Dutch pioneers of the earth sciences

History of Science and Scholarship in the Netherlands, volume 5

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Dutch pioneers of the earth sciences

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Koninklijke Nederlandse Akademie van Wetenschappen, Amsterdam 2004

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ISBN 90-6984-389-7

The paper in this publication meets the requirements of ♾ iso-norm 9706 (1994) for permanence

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Preface

Founded in 1808 by the King Louis Napoleon under the complicated, french-inspired name of 'Koninklijk Instituut van Wetenschappen, Letterkunde en Schoone Kunsten', the Royal Dutch Academy of Arts and Sciences (KNAW) is now a respected institution, with a number of important missions: advice to the government on strategic matters, scientific forum for Academy members, advanced research through its own institutes, etc. One aspect of these many activities has taken a relative importance in recent years: the preservation and elaboration of the cultural heritage of the country, either related to the Academy itself (Commissie Geschiedschrijving KNAW) or to other areas of scientific activities. This type of research falls broadly within the scope of the history of the sciences, which presents the challenge to combine a specialized scientific knowledge with the specific requirements of historical research. It is not easy to combine these skills in a single individual, especially for domains as broad as earth sciences, which includes disciplines as different as palaeontology, hydrology or geophysics. In 1974, R. Hooykaas, a chemist by training and a historian of science of international renown, had thus the idea to initiate a working group, including scientists and historians, that aimed at promoting the study of the history of the earth sciences. This Committee for the History of Earth Sciences (KNAW Commissie voor de Geschiedenis van de Aardwetenschappen) has regularly functioned since, after the retirement of R. Hooykaas under the leadership of E. den Tex.

The first task that the committee set itself was to support projects dealing with former Dutch colonies. One of the results was a substantial book on the geology of Suriname.* Towards the end of the nineties the committee started to focus on the development of geology in the Netherlands. It is almost self-evident that the period first chosen was the nineteenth century. It was in this period that here as elsewhere the foundations were laid for modern geology.

* Th. E. Wong et al. eds, *The history of earth sciences in Suriname* (Amsterdam 1998) viii + 479 p.

This time corresponds to a complicated, sometimes tumultuous period in Dutch history, in which in a relatively short time the country was transformed from a republic into the kingdom of the Netherlands. It is truly remarkable that in the first decades of the century, despite all political problems, a number of distinguished scientists managed to do research and stay in close contact with most of the leading scientists abroad, thanks notably to a travel aptitude and ability to master foreign languages which seem, at all times, have been characteristics of the Dutch. Another typical feature, together with a tradition of education, which dates back to the seventeenth century, is a relative modesty, a desire to stay aloof from triumphalistic pompousness as exhibited by countries like France or England. Dutch scientists were well informed, could be extremely critical of the 'masters' of the time, but they liked to present their findings in small, mostly provincial groups. Important for scientific exchange were the many learned societies, like the Hollandsche Maatschappij der Wetenschappen in Haarlem (founded in 1752 and still existing to-day), which were typical of the Dutch situation.

On November 10, 2000 our committee organized a symposium on 'Dutch pioneers of the earth sciences'. It was held at the Trippenhuis, the premises of the KNAW and met with an unexpected success, both from speakers and audience. It indicates a marked desire of to-day Dutch earth scientists and, we hope, from a broader public, to know more about their scientific predecessors. The present book, superbly edited and printed by the publishing department of the KNAW, is directly issued from this symposium. It has some supplementary chapters, which, for one reason or another, could not be presented at the symposium. In selecting the pioneers, we did not follow very strict rules, nor did we try to be exhaustive. There may have been other pioneers, some of them perhaps better known than those found in this book. But the choice was not at random. Broadly arranged in chronological order, the selected names reflect the desire of the different authors, most of them experienced university professors, to throw some light on individuals who have been important in the development of their respective disciplines and who have not the place they deserve in the international literature on the history of the earth sciences.

In the first contribution, W.H. Zagwijn pays tribute to Le Francq van Berkhey, a medical doctor roughly contemporaneous with another, more famous, doctor-geologist, James Hutton. In his 'Treatise on the grounds of Holland'(1771), marked by the influence of Buffon, van Berkhey approached the study of the very special Dutch geology, dominated by turf and sand, in a way that was decidedly modern. Next, E. den Tex, describing the debate between Martinus Van Marum and Adriaan Gilles Camper on the neptunistic versus plutonistic interpretations of basalt, opens a series of three contributions which, in fact, have some internal coherence. Directly or indirectly, all deal with the personality of Martinus van Marum, first director of Teyler's Museum and secretary of the Hollandsche Maatschappij der Wetenschappen in Haarlem. The very generous funding at his disposal from the bequest of the founder of the Teyler's Museum, the silk merchant Pieter Teyler van der Hulst, made this 'man who showed his gift of getting at the right side of eminent men', an important member of the Dutch scientific community and enabled him to acquire the most valuable specimens for Teyler´s collection. After years of difficult negotiations with the 'father of mineralogy', the abbé R. J. Haüy, he could obtain a complete collection of wooden crystal models, still preserved, almost completely, in Teyler's Museum. L. Touret stresses the importance of crystal models for the development of modern mineralogy and crystallography, and W. Saeijs, using these instruments, shows how they can be used to infer the right (sphene) or wrong (copper carbonates, zeolites) mineral determination by Haüy.

The contribution of G. Vanpaemel is of a very different nature. It concerns the developments in geology in the Belgian provinces during their short-lived union with the Netherlands under King William I. This chapter deals with prize competitions aiming at the geological description of the Belgian provinces and demonstrates how these contributed to the growth of geology as a distinctive discipline.

Other pioneers belong to a somewhat younger generation and are from a period when the earth sciences gradually acquired a more modern character. Two of them were professor at the Polytechnic University of Delft, both having introduced a new field of research in Dutch geology: microscopic petrography by Vogelsang, regional geology by Staring. Their fate was however very different. H. Vogelsang (J.L.R. Touret), of German origin, was very popular among students and colleagues, but he died prematurely, involved in mining scandals and family drama. W.C.H. Staring, on the other hand, commonly regarded as the 'father of Dutch geology', made a map that set the standard for all subsequent geological maps published in the Netherlands. Staring's geological lectures at Delft in 1863 have been exhumed from family archives by F.R. Van Veen, whereas P. Faasse summarizes the history and importance of his famous map.

The following two contributions are more thematic. J. J. De Vries presents a survey of the history of groundwater hydrology in the Netherlands, a relatively little known aspect of the earth sciences. E.W.A. Mulder studies the role of the discovery of the Cretaceous near Maastricht in the development of Dutch palaeontology.

Finally, D. Visser relates the discovery of the manuscript of an unpublished article by C.E.A. Wichmann, the first professor of mineralogy and geology at Utrecht University. This manuscript analyses a relatively rare mineral, chloromelanit, found in New Guinea. As constituent of many prehistoric objects this mineral is also of interest to archeologists and ethnologists.

The editors should like to thank all authors for their willingness to participate in this project and to acknowledge the constant support and encouragements they received from the KNAW and notably from their publishing department.

Berkhey's *Treatise on the Grounds of Holland* (1771): geology before the term existed

W.H. Zagwijn

GEOLOGY IN THE LOW COUNTRIES IN THE PERIOD 1800-1840

The oldest geological map of the Netherlands was published in 1822[1] by J.B.J. d'Omalius d'Halloy but was actually made considerably earlier. Already in 1813, Omalius became involved – on instigation of the French Bureau de Statistique – in the making of a geological map of the French Empire, which at the time included many more parts of Europe than France alone, such as the former Kingdom of Holland, and extensive parts of the Northwest German plain. The political events of 1814 and their aftermath prevented the completion of the project until Omalius – at that time governor of the Province de Namur of the newly founded United Kingdom of the Netherlands –finally could publish his observations of earlier days.

One of his major improvements was the introduction of the Cretaceous ('Crétacé') as a separate unit. All younger deposits of aquatic origin – widely spread, but still little known, as he put it[2] – are part of an undifferentiated mass of beds that he called 'terrains mastozootiques'.[3] The number and diversity of those beds would have permitted subdivisions, but their repeated superposition and lateral variation would have made it impossible to represent them in detail on a general map like this. Therefore, all deposits that nowadays are attributed to the Tertiary and Quaternary are presented in a uniform greyish tone (Fig. 1).

From Omalius' fourth memoir,[4] which deals with the Netherlands and Belgium and was written as early as 1808, it is obvious that his understanding

[1] J.B.J. d'Omalius d'Halloy, 'Essai d'une carte géologique de la France, des Pays-Bas…', *Annales des Mines* 7 (1822) p. 353-376. He published a more detailed version in his *Mémoires pour servir à la description géologique des Pays-Bas, de la France et de quelques contrées voisines* (Namur, 1828).
[2] Omalius, *Mémoires*, p. 18.
[3] Deposits containing fossils of mammals.
[4] Omalius, *Mémoires*, p. 195-210.

of the geologically young deposits was still based on landscape characteristics rather than on actual information of the underground. Thus the heath plains – stretching from the Campine area northward to Drenthe and Lower Germany, consisting of sandy subsoil, poor in lime – comprise one unit only.

