DRIFTING PEATLANDS AND SUBTERRANEAN FORESTS

NICOLAAS WITSEN, THE LANDSCAPE AROUND AMSTERDAM AND THE BASIC PRINCIPLES OF MODERN GEOLOGY

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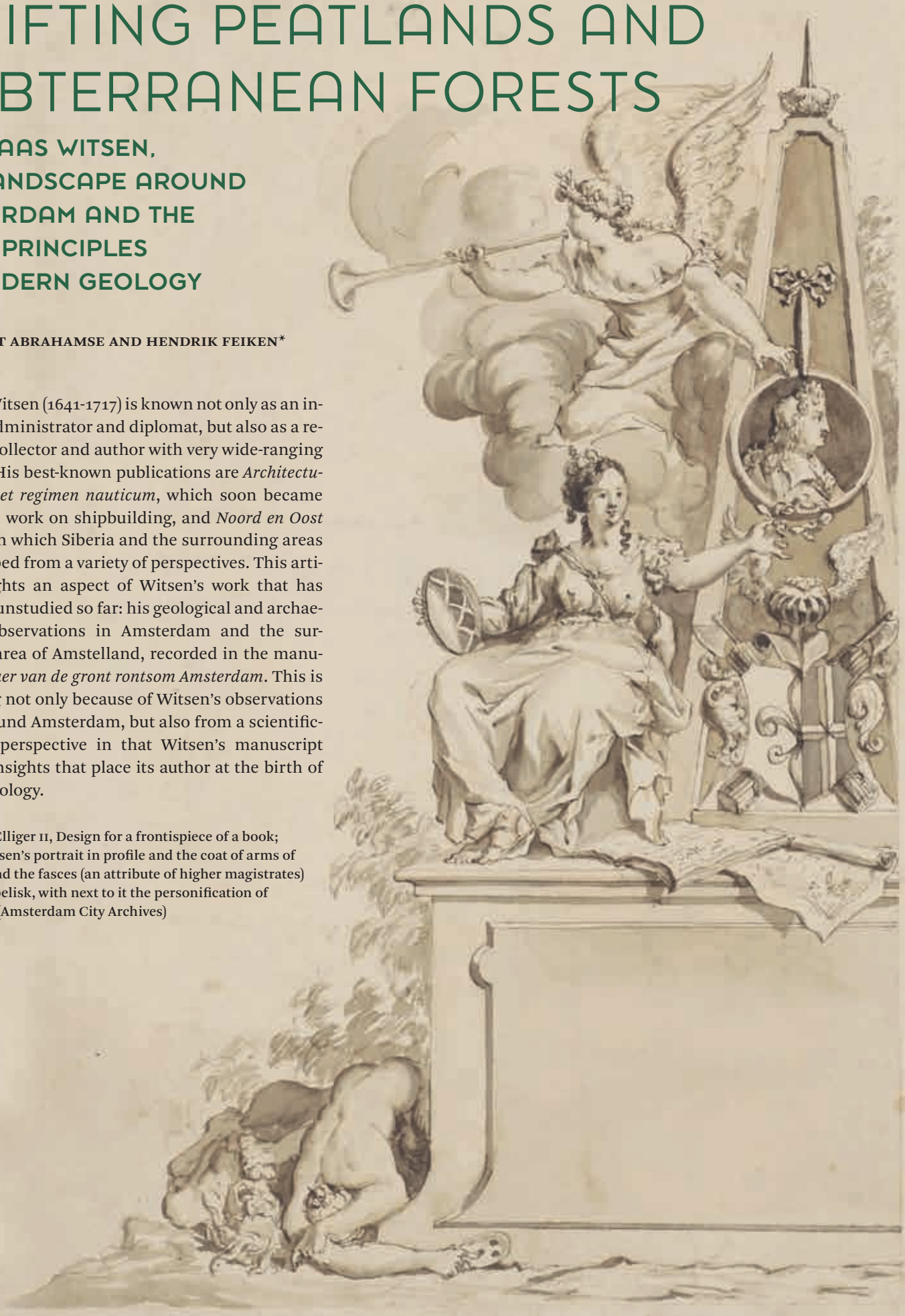
Nicolaas Witsen (1641-1717) is known not only as an influential administrator and diplomat, but also as a researcher, collector and author with very wide-ranging interests. His best-known publications are *Architectura navalis et regimen nauticum*, which soon became a standard work on shipbuilding, and *Noord en Oost Tartarye*, in which Siberia and the surrounding areas are described from a variety of perspectives. This article highlights an aspect of Witsen's work that has remained unstudied so far: his geological and archaeological observations in Amsterdam and the surrounding area of Amstelland, recorded in the manuscript *Natuer van de gront rontsom Amsterdam*. This is interesting not only because of Witsen's observations in and around Amsterdam, but also from a scientific-historical perspective in that Witsen's manuscript contains insights that place its author at the birth of modern geology.



1. Ottomar Elliger II, Design for a frontispiece of a book; Nicolaas Witsen's portrait in profile and the coat of arms of the family and the fasces (an attribute of higher magistrates) are on the obelisk, with next to it the personification of Amsterdam (Amsterdam City Archives)

2. Portrait of Nicolaas Witsen at the age of 36, engraving from 1677 (Amsterdam City Archives)

INTRODUCTION

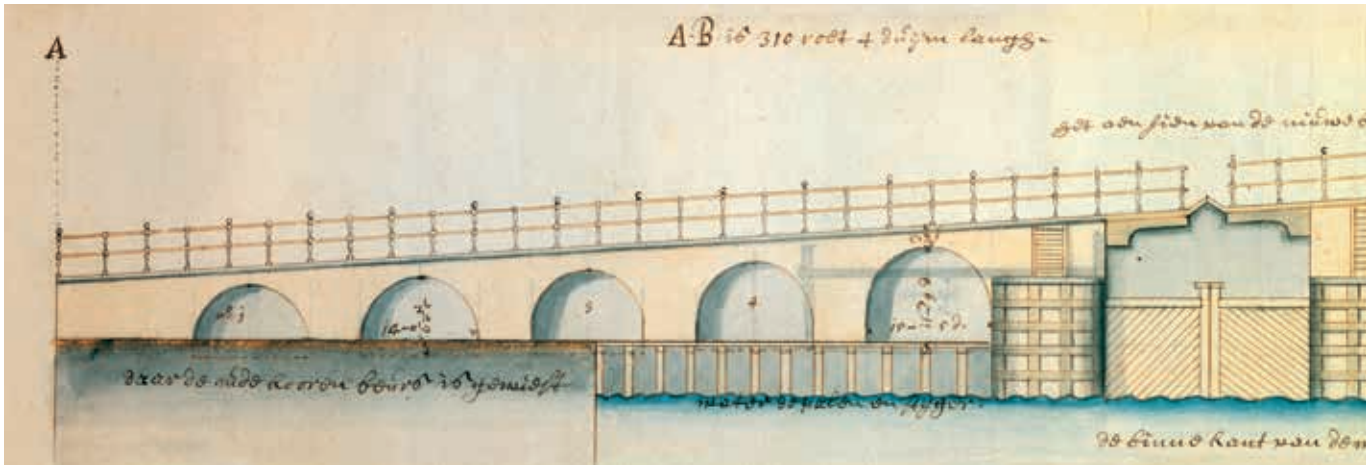
In Marion Peters' monumental biography of Witsen, *De wijze koopman*, the diverse scientific interests of Nicolaas Witsen (figs. 1 & 2) are systematically addressed.[1] In addition to his many posts in public administration – he was, among other things, a 'burgemeester' (mayor) of Amsterdam, 'bewindvoerder' (administrator) of the Dutch East India Company and ambassador to England – Witsen was a passionate researcher. His choice of subjects was determined not only by his varied scientific interests, but also by the economic and practical interests of Amsterdam: the expansion of trade, ship technology and hydraulic engineering works. Witsen studied geography, cartography, shipping and shipbuilding, but also subjects such as ethnography, linguistics, history, botany, zoology and astronomy.[2] He lived during the Scientific Revolution of the seventeenth century, when the writings of classical authors and the Bible gradually gave way to views informed by modern scientific methods, which transformed how society viewed nature. New insights rapidly emerged in many fields.

This article discusses a document that Peters mentions in her book but does not go into, simply referring to it as a work of 'juvenilia'.[3] It concerns a copy of a manuscript entitled: *Natuer van de gront rontsom Amsterdam, door mij in de jeugt opgestelt* ['Nature of the Soil around Amsterdam, as written by me in my youth'].[4] The observations recorded in this manuscript reflect an early interest in geology and archaeology, knowledge of which would later come in handy in the author's administrative career: in Witsen's day it was common for public administrators not only to make decisions but also to be proficient in the technical aspects, financing and management of complex projects.

The document can be found in the Manuscript Collection of the Amsterdam City Archives. We do not know how and when it ended up there or where it came from. Most of Witsen's archive was lost after his death. Until 1823 there were no documents by Witsen in the Amsterdam archive. Only after a public appeal from city archivist Jacobus Scheltema did the archives office manage to acquire some of Witsen's writings.[5] The subject of this article is a nine-page document in folio format. The preserved manuscript is not an original; it is a copy in a clearly legible seventeenth-century hand, to which Witsen himself has added a title, his signature and a few corrections and notes. Some topics are covered in several places in the text. The document is not dated, but its contents suggest that the original must have been written in the second half of the 1650s or early in the 1660s at the latest: Witsen refers to the great breach of the Sint-Anthonis dike on 4-5 March 1651 (fig. 3) as having taken place a few years previously ('for some years'). In any case, we can safely assume that Witsen wrote it before 1663 when, aged 22, he went to Leiden to study.[6]

It is not impossible that Witsen saw the dike breach and its consequences as a child, but he does not mention this in the document. In later life Witsen was involved as an administrator in the repairs and dike reinforcements aimed at preventing a recurrence of the disaster. On 9 May 1651, two months after the dike breach, which occurred outside the city, the community decided that the foot of the Amsterdam section of

3. Roelant Roghman, Breach of the Diemerdijk, 1651. Visible in the foreground of the upper picture is a pile frame used to insert piles for a new part of the dike. In the picture below, the dike repair has already been partially completed (Amsterdam City Archives)



4. Construction drawing of the Nieuwebrug ('New Bridge') over the Damrak canal, part of the flood barrier that was constructed under the leadership of Nicolaas Witsen in the years 1680-1682 (Amsterdam City Archives)

the Diemerzeedijk should also be reinforced by building up the earth on the outside of the dike.[7] At a later stage, Witsen would play a leading role in the reconstruction of the dike and in the construction of the new flood barrier in Amsterdam along the banks of the IJ, the current Prins Hendrikkade (fig. 4).[8]

The manuscript as such has remained unpublished, but Witsen must have handed it over to the seventeenth-century physician, geographer and historian Olfert Dapper, with whom he was very good friends.[9] Dapper paraphrased the text, without mentioning the source, in his 1663 *Historische beschryving der stadt Amsterdam* (Historical Description of the City of Amsterdam). That book was dedicated to Nicolaas's father Cornelis Witsen (1605-1669), a former mayor of Amsterdam and at that time councillor and treasurer of the city.[10] Dapper's paraphrase of Witsen's manuscript was later reproduced in Tobias van Domselaer's *Beschryvinge van Amsterdam* (with reference to Dapper), which appeared two years later.[11]

The manuscript consists of a series of detailed notes of Witsen's own observations in Amstelland, supplemented by second-hand observations and his own ideas and conclusions. The text is arranged geographically and thematically and includes all kinds of information of greater or lesser relevance. For the readability of this article we have therefore not followed the order of his manuscript. We discuss the various themes in a set order: we start with Witsen's observations, after which we discuss his own interpretation and, finally, the modern interpretation of what Witsen observed. At the end of the article we place the manuscript in a broader context.

