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published in
Environmental humanities: a rethinking of landscape archaeology?
2021

document version
Peer reviewed version

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CLUES
VOLUME 6
INTERDISCIPLINARY STUDIES IN CULTURE, HISTORY AND HERITAGE

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Published by Sidestone Press, Leiden
www.sidestone.com

Imprint: Sidestone Press Academics

Lay-out & cover design: Sidestone Press
Photograph cover: painting by George Hendrik Breitner (A Heath Landscape, Presumably in Drenthe, The Netherlands; c. 1880 - c. 1923; coll. Rijksmuseum Amsterdam SK-A-3533)

ISBN 978-94-6427-003-7 (softcover)
ISBN 978-94-6427-004-4 (hardcover)
ISBN 978-94-6427-005-1 (PDF e-book)

Contents

Geological and historical findings reveal differential anthropogenic substrate control in unique streets of Diemen, The Netherlands

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Introduction

Within the framework of a Ph.D. study in the field of 'Heritage Studies', we are currently carrying out research into the mutual influence of man and his natural habitat, in particular in the marshy west of the Netherlands. This research aims to contribute to the current discussion on the beginning, existence and definition of the youngest geological time scale: the 'Anthropocene' [1,2]. Currently the proposal to the International Stratigraphic Union is that the Anthropocene should have a lower temporal boundary dated to 1950 AD, coinciding with a suite of sharply increasing amount of anthropogenic materials, *e.g.* concrete, plastics, and most notably radionuclides[3]. The date of 1950 AD also coincides with what is known as the Great Acceleration [4,5]. Central to this paper are several basic questions, such as: can we clearly differentiate between natural and anthropogenic soil layers? What are the anthropogenic layers composed of? And to what extent can these human-induced layers possibly be differentiated in the soil?

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1 C. Waters et al., "The Anthropocene is distinct from the Holocene". Science 351 (2016): 6269, at 137.
2 S.J. Kluiving, S.J. & A. Hamel. Human niche construction as a perspective on the Anthropocene. RCC Perspectives: Transformations in Environment and Society. Münich, Germany, 2016.
3 C. Waters et al., ibid.
4 W. Steffen et al., "The Anthropocene". Ambio 36 (2007): 614-621.
5 W. Steffen et al., "The trajectory of the Anthropocene". The Anthropocene Review 2-1 (2015): 81-98.

The present-day Dutch landscape has largely been formed in the last 150,000 years: the last two ice ages from the Pleistocene and Holocene, the current geological period. More than two-thirds of the Dutch surface is formed by Holocene deposits. The drowning history during the Holocene of various areas, such as the delta of the rivers Rhine and Maas, and such as the Wadden Sea and surroundings in the 'north', has been of great importance for the history of habitation in the Netherlands. Itinerant hunters and gatherers lived by hunting wild boar, red deer, otters, beaver, primeval cattle and moose.

Large peat areas were created behind the contiguous coastline of beach walls and low dunes: peat bogs on the west side, bog areas on the east side of the 'Netherlands'. The peat bogs fed on rainwater and therefore became constantly thicker. The hunter-gatherers made way for farming communities, which were being driven further and further to the east by the advancing peat. Initially, houses were built at ground level; but to protect themselves against flooding, people started to increase the living space. People created artificial residential mounds (terps).

The settlement has had a major influence on the current Dutch landscape with its dikes and polders, especially in the last 1000 years. Along the coast and rivers, dikes of natural material were constructed. In provinces such as Noord-Holland – wherein the village of Diemen is located -, large lakes were created by peat excavations – for peat extraction – and the first polders were constructed. In the latest centuries man built houses and all kinds of roads, creating villages and towns.

The human influence on the earth, on land for example, has even become so great that our (possible) successors can view our presence in the geological layers of the earth in thousands of years: in the (remnants of) sand extractions, canals, coal mines, apartment buildings, dams and shifted rivers. But, also through the natural and sustainable materials (such as glass and concrete, used in construction), and unnatural products, some of which are non-degradable (such as plastics, waste oils, waste products), with which we make the geological layers a serious and 'sustainable' threaten to pollute. This epoch with new layers of earth created by human hand is called the Anthropocene.

Research into anthropogenic earth layers is interesting because it can give us insight into modern time images and customs. For example, what materials and products people use in a certain region in a certain period, and how their choices change over time. Smith and Zeder (2013) articulate the goal of anthropogenic research as follows: 'A closer consideration of regional-scale documentation of the long and complex history of human interaction with the environment that stretches back to the origin of our species up to the present day' (Smith and Zeder 2013).

Much research in this subject-area hasn't been done yet, therefore previously conducted insightful studies are scarce. Kluiving, Van Gelder et al. (2017) executed a geo-archaeological pilot-study aiming to unveil the 'Biography of a house'. They studied the history of this 1930's house, among others by boring in the natural and cultural substrates the house was built on. And researched underneath the house, searching for traces of the first habitants of the place. The researchers were successful and able to retrieve old house-hold materials, products and clothes of the oldest inhabitants. These data in combination with historical and anthropological data collected are useful to unveil the 'Biography of the house'. Also, the aims of

researches in the so-called *Garbage Archaeology* have much in common with the type of anthropogenic research in question.

If there is one type of soil in which the human influence on the natural environment can be observed, then it is the swampy soil in the western Netherlands, of which the peat was partly removed centuries ago. When houses are built or roads constructed on this soft soil, then care must be taken that they will not subside. The solution is not as simple as it seems. The soft, metres-thick remaining peat soil – which lies several metres below the surface, due to raising with all sorts of organic and inorganic remains by humans – settles under the weight of heavy constructions. This is why already from the 12th century AD, farms in this region were built on terps, which needed to be raised again every ten[6] to twenty years[7] because of the settling peat. Farm terps are an example of anthropogenic activity and a rich source of information on early humans and their impact on the surface of the earth[8,9]. For structures (such as stone houses and buildings) in Amsterdam, the capital of the Netherlands, which is located on the same swampy soil, wooden piles have been sunk into the ground since the eighteenth century[10]; the piles reach into the first (depth: 10-12 m. below National Ordnance Datum – N.O.D.) or second sand layer (depth: 25 m. below N.O.D.). The two deep layers of sand form a hard subsoil and were laid down during the last Ice Age, the Weichselian. The wooden piles under the centuries-old buildings are also a good example of an early human impact on nature. Sinking piles during construction – nowadays using concrete piles – as a matter of fact have always been and still is standard procedure in the western part of The Netherlands.

Streets and roads in the same region along the coast of the Netherlands also keep subsiding when nothing fundamental is done to prevent this. They constantly need to be maintained and raised, and it has been this way already for centuries.

The research is located in what was originally a farming village, Diemen, to the east of Amsterdam, located on the same soft soil as the capital. In Figure 1, the town and the village are central in the map, and the municipality of Diemen (in the past called 'Diemer bridge' (Diemerbrug), after the local bridge) is circled in red. What is clearly visible in this artfully created map is that town and village were located on a peat ('lilac-coloured') subsurface in 800 AD.

What the deeper layers of the eastern part of Amsterdam and the current village Diemen are constituted of, can be deduced from Figures 2a to 2c.

'De Nieuwe Buurt' is located directly on soft peat soil – the Formation Nieuwkoop Hollandveen (NIHO) (see Table 1). In contrast the Watergraafsmeer in Amsterdam-East is built directly on clay (Formation Naaldwijk/Laagpakket Wormer – NAWO). This is a consequence of the fact that Diemen is originally a peat polder and the Watergraafsmeer a marine clay polder from where the peat

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6 W. Krook, "Opgegraven schoeisel uit de 12e eeuw". Tijdschrift Historische Kring Diemen 26-2 (2016): 46-48, at 46.