In the latter two areas, rounded blocks of granite and other primordial rocks offer a remarkable geological phenomenon, as they occur at the surface or buried in the sands, without any visible connection with actual primordial rocks.[5] Their number must have been immense, as their frequency was still high in those heathlands, even though they had been widely used to pave roads and build jetties along the sea and rivers. The origin of these blocks presented a problem, which had already led to several hypotheses and, by the way, would produce many more in the years to come. One of them, more generally accepted at the time, supposed transport from the north in times when the Baltic Sea had not been incised yet. Another, rather peculiar hypothesis was presented by the famous Jean de Luc, who believed that these blocks had been launched like bombs by expanding fluids, trapped in collapsing big cavities in the interior of the earth.[6]

Notwithstanding the great authority of De Luc, Omalius preferred his own explanation. He referred to the observation that, usually, rounded granitic blocks are found in large amounts at the surface of disintegrated granite rock. Therefore, in his mind, the granite bedrock in these areas should not lie too deep and the disintegrated blocks were surrounded by sand transported from elsewhere. He wrote:

> As everybody knows, in a mixture of irregular broken matter, if shaken, the finer fragments will concentrate below, and the coarsest ones will continually appear at the surface. As one may understand, in a terrain composed of granite blocks covered by sand, some violent earthquakes will successively bring the blocks to the surface.[7]

In addition to the sand areas, the alluvial lands[8] form another main part of the 'terrains mastozootiques'. They cover nearly the whole of the provinces of Holland, Zeeland, Friesland and part of Vlaanderen (i.e. Flanders). They originated under circumstances that resemble those prevailing at present. From a well dug at Amsterdam in 1605 – 73 meters deep, not reaching their base – it appeared that their thickness can be substantial. They consist of

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5 *Ibidem*, p. 204.
6 J.A. de Luc, *Lettres physiques et morales sur l'histoire de la terre et de l'homme* (Paris/La Haye, 1779-1780).
7 Omalius, *Mémoires*, p. 207.
8 Called 'terrains d'atterrisements', *Ibidem*., p. 208. The term is from De Luc.

alternating beds of sand and clay, 'as if in an inundation the heavier sand grains have sunk first, and the clay afterwards'.[9]

Though Omalius mentioned the polders, he took no notice of the character of the beds of the reclaimed areas. Finally, he referred to the widely occurring peatlands, of two classes: on higher grounds and on lower grounds, the difference being of importance for their exploitation, i.e. above or below the ground water level.[10] Of interest is the reference to 'the beautiful experiments' by Van Marum,[11] who observed that algae can produce a peat bed of some thickness in five years' time. Van Marum's activities were not rated highly later, as can be concluded from Staring's remark: 'The otherwise so highly deserving Van Marum thought – because of his observations in his goldfish pond at Haarlem – that peat originates from algae [*Conferva rivularis*] alone whereas he should have crossed the Haarlemmermeer to copy from nature the true origin of Low Moor Peat'.[12] Neither he nor Van Marum mentioned the earlier experiment by Le Francq van Berkhey. (see p. 12)

Omalius did not give names to subdivisions of his 'terrains mastozootiques', but already one year later, Buckland published his book *Reliquiae Diluvianae* (1823), in which he grouped the youngest formations in earth's history in two units: Diluvium and Alluvium. To Buckland, clergyman and geologist, the diluvial flood of the Bible and the geological evidence of a recent and transient inundation were not contradictory. As he put it, 'I have felt myself fully justified in applying the epithet diluvial to the results of this great convulsion; (…), and postdiluvial, or alluvial, to (the state) which succeeded it, and has continued to the present time'.[13] The specific character of the diluvial sediments, rich in gravel and blocks, was considered the result of the action of strong and massive water currents, stronger than in the Alluvium, when sediments were generally finer in composition. Moreover, the occurrence of fossil bones of mammals (such as mammoth, rhinoceros and hyena), thought to have been transported from warmer areas, completed the picture of the devastating flood, which destroyed the antediluvial fauna,

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[9] *Ibidem*, p. 209.

[10] *Ibidem*, p. 210. The high-lying peat is called 'hooge veenen', the low-lying 'lage veenen'. Exploitation is for combustion and for soil improvement.

[11] M. van Marum, 'Waarneemingen en aanmerkingen omtrent den oorsprong van het veen', *Natuurkundige Verhandelingen van de Hollandsche Maatschappij der Wetenschappen* 1 (1799) p. 115-131.

[12] W.C.H. Staring, *De aardkunde van Salland en het Land van Vollenhove* (Zwolle, 1846) p. 4.

[13] W. Buckland, *Reliquiae Diluvianae or Observations on the organic remains contained in caves, fissures and diluvial gravel and on other geological phenomena, attesting to the action of a universal deluge* (London, 1823) p. 2 seq.

thriving before the disaster.[14] In defining the Diluvium and Alluvium, Buckland explicitly referred to Holland,[15] where he had seen the two deposits in immediate contact with one another. 'The Alluvium forms nearly the entire surface of the low and extensive river plain, whereas the diluvial deposits rise from beneath it into a chain of hills, composed of gravel, sand and loam, which cross Gelderland, between the IJssel and the Rhine.' Specially mentioned are the cliffs on the left bank of the Waal at Nijmegen and on the right bank of the Rhine from Arnhem to Amerongen. To identify these Diluvial beds as Omalius' sandy deposits and the Alluvial beds as his 'terrains d 'atterrissements' presents no problem.

Finally, Buckland pointed out that below the Alluvium of the river plain, Diluvial beds must occur because fossil elephant remains had come to the surface, when through bursting of dikes, deep excavations had been made by water through the Alluvium into the subjacent Diluvium.[16] Though Buckland's concepts were immediately supported by Sedgwick, they became never fully accepted in Great Britain, partly because of their rejection by Lyell. On the continent, in particular in Germany, they became popular and the term Diluvium persisted to the end of the nineteenth century and even later. However, Buckland's original concept of a universal flood was soon replaced by other theories in which ice functioned as carrier for the widely spread erratic blocks, either as floes or icebergs,[17] or finally, as glaciers.[18] Buckland himself was one of the first to acknowledge the mountain glacier theory in 1840, after having been won for this concept by Louis Agassiz during a joint field trip into the mountains of Scotland. In the Netherlands, only few studies on these subjects were done by native Dutchmen. A remarkably early one was that of S.J. Brugmans,[19] who in 1781 recognised the Scandinavian provenance of the erratic blocks in the province of Groningen. Half a century

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14 *Ibidem*, p. 171 seq.

15 *Ibidem*, p. 188-189. Buckland wrote 'Holland' but his examples are from places outside that province, from other parts of the Netherlands.

16 *Ibidem*, p. 189. Reference is made to big bones he had seen in the Museum of Natural History at Leyden and to a skull of more than 3 feet found after a dike breaching at Heukelom in 1820 and that is now in Teylers Museum at Haarlem. For the reaction of Sedgwick, see A. Sedgwick, 'On the origin of alluvial and diluvial formations', *Annals of Philosophy* 1825, p. 241-257. For Lyell see his *Principles of geology* (1830-1833).

17 E.g. by J.F.L. Hausmann, 'Verhandeling over den oorsprong der graniet en andere primitive rotsblokken', *Natuurkundige Verhandelingen van de Hollandsche Maatschappij der Wetenschappen* 19 (1831) p. 271-400.

18 See e.g. J. Charpentier, *Essai sur les Glaciers* (Lausanne, 1841) and L. Agassiz, *Études sur les glaciers* (Neuchatel, 1840).

19 S.J. Brugmans, *Dissertatio inauguralis de lapidibus et saxis agri Groningani* (Groningen, 1781).

later, the mineralogist J.F.L. Hausmann from Göttingen could conform this interpretation more precisely in a paper that was awarded a gold medal by the Hollandsche Maatschappij der Wetenschappen.[20] Hausmann also thought of ice floes and icebergs as carrier mechanisms for the big erratic blocks from the North, actually before the introduction of Lyell's drift hypothesis in 1835. The translator of this important paper was J.G.S. van Breda, who recognised a southern component of the erratic assemblage, especially in the southern and middle part of the country, supplied by the rivers Rhine and Meuse.[21] His pupil was Staring, who would later be called the Father of Dutch geology.[22] His thesis *De Geologia Patriae* (Leyden, 1833) was the first of a large number of geological writings that included the geological map of the whole country as well as a treatise on the soil of the Netherlands, which was in fact the first geological description of this country as a whole.[23]

From this account it may appear that in the period before the discipline of geology was established – say, roughly before 1790-1800 – knowledge of the subsoil of the country, more specifically of the provinces of Holland and Zeeland, was scanty. It were geologists from other countries, such as De Luc, who first added to our knowledge. Only through Staring's work at least the surface geology became known in some detail. However, this assumption does not do due justice to the fact that in Holland, perhaps more than elsewhere in Europe, man had had a great impact on the land and its underground since medieval times. The commonplace is that God has created the world, but the Dutch created Holland. It is hard to understand, however, how they managed to do so without knowledge of the nature of the deposits below their feet.

A FORGOTTEN SOURCE

About thirty years ago, the present author was involved in a project on the geology of the coastal dunes of Holland. At the time, large-scale excavations for industrial buildings and water supply works permitted a rarely occurring opportunity to study in detail the structure of the beds in the dune area. The sections showed cyclic successions of windblown sands and soils or peat

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[20] See note 17.

[21] A.S.H. Breure and J.G. de Bruijn, eds, *Leven en werken van J.G.S. van Breda (1788-1867)* (Haarlem, 1979) p. 229.

[22] J. van Baren, 'Dr. W.C.H. Staring in zijn betekenis voor de geologie van Nederland', in: *Dr.W.C.H. Staring gehuldigd op zijnen honderdsten geboortedag* ('s-Gravenhage, 1908) p. 12.

[23] For Staring see the contribution by F. van Veen in this volume.

beds. These successions are the result of alternating climate change, from dry to wet.[24] In the geological literature, little attention had been paid to these phenomena. Therefore, it was a surprise when our attention was drawn to a plate, dating from 1771, that showed a section with a very similar succession of beds. This plate, published by J. le Francq van Berkhey,[25] shows the face of a large sandpit near Katwijk, at the location where an outlet of the river Rhine existed in older times, which was later overblown by dune sand (Fig. 6). It is striking that, in the two hundred years between Berkhey' s observations and those in the years 1960-70, nothing similar had been published. Moreover, Berkhey's work had been largely neglected in the geological literature, with the exception of J. van Baren.[26] Even Staring did not cite Berkhey's observations in his *Bodem van Nederland* (1858-1860) although he had referred to Berkhey's publication several times in his thesis from 1833. In his introduction to this thesis, Staring had stated that Berkhey 'had collected many data on the soil of Holland, these being rather good if we take into account the state of Science of those times', in other words, not bad, but old-fashioned.[27] Renewed reading of Berkhey's book on the *Natural history of Holland*, in particular of the first six chapters of volume two,[28] led me to the understanding that the drawing of the sand pit does not stand alone.

Quite unexpectedly, the book proved to contain an elaborated description of the geological successions found in the younger beds of Holland. That means, in modern terms, the beds of the Holocene.[29] Berkhey's observations are quite to the point, perhaps not so closely spaced to allow for the making of a geological map, but detailed enough to enable the construction of a long geological section, which is unique for this period when geology had not yet been established as a scientific discipline in its own right. In addition to these accurate observations, Berkhey attributed the formation of the deposits to processes he could see still at work and tried to distance himself from wild speculations on unknown forces involved in the genesis of old deposits. Thus Berkhey's work, written just before the establishment of geology, is of wider interest than that of a local study in natural history alone.

