

TECTONIC MOVEMENTS AS RESULTING FROM THE COMPARISON OF TWO PRECISION LEVELLINGS

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The results of the precision levelling of the Netherlands executed between 1926—1940 present appreciable differences with those of the precision levelling dating from 1875—1887. These differences can be expressed as due to rising or sinking in regard to the bench mark at Amsterdam, which in this case is assumed to be a stable point, though probably it is not really so. Assuming further that both levellings do not contain errors, the risings and sinkings, when represented on a map (fig. 1), give an idea of the rises and sinkings (negative and positive movements) which the surface has undergone in the intervening 50 or 60 years.

If these figures are to be used to determine the actual tectonic movements of the subsoil, it is necessary to eliminate all movements due to compaction of superficial layers, especially of peat and clay, and to local influences such as underground mining and building of dikes, canals etc. Therefore a number of figures will have to be discarded. This cannot be done according to exact methods; personal opinions as to the reliability of certain figures must play a role. The result would even be worthless, if we did not mention the rules we followed in this evaluation of figures.

It is clear that compaction or local sinking of bench marks can only diminish the figures indicating a rising, and on the other hand can only add to the figures indicating a sinking. We further assume that no swelling of the superficial layers took place (e.g. by frost action), and that tectonic movements generally present variations over a large area and not local ones varying from one point to the next. Therefore in any group of figures in a rising area we have had to eliminate the smallest values and in a group in a sinking area the largest values. Examples of the first case are the Maastricht region, where the figures 49, 44, 44, 42, 16 and 45 mm occur, the figure 16 having to be rejected; or a region near Leerdam, where among the figures 4, 31, 19 and 14

the figure of 4 has certainly to be eliminated, perhaps even the figures 19 and 14 as well. An example from a sinking area is the Enkhuizen region, where among the figures —1, —3, —5, —51, —104, —174 mm, the latter three must be due to compaction of the superficial layers. Where apparent risings and sinkings alternate, the figures indicating a sinking should probably be eliminated.

In doing so the nature of the soil should also be considered, and consequently in the peat and clay regions many more figures have been discarded than in the sandy regions. Better results should have been obtained if, for each bench mark, a careful study could be made of local conditions and compaction, which, unfortunately, was impossible in most cases.

With the aid of the remaining figures we have tried to draw lines of equal rise or sinking (fig. 2). These too are subject to personal views, as the lines of levelling are so wide apart that they allow of many different constructions of the lines of equal rise and sinking between them. Therefore, one should be very careful in drawing geological conclusions from these lines².

One salient point of the map thus obtained is the general tilt of the country as a whole. The southern part has risen most, the northernmost part presents the deepest sinking. The deviations from the zero point are in both cases about 4 cm, giving a tilt of about 8 cm over a distance of 300 km in about 50 or 60 years.

A second point is that the lines in the SE present a general NNW—SSE direction, parallel to the great faults. The easternmost rise coincides roughly with the wellknown Peel Horst. A zone of lesser rise, parallel to it, and coinciding with the important Central Graben, passing through Roermond, is not established without doubt, owing to the absence of trans-

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² For the geological interpretation and the drawing of the lines we have consulted Dr. A. J. Pannekoek (Geological Survey, Haarlem), whom we wish to thank for his collaboration.