7 Blok (Ed.), Diemen in het land van Amstel.

8 Overbeke, van. Archeologische opgraving 'Boerderij Landzigt'.

9 J.A.G. Veerkamp, Terp-2; archeologische ontginningsterp Oud-Diemen. (Research master thesis Archeologie, Vrije Universiteit, Amsterdam 2011).

10 K. Koster, A geo-archaeological and historical geographical approach to examine 18th and 19th century pile driving in Amsterdam. (Research master thesis Geologie, Vrije Universiteit, Amsterdam 2011).

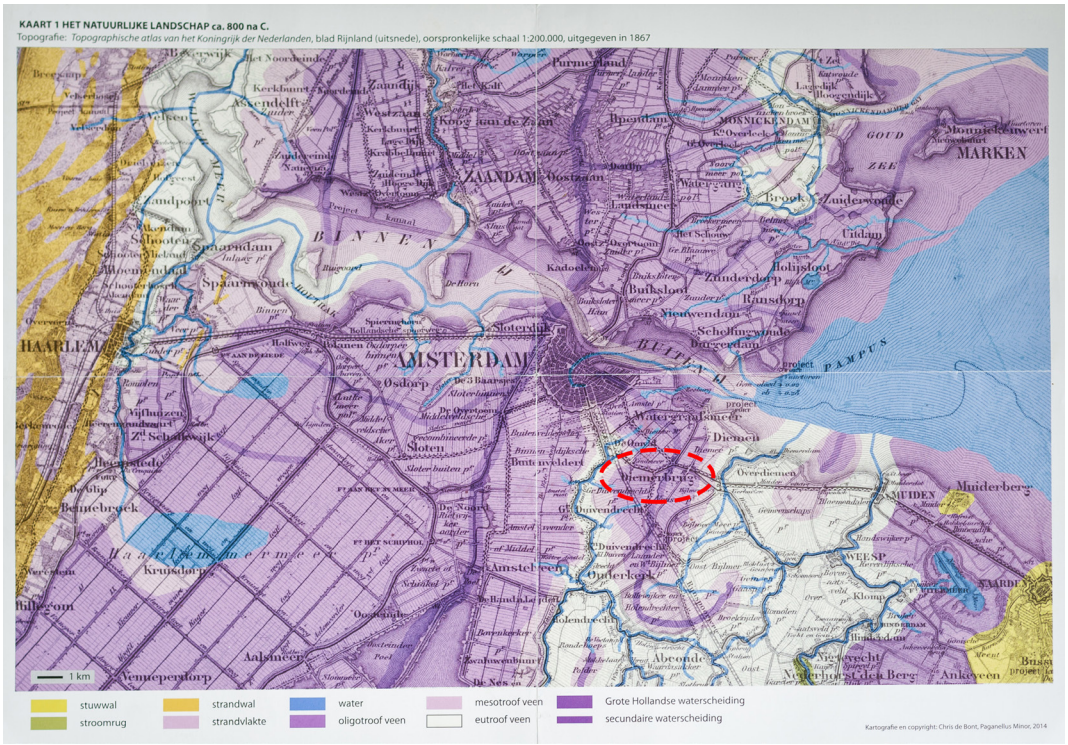

Figure 1. Projection of the ancient natural landscape in Amsterdam and its surroundings in ca AD 800 on the Topographische atlas van het Koningrijk der Nederlanden, page Rijnland (cutout), published in 1867. Cartography and Copyright: Chris de Bont, Pagamellus Minor, 2014. The capital of the Netherlands is located in the centre of the map, with the drained polder 'Watergraafsmeer' east of the town. Slightly further lies the village of Diemerbrug, which today is called Diemen. The capital and Diemerbrug lie on a soft soil of mesotrophic peat and clay.

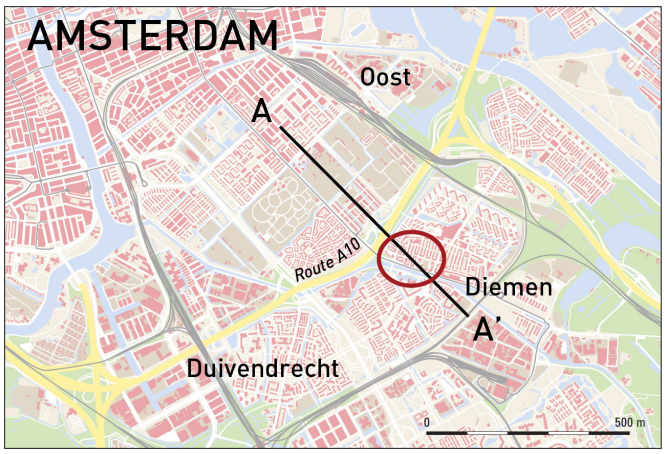

Figure 2a. Detail of the city map of Amsterdam-East and the adjacent municipality of Diemen. The line A-A' – from Amsterdam to Diemen – crosses the ring road around Amsterdam (Route A10 – in yellow). Just to the east of this ring road lies the municipality of Diemen; in the west of Diemen (Diemen centrum-west) is a neighbourhood, called 'De Nieuwe Buurt', wedged between the A10 and the local bridge over the barge canal. See Table I, Figures 2b and 2c.

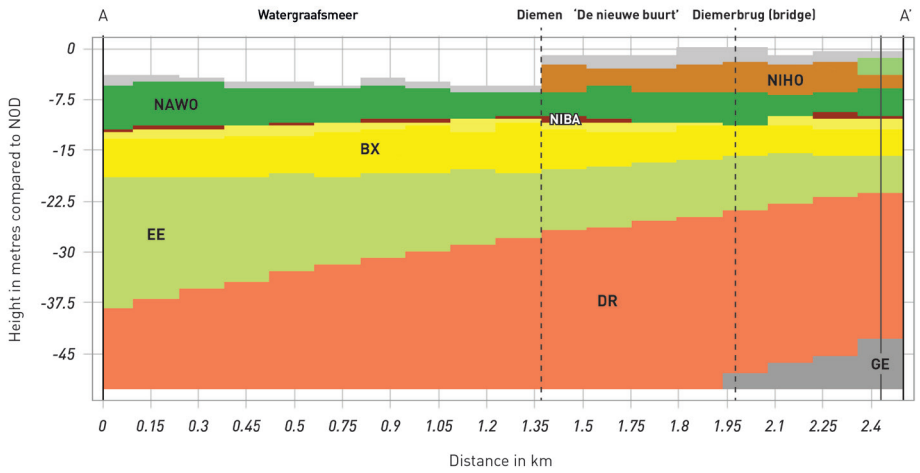

Figure 2b. Vertical cross-sections by means of GeoTOP v1.3 along the line A-A' (Amsterdam-East to Diemen). Just over halfway along the line, Diemen starts – in particular 'De Nieuwe Buurt'; just over three-quarters along the line A-A', Diemerbrug (bridge).
Legenda of colours: grey = anthropogenic deposits; orange = Nieuwkoop Formation/ Hollandveen (peat); darkgreen = Naaldwijk Formation/Hollandveen (weak, half fluid clay); brown = Nieuwkoop Formation/Basisveen Bed (basic peat); yellow = Boxtel Formation (sand); light green = Eem Formation; pink = Drente Formation; turquoise = Ice-pushed deposits. For more information on the stratigraphic units see Table 1.