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[24] See S. Jelgersma et al., 'The coastal dunes of the Western Netherlands', *Mededelingen Rijks Geologische Dienst* 21 (1970) p. 93-166.
[25] J. le Francq van Berkhey, *Natuurlijke historie van Holland*, vol. 2 (Amsterdam, 1771) pl. 2.
[26] J. van Baren, *De bodem van Nederland*, vol. 1 (Amsterdam, 1908) p. 29.
[27] W.C.H. Staring, *Specimen academicum inaugurale de geologia patriae* (Leiden, 1833) p. 2.
[28] J. le Francq van Berkhey, *De Natuurlijke historie van Holland, Tweede deel met noodige Afbeeldingen* (Amsterdam, 1771). p. 1-200.
[29] For a modern compilation on the Holocene of the area see W.H. Zagwijn, *Nederland in het Holoceen* (Haarlem/'s-Gravenhage, 1986).

le francq van berkhey, author of *De Natuurlijke historie van Holland*

The vicissitudes in the life of Johannes le Francq van Berkhey (1729-1812) have been comprehensively treated by Arpots.[30] Medical doctor, polyhistor, poet, he devoted his life to the glorification of his country, Holland, and its stadtholders from the House of Orange (Fig. 2). He was considered the best poet of his age for some time and used his skills in the defence of the Prince of Orange, which brought him nothing but the enmity of the anti-orangists, called the Patriots. Some of them, from his hometown Leyden, turned out to be false friends, accusing him of libel in a pamphlet.[31] An ensuing trial before a court of the University of Leyden led to temporary dismissal as university reader, and as it dragged along for years, finally ruined him financially. Although he was reinstated as a reader, he never got the chance to become an ordinary professor.

Unlike other Orangists, Berkhey did not go into exile in the period after the foundation of the 'Bataafsche Republiek' (1795). He kept quiet, while resuming writing his magnum opus on the natural history of Holland. In 1807 his house and other properties were destroyed by the explosion of a gunpowder ship. Five years later he died in poverty and almost forgotten. His main publication, on the natural history of Holland, however, is not completely forgotten, as some parts are still a major source for our understanding of daily life during the eighteenth century. The work was conceived as a special, regional treatise, not as a general one dealing with such topics as the origin of the earth. Though restricted in geography, its scope of subjects was wide, indeed. The first volume of the *Natuurlijke historie* appeared in 1769 and dealt with the geography and climate of the province. It was followed by volume 2, published in three parts in 1770-1771,[32] which discussed the deposits and the mineral resources. Next came further volumes, treating man, inhabitants of Holland, then animals, such as horses, and after a break of 25 years, the result of the setbacks in his life, the parts on cattle (1805-11). The work was never completed; plants for instance are missing.

The present paper will consider in particular the first six chapters of volume two, comprising 200 pages and dealing with topics that nowadays would be considered as geology in the proper sense. The remainder of the volume – totalling nine chapters and over 1000 pages – deals with mineral resources, such as earths, ochres, peat, clay and sand, minerals in a proper sense and 'stones'. In general, these topics were discussed if their origin could

30 R.P.L. Arpots, *Vrank en vrij. Johannes le Francq van Berkheij (1729-1812)* (Nijmegen, 1990).
31 *Ibidem*, p. 266-268.
32 *Ibidem*, p. 62. The frontispiece gives 1771 as the only date.

Figure 2 Portrait of Johannes Le Francq van Berkhey. Frontispiece of vol. 1 of *Natuurlijke historie van Holland*.

be traced down to the province of Holland, but imported stones and stones grown in humans and animals (e.g. kidney stones) were not forgotten either. A concise manual for the arrangement of a mineral cabinet, a popular hobby of the period,[33] concludes the whole.

In the next section, some interesting aspects from Berkhey's chapters on minerals will be discussed, but only as far as they elucidate topics of the more geologically oriented first six chapters of the volume. The discussion of these latter will not follow Berkhey's text in close order, but will try to highlight his methods of observation and his ideas on the genesis of the beds. The numerous practical applications, ranging from ceramics to peat cutting to harrowing of heavy clay soils – though beautiful examples of 'applied geology' – are outside the scope of our paper, as well as his remarks on groundwater conditions.

It should be mentioned that a forerunner of his treatise on the geology of Holland was published by Berkhey more than five years earlier. It concerns a gold-medal winning manuscript of 1763, printed in 1765, containing an answer to a prize competition of the learned society Hollandsche Maatschappij der Wetenschappen at Haarlem.[34] In this paper, some of the topics dealt with in the geological chapters of the *Natural history of Holland* were anticipated.

THE MINERAL RESOURCES OF HOLLAND

The chapters on mineral resources ('delfstoffen')[35] group different types of materials: earths ('aarden'), ochres and 'humus' ('oker- en dary-aarden'), peat ('veen'), sands ('zanden'), stones ('steenen'), minerals, metals, encrustings and petrifications. The nomenclature of such materials in natural history works has a long tradition, reaching back to antiquity. However, the definitions remained vague, partly because a clear distinction between physical and chemical properties was not yet possible. Berkhey applied a classification that was modern for his time and was introduced by the Swedish naturalist Wallerius. Though it used also chemical properties, one has to consider that the great revolution in chemistry had still to come. The processes underlying the formation and transformation of rocks became understood only after the

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[33] See R.P.W. Visser,'De geologische wetenschappen in Nederland gedurende de 18e eeuw', *Documentatieblad Werkgroep 18e Eeuw* 31-32 (1976) p. 28.

[34] J. le Francq van Berkhey, 'Antwoord… op de vraag… welke zijn de beste middelen om onze landen, zo hoogen als laagen, elk naar zijnen aart ten meesten voordeele aan te leggen', *Verhandelingen uitgegeeven door de Hollandsche Maatschappij der Weetenschappen* 8,2 (1765).

[35] Le Francq van Berkhey, *Natuurlijke historie van Holland*, vol. 2, p. 200 seq.

discovery of oxygen and of oxidation just before the turn of the century, and of many other elements, such as silicon and aluminium, at the beginning of the nineteenth century.

Given these restraints, credit must be given to Berkhey for his attempts to break away from ideas that were fashionable in his time. Among them was the belief that stones could grow in the subsoil, a belief based on the observations of farmers that after ploughing new stones always came again to the surface. Naturalists gave a scientific touch to this belief, by arguing that stones could accrete in the subsoil by chemical reactions, the way iron could accrete in bog ore or in rattlestones. Berkhey, however, did not favour such theories, as appears from his discussion of the concentrations of stones in the sands near Naarden. He wrote:

> As clay can petrify to stone, one can consider the possibility that this has happened in Holland also, and this may have happened indeed, [in the times] before man had populated the still barren land. It is even not quite impossible that Holland, shortly after the Creation of the Earth, was higher and rockier. Afterwards, Holland could have been deprived of these beds and have changed into the swampy sandy land of the present day. The removal of the rocky beds may have resulted from the Deluge, or earthquakes or the penetration of the rivers and the enlargement of the North Sea.[36]

He continued with a long passage, that started with the question 'Who will be able to follow here the trail of Nature' and ended with the conclusion that instead of following the adagium 'that there is nothing that cannot be traced by Man', he (Berkhey) preferred to keep silent and to acknowledge 'that one is unable to decide if in this country stones were formed in a natural way'. Similar rhetorical phrases can be found elsewhere in Berkhey's work, linked to problems of tracing old deposits, which he felt could not be understood by wild speculations beyond the authority of the Holy Script. Yet, in the case of the stones of Naarden, he took his turn. After saying that they were so numerous that 'their occurrence might be taken as a sign of natural growth in situ',[37] he pointed out that they were, in general, rounded 'by water transport', and suggested that rivers or the sea were likely to have been the agents which transported these stone beds, 'even more so, if one observes the mixture of so many types of rocks, rounded and polished, originating from various exposures along the mighty streams of the rivers'.[38]

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[36] *Ibidem*, p. 794-795.
[37] A. van der Woud, *De Bataafse hut: denken over het oudste Nederland (1750-1850)* (Amsterdam/Antwerpen, 1998) p. 90 mistook Berkhey's intentions when he suggested that Berkhey subscribed to the traditional theory of growing stones.
[38] The Naarden deposits are of Pleistocene age, partly of Saalian glaciofluvial origin and partly consisting of older river deposits.

The relation of clay, sand and stone is another problem about which Berkhey had his own ideas.[39] In this period before modern chemistry, his terminology is not always easily understandable. He said that 'Earth is an element [Dutch 'hoofdstoffe'], common to all bodies'; it probably included some silicates and probably the physical structure (e.g. sand) as well. Elsewhere, he stated that 'the nature of earth is difficult to determine, as most physicists [like Woodward and Buffon] consider it, if at the surface, as a mixture of several grounds and decayed matter [Dutch 'ontsloopte stoffe']. However, he also mentioned a fertile black earth, which is not a mixture but a substance of its own, and finally in his opinion 'pure clay is earth in its elementary form'.

Here,[40] Berkhey referred to the work of Buffon, who considered the inner part of the earth to consist of a glassy material, becoming clay through alteration [Dutch: 'verandering'] and decay [Dutch: 'ontsloping']. Berkhey developed, however, his own interpretation based on his microscopical observations that clay presents itself as very fine particles, similar to sand grains. Hence he concluded that these particles are earth in its elementary form. This being so, Berkhey could not believe that clay was a product derived from sand or decaying claystone. Rather he thought that those clay particles, in the presence of specific chemicals, can cluster to form sand grains and even stones. This would happen in the sea, in calm water. In a way, these ideas resemble those of Werner and other neptunists, who considered the early rocks of our planet as matter settled in the sea and solidified by chemical reactions.

In practice, such ideas do not cause problems to understand Berkhey's terminology of the sediments that occurred in Holland. Much of his terminology has remained in common use by geologists and soil scientists, even though Berkhey's definitions have been refined since and, what is more important, standardised. Especially soil scientists, who used such terms as being near to farming practice, have even revived old words in the last decades. One instance may suffice: i.e. the Dutch term 'katteklay' [Engl. cat clay] for indicating a clay that, by oxidation, sets free sulphuric acid and is therefore a clay of very bad quality.[41]

The term 'dary' should be specifically considered. Berkhey said that it comprises two types of peat: one is found along the beaches, along the estuaries and on the sea floor. It is impregnated with salt and can be used for its extraction.[42] The other type is found locally, in particular in the river area

39 Le Francq van Berkhey, *Natuurlijke historie van Holland*, vol. 2, p. 201, 210, 230-240.

40 *Ibidem*, p. 238.

41 *Ibidem*, p. 10.

42 *Ibidem*, p. 92-93. In the province of Zeeland it was used extensively for salt production ('darinck-delven').

below the upper clay beds. This type comprises organic mud, not burning well after drying.[43]

Breaking new ground, Berkhey reported on his experiments on peat formation in his prize-winning paper of 1763.[44] Between 1755 and 1760, he had carried out field observations at two localities of the Haagsche Bosch near the present day royal palace Huis ten Bosch. One locality was in a wet and swampy place near a stand of alders, interspersed with some large oaks. Here, he made a hole, one foot (= 0.31 m) deep, by taking out the peaty mud. A pole marked with notches was driven in. A parallel experiment was carried out in a dry spot at the same location, on top of a hillock. Every year, he registered the progress of accumulation. The hole in the wet spot had been completely filled after five years and the wooden pole was fully covered. The infilling turned out to be peat, which burned very well, with only little ash resulting. On the higher grounds, however, merely four inches of a material that could be incinerated with difficulty only and left large amounts of ash and sand behind had accumulated after five years. The low rate of accumulation was in part due to blowing away of dry leaves. Berkhey concluded that peat originates from plants. Adding that from his experiments it was evident that peat of good quality could stem from various (water) plants, he declined the theory put forward by Degner[45] that the presence of inflammable oil, supposed to occur in some species of moss, makes peat burn.