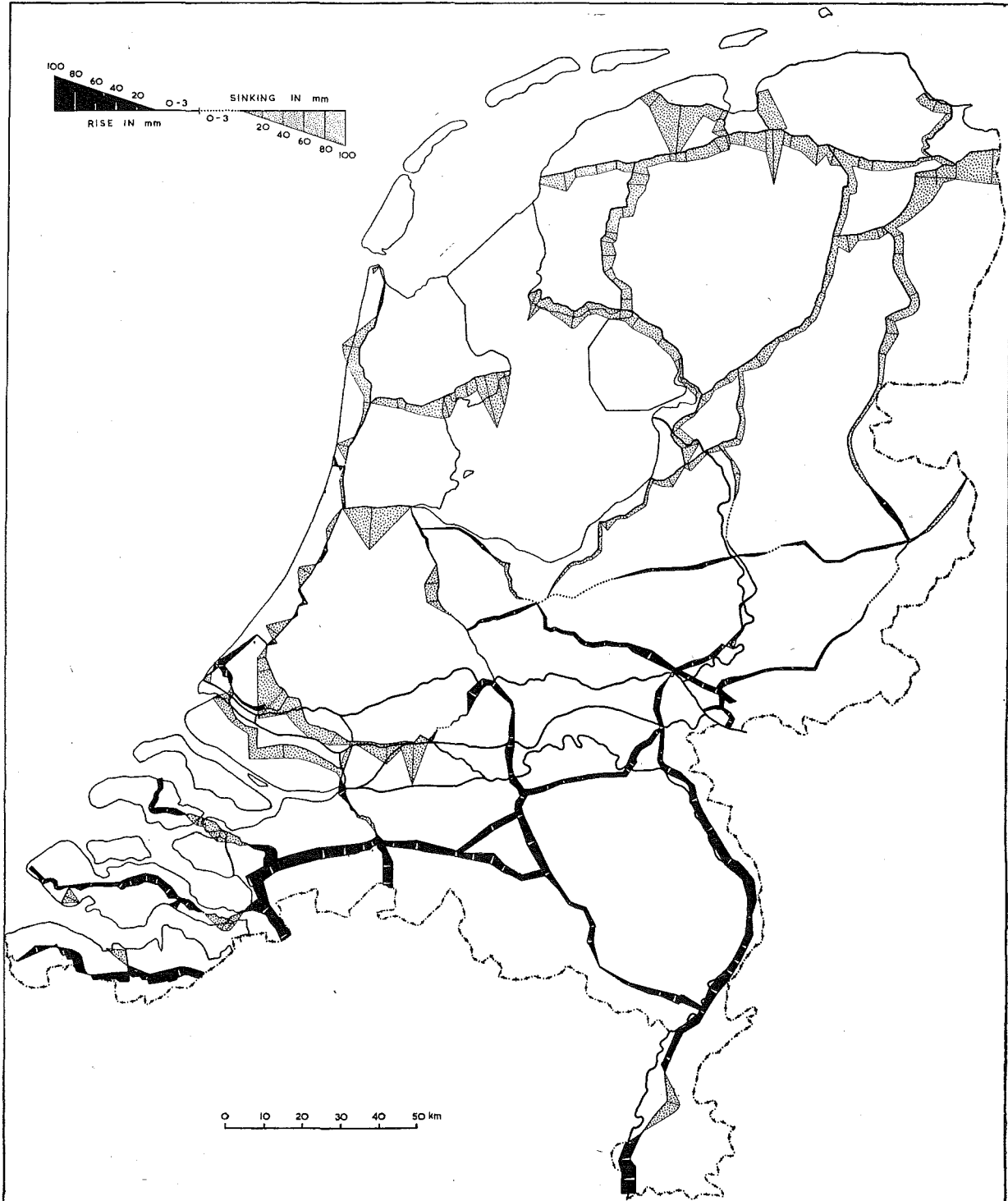


Fig. 1 — Differences between the levellings of 1875—1887 and 1926—1940 expressed in rise or sinking in regard to Amsterdam. The differences are plotted graphically along the lines of levelling. (Reproduced by permission of Public Works Department).