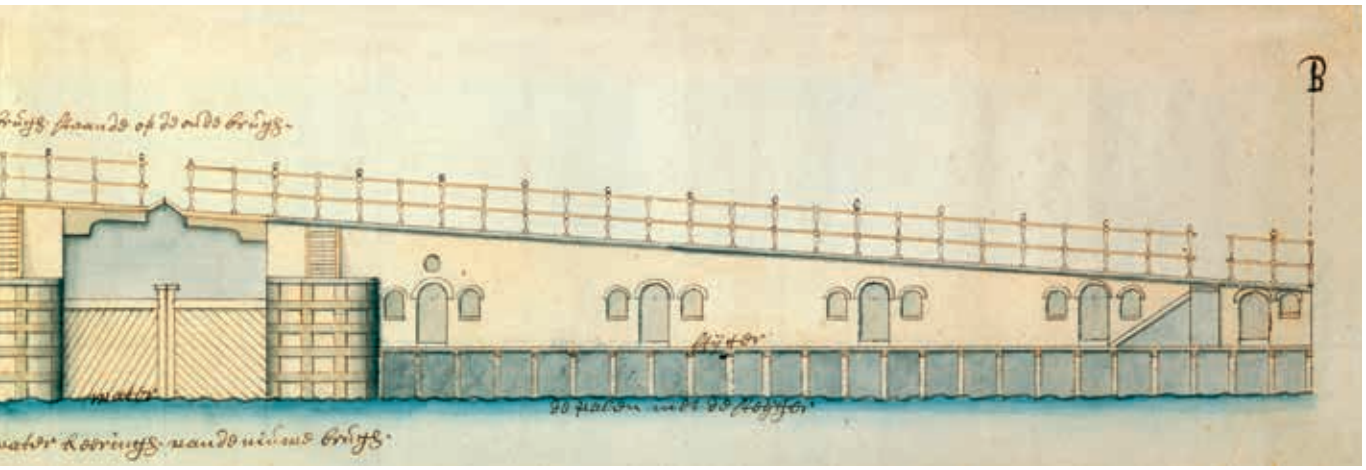
In order to elucidate Witsen's interest in the subsoil of Amsterdam and Amstelland, we start at the end of the manuscript, where Witsen refers to an earlier study of the composition of the subsoil of Amsterdam.

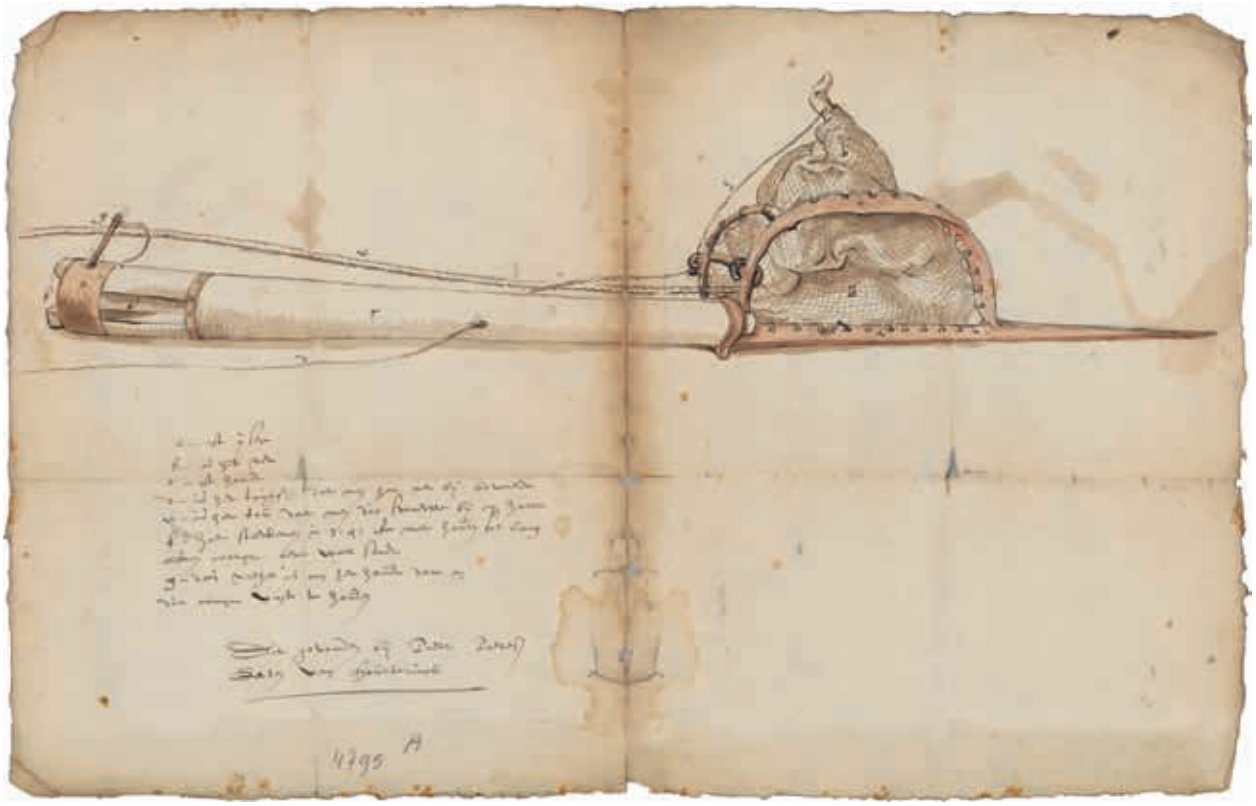
A FAMOUS DRILLING PROJECT FROM 1605

At the end of his text Witsen refers to an appendix (no longer present), detailing the results of a deep drilling operation in Amsterdam.[12] He also discusses this drilling in *Noord en Oost Tartarye* (North and East Tartary). In this book he recounts how his grandfather had been present at the drilling of a deep well in Amsterdam. During the drilling they found 'many thousands of sea snails and shells', along with hair and horse manure. The deeper they drilled, the smaller the shells. His grandfather had left him a lot of these shells, which to his surprise were very similar to shells from the East Indies and the West Indies.[13]

The well in question was drilled in 1605 by Pieter Ente on the grounds of the Old Men's and Women's Home, an almshouse for the elderly in the present Oudemanhuispoort. The drilling, the purpose of which was to find clean drinking water, took twenty-two days to reach its final depth of around 73 metres. The drilling was famous in its time and was mentioned in Varenius's standard work *Geographia Generalis* from 1650.[14] Constantijn Huygens described the tool used to drill the hole in a letter: 'the excavator, [was] pointed ... at the bottom, and [had] a net on a semi-circular cutting iron ... that at every turn caught the loosened soil, which was brought up in very small quantities'.[15] It has been suggested that Ente worked for the Rijnland Water Board.[16] In 1602 he had applied for and obtained a patent for this instrument from the States General (fig. 5).[17] During recent archaeological research on the construction site of the North-South Metro Line in Amsterdam, a similar instrument was excavated (fig. 6).[18] Huygens also describes how the walls of the well were prevented from collapsing by constantly filling the well with water.[19]

The sediment that came out of the auger was described (fig. 7) and from this the stratigraphy to about 73 metres below ground level can be deduced. Accord-





5. Pieter Pietersz Ente, Drawing of an auger from a patent application to the States of Holland in 1602 (National Archive)

6. Auger, excavated from the construction site of the North-South Metro line (Monuments & Archaeology Amsterdam, photo by Harold Strak)

7. Description of the stratigraphy as revealed by the deep drilling project in Amsterdam carried out by Pieter Ente in 1605, from Casparus Commelin, *Beschryvinge der stadt Amsterdam*, Amsterdam 1693

De Put in 't oude Mannen-huys.

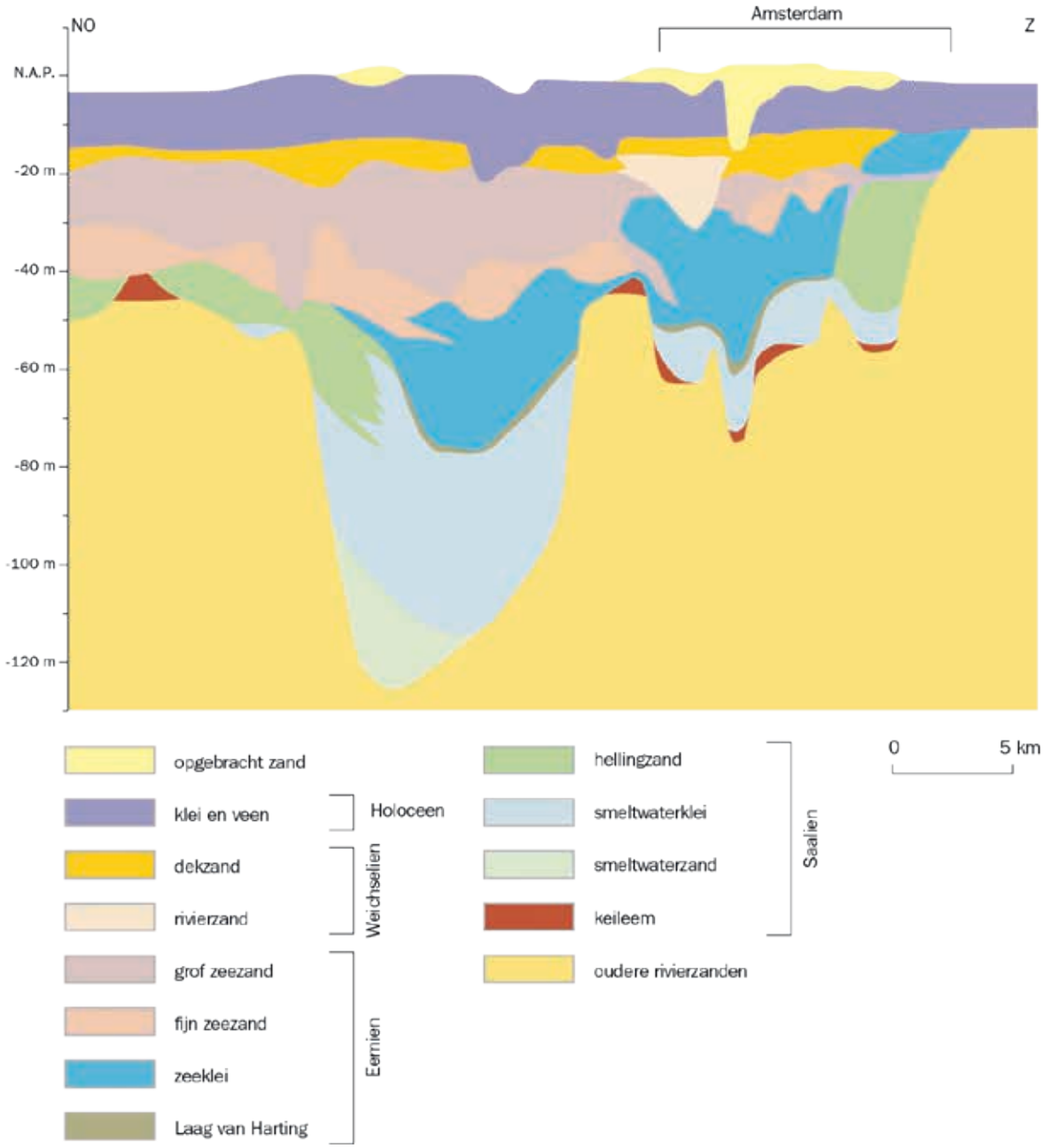
In 't Jaar duyſent ſes hondert vijf, de feſtiende dagh van Julius, is door *Pieter Pieterſz. Ente*, een Put geboort, in 't oude Mannen en Vrouwen Gaſthuys, binnen de Stadt *Amſtelredam*, welcker diepte is gekomen tot twee hondert en twee-en-dertigh voeten, zijnde omtrent twee-en-dertigh voeten dieper, als de Toorn van de oude Kerck hoogh is. 232. voeten diep.