Interestingly, Berkhey's experiments were more to the point than the highly praised experiments that Van Marum, carried out some thirty years later.[46] When workmen excavated Van Marum's garden pond, they found some freshly formed peat. The pond had been full of an algae species, which did not reappear afterwards. After five years, no new peat was found. Van Marum concluded that peat could only be formed in the presence of specific plants, such as algae in this case. The writings of the two men reflect two worlds: that of the practical observer and that of the drawing-room scientist. Berkhey also recognised the importance of floating mats in open-water peat formation[47] and also pointed out that peat moss (*Sphagnum*) formed peat in the provinces of Gelderland and Friesland, but was replaced by other mosses in Holland. Added to his remark that in the low areas, peat originated from

[43] Later, Staring believed it was a clayey type of peat. Cf. W.C.H. Staring, 'De veenen en de veenwording in Nederland', *Verhandelingen van de Commissie voor de Geologische Beschrijving van Nederland* 1 (1853) p. 69.
[44] See note 34, p. 47-49.
[45] J.H. Degner, *Dissertatio physica de turfis* (Leiden, 1729).
[46] See note 11.
[47] Le Francq van Berkhey, *Natuurlijke historie van H*olland, vol. 2, p. 486.

water plants and in the high areas from land plants,[48] this confirms that he was aware of the botanical difference between low-moor peat and high-moor peat. Later, Staring, who even claimed a priority in this matter,[49] elucidated the difference more accurately. That the greater part of the peat deposits in the lower areas of Friesland and Holland actually had originated as, botanically speaking, high-moor peat was only recognised much later, in the early twentieth century.[50]

Fossils of plants and animals were part of the natural history of Holland too.[51] In line with this general attitude, Berkhey explicitly stated that he would not conclude from such fossils to changes of the earth's surface. Therefore, as he saw the deposits of Holland as a result of recent actions, he was convinced that no fossils could be found except of species still living in these parts of the world. Finds of fossil elephant therefore had to be remnants of animals imported by the Romans.

THE DUTCH GROUND AUGER

The first chapter of the treatise on the grounds of Holland contains a passage that shows that knowledge of the subsoil of the region was obvious in the eighteenth century, and probably had already been for some time: 'On several occasions, such as the construction of dikes, the cutting of peat, and digging clay for pottery, a good knowledge of the beds and the nature of the grounds of Holland, was obtained.'[52] To acquire such information in a flat and low-lying country lacking natural exposures, it was necessary to dig or to drill. Drilling was widely carried out, usually down to three to five metres. Berkhey wrote[53] that the augers commonly used 'are, in this country, of very old use and rather widely known'. He mentioned a recent French book on land reclamation, the author of which, the Marquis de Turbilly,[54] had described a certain type of auger as a new invention (Fig. 3). With some satisfaction Berkhey remarked that 'this is no new invention at all, as the first knowledge and use of it can be attributed to the Hollanders (Dutch). In their mind, such a drill is as old as peat and clay digging.' And later on he said, 'Through the use of these drills, one knows for certain that the beds in

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48 *Ibidem*, p. 549.
49 W.C.H. Staring, *De bodem van Nederland*, vol. 1 (Haarlem, 1856).
50 E.g. by E. Dubois (1910) and B. Polak (1929).
51 Cf. R.P.W. Visser, 'Dutch palaeontologists of the 18th century', *Janus* 62 (1975) p. 135 seq.
52 Le Francq van Berkhey, *Natuurlijke historie van Holland*, vol. 2, p. 4.
53 *Ibidem*, p. 4 seq.
54 L.F.H. de Turbilly, *Mémoire sur les défrichements* (Amsterdam, 1762) p. 241 seq.

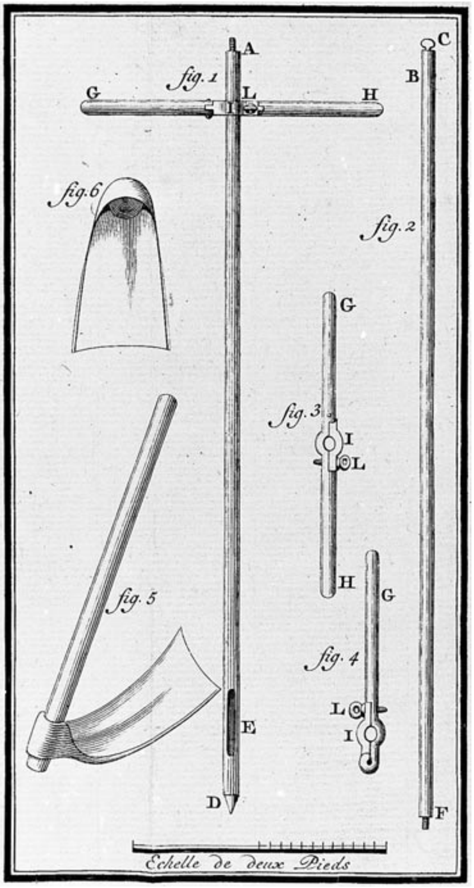

Figure 3 Drawing of an auger, which according to Berkhey is nothing else but the traditional Dutch ground auger. From: L.F.H. de Turbilly, *Mémoire sur les défrichements*, (Amsterdam, 1762). (Photo University Library Amsterdam.)

Holland, as far as the four main kinds of soil matter are concerned, are situated in a highly variable way'.[55]

After these introductory remarks, Berkhey explains that he will consider the natural position of the layers of the four main constituents as well as their thickness (or depth) and also mentions what overlies and underlies each of them. For a given area, there is a comprehensive description of thickness of various beds and their variations. From this, a typical section is compiled, comparable to modern well log descriptions. Twenty-two of such types are depicted in a uniform scale (thickness in Rhenish feet, 0.31 m). The text states how the build-up of the beds in other areas compared with the standard sections (Fig. 5, locations Fig. 4).

[55] Le Francq van Berkhey, *Natuurlijke historie van Holland*, vol. 2, p. 14 seq.

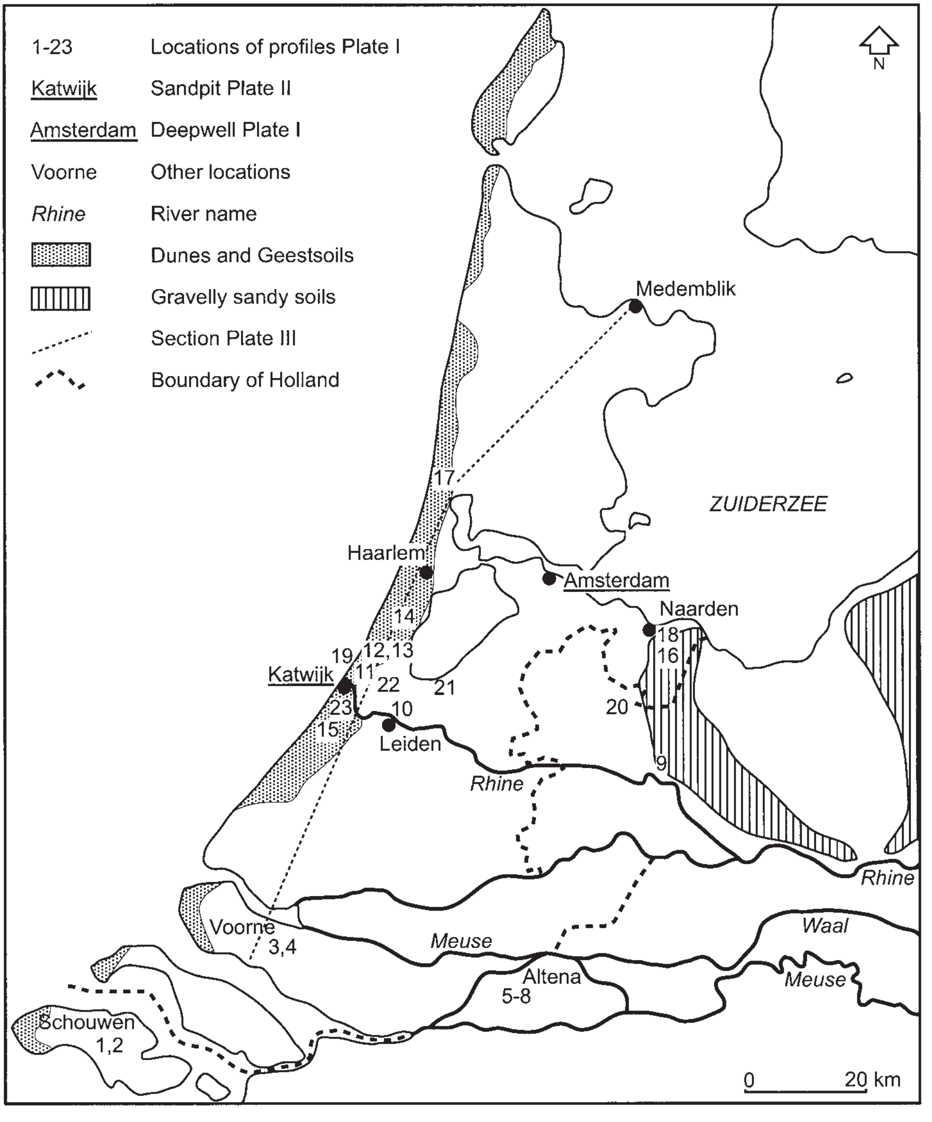

Figure 4 Map of the ancient province of Holland with the locations shown in Figs. 5 and 6, as well as that of the section in Fig. 7.

Even the code colours for different lithologies and their black-and-white signatures are remarkably similar to what would become customary in later times. Most of the types present information as deep as three to over five metres. This is clearly more than in the work of Omalius and even of Staring; in early twentieth-century mapping, routine drilling depth was 2 metres.

How did Berkhey obtain his information? Partly, he collected it in the field himself and partly, he received data from correspondents, such as administrators of polders, burgomasters, amateur scientists (sometimes the same persons as the former), and in part from literature. From the names cited, one gets the impression that much information collected in the preceding years must have been stored in archives. Cited are among others: 's-Gravesande, Cruquius, Baster and Paludanus. One may conclude that the upper part of the subsoil of Holland was no terra incognita in that period. However, information on deeper layers was restricted to one well only, as will be discussed presently.