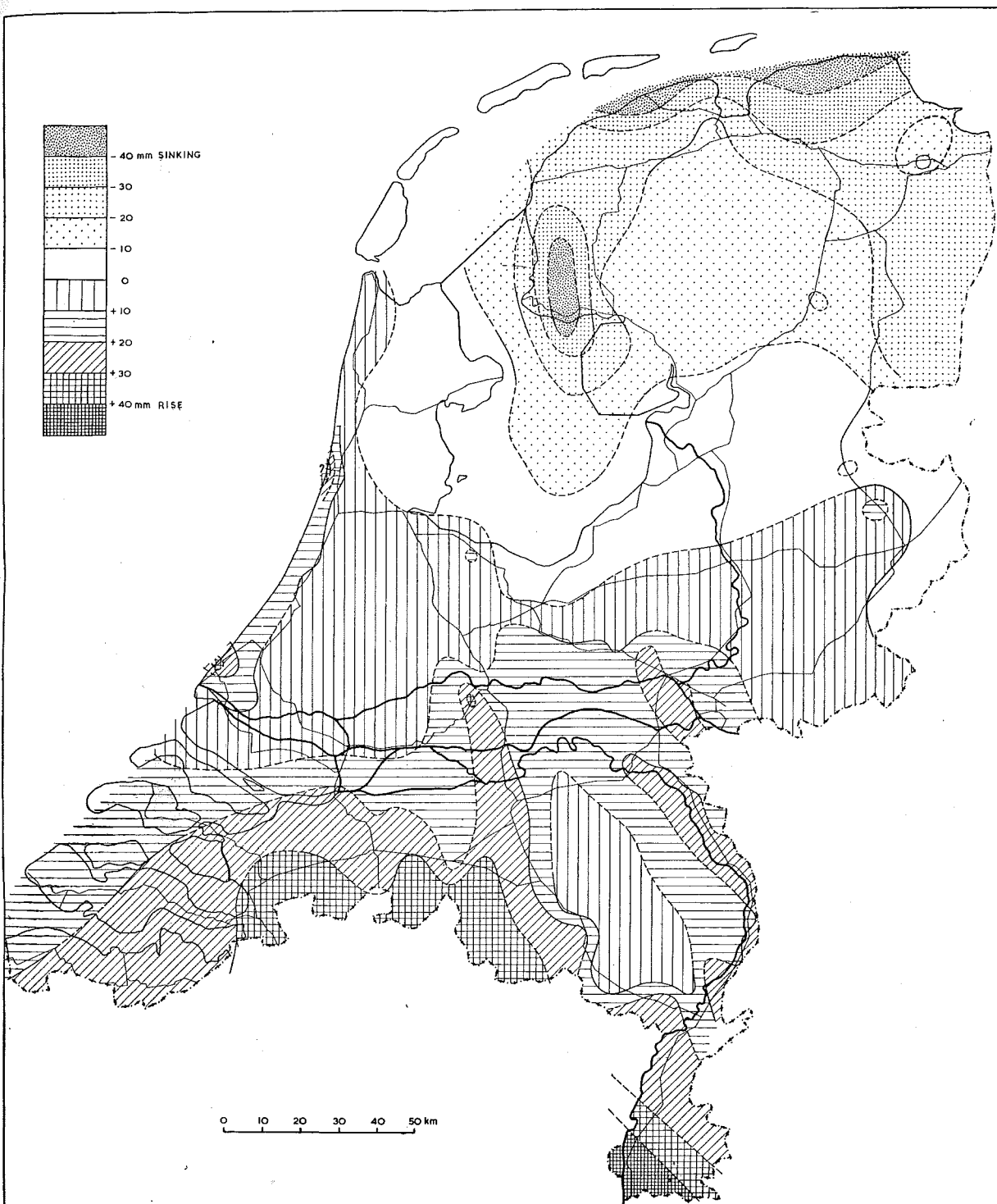


Fig. 2 — Lines of equal relative rise or sinking in regard to Amsterdam, based on the levellings of 1875—1887 and 1926—1940.

verse lines of levelling. The strong rise west of it, between Eindhoven and Bergen op Zoom, seems to reflect a region of uplift, continuing into Belgium.

More to the north, however, between 's Hertogenbosch and Utrecht, a narrow rise occupies the site of what might be the northern continuation of the Central Graben, which is contrary to what might be expected. The rise south of The Hague may have some relation to a tectonic high dating from the Tertiary, though it does not quite coincide with it.