Waar in ook te ſien is de verſcheyde Stoffen, die uyt de gemelde Put gekomen zijn, op yder dag, in orden geſtelt.

d'Eerſte dagh ſijnde Donderdagh geboort	51	Voeten, te weten,	7 Voeten gehooghde aerde. 9 Voeten dary en veen. 9 Voeten weeke klay. 8 Voeten zandt. 4 Voeten aerde. 10 Voeten klay, tamelijk hard. 4 Voeten aerde.
De tweede dagh Vrydagh	22	Voeten, te weten,	10 Voeten zandt, daar Amſtelredam meeſt op grond, en daar op geheyt wort. 2 Voeten heele blauwe klay. 4 Voeten wit zandt. 5 Voeten zavel aerde. 1 Voet mollem.
De derde dagh Saturdagh,	14	Voeten, welk anders niet dan zandt was.	
De vierde dagh Sondagh,	12	Voeten, te weten,	9 Voeten eerſt zand met klay vermengt, daar na ſchelpen en horentjes. 3 Voeten harde klay, ſomwijl met hayr en ſchelpen vermengt.
De vijfde dagh Maandag,	27	Voeten harde klay, ſomwijl met hayr en ſchelpen.	
De ſeſte dagh Dinghſdagh	16	Voeten, te weten,	6 Voeten harde klay, vermengt met hayr en ſchelpen. 10 Voeten harde klay.
De ſevende dag Woenſdag	14		
De achtſte dag Donderdag	14		
De negende dagh Vrydag,	11	Voeten harde klay,	
De thiende dagh Saturdag	9		
De elfde dagh Maandagh,	1		

De twaalfde dag Dingſdag	10	Voeten, te weten,	7 Voeten harde klay. 3 Voeten zandt met ſteenkens vermenght
De dertiende Woenſdagh	3	Voeten, te weten,	2 Voeten zandt met ſteenkens vermenght. 1 Voet zant alleen.
De veertiende Donderdag	5		
De vyfſtiende Vrydagh,	6		
De ſeſthiende Saturdagh,	5		
De ſeventhiende Maandag	4		
De achthiende Dingſdag,	3	Voeten, anders niet dan zandt.	
De negentiende Woenſd:	2		
De twintigſte Donderdag	2		
De een-en-twintighſte Vrydagh.	1		

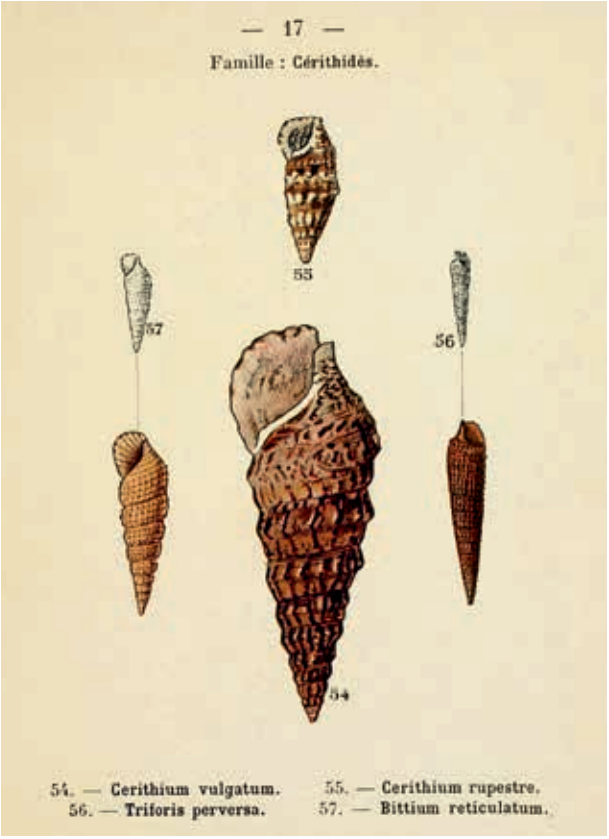
t' Samen in alles diep, 232 voeten.



8. Profile of the deep subsurface of Amsterdam (TNO)

ing to the drilling description, the shells passed down by Witsen's grandfather were found between 27 and 40 metres below ground level. Today we know that the shells found by Ente occur in marine sediments from the Eemian, an interglacial period about 126,000-116,000 years ago (fig. 8). These deposits are considered by geologists to belong to the Eem Formation.[20] At that time Amsterdam was on the edge of the Eem sea.[21] The Eemian was a warm stage, in which the average temperature was about two degrees higher than it is now. The sea was also warmer, comparable to the Mediterranean Sea today. The top of the Eem deposits in Amsterdam are located at about 25 metres below NAP.

A typical feature of these deposits are the marine shell layers. The diagnostic shells include *Bittium reticulatum* (vulg. small needle whelk, fig. 9), *Venerupis aurea var. senescens* (vulg. carpet shell), *Echinocyamus pusillus* (vulg. pea urchin) and *Ostrea* (vulg. oyster); the first two are the index fossils. His grandfather's shell collection and his stories about the spectacular drilling project may have contributed to the young Witsen's interest in shells and the geology of Amsterdam and its surroundings.



9. *Bittium reticulatum* from *Atlas de poche des coquilles des côtes de France*, 1913 (Wikimedia Commons)

THE STRATIGRAPHY OF AMSTELLAND

Witsen describes the stratigraphy of Amstelland and Amsterdam (fig. 10) for two locations, outside the dikes and inside the dikes. Nowhere in the text is it written how Witsen made these observations, but given the above description of the 1605 borehole, it cannot have been too difficult to drill up to 10 to 12 metres below ground level.[22] The manuscript indicates that Witsen drilled several holes.[23] Witsen and his siblings all had their own personal servants, so organizing such an expedition would have cost the young Witsen little effort.[24]

OBSERVATIONS OUTSIDE THE DIKES ALONG THE IJ

The first subject that Witsen discusses in his manuscript is the stratigraphy of the land outside the dikes to the east and west of Amsterdam, outside the Haarlemmerpoort and the Sint-Anthonispoort. In a number of places there were pieces of land between the IJ and the higher winter dikes ('hoge dijken'). These were usually surrounded by a lower summer dike or 'kadijk' (fig. 11).[25]

The upper, approximately one-metre-thick, layer consisted of 'pure, clean, hard clay' ('suivere schoone en harde kleij'). Underneath, Witsen noted a peat layer 10 to 11 feet thick (c. 2.80-3.10 m). And beneath that was a layer of 'pijpige dari', which is to say peat in which intertwined pieces of reed and reedmace ('pijpe of riden en duile') were visible. Below this reed peat, Witsen found a second layer of clay, '10 to 20 to 23 spit deep, or even less'; the closer to the IJ, the thicker the clay layer.[26] Underneath that was the first layer of sand, brown at the top, and paler further down.[27]

What follows is a digression, typical of Witsen's texts, on a related practical subject: foundations. The people of Amsterdam placed their foundation piles on this first layer of sand. Their ancestors had not always done that in the past: their houses were consequently 'unstable' and fell into ruin because the poles were too short, had a pointed end, or because they were placed on a foundation of 'wickerwork', or braided withy. The 'impressive buildings' ('magtige gebouwen')[28] from Witsen's time, by contrast, stood on 40-foot (approx. 11-metre) piles, with a flat end on the first layer of sand.

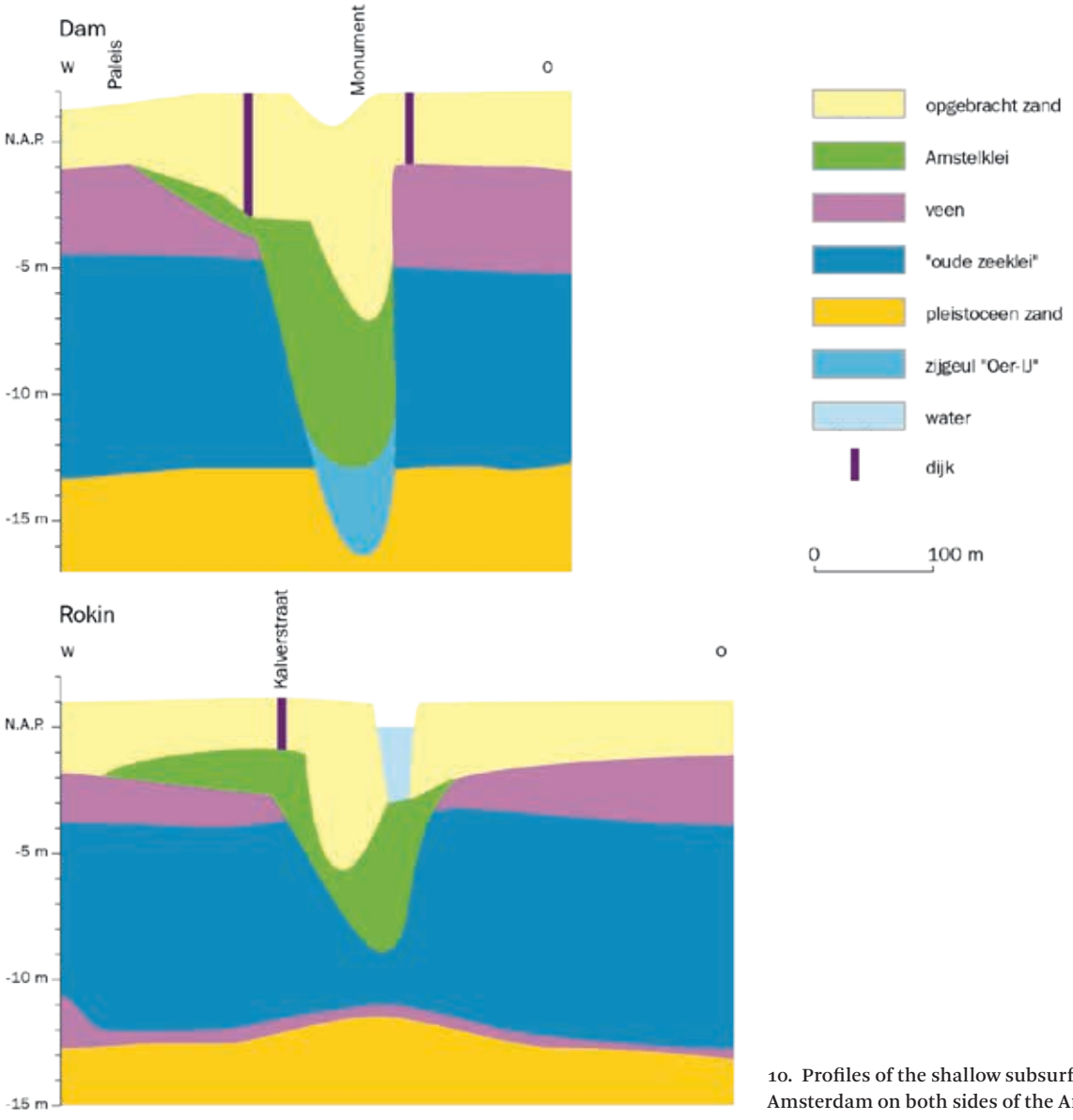
OBSERVATIONS IN THE AREA ON THE LANDWARD SIDE OF THE DIKES

The manuscript continues with a description of the stratigraphy of the land inside the dike and below the city, in which Witsen excludes the land-raising layers because he knows they are artificial.[29] In the area protected by the dikes, there was no clay layer. The clay layer outside the dikes dates from the period after their construction, which in Witsen's eyes obviously was a matter of course, as he fails to mention it. Below the top layer, consisting of mucky peat, one foot thick, was a layer of peat 12 feet (approx. 3 m) thick, and underneath that, just like outside the dikes, 3 feet (approx. 0.85 m) of reed peat. Below that were clay and sand layers of similar thickness to those outside the dikes. The thickness of the layers varied slightly (1 to 1.5 feet, approx. 0.28-0.42 m) depending on the location; only in places where there had once been buildings or military structures had the soil subsided as a result of peat compaction. In the city, both under the streets and on private plots, the original top soil was covered by a series of layers of various types of soil, but mainly sand, used to raise the level of the ground plane.