The data on the composition of the grounds of Holland are discussed in the first four chapters dealing with clay beds, sand beds, peat beds and 'earth', which includes top soils. In two further chapters, the author compiled his data and tried to reconstruct how the beds of Holland came into being by natural changes. These six chapters of the *Natuurlijke historie van Holland* were in fact a *Treatise on the Grounds of Holland*, a term used casually by Berkhey,[56] though it could well have served as the title of the work.

THE DEEP WELL OF AMSTERDAM

This well, in front of the Old Men's Home of Amsterdam, was made in 21 days in the year 1605. It was the deepest well of Holland at the time and remained so for many years to come until the middle of the nineteenth century. A curiosity on its own, the description of the beds it had penetrated drew the attention of most scientists who wanted to write something ingenious on the conditions of the inner earth. Among those who took it as foundation for their discussions, Berkhey quotes Varenius, Buffon, Gesner, Hartsoeker, and Lulofs.[57] Why this interest? Holland is the lowest country in Europe, hence such a deep well in those times was thought to give more information on what is found nearer to the original inner earth than a well in higher regions.

In the upper part of this well, alternating beds of clay and peat were found, 'similar to those elsewhere in the region', to a depth of 51 ft (16 m),

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[56] *Ibidem*, p. 127.
[57] *Ibidem*, p. 109-119.

at which the sand begins that is the foundation of the piles on which most of Amsterdam is built[58] (Fig. 5). It overlies more sand layers, with interspersed clay and peat beds, down to about 92 ft, (29 m), 4 ft of sand with seashells, and a bed of 102 ft (32 m), of hard clay, with seashells in its upper 36 ft (11.3 m) only. There is sand mixed with small stones at 198-203 ft depth (62-63.7 m) and a different kind of sand at the bottom, down to 230 ft (72.3 m).[59]

The first conclusion that Berkhey drew was that down to that major depth no solid rock was found. This contradicted what Woodward[60] and others had predicted. According to Buffon (his report is cited in full in the French original and a Dutch translation was added by Berkhey), the find of seashells at a depth of 100 feet indicated that the underground of Holland had been silted up by sediments (Dutch: 'aangezonken stoffen') to that depth.[61] 'The thick clay bed and the sand, at least 31 ft thick below it, are not lying far apart from the true, original old Earth, at the time of its first formation and before the water movement had changed its surface.' Berkhey seems to have been somewhat sceptical about Buffon's ideas, and therefore he doubted the change of the earth's surface by the movement of the water, which for Buffon had no allusion to the biblical deluge, but was part of his system describing the origin of the earth. Rather, Berkhey demonstrated his aversion of deductive speculations, 'because we have seen how the true knowledge of what is hidden in Nature escapes the ingenuity of even the most superior and clever minds'.[62]

ABOUT THE CLAY BEDS IN HOLLAND

The first chapter of the treatise[63] describes those areas where clay dominates at the surface. Eleven standard successions illustrate the sequences met with (Fig. 5, locations Fig. 4). The start is made outside the territory of Holland. On the island of Schouwen (Fig. 5, nos. 1-2), polders that had been diked recently were found to have a thick clay cover; in older polders, this cover was much thinner, and peat was frequently underlying it. At greater depth, quicksand (Dutch: 'wellzand') was found. In the highest regions, however, no

[58] This sand represents in modern terms the top of the Pleistocene.
[59] The uppermost, marine part of the clay-beds represents Eemian (last interglacial) beds, underlain by lacustro-glacial clay of Saalian age.
[60] J. Woodward, *Essay towards a natural history of the earth* (London, 1695).
[61] Le Francq van Berkhey, *Natuurlijke historie van Holland*, vol. 2, p. 115.
[62] *Ibidem*, p. 125.
[63] *Ibidem*, p. 11-28.

peat was found in these older polders but only sand.[64] On the Island of Voorne, the surface clay was of good quality in its eastern part, near the river Meuse, but towards the west it became sandy. According to Berkhey, this shows the relation with the sea, which brings in sand. In contrast, the river brings in clay. As on Schouwen, peat occurred. In the west, it was underlain by clay; going inland (i.e. to the east), this clay was gradually lying deeper, overlain by peat of increasing thickness (Fig. 5, no. 3). This situation matches modern observations very well.[65] Finally, in this area, near the banks of the river Meuse, the surface clay was found to increase in thickness (Fig. 5, no. 4). South of the river Meuse, on the island of IJsselmonde, peat beds were underlying the surface clay also, though they became scarce near the various branches of this river.

Another area, described in some detail is the Land of Altena (Fig. 5, no. 5-8) where the type sections differ from those discussed before. The variation at shorter distance is greater; near the rivers, the depth of several beds strongly changes; even over short distances, beds of one kind are separated by beds of another kind and continuous sequences are rare. Similar conditions are found in the lands to the north, including areas north of the river Meuse. In this description, one can recognise the many alternating clay and peat beds that are characteristic for the downstream area of the river belt of the Netherlands.[66]

The river Rhine, called Old Rhine or 'Binnen Rijn' by Berkhey, in its downstream area, runs through the city of Utrecht and then westwards to its ancient estuary, west of the town of Leyden. Dunes near Katwijk cut off the exit to the sea in ancient times (in modern view: since Roman time). All along the banks of this Old Rhine, a broad zone of thick clay beds is found as illustrated by three sections (Fig. 5, nos. 9-11). They overly sand or coarse sand.

Further to the north, in the province of Holland, superficial clay beds were found along the IJ estuary and the Zuiderzee. At the surface, these beds showed an admixture of clay and 'earth' (by which was meant organic matter). Of special interest are Berkhey's remarks on the occurrence of shells and snails in the clay beds. In beds near the surface, shells and snails were scarce. Seashells occurred in clays and sands in between the dunes at the western coast, and at depth below Amsterdam and near the Zuiderzee. More inland, any shells were usually river specimens. Hence Berkhey concluded that in

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64 This reflects locations where deeply eroded tidal channels occur that are filled in with sand.

65 See *Geologische Kaart van Nederland 1:50.000. Blad Rotterdam West, (37 W)* (Haarlem, 1975) Profile C-C'. Cf Also Zagwijn, *op. cit* (note 29) Fig. 15.

central Holland, near the rivers, the clays were of a different origin than in the coastal areas, 'having been born from the freshwater of rivers in the former, and from saltwater or the brackish Zuiderzee in the latter'.

PRESENTATION OF THE SAND BEDS

Two regions of Holland were reported as dominated by sand: a zone parallel to the sea, with high coastal dunes and lower inner dunes (called 'geestgronden') and further inland the hills, which extended from the town of Naarden to the east.[67] The region of the inner dunes had already been greatly affected by sand digging (Dutch: 'afzanden'), which had 'changed much of former barren grounds into fertile and shady country'. A section from a sandpit near Voorhout, in a low dune, 4 metres high, serves as a typical profile (Fig 5, no. 12). The black crust at the surface is underlain by some 12 feet (3.7 m) of dune sand and sand, overlying some black earth on top over one foot of peat. Intercalated in the dune sand are two horizons, the upper one blackish sand (1 foot), the lower one yellow ochre sand, merging into a hard, dark-brown ferrous bed (2 feet); in a modern view, the two horizons can readily be recognised as buried soils. The upper one is a humus soil, of a type commonly found in the dune area;[68] the lower is part of a podsolic soil. According to Berkhey, the peat at the base of the section corresponded with the general level of the surrounding land, which means the interdune or beach plain flats, in modern terms. Another section (Fig. 5, no. 13) presents the sequence of such a plain. Peat full of reed remains was found here, about 6 feet (1.8 m) thick, with some sandy black earth on top, and sand or sometimes clay below. Below these, another blackish sand was found. In principle, profiles of this kind occur in the sandpits of Hillegom and in all low dunes further north, up to the Haarlemmer Bosch.[69]

Berkhey continued his argument by saying that it was well proven that the sand dunes of our coasts were born from the overflow of sea floods or by overblowing of the sand. Hence he will not further argue on this matter.[70] He added that in a large part of the coast, the dunes overly clay, most clearly at

[66] For a modern description see H.J.A. Berendsen, *De genese van het landschap in het zuiden van de provincie Utrecht: een fysisch-geografische studie* (Utrecht, 1982).
[67] Le Francq van Berkhey, *Natuurlijke historie van Holland*, vol. 2, p. 38 seq.
[68] Cf. Jelgersma, *op.cit.* (see note 24).
[69] Le Francq van Berkhey, *Natuurlijke historie van Holland*, vol. 2, p. 42.
[70] One is reminded, in this connection, of a discussion between two antiquarians in 1714 who believed that the coastal dunes originated from the Creation, whereas the land-inward ones were derived from these. Cf. Van der Woud, *op. cit.* (see note 37) p. 85.

the location where the old course of the Rhine was stopped. This was shown by borings made on the beach and during construction (in 1571) of the sluice made for the discharge of inland water at the former river mouth. During the construction work at Mallegat near Katwijk, under ten feet of sand, more than six feet of clay were found, from which a Roman coin came to light.[71] The same clay bed is shown on the remarkable drawing by Berkhey (Fig. 6), depicting the face of the large sandpit of Katwijk, 32 feet (approximately 10 m) high. The top part of the clay has partly been replaced by sand from which water is welling up, whereas another water flow streams down over the clay surface, seeping from the overlying sands. Directly on top of the clay are 2 feet (0.6 m) of sandy peat. For this layer as well as for the following peat or earth horizons – the 'humus horizons' of modern geology – Berkhey consistently used the Dutch term 'aardschil' (i.e. earth skin), evidently his designation for a soil or old land surface. Overlying are three feet of windblown and blue sand, a thin bed of compact sandy earth and a thick (seven feet) bed of fine white sand. This is covered by ferruginous ochre sand and a bed of peat earth full of tree roots (a total of three feet). This marked horizon can readily be identified as a podsolic forest soil. On top of this are 4 feet of sand, a black peaty earth, overlain by yellow ochre sand (2 feet) and a third sand bed, about 4 feet thick. The latter is overlain by two black 'earth skins', each 1 foot thick, with white sand in between.[72]

Finally, at the top of the section is a fourth sand bed, indicated as 'common dune sand', which strongly varies in thickness from 1.5 foot up to more than 9 feet, depending of the height of the dune surface. Berkhey noted that the various sand beds found on top of the 'skins' showed two different types of accumulation. The lower sets varied little in thickness, which resulted in intervening soil horizons, which ran remarkably parallel. The topmost sand bed was very uneven in thickness, which was the result of overblowing; the flat-lying parallel surfaces could be rather the result of flooding. At the surface of the dunes all kinds of dunal herbs and shrubs are found, but where the black 'skin' is stripped off, nothing will grow. Closer to the sea, the dunes became higher, and poorer. No more intervening skins were found, and the dunes rose high, 30 feet above the uppermost 'skin'.