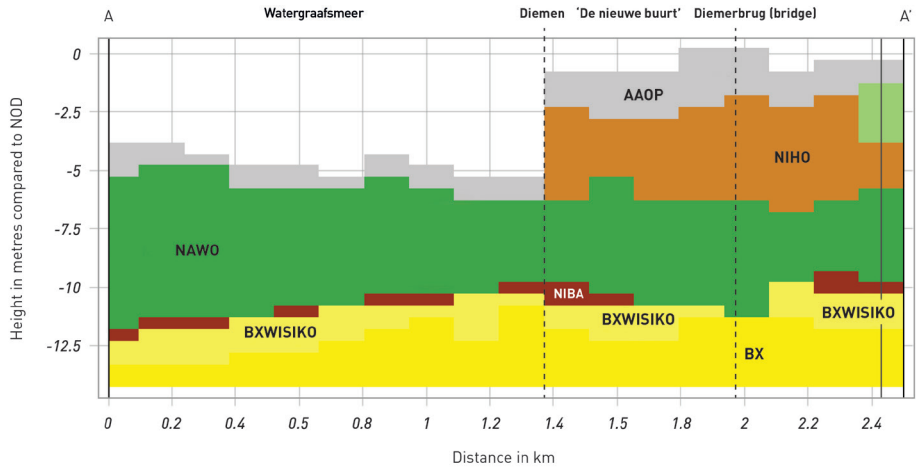

Figure 2c. This Figure is a detailed section of the vertical cross-sections of Figure 2b, to a maximum of 14 metres below N.O.D. The unique, metres-thick peat layer under a substantial anthropogenic soil layer in Diemen is clearly visible. A potential danger of that thick soil layer is that the peat settles at a higher rate when the weight on top is this great, or becomes even greater. Incidentally, it can be seen in this Figure how many metres higher Diemen (still) lies compared to the Watergraafsmeer, as a result of this peat layer.
Legenda of colours: grey = anthropogenic deposits; orange = Nieuwkoop Formation/ Hollandveen (peat); darkgreen = Naaldwijk Formation/Hollandveen (weak, half fluid clay); brown = Nieuwkoop Formation/Basisveen Bed (basic peat); yellow = Boxtel Formation (sand). For more information on the stratigraphic units see Table 1.

UNIT GEOTOP	GEOLOGICAL UNIT	DOMINANT LITHOLOGY	DEPOSITIONAL ENVIRONMENT	AGE
AAOP	Anthropogenic deposits	Sand, medium fine to very coarse; clay, sandy, humic; domestic waste; construction material	Anthropogenic (made ground)	Late Holocene *< 1000 years*
NIHO	Nieuwkoop Formation, Hollandveen Member	Peat, sometimes clayey	Organogenic	Middle to Late Holocene *1000-5000 years*
NAWO	Naaldwijk Formation, Wormer Member	Sand, very fine to medium coarse; shell-bearing; clay, sandy; sometimes humic	Marine (tidal channel and tidal flat deposits)	Middle Holocene *5000-8000 years*
NIBA	Nieuwkoop Formation Basisveen Bed	Peat	Organogenic	Early to Middle Holocene *8000 years*
BXWI	Boxtel Formation Wierden Member	Sand, medium fine	Aeolian (coversand deposits)	Late Pleistocene (Weichselian)
BX	Boxtel Formation	Sand, very fine to medium coarse; loam; clay, somtimes sandy, humic; peat	Aeolian, fluvial, lacustrine and organogenic	Late Pleistocene (Weichselian) *10.000-110.000 yrs.*
EE	Eem Formation	Sand, very fine to medium coarse, shell-bearing; clay, sometimes sandy or shell-bearing; diatomite	Marine	Late Pleistocene (Eemian) *110.00-120.000 yrs.*
DR	Drente Formation	Sand, very fine to very coarse, sometimes clayey; clay; sometimes sandy or varved	Glacial (meltwater deposits)	Middle Pleistocene (Saalian) *120.000-150.000 yrs.*
GE	Ice-pushed deposits	Sand, medium fine to very coarse, sometimes gravelly; clay, sometimes sandy	Glacial (ice-pushed deposits of older formations)	Middle Pleistocene (Saalian) *150.000 years*

Table 1. Lithostratigraphic units comprising the subsurface of Amsterdam and how these units are represented in the GeoTOP models (extracted from: J. Schokker, "3D subsurface modelling reveals the shallow geology of Amsterdam". Netherlands Journal of Geosciences 94 (2015): 399-417, at p. 401).

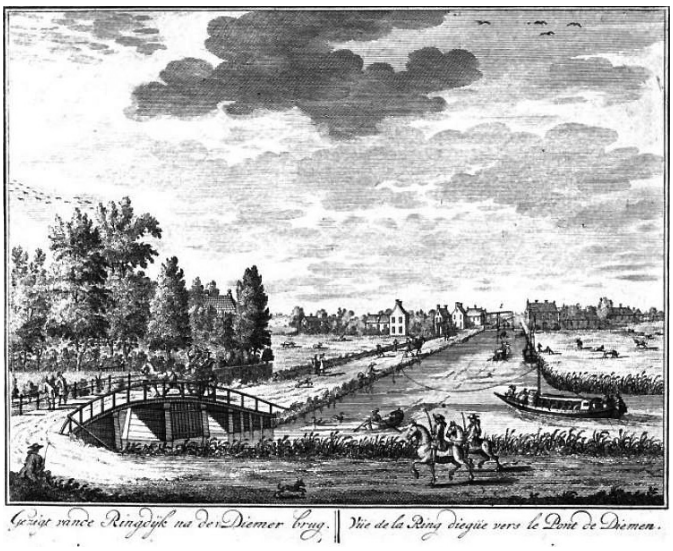

Figure 3. A view of the bridge of Diemen ('Gezigt van de Ringdijk na den Diemer brug'). The engraving by Daniël Stopendaal (1672-1726) from 1725 shows the Diemer bridge over the barge canal (previously named: 'Keulsche vaart'; nowadays: 'Weespertrekvaart'). Nearly three hundred years before the Amsterdam ring road (Route A10 – see Figure 2a) was constructed, horse riders rode on sand and tow paths in the same place (Overbeke, van. Archeologische opgraving 'Boerderij Landzigt', 11). Two hundred years after Stopendaal produced his engraving, 'De Nieuwe Buurt' was constructed to the left (to the north) of the barge canal – from the grove on the left in the picture to the Diemer bridge. (Collection Stadsarchief Amsterdam: drawings and prints).

has been reclaimed and removed since the last 400 years. Apart from that, the composition of the soil layers (see also Table 1) between Amsterdam-East and Diemerbrug is nearly identical to 45 metres below N.O.D.; the soil layers do, however, differ in their heights. See also Figure 2c.

The village of Diemerbrug was located on a barge canal constructed in the seventeenth century, between 1638 and 1640. On both sides of that canal were towpaths, so that the ships could be pulled along the canal. This can be seen on an eighteenth-century engraving of Diemerbrug (Figure 3).

The development of roads in the Netherlands has developed ever since. This was also the case for Diemerbrug, but road construction on a subsiding soil remained a major problem until the 1930s, even though it was in the twentieth century, after the industrial revolution, when the village of Diemerbrug slowly grew into the municipality of Diemen that we know today.

At that time, brick roads were built on manure, elder branches, fly ash and/or sand, to raise roads and prevent subsidence. For a short time, that was sufficient.