DRIFTING PEATS

One problem that arose during excavations was the 'pijpige dari', the reed peat mentioned above. The problem occurred during earthmoving works. When excavating the upper peat layer, the reed peat that was located below it floated upwards. Tenders for excavation work accordingly stipulated that any costs occasioned by rising peat were to be borne by the contractor.[30]

Witsen gave an example of this, which he may have seen with his own eyes. It had happened during the digging of the Nieuwe Vaart canal and the construc-



10. Profiles of the shallow subsurface of Amsterdam on both sides of the Amstel (TNO)

11. In a number of places there was land outside the Haarlemmerdijk, surrounded by a low summer dike and indicated on the map as 'kade' or 'kadijk'. Detail from the map of Amstelland by Daniel Stopendaal, c. 1750 (University of Amsterdam, Special Collections)

tion of the Kattenburg dock island, both in 1651.[31] Excavation had commenced and then been paused for one day. When work resumed on the following day, they discovered that the ground was back to its original level. They continued digging, but to no avail: the ground level did not drop due to the rising peat layer. The water level rose, and the land rose with it. Eventually the peat layer became so thin that it could no longer bear the weight of the diggers: one of the workers sank through the peat layer 'to his throat' and was narrowly saved by his co-workers throwing him planks and sticks.[32]

Accordingly, when excavating such land, the upper layer ('solder') was cut away and removed, raft-like. This removal of the peat reed layer was done by laying a rope with knots under it and pulling it back and forth. In the province of Holland, for example, entire pieces of reed land were cut out and offered for sale by farmers. They were apparently used for dike reinforcement, because Witsen says they were used in places where there was a lack of foreshore and where there was a threat of erosion.[33] In order to find out how deep to cut, a borehole was first drilled. They also learned that there were different types of peat: the top layer, which was dry, was bad peat, because it could not be processed into heating fuel. The upper layer did nevertheless ignite very easily; according to Witsen, dikes that had been heightened using peat often caught fire. This fire hazard is also mentioned in other archival documents: in the seventeenth-century Waterland polders, farmers were forbidden to burn old hay too close to the inner slope of dikes because the dike was liable to catch fire.[34]

Witsen then quotes Article 41 from the 'Previlege van Vrouw Maria'.[35] These were the rights granted to the Counties of Holland and Zeeland and the Seigniory of West Friesland in the Great Privilege ('Groot Privilege'), which was issued in 1477 by Mary of Burgundy, then Queen of the Low Countries, to the States General.[36] In that article a general ban was imposed on the extraction of 'moer'. The term 'moer' was (in this case) used to describe saline peat, which was extracted for the purpose of salt production. The excavation of the peat soil led to major damage to the land and the dikes. Witsen quotes the text and then adds the scarcely relevant and well-known fact that salt was extracted by burning the peat, which in a dry condition would be 'full of sulphur and salty parts' ('vol sulpher en zoutagtige deelen'). With this Witsen ends his treatise on the composition of the peat.

WITSEN'S INTERPRETATION

Witsen tries to explain how the great diversity in stratigraphy might have come into being. He describes and explains the different layers in a systematic way, from bottom to top. He uses not only his own observations but also data from much deeper wells, such as that from 1605 and later.

Witsen begins by observing that the sand from the bottom layer must have come from the sea, because it contained various type of shells and ('scelpen en hoorne') that could not have come from anywhere else.[37] This reasoning is broadly correct: Pleistocene top sand (the first sand layer) does not contain shells, because it is an aeolian sediment. The shells to which Witsen refers do occur in marine sediments from the Eemian, which is to say the deeper, second layer of sand.

That might have happened before or after the Deluge, Witsen writes, but 'that's no concern of me' ('dat raekt mij niet').[38] The upper part of the sand was brown because it was partially mixed with the clay layer above. Witsen speculated that the clay must have been deposited by the rivers, as was still happening in his own time around Oldenburg and along the sea coast, where new land was being created by silting.

According to Witsen, the peat layer above it had drifted into its current position, as seen at the breach of the Sint-Anthonisdijk in 1651, when complete fields of peat were set adrift and came to rest elsewhere. In earlier times, Witsen stated, this phenomenon occurred on a much larger scale because of the absence of dikes. That there had been 'widespread floods' ('generale vloeden'), which had inundated the whole of Holland and Friesland, was clear not only from the landscape situation, but also from old records. On this occasion a 'dari-solder', a floating layer of peat, had been deposited.[39]

Witsen had taken note of reports that around the town of Emden (in East Frisia) pieces of land complete with houses, people and cattle had gone adrift.[40] In the Ems-Dollard area, major sea ingressions took place after the reclamations and, according to chronicles, large areas of low-lying peatland were displaced. The chronicle of the Bloemhof monastery in Wittewierum describes how pieces of land were set adrift by the power of the water.[41] The *Annales Palidenses* record how pieces of peatland were torn loose and drifted around as islands: 'for three days, the waters, pushed up to unfathomable depths, rose and swelled, and all the rivers in the coastal areas burst their banks as a result of the influx, and they have set adrift many islands with people, draught animals, villages, houses, buildings, supplies, churches on them, and what is even more strange, with farmlands and farmyards and cemeteries, with the soil on which they stood, where they sadly drowned'.[42]

Land was reclaimed from the sea by means of rebuilding the dikes.[43] The disastrous dike breaches in the Ems-Dollard area were the subject of early modern historiography and have been extensively mapped

12. Map of Eastern Friesland by Ubbo Emmius, published in Amsterdam in 1633. The Ems-Dollard area can be seen on the left; the inset map at bottom right shows the loss of land after the great flood of 1277 (Groningen Archives)

(fig. 12).[44] These sea ingressions were mainly the result of large-scale medieval peat reclamations.[45] The sea drained a number of deep tidal channels far into the old peat landscape.[46] They caused strong erosion of the peatlands and set pieces of land adrift on a local scale.[47]

Witsen then turns to the upper layer of peat, which he felt would have come into being as 'reeds and rushes' ('liesen en biesen') were driven together and mixed with 'wood and other earth' ('hout en andere aerde'). According to Witsen, this peat formation was a very long process. In support of the notion that wood could travel long distances as a result of natural forces, Witsen refers to the diaries of Gerrit de Veer, first published in 1598 and reprinted many times. De Veer was a non-commissioned officer who took part in the expedition that was forced to winter on Nova Zembla in 1596.[48] De Veer writes about the plentiful supply of driftwood, with which the ship's crew built a house 'to be protected from the cold and wild animals'.[49]

Witsen believed that the accretion of waterborne materials could lead to a gradual raising of the ground level such as could be seen at the Mallegat, a waterway near the city of Leiden. Witsen rightly identifies the Mallegat as the place where the Rhine once flowed into the sea.[50] So the Rhine must have been much higher than the North Sea at some point in time; according to Witsen, the lowest level in his own time was only two inches higher than the seawater.[51] From his interest in hydraulic engineering issues, Witsen would have been familiar with the problems surrounding the drainage of the Rhineland: the Mallegat took its name from the failed attempt in 1570-1571 to restore drainage via the mouth of the Old Rhine for the benefit of the Rhineland. Plans for drainage via the Old Rhine had existed since 1404, but were not implemented until the early nineteenth century. Planning also took place in Witsen's day (figs. 13, 14).

Finally Witsen discusses the upper layer of clay he had found in the land outside the dikes and which could only have been deposited by tidal movements in the IJ. Inside the dike he observed the 'ordinary earth' ('gemene dari'), a mixture of peat, sand and other matter ('veenen, sant of andere aert'), that had raised the land ever higher.[52]

In his description of the area inside the dikes, Witsen does not include the layers added by human beings (the 'aenhoogsel'). His familiarity with these soils meant that he was able to recognize and exclude such artificial additions.

MODERN INTERPRETATION

What follows here is the modern interpretation of peat formation. At the end of the last Ice Age (about 11,700

13. Pieter Henricxzoon van Bilderbeeck, Map of the Old Rhine and the drainage via the Mallegat to Katwijk aan Zee, 1627. The Mallegat is the watercourse between Katwijk aan den Rijn and Katwijk aan Zee, cutting through the range of dunes on the left of the map (Rijnland Water Board, Map Collection, A-0389)

years ago), the climate changed dramatically. The temperature increased and the ice caps gradually melted. Sea levels rose many metres, filling the North Sea basin with melt water and creating the North Sea. The rise in the sea level slowed down about 6000 years ago. Under the influence of sea currents and wind, beach ridges and dunes were formed and the Dutch coastline gradually took shape. The closure of the coastline prevented adequate drainage of the hinterland, which consequently became marshy. This in turn led to peat formation. Behind the largely closed coastline, endless reed beds sprang up in large, shallow, nutrient-rich freshwater lakes. In this wet environment, which eventually covered the whole of the western part of the Netherlands, an extensive peat bog of mainly reed, came into being.

Peat formation has several phases. When reed dies it sinks into the water where the lack of oxygen prevents it from decomposing entirely. Reed accumulates on the bottom and gradually turns into reed peat. The bog gets shallower and shallower and eventually silts up altogether. Various plants and trees, such as sedges and alders, grow on top of the reed peat. They, too, die off, eventually forming sedge and alder peat layers on top of the reed peat and the ground level rises accordingly. The water in this thicker peat layer consists mainly of nutrient-poor rainwater retained by the peat. At this point, the next phase of peat formation begins.

The nutrient-poor peat contains only plants that require almost no nutrients, such as heather and wool grass and, in particular, sphagnum or peat moss. The resulting peat is called sphagnum peat, which is even spongier than reed peat. The peat continues to grow in this way, forming raised areas of peat known as 'veenkoepels' (raised bogs). Not all the rainwater is retained; along small streams the peat drains naturally into the lower areas and eventually to the sea. Near to natural channels in the landscape, the presence of nutrient-rich water stalled peat development in the first phase of reed peat formation. The peat area was not homogeneous in character and consisted of a mosaic of raised bogs, fens, ponds and streams. It was a marshy area of reed and peat moss and, on the higher spots, willows, alders and ash.[53]

Witsen's notion of peat formation, although not explicitly formulated, is broadly in line with the current one. Witsen observes that the peat landscape was very dynamic and distinguishes different types of peat formed from different vegetable material. For example, he states that 'the wood has helped create the peat to a great extent' ('het hout niet weijnig tot het turflant geholpen heeft'). Witsen identifies different types of peat but was unable to account for it.