A tectonic origin might also be suspected in the slightly rising area in the east near Almelo, which more or less coincides with the tectonically high Trias mass in the subsoil.

Otherwise, in the middle of the country a relation is sometimes found between surface geology and the trend of the movement, sandy parts showing a gentle relative rise and peaty or clayey regions relatively sinking, which might be attributed to compaction over a larger area. But there are also exceptions and these seem to me more important for establishing the real movements.

In the northern, relatively sinking half of the country differential tectonic influence is not very clear. Several regions of stronger sinking, as e.g. those north of Am-

sterdam, and especially in the western half of Friesland, are for a greater part peat and clay areas, and the regional sinking may be partly due to compaction of a larger area as a whole, which cannot be eliminated from the map by rejecting certain exaggerated figures. On the other hand also the sand and boulder clay areas have joined in the general sinking, as e.g. those of Drente and most strongly those of SW Friesland, indicating that the movement is a real one.

For some points in the subsiding NE with a slighter sinking than the surroundings, one may suspect a local relative rise of salt domes or anticlines, if they are not due to errors in the measurements.

When trying to sum up, we are aware that our conclusions are encumbered with many uncertainties, such as the strong influence of local and even regional surface conditions (compaction), the uncertainty as to the reliability of the figures, the personal element in discarding figures, the great distance between the lines of levelling and the personal views in drawing lines of equal rise or sinking. Still we feel that certain tectonic trends, especially a general tilt, and maybe some influence of the in the present-day movements of the country. structure of the subsoil, obviously play a part

DISCUSSION

Prof. Kuenen (Groningen) observes with regard to the map that the dune area stands out as a relative rise against the subsiding peat area behind it, which points to compaction of the latter. Would not Zeeland with its shallow depth of the Tertiary be a good place for the 0-line?

Mr. Edelman replies that the peat area as a whole may indeed have been subject to compaction between the two levellings, but he does not think it justifiable to omit this whole region from the map. He has no opinion as to the question what should be considered as the true 0-line.

Dr. Pannekoek (Geol. Survey) adds that the place of the 0-line does not depend on the local underground but on the movement of this part of Europe as a whole; it can only be decided after comparing levellings over a whole continent.

As to compaction, even if all the peat areas were left out, and only the sand areas were considered, the main trend would be the same: a tilting along a NNW-SSE axis — a movement different from that inferred from the base of the Pleistocene.

Prof. Vening Meinesz (Utrecht) suggests that for future levellings the zero-point should be taken in a stable sandy area instead of at Amsterdam. He inquires if the strongly sinking area in SW-Friesland is as narrow as it is indicated on the map.

Mr. Van der Weele (Geodetic Service, Public Works Dept.): For the second primary levelling

some bench marks were selected, after consulting the Geological Survey, in areas with a minimum of compaction.

The zero-point at Amsterdam has been connected with the German levellings in 1875 and again in 1940, without appreciable differences having been observed.

Dr. Pannekoek (Geol. Survey) in his reply to Prof. Vening Meinesz states that the negative area in SW-Friesland is only based on one bench mark on a stable underground, the surrounding ones being subject to compaction.

Prof. Faber (Delft) would welcome the publication of all the figures on which Mr. Edelman's map is based in order to make it clear which figures have been discarded. This is particularly important in view of the strong subsidence in the N of Friesland and Groningen.

Dr. Pannekoek replies that he has discussed these points with Mr. Edelman. Subsidence in the extreme N is not very certain, being based on one bench mark which, notwithstanding its rather sandy subsoil, may have undergone some compaction; the surrounding subsidence is mere extrapolation. By comparing the real values on map 1 with the corresponding points on map 2 the reader could find the discarded values. In the elimination of figures the geological setting has been considered.