Similar sandy areas, as the one discussed before for Voorhout, were found at the foot of the main dune area. Two types of sandy soils were seen: one type was fertile, the other infertile and similar in habit to the ground with

[71] Le Francq van Berkhey, *Natuurlijke historie van Holland*, vol. 1, p. 153

[72] In the hand-coloured copy of plate II in the *Natuurlijke historie van Holland*, vol. 2, used for fig. 2 this bed is coloured (by mistake) in ochre.

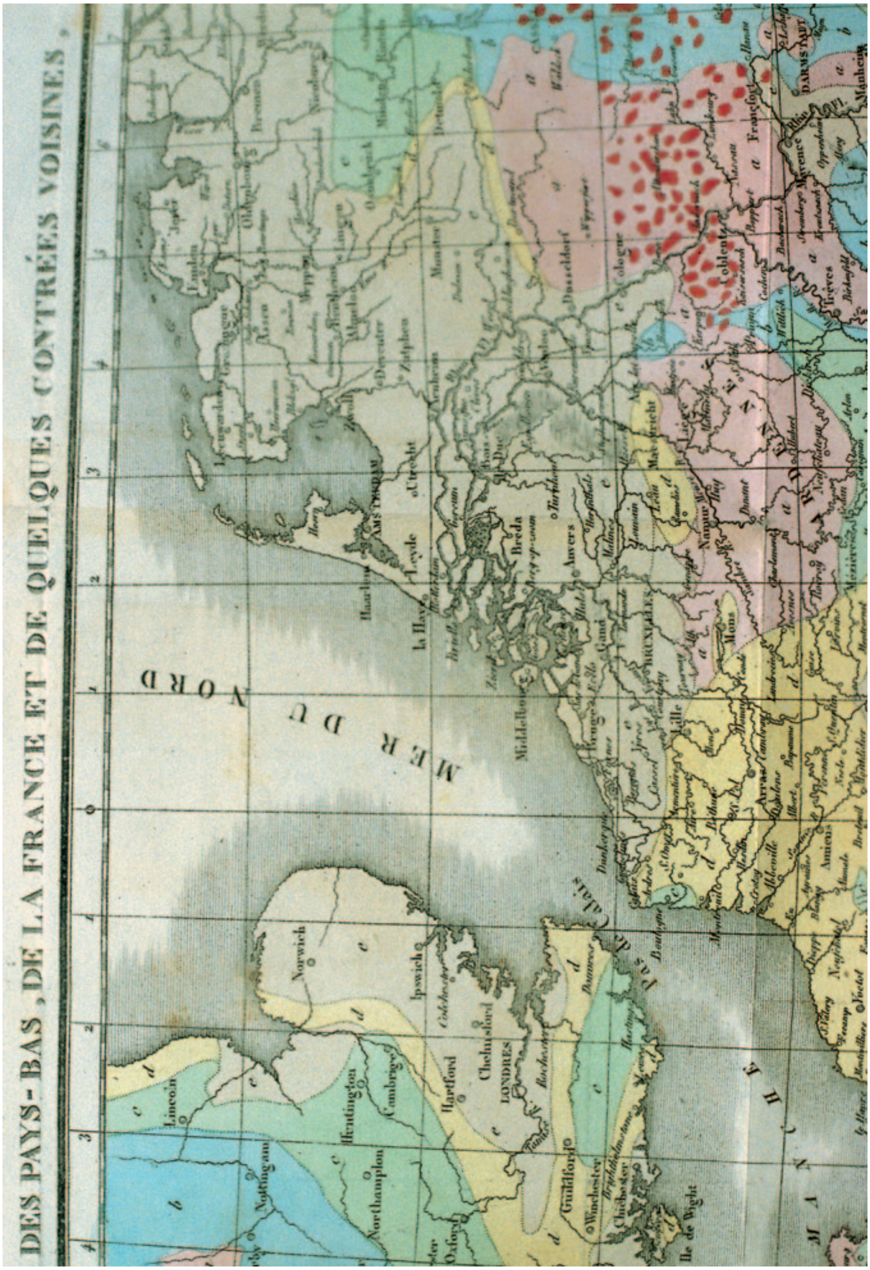
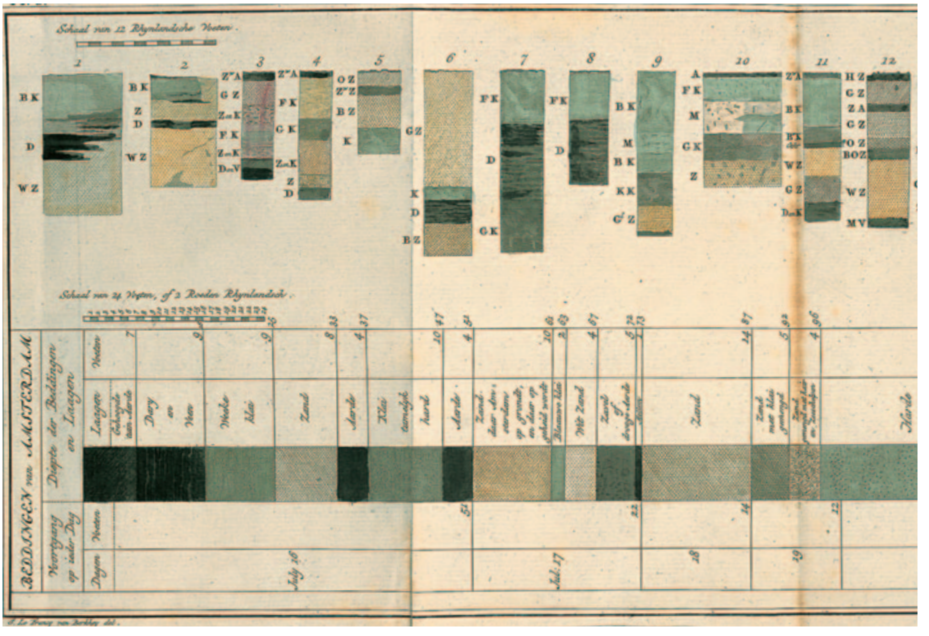


Figure 1 'Essai d'une carte géologique d'Omalius d'Halloy' (see note 1). The map dates from 1822 and is reproduced here from the edition of 1828. Fragment showing the area around the North Sea. Legend: terrains mastozootiques (i.e. Cenozoic) terrains crétacés (i.e. Cretaceous) terrains ammonéens (i.e. Jurassic and Triassic pp.) terrains pénéens (i.e. Triassic pp. and Zechstein) terrains primordiaux (i.e. all older rocks) terrains pyroides (i.e. volcanic rocks)



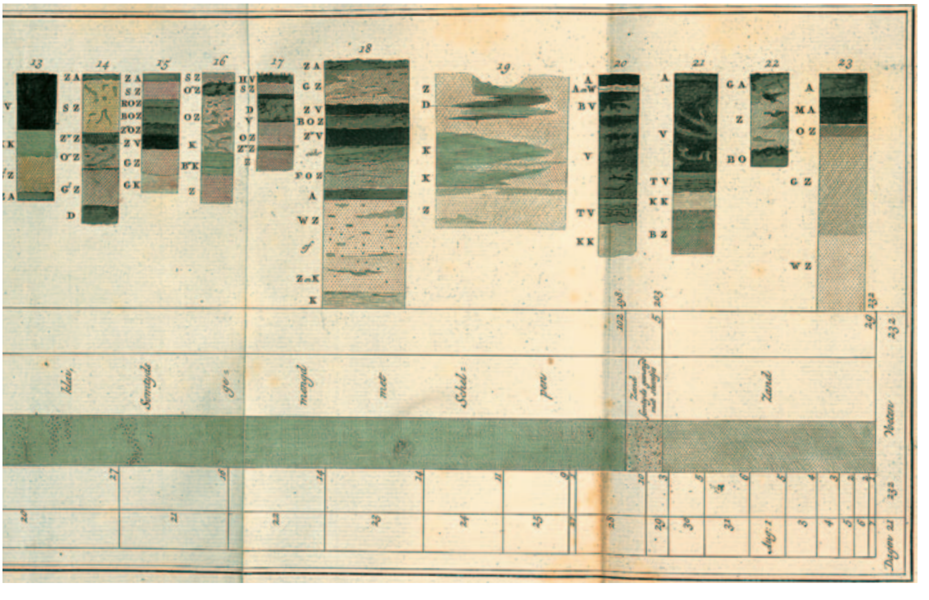


Figure 5 (top and bottom) Reproduction of Plate I from vol. 2 of *Natuurlijke historie van Holland*. It shows the standard sections discussed in this paper. The horizontal section at the bottom represents the deep well of the Old Men's House at Amsterdam made in 1605. (Photo Library Teyler's Museum.)

Figure 6 Face of the sandpit at Katwijk, as drawn by J.F. Le Francq van Berkhey (Plate II from volume 2 of *Natuurlijke historie van Holland*). (Photo Library Teyler's Museum.)

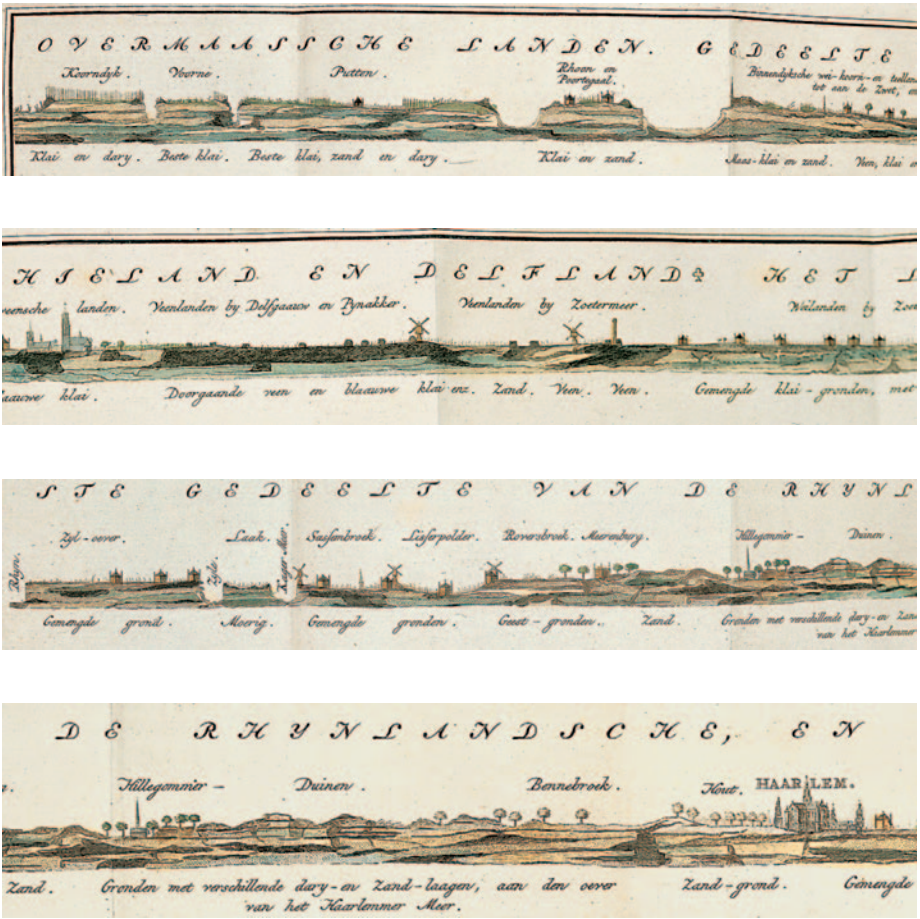


Figure 7 Details of the section, plate III from vol. 2 of the *Natuurlijke historie van Holland*. Location of the section: see Fig. 4. The details show the upper 5 metres of the subsoil in the areas south of the river Meuse, the peat lands east of The Hague, the river plains of the Old Rhine near Leyden, and the inner dune area north of it. The small scale of the complete section prevented reproduction of its full length. (Photo Library Teyler's Museum.)

