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The subsidence of the soil of the Netherlands.

By Prof. G. A. F. MOLENGRAAFF.

With regard to a sinking of the soil of the Netherlands one may derive from the latest chapters of the history of geology the following data.

In the tertiary era, probably already in the oligocene period, the subsidence commenced, but it did not affect the whole country to the same extent; on the whole it was more pronounced in the west and the north of the country than in the east and the south, in such a way, that the south-eastern and eastern parts of the country were hardly affected by the movement, if at all, whereas the effect gradually increases towards the north-west.

This is proved by the fact that shore- and shallow-water deposits of the same age formed during that period are now found in very different altitudes, as appears from the subjoined table compiled from the results of several deep borings. ¹⁾

T A B L E I.

	Grave	Goes	Gorkum	Utrecht	Amsterdam
Holocene + Pleistocene	above 4	above 29	above 117.5	above 152	above 200
Amstelian		29—34	117.5—178	152—240	200—235
Waltonien = Scaldisien + Poederlien	4—7.5	34—54.5	not reached	240—268	not reached
Diestien = Gedgravien	7.5—20	54.5—93	„	268—365	± 450 ²⁾
Rupelian		93—220			

Depths in meters below A. P. (Amsterdam level) ³⁾.

The south-eastern and the eastern portion of the Netherlands remained, however, not entirely unaffected. The country there is

¹⁾ See H. G. JONKER List of Literature Verh. Kon. Akad. van Wet. XIII LORÉ, No. 680, No. 783, and No. 849, HARMER No. 1004, and No. 1191, particularly LORÉ No. 1265. and P. TESCH. Der Niederländische Boden und die Ablagerungen des Rheines und der Maas aus der jüngeren Tertiär- und der älteren Diluvialzeit. Meded. Rijksops. v. Delfstoffen (Communications of the government institute for the geological exploration of the Netherlands) N. 1. 1908. p. 12.

²⁾ This depth is not reached in the boring, but the figure 450 is found by calculation.

³⁾ The Amsterdam level (A. P.) is considered to be the normal average level of the sea.

broken and faulted; elongated tracts of land which took no part in the downward movement, so-called "horsten", (uplifted blocks, "Horste") alternated with tracts which took part in it, so-called "slenken" (sunken blocks, "Gräben").

The trend of these tracts of ground, whose existence has got known of late years particularly by the deep borings made by the government Institute for the geological exploration of the Netherlands is in general northwest-southeast in the south-eastern part of the land.

Moreover it is known that for a great part of the Netherlands this subsidence has never given rise to great differences of level on the surface, because the effect of the sinking was continually more or less counterbalanced by the accumulation of deposits of sand and silt on the sinking blocks. This is proved by the fact that the character of the fauna of these tertiary deposits down to the greatest depths reached until now, continues to be that of a shore or shallow-water fauna.

Without any doubt the depth of the sea was never more than 60—70 meters in spite of the great amount of this subsidence.

We must accordingly assume that in tertiary, especially in late-tertiary time the rivers already carried along large quantities of fine sediments (sand and silt), towards the North sea in our country as it was then, which sediments slowly raised the sinking bottom of the sea to such an extent that the accumulation always kept pace with the subsidence. As the amount of this subsidence increased towards the north-west, the quantity of the sediments deposited in an equal space of time had also to increase in that direction, as clearly appears from table I.

The same thing is observed in the east and the southeast of the country in the sunken tracts "slenken". In a "horst" a certain formation deposited in a certain space of time can be very thin, or may fail altogether, whereas in the adjoining "slenk" the deposits formed in the same space of time may have a considerable thickness as appears from table II ¹⁾. (See p. 470).

Towards the end of the tertiary period the transporting power of the rivers gradually increased, and the amount of sediments deposited was consequently augmented. The subsidence of the soil ceased temporarily, or was possibly interrupted by a feeble movement in the opposite direction. A real or apparent upheaval of the land, at all events a negative shifting of the shore line was the result; the sea was forced back, and the Netherlands became for the greater part, or entirely, dry land.

¹⁾ See P. TESSI *loc. cit.* and Verslag der Rijksopsporing van Delfstoffen 1906.

T A B L E II.

	Boring Vlodrop 1 in "slenk" South- west of Peelhorst.	Boring Vlodrop 3 in Peelhorst.	Boring 7 in "slenk" North- east of Peelhorst.
Pleistocene	28 + A.P. — 161—A.P.	70.9—65.9 + A.P.	31.9—16.9 + A.P.
Pliocene	"kieseloolith stage"	161—532—A.P.	16.9 + A.P.—26.1—A.P.
			Marine
Miocene	Lignitiferous sand	65.9 + A.P.—171—A.P.	below 118.1 —A.P.
Oligocene		below 17.1 —A.P.	
Thickness Pleistocene	189	5	15
Thickness Pliocene	371	fails	135
Thickness Miocene	not reached	83	

Also a great portion of the North sea must have become dry land in the late pliocene times, so that a branch of the Rhine flowed through the eastern provinces of England, as HARMER has shown. The approach of the glacial epoch announced itself by the increasingly marked boreal character of the fauna of the transition strata between Pliocene and Pleistocene, the Scanien and Weybournien.