Prof. Thijsse (Delft): If we had exact knowledge of the changes of sealevel in regard to Amsterdam

level as given by tidal gauges, of the present differential movements as given by precise levellings, and of the absolute rising of sealevel, we should have all necessary data, needed from a practical point of view. Unfortunately none of these is absolutely reliable.

Three successive levellings have been executed in the Netherlands. Krayenhoff's at the beginning of the 19th century is not very accurate. Nevertheless it indicates a tilting in the same sense as the one derived from the later levellings. The 1875-'87 levelling by Cohen Stuart is very reliable, and quite comparable with the third under Prof. Schermerhorn's direction. The possible error in the difference between the two levellings (for which $2\frac{1}{2} \times$ the standard error is allowed) may be about $2\frac{1}{2}$ cm over 200 km, or 5 cm over 400 km. The general tilting shows greater differences, so the levellings must be considered as an absolute proof that tilting does occur. It also indicates the order of magnitude of the tilting; between 5 and 10 cm in half a century between the extreme North and the South of the country. But no more may be deduced from the levellings. The tectonic movements are smaller than the uncertainty in the observations. The only safe conclusion is that the well known tectonic movements do not contradict the results of the levellings.

Prof. Bakker (Amsterdam) observes on fig. 1 that some bench marks with a remarkably high subsidence are situated on deep holocene gullies with strong compaction and sometimes quicksands (near Franeker, Zijpe, Castricum). Some points with less subsidence in Friesland are situated in areas (subterranean plateaus) with firm Pleistocene near the surface.

Prof. Geuze (Delft) agrees with Prof. Bakker, that such bench marks may show considerable subsidence. He quotes an example, which has come to his knowledge by an information from Mr. Smits, Scientific Officer of "De Wieringermeer", and which in his opinion represents an extreme case of strong local compaction of a mud-filled gully in the Y-polders. In the course of 75 years a settlement of 250 cm has been measured on this particular spot. This case is being studied now from the soil mechanics point of view, but as the long-period laboratory tests are not sufficiently advanced, no definite information about the outcome is yet available.

Prof. Baarda (Delft) agrees with this last remark and also warns against conclusions before the soil properties at each bench mark have been studied.

Mr. Edelman replies that the foregoing remarks fully confirm his own warnings concerning possible errors in the map. He does not agree with Prof. Bakker on quicksand having a strong compaction, except if it can escape sideways.

Prof. Bakker thinks that the excavations for the new lock and canal near Harlingen may have influenced the compaction of the quicksand.

Prof. Mac Gillavry (Amsterdam) observes that the tilting as it appears on Mr. Edelman's map is of the same order of magnitude as the movements of deeper levels as shown on Dr. Pannekoek's maps.

Prof. Vening Meinesz (Utrecht) remarks that two consecutive levellings in Belgium also revealed a tilt along an E-W axis. To a question of Prof. Faber he replies that the two countries probably form part of a single tilting block. This tilting is not a consequence of subsidence around Fennoscandia, but may be influenced by the general rise of the region N of the Alps.

Prof. Grond (Delft) supplies additional information on the differential movements in Limburg. From recent levellings undoubted evidence has been gained that the faults bordering the Central Graben have moved during the last few decades, and it is almost certain that the Peel horst has risen 2 cm in relation to the Graben during the last 25 years.

The tilt inferred by Mr. Edelman closely agrees with a similar tilt in the Rhine—Westfalen region (according to Weissner), the Burscheid—Wipperfurth line having risen 30 mm and the Wesel—Haltern line having subsided 20 mm in relation to an assumed axis through Duisburg—Dortmund up to 1929.

Dr. W. A. Visser (Nederlandse Aardolie Maatschappij) suggests that the casingheads of abandoned N.A.M. borings be used as bench marks for future levellings. There are some 160 of such borings distributed all over the country; in several of them a casing cemented at considerable depth has been left behind. N.A.M. will certainly collaborate in this matter, which statement is gratefully appreciated by the audience.