sodium clay into calcium clay and other conversion processes. For this purpose ditches were dug and drains were laid down at various intervals on 8 plots, whilst 6 plots were left untreated. The result of these drainage systems was for the moment studied only by means of:

a. soil tests (changes in volume-weight, permeability for water, water and NaCl content, etc.),

b. the changes in the level of the soil-water in 300 soil-water-level pipes distributed over the field.

A detailed report of the results of these investigations will be published later. It may suffice for the moment to say that a difference has been found to exist between the physical condition (the structure) of the original muddy mass of the Experimental Polder near Andijk and that of the clay soil of the Experimental Field near Kolhorn. In 1927 the former was very wet, without any structure; fissures, however, very soon appeared (see photo), the soil speedily becoming permeable for water (*see Table B*). The clay soil of the Experimental Field near Kolhorn (Wieringermeer Polder) is, however, a much older soil. On becoming exposed, it consequently contained somewhat less water, was more compact and already had a slight permeability for water. In contrast with these advantages, however, the formation of fissures will possibly be less rapid, so that a good permeability for water may be reached more slowly.

Besides the drainage experimental field near Kolhorn, experiments are being made with a new drainage system devised by Prof. Ir. M. F. VISSER, Wageningen. In this system a wooden pipe with a square cross section (3 in. by 3 in.) is pulled through the soil by means of a mole drain plough across the whole width of a parcel (275 yards).

Most of the soils in the clayey areas were still, in the autumn of 1931, too salty to sow plants in. Of course, it is of great importance to investigate at certain intervals the stage reached by the de-salting process, in order to determine when it will be possible to begin sowing. With this object the contents of water and of NaCl of the various parcels of the Wieringermeer Polder were constantly tested in 1930 and 1931. This work, which is more particularly under the supervision of Engineer A. ZUUR, will be repeated early in 1932. In order to give an idea of the drying and de-salting processes, the course of these processes in the soil of the experimental field near Kolhorn will be dealt with by Engineer ZUUR in the next article.

I hope that it will be possible to communicate more of the results of all the above investigations to those who visit the meeting of the Sixth Commission of the International Society of Soil Science, to be held at Groningen in July 1932, and also to show them something of the practical side of these experiments on the various experimental fields, and especially on that near Kolhorn.

Groningen, November 30th, 1931.