But the weight of such an extra body of soil, of the brick road and of the (at the time still limited) traffic soon led to such a degree of settling of the soft soil – on average about a centimetre per year[11] – that the council had to intervene after one or two years[12] and raise the ground again. Unevenness and bumpiness made the roads hard to use and thus unsafe.

The Archive of the municipality of Diemen contains more detailed geological information. The council claims: '… beneath the peat lies a layer of clay, but it is a very soft and wet clay with (probably) little more supporting power than the peat layer'[13]. And the Explanatory Memorandum of May 1935 states[14] that the roads in the western part of Diemen, adjacent to the Watergraafsmeer, were raised on average about 50 centimetres with black soil and again on average a metre and a half with sand. On top, bricks were laid to cover the road[15].

However, at the time the council was unsatisfied about the fact that the roads frequently subsided and that unsafe situations arose as a result of the constant settling of the soil[16]. Moreover, it felt that the financial costs for road maintenance became too high for the municipal budget. Both factors account for why the council tried out new foundation techniques[17,18] in this period, especially techniques supposed to be more sustainable and cheaper, which would thus lead to structural solutions.

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11 Cf. Van Asselen, Peat compaction in deltas

12 Diemer Archives (1931-1987), INV. 85 Correspondence Council with Financial Department Haarlem, 6 april 1935.

13 Diemer Archives (1931-1987), INV. 85 Correspondence Council 6 oktober 1933.

14 Diemer Archives (1931-1987), INV. 85 Explanatory Memorandum B&W, 22 mei 1935.

15 Diemer Archives. Description on the backside of an undated and non-archived picture of the road. One of a series of pictures donated by the widow of the municipal building designer and clerk of the public works at that time, Jan de Boer.

16 Diemer Archives (1931-1987), INV. 85 Correspondence Council with Financial Department Haarlem, 6 april 1935.

17 It is highly probable that the municipality of Diemen was able to do groundcorings and measurements in 'De Nieuwe Buurt' with the aid of two independent Dutch institutes, working in the field: the Amsterdam 'Bureau Grondmechanica van Publieke Werken' and the advanced Delft 'Laboratorium voor Grondmechanica'.

18 Cf. Kuiper, Grondonderzoekingen en Betonberekeningen.

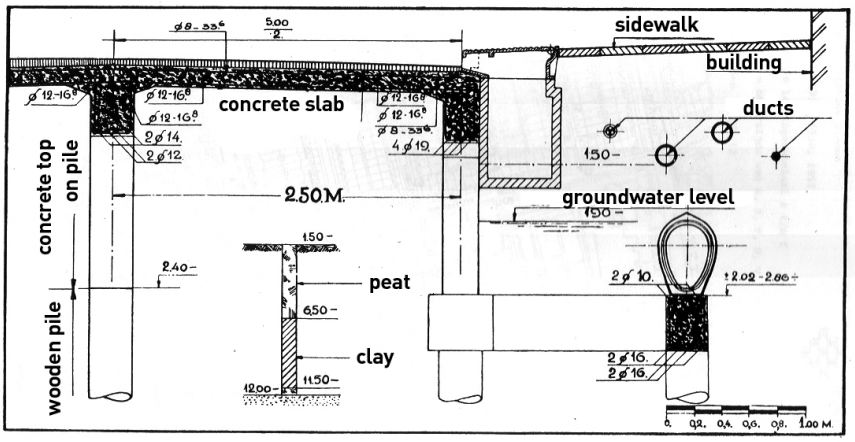

Figure 4. The roads were built on sunken piles according to Huizinga & Dibbits (T.K. Huizinga & H.A.M.C. Dibbits, De ondergrond der wegen. (Rapport, Association Internationale Permanente des Congrès de la Route, 's Gravenhage 1938). This is an original illustration from the report 'De ondergrond der wegen' (1938) by prof.dr. T.K. Huizinga (director laboratory for ground mechanics, Delft) and ir. H.A.M.C. Dibbits (engineer at Rijkswaterstaat). A whole page (pp. 30-31) of the report, which contained a series of lectures held at the VIIIth World Road Congress (1938) in The Hague (Netherlands), was devoted to the underground construction of 'De Nieuwe Buurt' in Diemen.

In the early 1930s, it was decided that hundreds of wooden piles with a length of 11-13 metres (reaching into the Late-Glacial sand of the Boxtel Formation) would be driven into the ground of 'Diemen centre-west', reaching below the ground water level (see Figure 4), for the building of a new neighbourhood between 1934 and 1936 (the so-called 'The Nieuwe Buurt')[19]. Concrete top-pieces were placed on top of the wooden piles, on which subsequently a road of reinforced concrete with an asphalt layer was laid (see also Figures 5a and 5b).

Clearly visible in this illustration is how the wooden piles sunk under the road are lengthened by concrete top-pieces. The tops of the piles are 50 centimetres below ground water level (- 2.40 N.O.D.).

The natural soil layers, depicted in the bottom centre of this 1938-illustration, roughly coincide with those recorded by the technical engineering agency MABEG, Utrecht and B.& W. Diemen (1935)[20] – cf. Figure 7-(coring)A and Table II-(coring) A. Only a few slight differences are visible when the records of MABEG et al. and those of Huizinga & Dibbits are compared; this mainly concerns the starting heights of the various soil layers.

19 Underpiling of a complete neighbourhood is unique. The Etruscs and Romans are said to be the first to underpile bridges and roads in their empires (Smolenaars, 2004). The Romans built 2000 years ago also roads on black oak-wood piles (Naber, 1999) in the 'Limes ad Germaniam inferiorem' – nowadays: The Netherlands, where the Dutch municipalities of Vleuten and De Meern are located. The idea of underpiling 'De Nieuwe Buurt' in Diemen stems – highly presumable – from the municipal building designer and clerk of the public works, Jan de Boer, who lived and worked in Diemen from 1929 to 1960.

20 Diemer Archives (1931-1987), INV. 85 Explanatory Memorandum B&W, 22 mei 1935.

Figure 5a. The Paulus Emtinckweg (one of the roads built on sunken piles) under construction in 'De Nieuwe Buurt'. In the background is the crossing Burgemeester Van Tienenweg (built on sunken piles in 1934), behind which the back of the Sint Petrus Banden church can be seen (1910); on the right of the photograph, parallel to the Emtinckweg, are the Schoolstraat (constructed in 1934) with the Sint Petrus school and on the other side of the road, houses. Visible sticking out above the houses is the roof of the former town hall of Diemen (1882). (Photography: Jan de Boer, 1934) For details on the location of the streets, see Figure 6.

Figure 5b. Under the road surface of the Schoolstraat. To the left, in the middle of the road, the concrete top-pieces on the wooden piles are clearly visible (Photography: Ronald van Gelder, 2013).