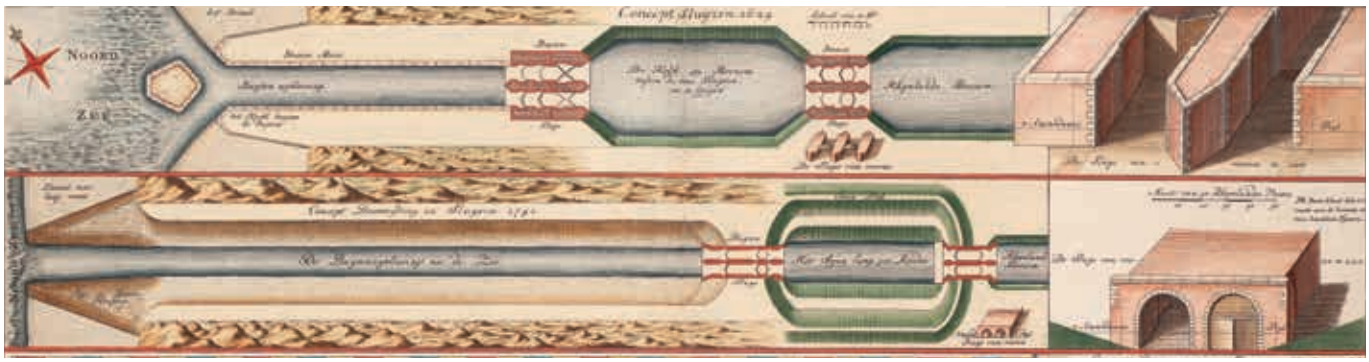
AN UNDERGROUND FOREST

Witsen also writes about a subterranean forest on both sides of the Amstel, stretching as far as Ouderkerk.[54] It concerned a strip of land of about 60 rods (approx. 220 metres) under which at a depth of 5 to 6 feet was a 'huge subterranean forest of trees' ('gants onder-aerts-bos van boomen').[55] The thicker trunks lay in south-westerly direction; the smaller trees were upright. There were different types of trees and some were still 'laden

with nuts' ('met noten … behangen'). A little further to the south-east, near Abcoude, the subterranean forest expanded laterally and consisted entirely of oaks. This wood was very strong and serviceable; farmers used it to build their barges. Closer to the city, the wood was too decayed to be used for anything; it crumbled when picked up.

The presence of this subterranean forest regularly led to construction problems. Witsen mentions a concrete example: the construction of the municipal carpenters' yard near the Amstel. In 1651, after the attack on Amsterdam by Stadholder William II in the previous year had shown that the city's defences were inadequate, the city council decided to erect two defensive 'block houses' in the Amstel river. In connection with this project, a new carpenters' yard was planned nearby, (Fig. 15) on the spot where the construction of the roof structure for the new town hall on Dam Square (the present Royal Palace) took place.[56] Witsen's father, Cornelis Witsen, was directly involved as a member of the council committee that supervised this project.[57] It is not impossible that ten-year-old Nicholas accompanied his father when he went to inspect the site at the request of the council: as a boy Witsen accompanied his father on business trips at home and abroad.[58] When it came to laying the foundations for the buildings on the carpenters' yard, a lot of extra work was required to dig out the underground wood 'that the spade refused' ('dat de spa weijgerde'). The construction costs of the complex had risen considerably because of this. According to Witsen, in the tendering procedure for groundwork near the Amstel it was therefore customary to include a clause stating that the contractor was responsible for the expense of removing any underground wood and tree roots present on the construction site.

14. Design for a new lock in the Mallegat from 1629. Detail of an engraving that Melchior Bolstra made in 1740 on behalf of the Rijnland Water Board (Library Vrije Universiteit, Amsterdam)



WITSEN'S INTERPRETATION

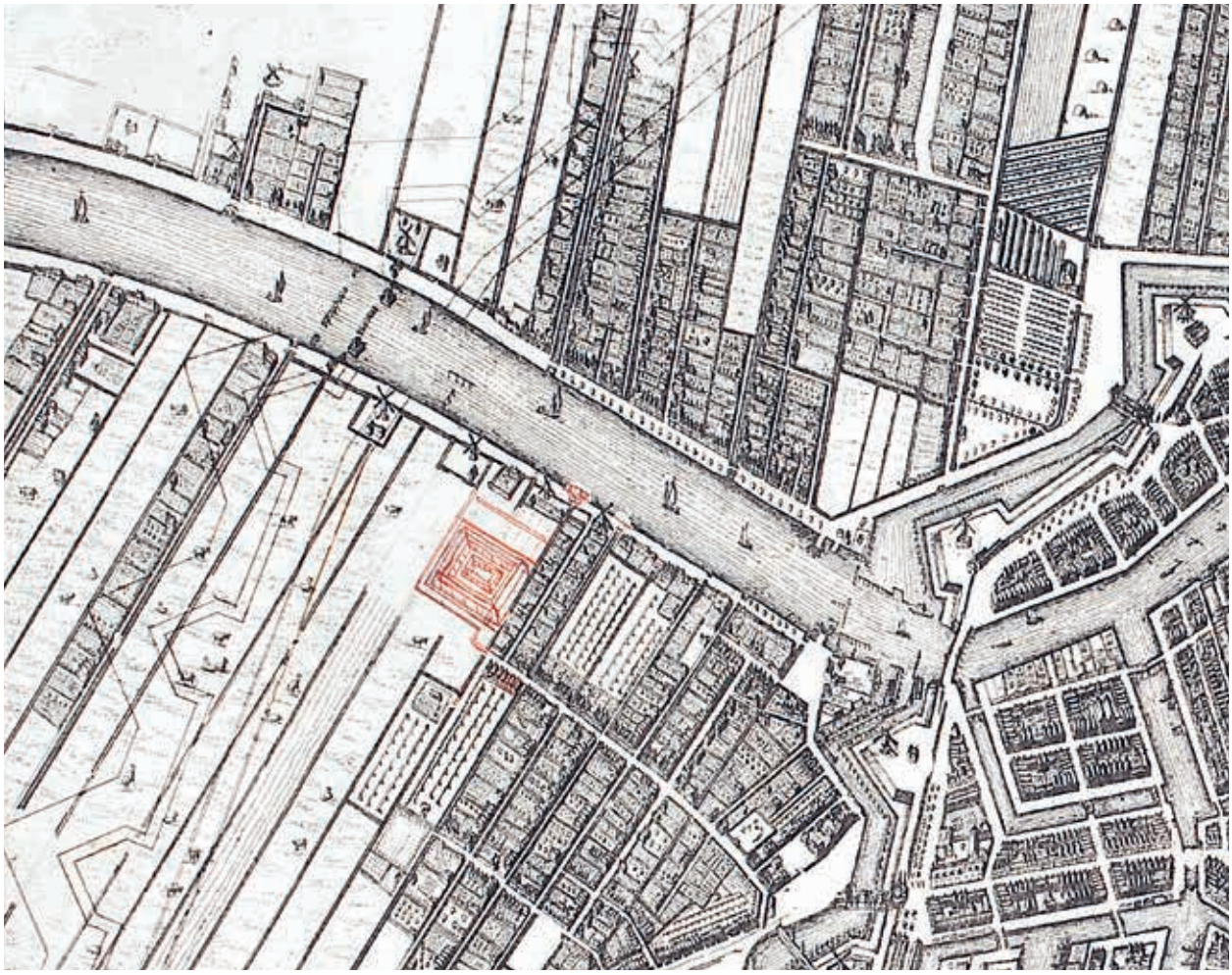
Witsen believed that the trees he had seen in the soil, whether horizontal or erect, indicated that the land had once been uninhabited and wooded. The presence of forests had, as he noted, triggered or at least contributed to the formation of peat: 'the wood has helped create the peat to a great extent'.

MODERN INTERPRETATION

Witsen's description of the subterranean forest seems unlikely, but it is not. In the Vecht basin, heavy oak trunks, up to six metres long and usually with parts of the root system attached, have been and continue to be regularly dug out of the peat bog. In the past they were used as timber, firewood or for dam reinforcement.[59] These were individual trees, but recently well-documented observations of primeval forests have also been made. When new ditches were dug during the construction of the Diemerbos in 1997, trunks of more than seventy ancient oaks were found.[60] They were dated by means of tree-ring analysis and turned out to have grown between 1200 BC and 300 AD. The oaks grew together with willows, alders and ashes in a peat bog forest. During archaeological research at Abcoude in 2009, part of a primeval forest was excavated. The remains consisted of roots and trunks of a variety of trees – mainly alders but also some oaks, birches and elms – standing upright in the soil, that were part of an alder bog forest.[61] This forest had undergone an evolution: from 230-110 BC it was an open alder forest, after 110 BC it developed into a closed alder forest. Tree-ring analysis dates the end of tree growth very precisely to 137 AD, when the Angstel river deposited 1.5 metres of sediment in a short space of time, causing the trees to die.

The trees at Abcoude were not blown down; the trees in the other two areas were. The trees in Witsen's subterranean forest were lying in a south-westerly direction, with the smaller trees still standing, while most of the trees in Diemen were lying in a north-easterly direction. Both forests must have been knocked down in a big storm; in the Abcoude forest it came from the

15. A fortification plan for Amsterdam from 1652. The new municipal carpenters' yard on the Amstel river has been drawn in red. The 'block houses' in the river Amstel are visible next to the projected fortification (Leiden University Library, Bodel Nijenhuis Collection)



16. The Muidertrekvaart barge canal, dug in 1640, between the Watergraafsmeer polder and the western city wall of Muiden. Detail from the map of Amstelland by Daniel Stopendaal, c. 1750 (University of Amsterdam, Special Collections)

southwest and in the Witsen forest from the northeast, where the already dying trees offered little resistance.

The primeval forest described by Witsen can indeed be found in Amstelland and its immediate surroundings and, like the forests excavated in our own time, probably dates from the Iron Age (800-12 BC). They ceased growing somewhere in Roman times (12 BC-450 AD).

THE DISCOVERY OF A DUGOUT CANOE

Archaeological finds in the Golden Age were, as now, made during the construction of infrastructural works. In his manuscript Witsen not only describes his own observations, but also incorporates earlier observations made by others, including a find that had taken place during the digging of the barge canal to Muiden, the 'Muidertrekvaart' (fig. 16), probably in 1640.[62] In June 1639, the town councils of Muiden and Naarden had proposed constructing a canal link from Amsterdam via Muiden to Naarden.[63] Planning commenced in 1640.[64] In October of that year the necessary permission was obtained from the States of Holland.[65] During the digging of the canal, at a depth of 'several feet', a small boat ('schuijtje') was found, made of a hollowed-out tree trunk.[66] The boat was suitable for two or three persons; holes had been made in the sides, which Witsen thought would have accommodated two pairs of oars. Witsen does not mention an exact location for the find, but it must have been excavated somewhere between the Watergraafsmeer polder and the town of Muiden. The boat has not been preserved.

WITSEN ON THE FIND

Witsen compared this find with the boats built by the Indians in New Netherland, the colony on the east coast of America, which the Dutch had first settled in 1621. There were all kinds of prints and maps in circulation showing Indian canoes. Indeed, Witsen himself later owned a large collection of maps, some of which featured pictures of such boats (fig. 17).[67] Witsen's collection also contained fifteen exotic ships.[68] Because of the finding of the dugout canoe near Amsterdam Witsen had come to realize that his ancestors were just as backward as the Indians from New Netherland: 'it turns out that our ancestors were not always as smart as we are now', Witsen stated.[69] This remark shows that Witsen, unlike many of his contemporaries, did not see history as a reflection of the great deeds of his ancestors. He seems to have recognized that human beings evolve over time; notwithstanding their great deeds in the recent past, his ancestors were not inherently superior to primitive peoples.

MODERN INTERPRETATION

Archaeological dugout canoes are not in fact rare in the Netherlands. An overview from 2008 shows that 42 of these boats have been found in the Netherlands.[70] The oldest one comes from Pesse and is about 9700 years old. Dugout canoes were used until the Middle Ages. Two more dugout canoes were found near the boat mentioned by Witsen: one in Nigtevecht (found in 1987) and another in Muiden (found in 2015). Both date from the Iron Age (800-12 BC). A little further away, at Uitgeest in the Oer-IJ region, a dugout canoe from the Iron Age was found in 2003 during the construction of a railway tunnel.