‘Oehr’ (i.e. iron pan, limonite) in the hills of Gooi and Gelderland in the east. Clearly described is the difference between dunes with calcareous subsoil below humus rich top soils and lime-free areas, deeply leached, with heather podsolic soils (see Fig. 5, no. 14 for the first type, and Fig. 5, no. 15 for the second).

Also, the conditions of the beaches are discussed.[73] Of special interest are remarks about their flat appearance, whereas further into the sea the surface of the seafloor is as irregular as the surface of the land in inland areas. A description clearly referring to the banks of the breaker zone and beyond follows. Reference is made also to ripple marks. Borings on the beach, made on ‘High Order’ (probably the Staten van Holland), had shown that clay occurs below 6-7 feet of sand, at the same level as in the Katwijk sand pit. Fig. 5, no. 19 represents an example of the various beds found below the beach and their lateral variation.

The eastern sand region, reaching from Naarden into the Gooi district and outside of Holland into Gelderland and further, was characterised by heath and an uneven surface, consisting of the hills themselves or of sand dunes (Dutch: ‘klingen’). Below the surface dirty sand was found, which produced turfs (Dutch: ‘zode’) of heather. In these areas, heavy ore lumps abounded, not to be found elsewhere in Holland[74] (Fig. 5, no. 16 and 18). Section no. 18 was obtained from a sandpit near Naarden, showing a face 17 feet (5.3 m) high. In this place, below the turf, yellow sand with some gravel occurred (3-4 feet), then 1 foot of peaty earth, brown ochre sand (1 foot), and peat (1.5 ft) again, below this 1.5 foot of brown ochre sand. Below this sequence, a completely different mixture of beds was seen, starting with beds rich in iron ore, full of stones and gravel, and a black silt layer.[75] This was on top of several metres of white sand with white and other gravel, densely packed. Very low in the section, below the water level of the canals made by the dredgers to facilitate the sand transport by ships, clay was encountered, interspersed in sand with fine gravel. As Berkhey wrote, these beds certainly continued into the subsoil of the Zuiderzee, and in the other direction to Amersfoort, as in both areas similar sand with gravel was found.

Interesting is that in the special part of his book, Berkhey mentioned among the stones from Naarden triangular ones that show three faces[76] and which he described as unknown from the stonerich areas in the Drenthe

[73] *Ibidem*, p. 64-70.
[74] *Ibidem*, p. 58-63.
[75] Probably owing its colour to manganese oxides.
[76] *Ibidem*, p. 807-808, plate VII, Fig. 3. Berkhey called these ‘driekanthoekige keien‘. Nowadays they are known in Dutch as ‘driekanters’.

region. At first, he thought of some fossil kind of Echinoid, but later on he dropped this explanation, confessing that he could not think of any reasonable explanation. Clearly, he described ventifacts, shaped at least partly by wind action under the polar-desert conditions of ice ages.

Evidently, the sand beds of Naarden and beyond belonged to the same group of deposits as Omalius described later from the heath region between Rhine and IJssel. As we have seen before, Buckland included them in his Diluvium. The uppermost part of the Naarden section consisted of sand overlying peaty earth and ochre sand (a podsolic soil), which Berkhey compared with similar sequences of the lower dune area in the west. In modern terms, this is subrecent windblown sand overlying a Holocene podsolic soil, roughly in line with the feeling of Berkhey.

ABOUT PEAT BEDS AND EARTHS

Berkhey's experiments on the formation of peat have been discussed in an earlier section. Knowledge of peat must have been common in Holland, in view of the economic importance of this material. Several earlier books on the conditions of the Republic contain discussions on peat and its formation. Berkhey was, contrary to other writers, aware that the colouring of the peat was due to the measure of decomposition,[77] younger peat being of lighter colour than older. He admitted, though, that the substratum on which the plants grew may have played a role too in the kind of colour that the peat adopted.

He described several peat sections, partly from observations by others (Utrecht area, Fig. 5, no. 20) and some by himself (Roelof Aartgensveen – Fig 5, no. 21). From some places, reed peat is mentioned, from others wood peat. He wrote that tree roots were common, especially in the lower part of the beds. In several places, tree trunks were found, about which a lot had been written by antiquaries. There is a general direction in which these trunks were found lying (toward the east or southeast). Hence, a belief arose that some common catastrophe (a storm, a flood) was the cause of the fall of these trees. Berkhey showed himself a critic of these views. He observed that many of the so-called determinations of the kind of trees involved are doubtful (e.g. those of pine). Further, he pointed out that the trunks showed signs of decay by insects or by air. Therefore, he preferred a natural process in which dying trees decomposed and fell down, mainly in the dominant wind direction. He also pointed out that the occurrences of the trunks in the peat were local rather than widespread.[78]

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[77] *Ibidem*, p. 487.
[78] *Ibidem*, p. 86. See also his prize-winning essay (note 34) p. 46.

The soils and earths have already been discussed in the section on the sand areas. Berkhey's studies on the subrecent tuffaceous limestones of the dune lake near Rockanje (Voorne), about which he held views that differed from those of the famous Peter Simon Pallas,[79] are also only mentioned cursorily here.

THE NATURAL CHANGES WHICH THE BEDS UNDERWENT AND SYNTHESIS

Chapters 5 and 6 of the treatise cover the genesis of the beds, and a synthetic cross section of the uppermost 4 to 5 metres all along the length of the province of Holland concludes the work.[80] As the style of Berkhey and the words used in his time are not readily understandable to the modern reader, it takes some effort to follow his argument. This especially holds true when conditions of very old age are discussed, where speculation on deluges and other floods lurks. The time scale used remains vague or is non-existent. His primary aim was to describe the present situation and the role of sedimentation (Dutch: 'aanhoging') which generated the beds.[81] Berkhey started his considerations with an event, somewhere in an undefined past, which he repeatedly indicates as 'deluge or other flood' (also: Cimbrian flood). Berkhey referred specifically to the book of Genesis, but cited many others[82] – such as Lucretius, Ovidius and the scientists of his own 'enlightened age', such as Buffon – as sources adopting the starting point that, after the earth had been generally disturbed by the waters, a process began in which new beds settled and mountains could be seen again. In settling, the substances became separated because of their physical and mathematical properties; the heaviest went down first, the lightest last. Berkhey wrote:

> In the beginning of the world or if you like it, after the deluge, there was this uniform sedimentation on the foundations of the Earth, unknown to us. But naturally, there is a following change, as the rivers Rhine and Meuse, brought in, from their source areas, mud and sand to the area of Holland. There is also the sea, and its distance and level, bringing sediment by flooding.[83]

This being the general concept, we must look at how it was applied to those scarce details known of the deeper underground. The deepest known beds are sand with some overlying gravel, at depths of 203 feet and more below

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[79] *Ibidem*, p. 980-1001. He had also paid attention to this phenomenon in his prize-winning essay (note 34).
[80] *Ibidem*, p. 128-200 and plate III.
[81] *Ibidem*, p. 127 seq.
[82] *Ibidem*, p. 171-172.
[83] *Ibidem*, p. 167.

Amsterdam. These beds must be extensive, and also the overlying thick clay bed, containing seashells in its upper part, that proves flooding by the sea. Berkhey deduced from data of other thinner clay beds a model for the relation between the thickness of a clay bed and its lateral extension, hence his belief that thick beds must underlie the greater part of the region of Holland. During deposition of the shelly clay, sea level must have been about 100 feet (31 m) lower, but then the North Sea may have been smaller, as 'from recent observations it is known, that in flooding it tends to affect the coasts'.[84]

As in these beds, and also in all higher deposits, including those that underlie the reclaimed polders of Holland, there are no thick banks of shells but thin layers only. Berkhey concluded that all these beds originated in an environment that was only occasionally flooded by the sea. This meant to him that these beds had been formed at around sea level, not in a permanently deeper sea. The process of sedimentation already began when the beds of Naarden, containing stones and gravel, were formed. He conjectured that these beds occur over a rather large area in the subsoil of the Zuiderzee and of North Holland. There, they must underlie the clay beds found in higher levels (i.e. those underlying the reclaimed polders).[85] As the North Sea became gradually larger, the land became higher as a result of materials washed away from the coasts, as well due to the mud and clay of the rivers Rhine, Meuse and Scheldt. The observations in the floor of a reclaimed lake at Hazaartswoude (near Leyden) might serve as proof of this process. Here, remnants of seashells and river snails indicated such a mixed provenance, although the absence of seashell banks pointed towards a stronger influence of the rivers. Generally speaking, the southern part of Holland, in Berkhey's view, had always been higher than the area further North because it was heightened more through the flooding by the great rivers than by the sea. Also, the whole of Holland is sinking because, as a result of the reclamation of the former lakes left after peat cutting, the sediments subside and become more compact (by drainage). This was also happening in the diked peat lands. Originally, however, the latter should already have been lower than the surrounding land, as sand and clay layers were found overlying the peat. On the other hand, in large areas, peat was found overlying the aforementioned deeper clay and sand; it cropped out at the surface when lakes that originated from

[84] According to modern interpretations, the level of 31 m is of interglacial age. Therefore, no continuity exists with the overlying beds, as Berhey supposed there was. However, the latter certainly originated when the sea-level was rising, but in the Holocene, and, therefore, during another sea-level cycle.