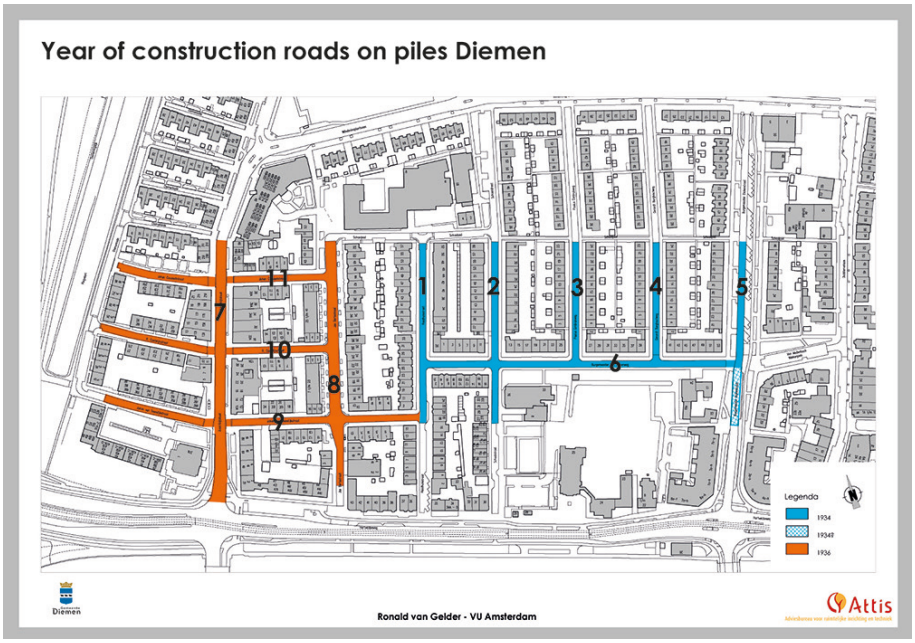

Figure 6. The neighbourhood was constructed by sinking piles in two phases; the 'oostwijk' in 1934 (blue) and the 'westwijk' in 1936 (orange) (Image design Attis BV Consultancy, Dronten The Netherlands). Streets and roads in the 'oostwijk (in blue)': 1. Raadhuisstraat, 2. Schoolstraat, 3. Paulus Emtinckweg, 4. Gerardt Burghoutweg, 5. Burgemeester Bickerstraat, 6. Burgemeester van Tienenweg. Streets and roads in the 'westwijk' (in orange): 7. Arent Krijtsstraat, 8. Jan Bertsstraat, 9. Johan van Soesdijkstraat, 10. Johan Coussetstraat, 11. Reinier Castelijnstraat.

The roads of the neighbourhood were constructed in two phases: piles for the eastern part of the neighbourhood (to be called: 'oostwijk' – eastern neighbourhood; Figure 6: street numbers 1-6) were sunk first in 1934 and subsequently for the western part of the neighbourhood (to be called: 'westwijk' – western neighbourhood; Figure 6: street numbers 7-11) in 1936.

To sum up, it is because of the constant interaction of humans and nature that the western Dutch soft soil seems eminently suitable for research questions related to soil characteristics concerning the 'Anthropocene' debate [21,22]. This is especially the case for Diemerbrug/Diemen, because the inhabitants of this region already had to resort to raising the subsiding natural soil with organic and/or inorganic materials at an early stage.

Second, the western Dutch soil is suitable to address Anthropocene research questions because the soil *under* the roads built on sunken piles seems easily accessible for further investigation.

21 C. Waters et al., "The Anthropocene is distinct from the Holocene". Science 351 (2016): 6269, at 137.
22 S.J. Kluiving, S.J. & A. Hamel. Human niche construction as a perspective on the Anthropocene. RCC Perspectives: Transformations in Environment and Society. Münich, Germany , 2016.

And finally – an additional factor – the local council workers, since the construction of the roads built on sunken piles in the 1930s, have accurately recorded and archived the state of the roads and what was done or should be done to them.

This unique combination of circumstances makes it possible to address the following research questions:

1. Which geological layers are to be found in the Diemen soil in the 20th-century 'De Nieuwe Buurt'? Do the layers of today (*e.g.* 2015) differ from the layers of several years ago (1935), when 'De Nieuwe Buurt' was built? Which soil layers are still the same and which are not?
2. What is the stratigraphical record of the shallow subsurface of Diemen, particularly in 'De Nieuwe Buurt'?

3a. Can different layers be distinguished within the anthropogenic soil layers in the separately investigated periods? If this is the case, how can these layers be characterised?

3b. Can the separately distinguishable anthropogenic layers be dated?

4. Is there a difference in penetration potential below the roads of the 'westwijk' and those of the 'oostwijk'? Can eventual differences be reduced to certain substrates and will it then be possible to date the emergence of these substrates?

Research methods

Archival research

The centuries-old, incompletely digitalised archive of the municipality of Diemen was and still is well maintained by the local archivists. Correspondence, reports of meetings, plans, drawings and designs related to the unique Diemen neighbourhood over time are relatively complete and documents are easily retrieved. In 2016, the easily accessible municipal archive was searched within the framework of our research and information relevant to the study was collected, analysed and used for the present article.

Technical inspections

Since the 1980s, five large technical inspections into the state of the roads built on sunken piles have been carried out, commissioned by the Diemen council (1986[23], 1994[24], 1996[25], 2013[26] and 2015[27]). The various technical inspection reports are also present and retrievable in the Diemen archive. Intensive use of the reports has

23 Haskoning, Onderzoek betonnen wegconstructies – Dienst gemeentewerken grondbedrijf Diemen (Technisch onderzoeksrapport, Haskoning Koninklijk Ingenieursbureau, Nijmegen 1986).

24 Haskoning, Onderzoek betonnen wegconstructies – gemeente Diemen (Technisch onderzoeksrapport, Haskoning Koninklijk Ingenieursbureau, Nijmegen 1994).

25 Omegam, Technische Inspectie van een wijk op palen in Diemen. (Technisch onderzoeksrapport, Onderzoeksdienst voor Milieu en Grondmechanica, Amsterdam 1996).

26 P. Hellinga, Bestaande betonnen wegconstructie te Diemen. Beschouwing. (Technisch onderzoeksrapport, Bartels, Leeuwarden 2013).

27 J.R.A. Kattenberg, Geotechnisch en milieutechnisch onderzoek. Wegreconstructie Centrum West Diemen. Plan van aanpak. (Technisch onderzoeksrapport, Mos Grondmechanica, Rhoon 2015).

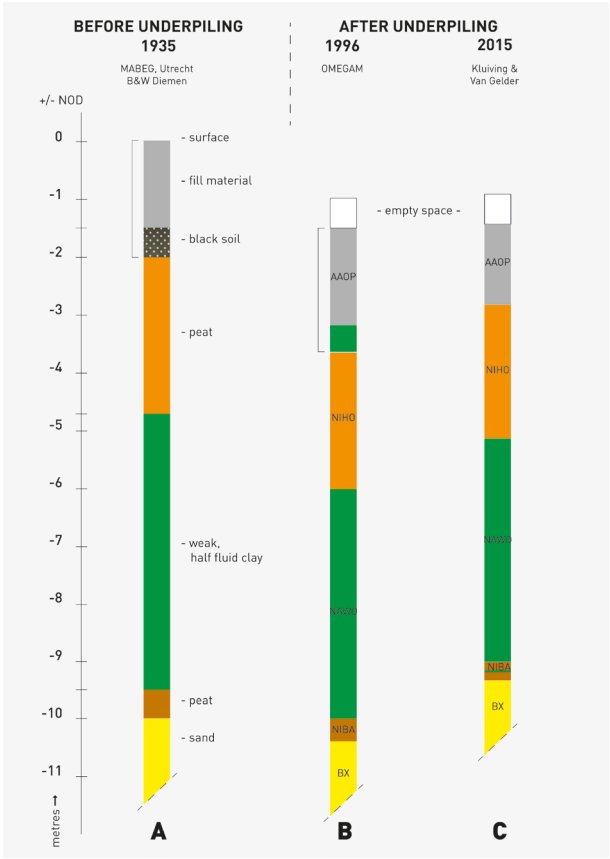

Figure 7. Comparison of corings in 'De Nieuwe Buurt', carried out in 1935 (A), 1996 (B) and 2015 (C). On the basis of hard circumstantial evidence, we are led to conclude that the municipality has inspected the underground in the area, denoted in this article as 'westwijk' (underpiled in 1936). For description of similarities and discrepancies between corings A, B and C, see results section: Table 2. Legenda of colours: grey = anthropogenic deposits; orange = Nieuwkoop Formation/Hollandveen (peat); darkgreen = Naaldwijk Formation/Hollandveen (weak, half fluid clay); brown = Nieuwkoop Formation/Basisveen Bed (basic peat); yellow = Boxtel Formation (sand). For more information on the stratigraphic units see Table 1.

been made in our study, especially the most recent technical report[26] which contains essential data for our research into geological soil layers. MOS carried out several depth probes and extensive corings under the various roads of the neighbourhood. Aggregation of data relevant to us, plus recalculation and reanalysis of the various results provided important information for our study.