It is not possible to date the boat Witsen mentions from his description, but the area of the Vecht and Angstel was only inhabited from the early Iron Age (800-500 BC) and given the discovery of two other Iron Age canoes in the area, it is quite possible that the canoe described by Witsen also dates from the Iron Age.[71] The 'holes for two pairs of oars' ('roigaten voor twee paer riemen') described by Witsen did not function as oarlocks, rather, as in the canoe excavated in Vlaardingen in 2005 (fig. 18), they were used to pull the canoe ashore with a stick or a rope (fig. 19). Such holes are common in dugout canoes.[72] Witsen's is the first description of a dugout canoe discovery in the Nether-

lands. According to the 2008 overview of dugout canoe discoveries, the next description dates from 1870, some 200 years later.[73]

PHILOLOGY AND EMPIRICISM

According to most historical overviews, the development of modern geology began in the eighteenth century, influenced by industrialization and the accompanying acceleration of mining. The foundations of geology as a science, and of its historiography, were laid in the nineteenth century.[74] Some overviews do not pay any attention to the preceding period.[75] However, modern scientific-historical surveys of geology, such as that of Ellenberger, pay ample attention to the rapid development of geological insights during the Scientific Revolution of the seventeenth century.[76]

In a time when the Bible and classical texts were the starting point for research into almost anything, Witsen's manuscript bears witness to a critical mind and a strictly scientific methodology. Witsen combines philology with empiricism – attaching significantly more importance to the latter.

Witsen lived in a culture in which the authority of the Scriptures was starting to questioned, although there was no general tendency towards secularization.[77] It was generally assumed that the earth had remained unchanged since its creation. Irish bishop James Ussher had calculated in 1650 that the earth was created on 26 October, 4004 BC, to be precise, at nine o'clock in the morning.[78] This idea was widely accepted.

In the seventeenth century, the question of the Deluge – at what point in time it had occurred and what, if

17. Map of New Netherland by Allard Ottens, with a number of dugout canoes in the lower right corner (Library Vrije Universiteit, Amsterdam)

18. Excavation of a dugout canoe in Vlaardingen in 2005. The canoe is a little over ten metres long and dates from around 683 BC (City of Vlaardingen, Archaeological Collection)

19. Detail of the dugout canoe found in Vlaardingen, showing that two rectangular holes have been cut out on both sides near the front. These probably served to pull the canoe using a stick or rope. Many canoes with such holes have been found (C. Vermeeren/ BIAX Consult)

any, effect it had had – was central to the investigation of geological phenomena. In his manuscript, the youthful Witsen explicitly states that he is not interested in this specific problem: 'Except for wiser people's judgment, it seems to me that it is clear, that the deepest layer has been the bottom of a sea, as is shown by the shells we find there, whether this was the case before the Deluge, or after, I don't care'.[79] Witsen did not even attempt to test his observations against the Scriptures. He made his own observations and the conclusions he drew from them were more important to him than any attempt to make the observed stratigraphy fit the story of the Deluge.

Scientific historian Eric Jorink describes the *Natuer van de gront* as the starting point of Witsen's presumed 'fixation with the story of Fall, the Deluge and Babel'.[80] It seems that Jorink applies Witsen's later views retroactively to his early work: in fact, the *Natuer* shows the opposite. It may be that Witsen in later life tried to relate the interpretation of natural history objects to the text of the Bible, but the young Witsen was clearly not interested in conforming to the traditional exegesis.

WITSEN AND THE LAWS OF STENO

A comparison between the stratigraphy observed by Witsen and the borehole of 1605 reveals a discrepancy in the thickness of the various layers. Witsen offers two explanations for this: it may be that the borehole of 1605 showed an exceptional situation, while he himself had made a more general analysis of the soil profile. However, the dynamics he had observed in the soil structure may also have been the cause of the discrepancy. In Witsen's words: it could be that 'one [layer] has shifted over another, in such a movement as I described, which has caused such a change'.[81]

20. Portrait of Nicolaus Steno (1638-1686); copy of a portrait painted between 1666 and 1677 by Justus Sustermans as part of a series of portraits of eminent men at the court of Ferdinand II and Cosimo III de' Medici (Copenhagen University)

21. Title page of Nicolaus Steno's *Prodromus* from 1669, dedicated to Ferdinand II de' Medici (1610-1670), Grand Duke of Tuscany

Witsen's conclusion was implicitly based on his perception of the close relationship between archaeology and geology. This sometimes seems to have been forgotten nowadays, but it is especially relevant to the complex stratigraphy of the Dutch delta. Of greater importance, however, are the soil dynamics as observed by Witsen. His manuscript is the first known example of the earth viewed as a dynamic system. This idea lies at the basis of modern geology, which tries to derive the age of soil layers from their stratigraphy. The basics of stratigraphy were first formulated by the brilliant Dane Niels Stensen, alias Nicolaus Steno (1638-1686) (fig. 20), in his thesis *De solido intra solidum naturaliter contento – Dissertationis prodromus*, published in 1669 and generally known simply as *Prodromus* (fig. 21).[82] Witsen owned no fewer than three copies.[83] Until recently it was assumed that Steno was the first person to discuss the relative age of soil layers in a publication. The basic principles of stratigraphy are known as the Laws of Steno.[84] The first law states that soil layers are arranged in such a way that the oldest lies at the bottom, and the youngest at the top (Law of Superposition). The second is the principle of original horizontality; it states that layers are always deposited horizontally; if layers are not horizontal, there is a later cause for this. The third law is the principle of lateral continuity: layers always continue in the original situation, even if they are separated at a later stage by, say, a river. Steno's last law, the principle of cross-cutting relationships, states that at the time when any given stratum was being formed, all the matter resting upon it was fluid and, therefore, at the time when the lowest stratum was being formed, none of the upper strata existed.

Witsen's manuscript reflects the application of these principles. Witsen describes how layers were superimposed: the lower layers were the oldest (and possibly very old), the upper layers were very recent, because they were laid down in the context of construction projects or urban expansion. Witsen also noticed that changes had occurred in underlying layers due to natural causes or human intervention; he mentions as examples the mixing of peat, clay and sand in the upper layer, and the subsidence of the land as a result of building activity. Witsen also describes the earth as a dynamic system – with the 'drifting peatlands' as an example.

Steno was a university friend of Witsen's.[85] From March 1660 Steno spent a number of years in the Dutch Republic, the first few months with Gerardus Blasius, an anatomist and professor of medicine in Amsterdam, then at Leiden University.[86] Anatomy was Steno's main interest, but during his stay in Amsterdam and Leiden he also studied geology, or the 'anatomy of the earth'.[87] In the summers of 1661, 1662 and 1663 Steno

travelled extensively in the Low Countries, studying the interaction between land, sea and rivers.[88] He was accompanied by a group of friends with a variety of scientific interests; this group was led by the Danish scientist Ole Borch, one of Steno's teachers.[89] There are no indications that Witsen went along on those trips, but he certainly met the company. The group spent a week in Amsterdam from 27 July to 3 August 1661, due to the illness of two of the participants.[90] On 28 July 1662, Witsen showed Steno, Borch and his friends around the new town hall, the Prinsenhof (Admiralty House), and the Diaconie Orphanage on the bank of the Amstel.[91]

The origins of Steno's interest in geology remain unclear, but it seems likely that his contacts with Witsen contributed to his formulation of the 'laws' of stratigraphy. Witsen describes how layers of sand, peat and clay were deposited over time and were influenced by each other and by human intervention. The basic principles of modern stratigraphy, as described in the *Prodromus*, can be found in Witsen's manuscript and the versions published later by Dapper and Van Domselaer. Thus Witsen's manuscript can lay claim to being the first written account of these principles, which must have arisen from the exchange of ideas between Witsen and Steno.

It is not surprising that these insights emerged in Amsterdam: on the one hand, Amsterdam was developing into a scientific centre of great importance in the seventeenth century, and on the other hand, it was located in the peatlands in the western part of the Low Countries. Urban expansions, major construction projects and hydraulic engineering works led to large-scale interventions in the subsurface. Knowledge of stratigraphy, peat formation and landscape development was greater than we realize in the Golden Age. The rise of an internationally oriented and scholarly urban elite meant that this practical knowledge was part of a much broader body of knowledge: the Scientific Revolution of the seventeenth century.

NOTES

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1 M. Peters, *De wijze koopman. Het wereldwijde onderzoek van Nicolaes Witsen (1641-1717), burgemeester en VOC-bewindhebber van Amsterdam*, Amsterdam 2010. The title of the book refers to the ideal of the *Mercator Sapiens* or 'learned merchant', as described by Casparus Barlaeus in 1632.

2 Peters 2010 (note 1), 9-23.

3 Peters 2010 (note 1), 32. In Gebhard's biography of over a thousand pages, the work is not mentioned: J.F. Gebhard, *Het leven van Mr. Nicolaas Cornelisz Witsen (1641-1717)*, Utrecht 1881.

4 Stadsarchief Amsterdam (Amsterdam City Archives; SAA), 5059, Handschriften, inv. no. 173, 'Natuer van de gront rontsom Amsterdam, door mij in de jeugt opgestelt' (undated). From now on, this will be referred to as the 'Witsen Manuscript', in which the folios are numbered. A scan and a transcription of the manuscript can be found at: https://cultureelerfgoed.academia.edu/JaapEvertAbrahamse.

5 Peters 2010 (note 1), 19-22.

6 Gebhard 1881 (note 3), 24.

7 SAA, 5025, Archief van de Vroedschap: resoluties met munimenten de bijlagen, inv. no. 19 (Resoluties, 12 January 1649-29 August 1652), fol. 150vo (9 May 1651). The dike had broken through in two places, exactly where it had been pierced the year before, when the land behind it had been deliberately inundated to repulse an attack on Amsterdam by Stadholder William II: A. Fransen, *Een kleine dijk met een groot doel. De financiering van de Diemerdijk, 1591-1864*, PhD thesis, Vrije Universiteit Amsterdam, 2009, 61, 69.

8 Fransen 2009 (note 7), 129. For the planning and execution of the flood barrier project and the prominent role played by Nicolaas Witsen, see: J.E. Abrahamse, *De grote uitleg van Amsterdam. Stadsontwikkeling in de zeventiende eeuw*, Bussum 2010, 327-330. An English version will be published in 2019: J.E. Abrahamse, *Making of a Metropolis. A Planning History of Amsterdam in the Dutch Golden Age* (in press).

9 Peters 2010 (note 1), 331-332. According to the acknowledgement in the book, Dapper also used documents provided by Cornelis Witsen for his city description.

10 O. Dapper, *Historische beschryving der stadt Amsterdam* (vol. I), Amsterdam 1663, 25-27.

11 T. van Domselaer, *Beschryvinge van Amsterdam* (vol. III), Amsterdam 1665, 174-176.

12 Witsen Manuscript (note 4), fol. [9].

13 N. Witsen, *Noord en Oost Tartarye*, Amsterdam 1705, 742-743. Witsen probably used the term 'zeehoorntje' ('sea horn') to refer to the *Bittium reticulatum*.

14 'Cum Amstelodami aliquando ad puteum faciendum effoderetur terra usque ad ducentorum & triginita duorum pedum profunditatem': Bernhardus Varenius, *Geographia Generalis, in qua affectiones generales Telluris explicantur* (vol. II, chapter VII, propositio VII), Cambridge 1672, 46.

15 'la terrière, qui estoit pointue en bas et, à un démi-cercle de fer couppant, avoit une petite rets, qui à chaque tour recevoit la matière couppée, laquelle se tiroit en haut par de si petites quantités': R. Rasch, *Duizend brieven over muziek van, aan en rond Constantijn Huygens*, Constantijn Huygens (The Hague) to Marin Mersenne (Paris) 1 April 1640, no. 2335, www.let.uu.nl/~Rudolf.Rasch/personal/Huygens-Brieven/BR2335.pdf (3 December 2018).