In the succeeding diluvial or pleistocene period the soil of the Netherlands resumed its descending movement, but the transporting power of the rivers also increased greatly; besides silt and sand, large quantities of gravel were brought to our country, from which material the so-called gravel-diluvium was formed. And not only the rivers conveyed material, but also the Scandinavian land-ice reached our country in the chief glacial epoch (the Riss glaciation), and covered it with the exception of the portion south of the Rhine. The same thing took place on a much smaller scale according to some scientists in the succeeding last or Baltic glacial epoch. By the pressure of the ice the surface of the gigantic fluvial sand and gravel-delta over which it moved was greatly altered, and the ice itself left much material of Scandinavian and Baltic origin behind in its ground moraine (the "keileem") and its other moraines, while also the glacier streams modified or covered the pre-glacial stream-deposits both by erosion and by depositing. The country however continued to sink, and the enormous quantities of gravel and sand, carried on by

water and ice, could not do much more than neutralize the influence of the subsidence.

In the interglacial periods with their drier climate the influence of the sinking was decidedly very marked again. Thus LORÉ¹⁾ succeeded in showing that, in the interglacial period which succeeded the great (Riss) glacial epoch, thus previous to the last great period of extension of the pleistocene glaciers, the effect of the subsidence was greater than the counterbalancing effect caused by the accumulation of sediments. The northwestern and western part of the Netherlands was then partly flooded by the sea, and in a gulf the strata of the so-called Eem-system, a shallow-water and shore formation were deposited. But then the influence of the sedimentation compared with that of the subsidence became stronger again; riversand again covered the sea-clay of the Eem-system, the sea was forced back again, and rows of dunes originated successively further and further to the West and Northwest far out in the sea as compared with the present shore. But the sinking continued; the strip of land lying inside the dunes was flooded by the sea and covered with water. Holland was for a great part converted into a lagoon or "haff". More than once the water in the lagoon, probably during short intervals of contrary movement, became shallow, brackish and finally fresh enough to be filled up with a peat-vegetation. Then the sinking of the ground increased again, and sea-clay covered the peat once more. Almost everywhere in South-Holland and North-Holland these old peat deposits are found under the blue sea-clay, generally at about 12 m. below A.P., sometimes at greater depth, e.g. at 19 M. below A. P. at IJmuiden, and between Hoorn and Zaandam. Probably the origin of the natural gas, which is used for illuminating purposes in many farmhouses in North-Holland and South-Holland, is to be found in these deep peat-deposits under the sea-clay. Our knowledge, however, of these deep peat-deposits and the natural gas is still very imperfect.

Perhaps it is to be recommended to fix the beginning of the holocene or recent period in the latter part of the lagoon stage. In the first, pre-historic part of the holocene the dunes extended a good distance further sea-ward than now, but the considerable destruction of the coast line by the action of the waves (only after the Pas de Calais was formed, probably at the end of the pleistocene, the destructive effect of the sea became very powerful) made them decrease rapidly, just as is still the case at present. The lagoon was filled with sea-water down to a depth of about 6 meters. As LORÉ has shown, a short period of upheaval amounting to about 6 meters, followed, which

¹⁾ See JONKER's list N^o. 725.

was again succeeded by an equally great subsidence. In consequence of this rise the lagoon was almost converted into dry land, the water became fresh, and a peat vegetation filled the lagoon. This peat continued to grow during the slow sinking that followed, till it reached the thickness of ± 6 meters, which it now has.

Now the second, historical part of the holocene follows. The transporting power of the rivers is slight, and modified by man in a sense unfavourable for the accumulation of deposits by canalisation and normalisation of the rivers. The sinking continues and the loss of land is accelerated by the rapid wearing away of the dunes on the sea-side, and more inland by floods caused by storms. A subsidence of the soil in historic times is proved by the situation of structures of Roman origin, as the Brittenburg near Katwijk, and the Nehelennia temple near Domburg, which were still inhabited A. D. 300, as appears from the coins found there, and which therefore cannot have been below A.P. then, whereas now they are resp. 1,5 and 4 m. below that level. For a continuous sinking also in later ages, between 1300 and 1750, urgently pleads also the fact that the polders lie the deeper below A.P. as it is longer since they were drained. This is sometimes ascribed to a prolonged shrinking of the ground, but the conditions which give rise to this phenomenon, are only realised in the upper portion of the ground of the polder which lies now above the artificially lowered level of the ground-water, while it is difficult to imagine dessiccation and shrinking in consequence of it in the deeper lying portions of the ground, which are perfectly saturated with water. Thus it seems very unlikely that shrinking can have given rise to any considerable lowering of the ground, and can have continued for several ages.