Hand corings

The first two authors of the present paper have carried out test corings with a hand core in representative roads of the Diemen neighbourhood. These corings were carried out in the Gerardt Burghoutweg (in the 'Oostwijk', piles sunk in 1934; Figure 6, street number 3) and in the Jan Bertsstraat (in the 'Westwijk', piles sunk

in 1936; Figure 6, street number 8). A hand core (Edelman, 7 cm width) with several long T-parts and a gauge core of 90 centimetres (3 cm width) long were used. Hand corings were carried out to a maximum depth of 10 metres.

Results

Two technical reports from the archives of the municipality of Diemen (from 1935 and 1996), and an internal publication from VU University Amsterdam (2015)[28], about recently executed coring research present the results of three representative geological corings in study area of 'De Nieuwe Buurt' (Figure 7). The earliest coring from 1935 was executed by the technical company MABEG from Utrecht, hired by the late Council of Diemen in the 1930s (Figure 7-(coring)A); the latest coring (2015) was done by Kluiving & Van Gelder (Figure 7-(coring)C), and the coring in between was carried out by the Amsterdam Research Agency for Environment and Ground Mechanics (Onderzoeksdienst voor Milieu en Grondmechanica – OMEGAM) in 1996 – Figure 7-(coring)B.

A comparison of the three cores show between -9 and -11 meters below ordnance datum the top boundary of a sand unit (BX, Figure 7). That has been interpreted as the Boxtel Formation, dating from the last Glacial. All three cores show a thin unit (0,5 – 0,2 m) of peat, Basal Peat (NIBA), occurring on top of the sand. The basal peat reflects the influence of rising groundwater as a consequence of rising sea level in the Early Holocene, between 7,000 and 9,000 years ago.[29] A 3 -5 thick meter clay unit, also described as a 'weak, half-fluid clay' with shell fragments has been interpreted as the Wormer Member of the Naaldwijk Formation (NAWO) and follows the basal peat concordantly on top of it (see Figure 7). The transition from the clay to reed peat and sedge peat marks the closing of the Holland tidal basin with sand bars further west. As a consequence of the decreased energy conditions and transition between an open and closed coast in the Holocene history of the western Netherlands, the peat developed as a 2-3 thick meter peat layer and is interpreted as the Hollandveen layer of the Nieuwkoop Formation (NIHO).

On top of the Hollandveen layer the unit between the three cores slightly varies (see Figure 7): core A has a 'black soil' followed by fill material until the surface, core B shows a clay layer with little debris followed by a weak silty sand with little too much debris interpreted as an 'anthropogenic layer', similarly as in core C the anthropogenic layer (AAOP). As defined earlier, an anthropogenic layer is regarded as a geological layer in which the mutual influence of humans and their natural habitat is clearly notable.

The anthropogenic layers in the Diemen soil, at the location of 'De Nieuwe Buurt', can clearly be distinguished from the natural soil layers. Within these anthropogenic soil layers, several different layers can be distinguished in the separately investigated periods: in 1935 (Figures 7-(coring)A and Table 2-(coring) A), there is a layer of black soil in the 'westwijk' with a layer of material on top to raise the ground (the grey block in the Figure). The raised layer contains fly ash

28 S.J. Kluiving and R.S. van Gelder, Geological investigation of the Gerardt Burghoutweg in Diemen (The Netherlands) (Internal publication, Vrije Universiteit, Amsterdam 2015).

29 J. Schokker et al., "3D subsurface modelling". Netherlands Journal of Geosciences 94 (2015): 399-417, at 401.

and sand, according to the then leading municipal building designer De Boer[30]. In the anthropogenic layer (Figure 7-(coring)B/Table 2-(coring)B) mentioned in the inspection report from 1996, clayish sand and peat (the green block) and 'redeposited soil and rubble'[31] was found in the 'westwijk' – grey block in Figure 7-B. The anthropogenic layer observed in 2015 (Table 2-(coring)C – in the 'oostwijk') contained mainly sand as a raising material (grey block in Figure 7-C).

Most of the lithostratigraphy in the Diemen soil, at the location of 'De Nieuwe Buurt', has stayed the same in the past century with regard to the soil layers found today in corings, but the layer contacts are not identical in elevation everywhere. The layer contacts of the soft peat and clay layers (NAWO and NIHO) from 1935 (Figure 7-A), vary considerably up to meter 1.5, especially the upper contact of the NIHO layer, during the century (Figures 7-B and 7-C).

The anthropogenic soil layer has changed strongly over time (Figure 7a-A-B-C). The raised layers observed in 1935 (Figure 7a-A) are suggested to have been laid down in 1929 during the original construction of the roads of the 'westwijk' – before the underpiling. The raised material in the 'westwijk' found in the technical report from 1996 dates from the time that the underpiled roads were constructed in 1936. The raised material found in 2015 in the 'oostwijk' dates from 1934 and from later – limited – extra deposits of sand, necessary to prevent movement and sliding of 'dune or river sand' from under the pavements to the empty spaces under the road (Personal Messages, Kooijman resp. Berkhout, 2015)[32].

During the fieldwork there appeared to be a difference in corability between the hollow spaces under the roads in the 'westwijk' and those in the 'oostwijk'. Reanalysis and recalculation of the data from the technical research report of Technisch Bureau MOS Grondmechanica from Rhoon[33] led to the conclusion that materials of a completely different consistency lay under the surface of the roads of the 'westwijk' (underpiled in 1936) and those of the 'oostwijk' (underpiled in 1934). Under the roads of 1934 ('oostwijk') there is a clear distinction between the natural soil layers consisting of weak silty peat or mineral-poor peat (Dutch: rietzeggeveen) and culturally deposited layers consisting of weak silty sand or silty peat around the means of 3.9 m. and 3.2 m. below NOD. Under the roads constructed in 1936 ('westwijk') this distinction is completely absent – anthropogenic layers make it impossible to core through the ground surface, which consists – at about a mean of 2.45 m. below NOD – of weak silty sand, with slickstones and punestones added.

30 Diemer Archives. Description on the back of an undated and non-archived picture of the road. One of a series of pictures donated by the widow of the municipal building designer and clerk of the works at that time, Jan de Boer.

31 Diemer Archives INV. 5733: Bestek van gemeentelijke Dienst, 1935.

32 Personal messages from former labourers of Diemen public works: Hans Kooijman (Lelystad, The Netherlands) resp. Rob Berkhout (Almere, The Netherlands), 26 april 2016.

33 J.R.A. Kattenberg, Geotechnisch en milieutechnisch onderzoek. Wegreconstructie Centrum West Diemen. Plan van aanpak. (Technisch onderzoeksrapport, MOS Grondmechanica, Rhoon 2015).