16 Ente lived at the Huis ter Hart in Halfweg, halfway between the cities of Amsterdam and Haarlem: P. Harting, *De bodem onder Amsterdam onderzocht en beschreven*, Amsterdam 1852, 5-6. Since the sixteenth century, the Rijnland Water Board has had its most important drainage point there. The lock complex at Halfweg was a crucial element of the flood defences along the IJ. To be able to act quickly in the event of calamities, Rijnland built a workshop and 'dike storehouse' there, which was later incorporated into the large 'Gemeenlandshuis', the new headquarters of the Water Board: J.E. Abrahamse, M. Kosian and E. Schmitz, *Tussen Haarlemmerpoort en Halfweg. Historische atlas van de Brettenzone in Amsterdam*, Bussum 2010, 20-21, 30-31. That is why Harting states that Ente must have worked for the Water Board.

17 G. Doorman, *Octrooien voor uitvindingen in de Nederlanden uit de 16e-18e eeuw. Met bespreking van enkele onderwerpen*

uit de geschiedenis der techniek, The Hague 1940, 107-108. See also: C. van den Heuvel, '"As the author intended". Transformations of the Unpublished Writings and Drawings of Simon Stevin (1548-1620)', in: S. Fransen, N. Hodson and K.A.E. Enenkel (eds.), *Translating Early Modern Science*, Leiden 2017, 119-153.

18 J. Gawronski and P. Kranendonk, *Stuff. Catalogue of Archaeological Finds from Amsterdam's North/South Metro Line*, Amsterdam 2018, 199.

19 Rasch 1640 (note 15), (24 August 2018).

20 J.H.A. Bosch, F.S. Busschers and H.J.T. Weerts, 'Eem Formatie', *Lithostratigrafische Nomenclator van de Ondiepe Ondergrond*, 2003: www.dinoloket.nl/eem-formatie (21 November 2018).

21 J. Veerkamp, *Mammoeten in Amsterdam. Een archeologische verkenning langs de Noord/Zuidlijn*, Amsterdam 1998, 10.

22 In any case, it is clear that Witsen had bores drilled: one well filled with water 'after the third or fourth spit', according to Witsen, and then a shoring had to be laid to keep an excavation dry.

23 Witsen Manuscript (note 4), fol. [2].

24 Peters 2010 (note 1), 30.

25 With regard to the landscape, see: E. Schmitz, 'Het landschap van Rembrandt. Het gebied rondom Amsterdam in het midden van de zeventiende eeuw', in: B. Bakker et al. (eds.) *Het landschap van Rembrandt. Wandelingen in en om Amsterdam*, Bussum/Amsterdam/Paris 1998, 42-68.

26 The term 'spit' denoting a layer of earth whose depth is equal to the length of the blade of a spade, is not used in modern Dutch. The clay layer would have been between 2.5 and 6 metres thick.

27 Witsen Manuscript (note 4), fol. [1].

28 Witsen Manuscript (note 4), fol. [2].

29 Artificial layers are called 'aenhoogsel' by Witsen: Witsen Manuscript (note 4), fol. [2].

30 'alle opdriften ten sijnen laste te nemen': Witsen Manuscript (note 4), fol. [4].

31 Kattenburg is mentioned in the council resolutions of 1651: SAA, 5025, Archief van de Vroedschap: resoluties met munimenten of bijlagen, inv. no. 19 (Resoluties, 12 January 1649-29 August 1652), fol. 177 (1 September 1651). The Nieuwe Vaart was constructed in that same year: Abrahamse 2010 (note 8), 325-326.

32 Witsen Manuscript (note 4), fol. [5].

33 'doorsaegde dese solder en voerde se met stucken gelijk vlotten weg, waer men se hebben wilde, want het water te loosen was niet doenlijk, welk doorsagen of snijden dus toegaet: sij nemen een tou dat se vol knoopen leggen, en weten dat door de gront te krijgen in 't water en op de andere sijde van 't lant weer uijt, dan treckende, schijde sij he lant van den ander. Op dese wijs saegt men hier in Hollant op veele plaetsen heele rietlanden eenige voeten dick af, die de boeren dan te koop voeren, daer men hier en daer voorlant gebreck heeft': Witsen Manuscript (note 4), fol. [5].

34 W. Wolters, *Historisch-geografische aspecten van het hoogheemraadschap der Waterlandse meren op grond van enige historische bronnen in de periode 1623-1855*, master's thesis GU, Amsterdam 1965, cited in: C. de Bont, 'Verstofte kaden. De historisch-geografische inbreng in de discussie over de veiligheid van veenkaden in Nederland', in: J.J.M. Beenhakker et al. (eds.), *Landschap in ruimte en tijd*, Amsterdam 2007, 56-65, here: 56

35 Witsen Manuscript (note 4), fol. [6].

36 A.G. Jongkees, *Het Groot Privilegie van Holland en Zeeland (14 maart 1477)*, Heule/Kortrijk 1985, 229.

37 'welk de scelpen en hoorne ook uijtwijsen die nergens als aen zee grojen': Witsen Manuscript (note 4), fol. [6].

38 'Behoudens wijser lieden haer oordeel, dunkt mij dat het klaer is, dat het alderonderste het lant van de bodem van een zee geweest is, 't sij voor de sontvloet, of na, dat raekt mij niet', Witsen Manuscript (note 4), fol. [6-7].

39 'En waerom dan tegengesprooken, dat hier dese dari-solder soude komen drijven sijn': Witsen Manuscript (note 4), fol. [8].

40 'Men sag, dat nog in mensen gedagten is, omtrent Embden, heele huijsen en erven met mensen en vee daerop, drijven': Witsen Manuscript (note 4), fol. [8].

41 H.P.H. Jansen and A. Janse (eds.), *Kroniek van het klooster Bloemhof te Wittewierum*, Hilversum 1991, 469, 471.

42 'Per triduum enim aque de profundo abissi exagitate ibant et intumescebant, et omnia circa maritima flumina alveos suos pre inundatione excedentes, multas insulas cum hominibus et iumentis villis domibus edificiis substantiis ecclesiis et, quod dictu mirum, agris et domorum areis et cimiteriis cum soliditate alias transpositis, miserabiliter suffocaverunt': G.H. Pertz, *Monumenta Germaniae Historica inde ab anno Christi quingentesimo usque ad annum millesimum et quingentesimum* (vol. XVI), Hanover 1859, 92-93.

43 P.C. Vos and E. Knol, 'Ontstaansgeschiedenis van het Dollardlandschap. Natuurlijke en antropogene processen', K. Essink (ed.), *Stormvloed 1509. Geschiedenis van de Dollard*, Groningen 2013, 31-43; P.C. Vos and E. Knol, 'Holocene landscape reconstruction of the Wadden Sea area between Marsdiep and Weser', *Netherlands Journal of Geosciences* 94 (2015), no. 2, 157-183.

44 O. Knottnerus, 'Dollardgeschiedenis(sen). Mythe en realiteit', in: K. Essink (ed.), *Stormvloed 1509, Geschiedenis van de Dollard*, Groningen 2013, 95-116.

45 H.J. Pierik et al., 'Late Holocene coastal-plain evolution of the Netherlands – the role of natural preconditions in human-induced sea ingressions', *Proceedings of the Geologists' Association* 128 (2017), no. 2, 180-197.

46 Pierik et al. 2017 (note 45); O. Brinkkemper et al., *Cultuur, Mens en Natuur in de Mieden* (vol. 1. Biografie van de Mieden. Landschapsgeschiedenis van de miedengebieden bij Buitenpost, Surhuizum en Zwaagwesteinde [Noordoost-Friesland]), Amersfoort/Leeuwarden/Veenwouden 2006, 41.

47 Pierik et al. 2017 (note 45), 189-190.

48 'die sulke aendrift van hout, aerde en biese lochent, sende ik tot de journaels van de geene die bij Nova Zembla, na Oost Indiën sogten te vaeren, dewelke daer aendrijvende boomen en balcken tot haer gebruick verorberde': Witsen Manuscript (note 4), fol. [8].

49 'om voor de coude ende wilde beesten beschermt te zijn': G. de Veer, *Waerachtige beschryvinghe van drie seylagien, ter werelt nog noyt soo vreemt ghehoort*, Amsterdam 1598, fol. 24r: www.dbnl.org/tekst/origineel.php?origineel=veer-013waer01_01_scan0062 (6 December 2018).

50 'en men hoeft niet ver te loopen om imant aen te wijsen, dat dese verandering mogelijk is, hij besie het Lijtse-mallegat, daer den Rijn uijtgeloopen, en veel hooger als de zee geweest is, daer se nu met het leegste water nog twee duijm hooger als het zeewater is': Witsen Manuscript (note 4), fol. [8].

51 We know that this is caused by the relative rise in sea level, but Witsen did not. S.J.H. Fockema Andreae, *Het hoogheemraadschap van Rijnland. Zijn recht en bestuur van den vroegsten tijd tot 1857*, PhD thesis, Leiden University, 1934, 150; J.E.A. Boomgaard, 'De eerste doorgraving van de duinen bij Katwijk. De aanleg van duikers en plannen voor een uitwateringssluis in de periode 1404-1629', in: *De uitwateringssluizen van Katwijk 1404-1984* (Hollandse Studiën 13), Leiden 1984, 9-17; G. van de Ven, 'Rijnland en Woerden', *Tijdschrift voor Waterstaatsgeschiedenis* 12 (2003), 59-68; G. van de Ven, *Man-made Lowlands, History of Water Management and Land Reclamation in the Netherlands*, Utrecht 2003, 204.

52 'Binnensdijcks volgt de gemeene dari, dit oordeel ik is een vermenginge van veenen, sant of andere aert, daer onse landen steets mede gehoogt worden': Witsen Manuscript (note 4), fol. [9].

53 J.E. Abrahamse et al., 'Until AD1000 – On the edge of the world', in: J.E. Abrahamse, M. Kosian and E. Schmitz (eds.), *Atlas of Amstelland. The biography of a landscape*, Bussum 2012, 11-18.

54 'Aen weersijde van den Amstel, 60 roeden, en dat al heel verbij Ouderkerk heen, na 5 a 6 voet gravens in 't veen, vint men en [sic] gants onder-aerts-bos van boomen, waer van de groote en dicke stammen al na den zuijtwesten omgeslagen sijn, en de kleijndere staen overent': Witsen Manuscript (note 4), fol. [3].

55 An Amsterdam rod had a length of 3.677 metres, or 13 Amsterdam feet.

56 SAA, 5025, Archief van de Vroedschap: resoluties met munimenten of bijlagen, inv. no. 19 (Resoluties, 12 January 1649-29 August 1652), fol. 139-139vo (1 March 1651). For the construction of the carpenter's yard, see: Abrahamse 2010 (note

8), 138-139; G. van Essen, 'De eerste fase (1650-1662) van de Vierde Vergroting van Amsterdam herbezien', *Jaarboek Amstelodamum* 94 (2002), 90-109; G. van Essen, *Het stadsfabriekambt. De organisatie van de publieke werken in de Noordelijke Nederlanden in de zeventiende eeuw*, PhD thesis, Utrecht 2011, 237-238. For the construction of the block houses, see: Abrahamse 2010 (note 8), 122-124.

57 SAA, 5025, Archief van de Vroedschap: resoluties met munimenten of bijlagen, inv. no. 19 (Resoluties, 12 January 1649-29 August 1652), fol. 136 (4 February 1651).