The exact amount of the sinking in historic times cannot be determined with perfect certainty, but it may be assumed that it was greater in the north of the country than in the south, whereas the estimations vary between 25 and 90 cm. per century¹⁾.

If we finally proceed to recent history, say of the last two centuries, it strikes us that investigations about the relative position of the land with regard to the sea-level during that time have led to divergent results.

LORIE assumes that the subsidence of the soil of the Netherlands came to a (temporary) stop in the middle of the 16th century, which took place somewhat earlier in Belgium according to RUTOT.

RAMAER²⁾ has derived from observations on gauges, carried out

¹⁾ Cf. JONKER's list No. 313, 782, 785, 810, 913.

²⁾ J. C. RAMAER. De daling van den bodem van Nederland. Verh. Kon. Inst. tuut van Ingenieurs 1907/08, p. 1.

during the years 1862—1906, that the soil of the Netherlands is still sinking, and that this sinking amounts to about 18 cm. a century.

On the other hand VAN DE SANDE BAKHUYZEN¹⁾ has derived from observations concerning the level of the official A.P. at Amsterdam, that it remained constant from 1700—1860, and that accordingly the ground of Amsterdam neither rose nor sunk during that period.

The results to which RAMAER and VAN DE SANDE BAKHUYZEN have come, are not very well to be brought to accordance, unless we assume that the sinking set in again after the year 1860 after a period of rest, or as Mr. RAMAER is inclined to believe, that at Amsterdam also previous to the year 1860 the same sinking took place, but that it was just counterbalanced by a movement of the ground in consequence of the upward pressure of the underground marsh-gas. Neither of these explanations appears to be exempt from arbitrariness; for the present, acknowledging the question as an unsettled one, I will choose the case which is the most favourable for the Netherlands, viz. that of stability of the ground during the two centuries preceding the year 1860.

Summarizing the geological history teaches, that at least from the late-tertiary time the ground of the Netherlands has sunk, that this sinking, however, has not been continually perfectly gradual, but that it has now and then been interrupted by shorter or longer periods of rest or movement in an opposite direction. LORIÉ has demonstrated one period of opposed movement with certainty in the lagoon stage while we may conclude to others with great probability on similar grounds. Also it has been concluded from the stability of the level of the A.P. at Amsterdam that there has probably been a period of rest during the two centuries preceding the year 1860.

Before discussing the practical signification of this result it is necessary to inquire into the real nature of this subsidence.

The movement of a block of land with regard to the surface of the sea may be caused either by actual movements of the land or by variations of the height of the sea-level. To evade the difficulty of giving a decision in every case, a neutral nomenclature has been adopted, and we speak of a positive and a negative shifting of the coast-line.

In our case, however, the decision is not difficult.

The sinking of the soil of the Netherlands has been an exclusively local phenomenon as appears from the above tables I and II. At short

¹⁾ H. G. VAN DE SANDE BAKHUYZEN. "The height of the mean sea-level in the Y before Amsterdam from 1700—1860". These Proc. X p. 703.

distances the differences are very great; since the beginning of the Diestien the ground has e.g. sunk 20 meters at Grave, 92 meters at Goes, 450 meters at Amsterdam. The countries adjoining on the south and the west, Belgium and England, have not taken part in this movement.

So we find a real sinking of the land in the Netherlands, which movement has been confined to a comparatively small region.

What then can be the practical significance of the supposed stability during the 200 years preceding the year 1860 in connection with the gradual considerable sinking in the latest geological periods?

Not one single movement of the crust of the earth takes place uninterruptedly in the same direction without intervals of rest or of movement in the opposite direction. Nor does it here. At least since pliocene times the ground has continually sunk, but no doubt this movement has been interrupted by periods of rest or slight opposed movement, which can be really proved, as was stated above.

But these are only slight sinuosities in a continuous line, whose general direction is downward. We cannot assume on geological grounds, that a movement, which has proceeded regularly in the same direction during a long series of centuries, however irregular it may be if only a short portion of time is considered, should have ceased just now, because we have not succeeded in demonstrating it by measurement during the last two centuries. No, we must much sooner assume that the two centuries before 1860 present one of the numerous small inflections in the line of movement, which on the whole runs downward. The rest will certainly be of short duration, probably it has already been replaced by a descending movement, and geologically speaking we may say in spite of the rest during the 200 years preceding the year 1860 observed at Amsterdam: the ground of the Netherlands has constantly sunk at least since pliocene times, and is still in the same long period of subsidence.

The Hague, June 11th 1909.

G. A. F. MOLENGRAAFF.

Note on the sinking of the level of the ground of the Netherlands. By J. M. VAN BEMMELÉN.

The depths at which the old layers of peat in the quaternary period of the strata of the earth are found, render the assumption of a lowering of our soil necessary, which is not unimportant. Dr. LORIÉ has derived from several borings that the sinking in that time has at least amounted to 18 meters, for at this depth the layer of peat has been found, though originally it has lain at the surface, and the