A			B			C		
BEFORE UNDERPILING			AFTER UNDERPILING			AFTER UNDERPILING		
YEAR OF RESEARCH	1935		**YEAR OF RESEARCH**	1996		**YEAR OF RES**	2015	
SURFACE		50 cm. above NOD	SURFACE		83 cm. below NOD	SURFACE		80 cm. below NOD
GEOLOGICAL UNITS			**GEOLOGICAL UNITS**			**GEOLOGICAL UNITS**		
UNIT GeoTOP			**UNIT GeoTOP**			**UNIT GeoTOP**		
				empty space	80 cm. - 1,40 m.		empty space	80 cm. - 1,50 m.
AAOP	heightening added: black soil	0 - 1,50m. below NOD 1,50 m. - 2,00 m.	AAOP	*fill material* sand (moderate fine), weak silty, with little debris sand (moderate fine), weak silty, with much debris clay (solid), weak silty, weak soily, with little debris	 1.40 m - 3,1 m. 3,1 m - 3,5 m.	AAOP	*fill material:* clayey, silty sand	 1,50 m. - 3,00 m.
NIHO	peat	2,00 m. - 4,7 m.	NIHO	peat (solid) *locally formed material:* Hollandpeat	3,5 m - 5,9 m.	NIHO	Hollandveenpackage sedge peat reed peat	3,00 m. - 5,00 m.
NAWO	weak, half fluid clay	4,7 m. - 9,5 m.	NAWO	clay (moderate weak, moderate solid and solid) wad deposition	5,9 m. - 9,9 m.	NAWO	blue clay Wormerlaagpackage	5,00 m. - 9,50 m.
NIBA	peat	9,5 m. - 10,00 m.	NIBA	peat (solid), weak clayey *locally formed material:* basal peat	9,9 m. - 10,3 m.	NIBA	basal peat brown and blue clay basal peat	9,00 m. 9,05 m 9,30 m.
BX	sand	10,00 m. and deeper	BX	sand (very fine) weak silty, weak soily periglacial deposition	10,3 m. and deeper	BX	sandlayer of last Ice Age top of Pleistocene	9,40 m. and deeper
RESEARCHERS	*MABEG, Utrecht*		***RESEARCHERS***	*OMEGAM, Onderzoeksdienst voor Milieu en Grondmechanica, Amsterdam*		***RESEARCHERS***	*Kluiving S.J. & Van Gelder R.S., VU University Amsterdam*	
REFERENCE	*Explanatory Memorandum of* *The Mayor and City Counsel Members Diemen,* *May 22 1935.* *(in: Archives of Municipality Diemen)*		***REFERENCE***	*Report of Technical Inspection* *Underpiled roads of Diemen* *Amsterdam, May 13 1996.* *(in: Archives of Municipality Diemen)*		***REFERENCE***	*Gelder, R.S. van, Kluiving, S.J. Leemans, I.B.Ouden, R. den & Goedhart, J.* *Geological findings in unique streets of Diemen, The Netherlands,* *reveal different anthropogenic substrate control* *Presentation at 4th International Landscape Archaeology Conference.* *Uppsala: 22-25 August 2015.*	
LOCATION	*western part of neighbourhood (no further specifications)*		***LOCATION***	*western part: Arent Krijtsstraat (see figure 6, street number 7)*		***LOCATION***	*eastern part: Gerardt Burghoutweg (see figure 6, street number 4)*	

Table 2: Detailed information about the three respective cores A, B and C, and reports mentioned above. Table 2-A relates to Figure 7-A, Table 2-B relates to Figure 7-B and finally, Table 2-C to Figure 7-C. For further explanation with regard to the geological soil layers mentioned here, see Table 1.

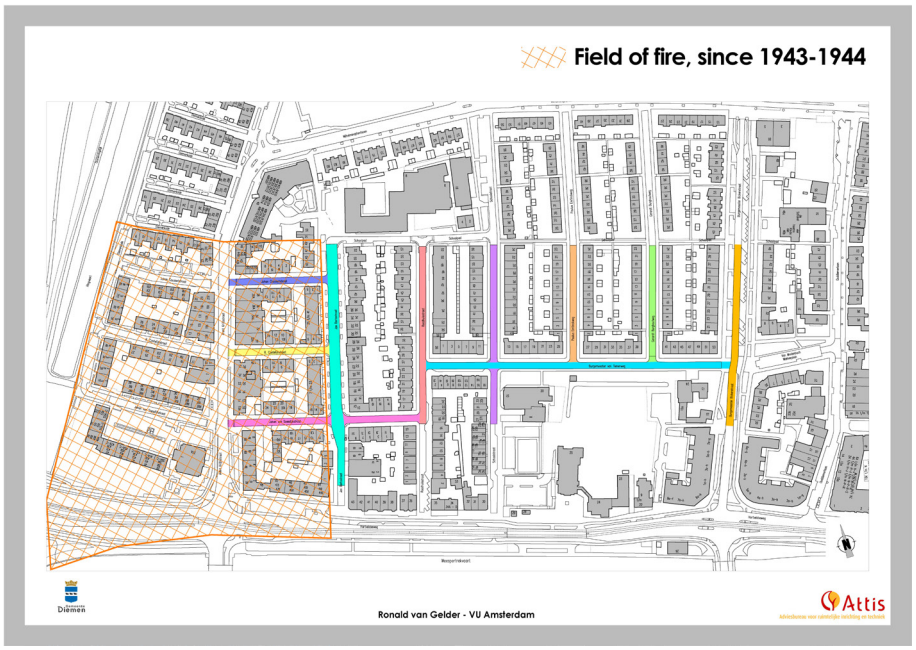

Figure 8a. During World War II the German occupier tore down one third of the neighbourhood on piles, namely the western part. The area, according to the Germans was urgently needed as a field of fire to defend Amsterdam against their enemies. The western part of the neighborhood (on the left) is marked in the illustration by hatching. Image design by Attis BV Consultancy, Dronten The Netherlands.

Figure 8b. The western part of the neighbourhood is completely demolished. The eastern part is untouched, which is visible in the background of the picture. Photography: A. Magrijn-Hooiveld (1943).

Discussion

Contrast in anthropogenic layers of 'westwijk' and 'oostwijk'

Ground corings by hand by Kluiving & Van Gelder (2015) yielded identical research results. The sunken-pile construction under the Jan Bertsstraat (representative for the 'westwijk') is *not* corable below -2.50 N.O.D. due to the presence of stones, little and heavy debris and rubble, whereas the road constructed on sunken piles of the Gerardt Burghoutweg representative for the 'oostwijk' is. The geological layering of this latter road can be mapped easily, even to a great depth (a minimum of 10 metres below N.O.D.). It is not immediately clear why and since when the substrate of the 'westwijk' has been difficult to penetrate.

How can it be explained that the roads of the 'oostwijk' (underpiled in 1934) turn out to be easily penetrated while the roads of the 'westwijk' (underpiled in 1936) are not? The first explanation is that the streets under the 'westwijk' were already constructed in 1929 on a foundation of black soil and raised materials, such as fly ash and sand. Until 1936, these streets were raised with cheap residual materials, so probably also with fine and course rubble, to maintain the elevation of the road surface. The underpiled road was constructed on top – on wooden piles – in 1936. There was no empty space under the road – that is why the top layer of these roads is not easy to core. An explanation why this is different for the roads of the 'oostwijk' is probably due to the fact that these roads were constructed high above a wasteland that had not been raised.