58 Gebhard 1881 (note 3), 22-24; Peters 2010 (note 1), 31.

59 L.H. van Wijngaarden-Bakker, 'De voorgeschiedenis van Baambrugge en Abcoude', in: D.G. Carasso and M. Carasso-Kok (eds.), *Abcoude en Baambrugge 900 jaar. Uit de historie van twee dorpen*, Abcoude 1985, 10-17. See also: L. Smids, *Schatkamer der Nederlandsse oudheden*, Amsterdam 1711, 39-40: 'Ontrent Abkoude en Ouwerkerk, by Woerden en Oudewater, te Kamerik en in de Loosdrecht; ja selv ook in de zee (ik spreek nu van geen landschappen, buiten Holland) ontrent de stranden, worden somwylen opgedolven en uitgegraven stammen van boomen, alle swart en hard; schoon hout om te timmeren en daaken te leggen.'

60 B. van Geel, E. Jansma and H. van der Plicht, 'Het oerbos van Diemen en de gevolgen van verminderde zonne-activiteit rond 850 voor Chr.', in: H. Blok et al. (eds.), *Diemen in het land van Amstel*, Amsterdam 2009, 338-350.

61 N. Bouma, 'De ontdekking van een begraven oerbos', in: N. Bouma (ed.), *Van begraven oerbos tot vroegste middeleeuwse ontginning en bewoning. Een archeologische opgraving in de Winkelbuurt in Abcoude Zuid* (ADC-report 2400), Amersfoort 2011, 137-161.

62 N. Brand and J. Luiten van Zanden, 'Infrastructuur in een stedenlandschap. Holland 1200-1850', *Tijdschrift voor sociale en economische geschiedenis* 10 (2013), nos. 3, 3-32, here: 17, 31; K. Zweerink, *Ruimtelijke transformaties van de steden in het Randstadgebied (12de-20ste eeuw). Een vergelijkende analyse van de stadsplattegronden*, PhD thesis, Delft University of Technology, 2017, 90.

63 SAA, 5025, Archief van de Vroedschap: resoluties met munimenten of bijlagen, inv. no. 16 (Resoluties, 6 June 1633-22 July 1639), fol. 250 (11 June 1639).

64 SAA, 5025, Archief van de Vroedschap: resoluties met munimenten of bijlagen, inv. no. 17 (Resoluties, 26 July 1639-2 February 1644), fol. 35vo (22 August 1640).

65 SAA, 5055, Charters afkomstig uit de secretarie, inv. no. 300, Octrooi van de Staten van Holland voor de regeringen van Amsterdam, Muiden en Naarden, tot het maken van een vaart met trekpad en wagenweg tussen deze steden (25 October 1640).

66 'In 't graven van de Muijervaert heeft men een schuijtje gevonden eenige voeten diep in 't veen, geholt uijt een boom, bequaem voor 2 à 3 menschen, de roigaten voor twee paer riemen waeren nog blijckelijk': Witsen Manuscript (note 4), fol. [3-4].

67 Peters 2010 (note 1), 379-381.

68 Peters 2010 (note 1), 385-388, 456-457.

69 ''t blijkt dan klaer, dat onse voorouders altijt soo politieck niet geweest sijn als nu': Witsen Manuscript (note 4), fol. [4].

70 T.J. Maarleveld and R. Oosting, 'Schematisch overzicht van boomstamboten in Nederland', in: R. Oosting and J. van den Akker (eds.), *Boomstamkano's, overnaadse schepen en tuigage. Inleidingen gehouden tijdens het tiende Glavimans Symposion, Lelystad, 20 april 2006* (bijlage), Amersfoort 2008.

71 The canoe cannot be older than the Iron Age. Excavations for the construction of the Muidertrekvaart were no deeper than two to three metres below the surface. The canals in Amsterdam were about eight feet (approx. 2.25 metres) deep. The canal, which was only accessible to ferrymen with their flat-bottomed boats, was certainly not deeper than eight feet. The canoe as described by Witsen was therefore no deeper than two to three metres below the surface. Late Neolithic remains were found during the construction of the North/South metro line at c. 12 metres below NAP: P. Kranendonk, S.J. Kluiving and S.R. Troelstra, 'Chrono- and archaeostratigraphy and development of the River Amstel: results of the North/South underground line excavations, Amsterdam, the Netherlands', *Netherlands Journal of Geosciences* 94 (2015), 333-352, here: 340. Even if subsidence of the soil is taken into account, the Neolithic level would not have been reached when digging the canal. Furthermore, there are no indications of habitation or use of the Vecht-Angstel area from the Bronze Age or the Neolithic period: I.J. Bos, H. Feiken, F. Bunnik and J. Schokker, 'Influence of organics and clastic lake fills on distributary channel processes in the distal Rhine-Meuse delta (The Netherlands)', *Palaeogeography, Palaeoclimatology, Palaeoecology* 284 (2009), 335-374.

72 C. Vermeeren and Y. Vorst, *Onderzoek naar de bewerkings- en gebruikssporen van de IJzertijd kano uit Vlaardingen Vergulde-Hand West*, Zaandam 2007, 3 and fig. 15.

73 Maarleveld and Oosting 2008 (note 70), 12-13.

74 The first historical overviews of geology were published around 1900. See for example H.B. Woodward, *History of Geology*, New York 1911 (facsimile New York 1978); A. Geikie, *The Founders of Geology*, London 1897; K.A. von Zittel, *Geschichte der Geologie und Paläontologie bis Ende des 19. Jahrhunderts*, Munich/Leipzig 1899.

75 K.D. O'Hara, *A Brief History of Geology*, Cambridge 2018, 1-27.

76 F. Ellenberger, *Histoire de la géologie* (vol. 1), Paris 1988, 213-315.

77 E. Jorink, *Het Boeck der Natuere. Nederlandse geleerden en de wonderen van Gods Schepping, 1575-1715*, PhD thesis, Groningen University, 2005, 265-266.

78 This calculation can be found in: J. Ussher, *Annales Veteris Testamenti, a prima mundi origine deducti, una cum rerum Asiaticarum et Aegyptiacarum chronico, a temporis historici principio usque ad Maccabaicorum initia producto*, London 1650.

79 'Behoudens wijser lieden haer oordeel, dunkt mij dat het klaer is, dat het alderonderste het lant van de bodem van een zee geweest is, 't sij voor de sontvloet, of na, dat raekt mij niet, 't welk de scelpen en hoorne ook uijtwijsen die nergens als aen zee grojen': Witsen Manuscript (note 4), fol. [6-7].

80 'fixatie op het verhaal van Zondeval, Zondvloed en Babel': Jorink 2005 (note 77), 263-268.

81 'het eene over het ander gescoten heeft in sulke d[r]ifte als ik gemelt hebbe, en soodanige verandering veroorsaekt heeft': Witsen Manuscript (note 4), fol. [9].

82 For a translation, see: T. Kardel and P. Marquet (eds.), *Nicolaus Steno. Biography and Original Papers of a 17th Century Scientist*, Heidelberg etc. 2013, 634-636.

83 Peters 2010 (note 1), 352.

84 J.G. Winter, *The prodromus of Nicolaus Steno's dissertation concerning a solid body enclosed by process of nature within a solid. An English version with an introduction and explanatory notes* (Contributions to the history of science, vol. XI), New York 1916, 175-189.

85 Witsen and Steno studied together in Leiden; their friendship was maintained for many years: Peters 2010 (note 1), 35, 49-50. The publication of Steno's dissertation (N. Steno, *De solido intra solidum naturaliter contento. Dissertationis prodromus*, Florence 1669) led to a conflict with the Church. Steno was ordered to accept Ussher's view of the dating of the earth, which he did. Steno even became a bishop and was canonized in 1988. Steno continued to follow Witsen's work: in 1671 a visitor found him engaged in reading Witsen's *Architectura Navalis*: G. Scherz, *Nicolai Stenonis epistolae et epistolae ad eum datae* (vol. I), Freiburg 1952, 29.

86 J.G. Vugs, 'Steno in Amsterdam', *Janus. Revue internationale de l'histoire des sciences, de la pharmacie, de la technique* 57 (1970) 163-172; G. Scherz, *Pionier der Wissenschaft. Niels Stensen in seinen Geschriften*, Copenhagen 1963, 17-21.

87 Vugs 1970 (note 86).

88 Scherz 1963 (note 86), 17-21.

89 Kardel and Marquet 2013 (note 82), 76-80, 96-102.

90 Kardel and Marquet 2013 (note 82), 78-79.

91 H.D. Schepelern (ed.), *Olai Borrichii Itinerarium, 1660-1665. The journal of the Danish polyhistor Ole Borch* (vol. II [October 1661-May 1663]), Copenhagen/London 1983, 169.

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DRIFTING PEATLANDS AND SUBTERRANEAN FORESTS

NICOLAAS WITSEN, THE LANDSCAPE AROUND AMSTERDAM AND THE BASIC PRINCIPLES OF MODERN GEOLOGY

JAAP EVERT ABRAHAMSE AND HENDRIK FEIKEN

Nicolaas Witsen (1641-1717) was not just a prominent administrator and diplomat, but also something of a polymath. He delved into geography, cartography, nav-igation and shipbuilding, as well as ethnography, phi-lology, history, botany, zoology and astronomy. Apart from scientific curiosity, his choice of subjects was in-fluenced by the interests of Amsterdam, of which he was lord mayor on several occasions: thus he took an interest in the expansion of trade, ship building tech-nology and hydraulic engineering works. This article discusses a manuscript by Witsen that we date to the second half of the 1650s: Natuer van de gront rontsom Amsterdam, door mij in de jeugt opgestelt (Na-ture of the ground around Amsterdam, penned by me in my youth). The manuscript consists of a series of de-tailed notes of his own observations, supplemented by ideas and observations at second hand. We discuss the themes Witsen touches on in a set order: firstly Wits-en's observations, then his own interpretation, and fi-nally the modern interpretation of what Witsen ob-served.Witsen described the soil structure in and around Amsterdam, both outside and inside the dikes, proba-bly based on drilling data. He described the stratigra-phy systematically, from bottom to top. He then tried to explain the variations in the soil structure, using not just his own observations, but also data from deeper drillings, such as the famous one carried out by Pieter Ente in 1605, which reached a depth of 73 metres. From this he deduced how the soil must have come into be-ing under the influence of the sea. Witsen encountered large numbers of bog oaks – a subterranean forest – which he believed to have contributed to peat forma-tion. He also described the discovery of a tree-trunk canoe, which he compared with the boats used by the Indians in New Netherland.Witsen's manuscript attests to keen powers of obser-vation and a rigorous scientific method. He combines philology with empiricism, while giving considerably more weight to the latter. Witsen describes how, over the course of time, sand and clay were deposited and peat was formed and how those layers were influenced by one another and by human intervention. His manu-script reflects a view of the world as a dynamic system, an idea that underlies modern geology, which tries to deduce the age of layers of earth using stratigraphy. The basic principles of stratigraphy, laid out in 1669 in the celebrated Prodromus by Witsen's friend Nicolaus Steno, can be found in Witsen's manuscript, making it the first written record of the thinking behind the Steno Laws, which must have emerged from an ex-change of ideas between the two men.It is hardly surprising that these insights were gained in Amsterdam. For one thing, Amsterdam was evolving into a centre of scientific endeavour in the seventeenth century, for another, it was located in the West Nether-lands peat region where the dynamics of landscape de-velopment were clearly visible in the soil. Urban expan-sions and hydraulic engineering and construction projects entailed interventions in the soil, leading to the inadvertent creation of 'peepholes' for studying the soil structure. Knowledge of the soil structure and landscape development was far greater in the seven-teenth century than we realize. Thanks to the rise of an internationally oriented and scientifically aware urban elite, that practical know-how became part of a much broader flow of knowledge: the scientific revolution of the seventeenth century.