A second explanation is related to the economic circumstances in 1934, which were better compared to those in 1936 (in the middle of the crisis years); that is why it was easier to financially complete projects in 1934 than in 1936. For example, the government contributed to a greater extent to the payment – and thus motivation – of roadworkers in 1934, for instance through employment projects for the unemployed. And – as was also discovered during recent technical research under the roads[34] – , of the materials used in 1934 (such as wooden piles, but also the raw materials necessary for road construction) were of a higher quality and were used to a greater degree compared to the road building in 1936. The quality control of the construction in 1934 was also much better than in 1936. Overall, as a result the roads in the 'westwijk' are considerably less sustainable than those in the 'oostwijk'.

Another alternative explanation for the observed difference is related to the demolition of the 'westwijk' by the Germans during the Second World War to create a field of fire and to protect Amsterdam from enemy aerial attacks. This part of the neighbourhood was demolished to the ground by the German occupiers in late 1943, early 1944 – see Figures 8a and 8b. At that time, the houses and buildings were systematically broken down – 32% of the housing stock in Diemen – and the remaining usable materials were transported to Germany by ship. The ships left along the Weespertrekvaart (see also Figure 3) – the former Keulsche Vaart – to war-stricken areas in Germany, such as Cologne[35] and Hamburg. As a matter of

34 Personal message: Jan Goedhart (2015), Attis BV Consultancy, Dronten, The Netherlands.

35 Literally is 'the Keulsche Vaart': the barge canal to Cologne in Germany.

fact the text 'Liebesgaben aus den Niederlande' was written on the ships' hulls! The inhabitants of the 'westwijk' had to move to a neighbourhood in *Amsterdam*, the Jewish inhabitants of which had been deported by the Germans. The demolition was contracted out by the Germans to collaborating Dutch companies, which carried out the demolition of the neighbourhood and the loading of the ships for them for a paltry fee. It is not unthinkable that the underpaid employees of these companies were not very particular about the – poorly paid, but urgent – commission and that they dumped scrap material under the underpiled roads.

A final explanation is a combination of the second and third explanations. It is possible that the already less durable roads in the 'westwijk' deteriorated more due to the demolition of houses and buildings, the clearing of rubble and preparation for the construction of the field of fire than the roads in the 'oostwijk', where this dramatic scenario never took place.

The historical developments in the research area Nieuwe Buurt are potentially correlated to the described stratigraphy of the anthropogenic deposits. This paper provides the first step in order to collect more combined historical and geological data to support the so-called 'late' hypotheses of the onset of the 'Anthropocene'[36]. Is the process of improving road conditions in the 1930s a consequential developmental step after the Industrial Revolution and an unavoidable preamble for the Great Transformation[37,38]?

Conclusion

Archival and literature studies (Diemer Archives: 1986, 1996, 2000, 2015) as well as our own cores have demonstrated that the soil under the Diemen neighbourhood 'De Nieuwe Buurt' has consisted of the same soil layers (lithostratigraphy) for nearly a century[39]. Under the anthropogenic first soil layer, the natural soil layers of, in succession, peat, clay, basal peat and a sturdy layer of sand, a remnant of the last Ice Age, are found. The elevations of the layer contacts of the natural strata, however, appear to have changed a little over time: in particular the highest peat and clay layers have subsided – almost certainly also[40] due to settling over the last 80 years.

The top, anthropogenic soil layer has certainly changed during the course of the century; this appears not only from the archival and literature studies concerned, but just as much from the cores we carried out ourselves in this soil layer in the Diemen neighbourhood. These deviations can mainly be found in a part of Diemen centre-west, the so-called 'westwijk', which was underpiled in 1936. The anthropogenic layer from before 1936 turns out to consist of black soil and raised material: 'redeposited soil and sand', as the plans at the time mention[41]. Later, investigations in this location mainly encountered fly ash and sand with fine or coarse rubble in this first soil layer(s) (1996). The research report of MOS

36 C.Waters et al., "The Anthropocene is distinct from the Holocene". Science 351 (2016): 6269, at 137.
37 W. Steffen et al., "The Anthropocene". Ambio 36 (2007): 614-621.
38 W. Steffen et al., "The trajectory of the Anthropocene". The Anthropocene Review 2-1 (2015): 81-98.
39 The focus is mainly directed here at the first 10-12 metres below N.O.D. – untill the first sand layer.
40 According to calculations, the western parts of Holland have lowered in the past 1000 years for more than three metres.
41 Diemer Archives INV. 5733: Bestek van gemeentelijke Dienst, 1935.

Grondmechanica[42] and our own corings even show that we cannot core through these first soil layers under the underpiled roads in the 'westwijk' to a depth of more than 2.5 metres below N.O.D. A remarkable finding. And this while the council of Diemen at that time so clearly stated in its plans for underpiling of the roads that: 'eventually hollow spaces will arise under the roads and under the beams on which the sewers are laid'[43].

The most likely explanation for this is that the streets under the 'westwijk' were already constructed in 1929 on a foundation of black soil and raised materials, such as fly ash and sand. Up to 1936, these streets were raised with cheap residual materials, including fine and course rubble, to maintain the height of the road surface. And in 1936 the underpiled road – on wooden piles – was constructed on top. No space remained under the road – that is why the top layer of these roads is not easily corable; at least in the locations where the most recent studies were carried out (by MOS Grondmechanica in 1996 and Kluiving & Van Gelder in 2015). That this is different for the roads of the 'oostwijk' is related to the fact that these roads were constructed high above a wasteland that has never been raised. Further research will reveal whether these are the correct hypotheses.

Finally, based on the above we can conclude that the discussion regarding the onset of the 'Anthropocene' (cf. Waters[44] and Kluiving[45]) can be alternatively described in more detail in the Dutch Late-Holocene soil and that in the western part of The Netherlands, it consists of several clearly distinguishable soil layers: moderate fine sand, weak silty, with unsorted debris and solid clay, weak silty, weak soily with little debris. The geological results combined with historical data in the research area reveal different anthropogenic substrate control in unique streets of Diemen. At this stage of our research, however, it is too soon to date the soil layers concerned more precisely than the beginning of the 1930s. We expect follow-up research will lead to better constrained and integrated geological and historical data focussing on events of the last 300 years.

Acknowledgements

We are most grateful to Bert Brouwenstijn and Joost van Ommen for their creative designs of Figures 2a-2c resp. Figure 7. Also we want to thank Tamme Stallinga of the Municipality of Diemen for his patient support when we were digging in the municipal Archives of Diemen. We are grateful to Jan Ronday for his photographic artworks. The paper benefitted greatly by reviews of Guillermo S. Reher and one anonymous reviewer.

42 J.R.A. Kattenberg, Geotechnisch en milieutechnisch onderzoek. Wegreconstructie Centrum West Diemen. Plan van aanpak. (Technisch onderzoeksrapport, MOS Grondmechanica, Rhoon 2015).

43 Diemer Archives INV. 5733: Bestek van gemeentelijke Dienst, 1935.

44 C. Waters et al., "The Anthropocene is distinct from the Holocene". Science 351 (2016): 6269, at 137.

45 S.J. Kluiving, S.J. & A. Hamel. Human niche construction as a perspective on the Anthropocene. RCC Perspectives: Transformations in Environment and Society. Münich, Germany , 2016.

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Diemer Archives (1931-1987), INV. 85 Explanatory Memorandum B&W, 22 mei 1935

Diemer Archives INV. 5733: Bestek van gemeentelijke Dienst, 1935

Diemer Archives. Description on the backside of an undated and non-archived picture of the road. One of a series of pictures donated by the widow of the municipal building designer and clerk of the public works at that time, Jan de Boer.