[85] *Ibidem*, p. 193 seq. These stony beds are Diluvium sensu Buckland and Middle Pleistocene in modern terms.

peat cutting were made dry. Along the rivers, sand overlies older clay beds because it settled first when the river flooded, later clay having been deposited on top. By this process, lower areas originated, away from the rivers, which could be filled in and formed large peat lands. The basin shape of such former peat areas could well be observed in several reclaimed polders, the clay floor of which rises near their edges. In contrast, in the higher grounds of the coastal inner-dune areas, no such gradual, large-scale changes in thickness and heights of the sediments were found. Here, the changes of the iron ore and ochre beds and those of compact sand beds could not be traced over larger distances, as they were replaced by similar beds on top of or under them.

A most remarkable plate is added (Fig. 7) to serve as synthesis of the foregoing considerations. It shows a section through the upper 5 metres along the greatest distance across Holland (Fig. 4). Berkhey stated: 'Its distances are geometrically correct, but the depths and boundaries of the beds are less extremely accurate as shown in the examples [Figs, 5 and 6]; this is also the result of smallness of proportions. But all of it is based on good tests'.[86] Such a geological profile over such a distance, based on point observations, is a remarkable achievement for its time, and to my knowledge the earliest geological section of this kind. As it proved difficult to reproduce it fully, because of its small dimensions, Fig. 7 reproduces parts of it, from four areas:

1. the areas south of the river Meuse, mostly sand and clay, fewer peat beds;
2. the peat lands east of the town of The Hague;
3. section through the river plain of the Old Rhine, where peat is missing;
4. the inner dune area around Haarlem, mostly sands with intercalated peat and soil lenses.

The deeper beds in the section are known in less detail and indicated in writing only. Probably, the colours used will be familiar to modern readers, as they are similar to modern conventions (e.g. sand: yellow, clay: blue etc). Underlying the colours are signatures in black that are, likewise, still in use in modern geological literature (e.g. sand: stipples, clay: horizontal hatching etc.) Comparing the above-mentioned examples with modern data, it becomes clear how well informed Berkhey was.[87] Some 80 years later, Staring's map may have had more information on surface patterns, but vertical information was much less detailed, if not absent. Only the sections published in the twentieth century show comparable detail.

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86 *Ibidem*, p. 195.

87 E.g., compare the section across the Rhine (Fig. 7 sub 3) with Fig 16 in Zagwijn, *op. cit.* (see note 29).

Berkhey's *Treatise on the Grounds of Holland* was written a few decades before geology became a discipline in its own right. In his time, the nature of the interior of the earth, the origin of solid rocks, as well as the nature of fossils were matters of great uncertainty and speculation. Therefore, it is understandable that Berkhey, in citing contemporary work, e.g. that of the naturalist Buffon, repeatedly used a kind of standard rhetorical phrase, saying that even the enlightened scientist cannot give answers to all questions posed by nature. Perhaps this attitude was induced by an affinity to ideas widely spread in Calvinist Holland, classified now as physico-theology, seeking God's hand in nature.[88] In particular, Martinet's *Katechismus der Natuur*, written some years after Berkhey's book, was highly popular in its time and was reprinted several times. Here, the reader could find the proper biblical answers that he was looking for, if confronted with the enigmas of the past of the earth. In this respect, Berkhey's work must have been disappointing to his contemporaries. He did not provide certainty. Even when he referred to the Deluge, he hastened to add, 'or some other flood'. This part of his work probably appeared rather dull to his audience, even though Berkhey tried to enliven his book by descriptions of practical matters.[89] His book on the grounds of Holland is a factual description of the subsoil of the region with a lot of detailed information, astonishingly accurate when compared to modern geological knowledge. In Berkhey's time, stratigraphic classification and corresponding nomenclature had still to be invented. Nevertheless, he was evidently aware of the importance of the position of a bed in relation to those overlying and underlying it, as he indicated repeatedly. However, he gave no indication that he was familiar with the writings of Steno, who is commonly regarded as one of the first to formulate this stratigraphic principle, which lead to the recognition of sequences and eventually to that of geologic time. Berkhey is at the base of this evolution, and hence the attribution of the beds described, though their succession is known, to events in the past is extremely vague, unless a specific find like a roman coin presented a point of reference.

Therefore, it remained obscure whether the oldest (or deepest) beds in Holland, could be 'dated' back to the biblical deluge or not. Carefully he tried, as far as the scanty data allowed, to deduce the way in which these beds underlie the better-known clay beds of Holland. As he had no suitable

[88] See J. Bots, *Tussen Descartes en Darwin: Geloof en natuurwetenschap in de 18e eeuw in Nederland* (Assen, 1972).
[89] Cf. Arpots, *op.cit.* (see note 30) p. 66.

nomenclature at his disposal, as Buckland had when he introduced the Alluvium and the Diluvium, Berkhey needed far more words to express his intentions. Fossils of any kind were considered to belong to still living species and exotic finds, like those of elephants, did not belong to some extinct creature but to elephants introduced in this area by Roman troops. On the other hand, as all fossil shells were considered to represent extant species, one could use them as indicators of the depositional environment of the sediments. Berkhey thus used them to distinguish beds laid down by rivers from those originating from the sea and even gave estimates on mixed environments. Formally, the use of what is called 'facies fossils' in solid rocks was introduced in 1762 by the German pioneer in stratigraphy, Füchsel.[90] It is highly improbable that Berkhey was familiar with Füchsel's work.

By combining these data with the distribution of the sediments, Berkhey was able to draw a dynamic model of the genesis of the beds of Holland. On the one hand, the rivers had laid down their sediments, heightening the land surface during this process, in particular in the southern part of the province. On the other hand, the sea was active in the North, i.e. the region around the Zuiderzee and in the far South, in the province of Zeeland and adjacent areas. The sand area parallel to the coast – partly dunes – had been formed 'by the combined action of the sea and the wind'. Accurately described are old surfaces (i.e. soil horizons), partly in several sequences on top of each other. Under all these beds clay was found, which also formed the floor of the reclaimed peat lakes. Having studied the formation of peat by plants, Berkhey described how thick peat beds fill basin-like depressions between river arms and other channels. Such basin shapes can be studied particularly well in reclaimed lakes ('polders'). He attributed the formation of the beds to specific agents and ascribed the process of continued sedimentation, which in his view raised the level of the land, to rising sea level, an opinion akin to modern ideas. Staring, in contrast, adopted a model of stable sea level about a century later.

The most remarkable aspect of Berkhey's work are his accurate geological sections, such as the Katwijk section (Fig. 6) drawn after nature, or the detailed section, 130 km long across Holland, constructed from point observations, and very different from the schematic profiles of early geological literature. Moreover, this profile (Fig. 7) is probably the oldest section across such a large area. Berkhey must have been a good observer in the field and this means that he was not afraid of getting his shoes dirty. Indeed, he

[90] See K.A. von Zittel, *Geschichte der Geologie und Palaeontologie* (München/Leipzig, 1899) p. 52.

described how he looked for a suitable place for his experiment on peat formation until he found a place where he sank ankle-deep in the mud. He carried out the borings himself, such as peat borings, and was evidently not worried about looking a bit muddy. Owing to the many special stones and minerals collected from sandpits, he must have studied their faces regularly. He certainly was not an arm-chair academic.

Finally, we should consider why his work was nearly forgotten afterwards, at a time when other early pioneers in the geology of the Low Countries were mentioned repeatedly. One reason may have been that Berkhey seems to have lost interest in this matter after he finished in 1770 the second volume of the *Natural history of Holland*. Further, it seems that the troubles he had in political, poetical and academic matters after his best years – i.e. after 1775 – placed him outside the mainstream of scientific developments. Having won two gold-medals from the most outstanding scientific society, the Hollandsche Maatschappij der Wetenschappen in Haarlem, he was never appointed a member of this venerable society. The fact that the famous Van Marum, by the end of the century, described a similar experiment on peat formation without mentioning Berkhey may be indicative. One may suppose that his work was considered as old-fashioned and certainly his terminology must have been outdated. In any case, his work, which contained a wealth of accurate geological observations on the younger beds in Holland, including geological sections, has had no visible influence on the further development of geology of the region.

Was basalt derived from water or from fire? Dutch contributions to an 18th-century controversy

Emile den Tex

introduction

Around 1800, the nature and origin of basalt became fiercely disputed topics between naturalists belonging to two schools of thought:

– the neptunists, for whom the 'element' water was the medium of its deposition; and
– the vulcanists-cum-plutonists, who relied on the 'element' fire for its transformation or fusion from a pre-existing rock.

Neptunism was a theory developed by Italian, Scandinavian and German naturalists to explain the undisturbed bedded rock-sequences in lowlands and hilly ground. It was perfected and established by the great Saxon mining engineer and geognost, Abraham Gottlob Werner (1749-1817).

In contrast, the vulcanists had their stamping grounds in regions rich in active volcanoes (essentially southern Italy and Iceland), and in those sprinkled with dormant or recently extinguished volcanoes, such as central and southern France, northern Italy and even north-eastern Scotland and north-western Ireland. The few plutonists of the period were virtually confined to northernmost England and Scotland.[1]

werner's neptunistic interpretation of basalt

Werner's theory of neptunism and his corresponding threefold (later fourfold) lithostratigraphy were partly based on sound empirical observations and partly on almost pure speculation.[2] For the genesis of the upper

[1] E. den Tex, 'Clinchers of the basalt controversy. Empirical and experimental evidence', *Earth Sciences History*, 15 (1996) p. 37-48.
[2] A.G. Werner, *Kurze Klassifikation und Beschreibung der verschiedenen Gebirgsarten*. Facs. of the 1786 ed. (New York, 1971).

members – the 'Aufgeschwemmtes' and 'Flötzgebirge' – Werner saw distinct analogies in contemporary sedimentary basins, where suspended mineral particles could be seen to settle out of cold water, whereas he gave the lowermost member – the 'Uranfängliches' or 'Ganggebirge' – a wholly speculative origin as a crystallisation product from a hot-water solution.[3] A related problem arose over his interpretation of the crystalline rock basalt. Although it is true that Werner's mental switch from a provisionally acknowledged volcanic nature to a firmly convinced sedimentary origin of basalt – which he deduced from the exposures at Stolpen (1776) and the Scheibenberg (1788) – was generally warranted in the contemporaneous state of the art, it contained an awkward paradox regarding the environment in which the basaltic rocks and the sedimentary strata below and above them had formed. Incredibly rapid changes from cold to hot water and vice versa were implied to have prevailed in a sea where settled sediments of the 'Flötzgebirge' (to which Werner had essentially confined his volcanic and basaltic rocks) and unmistakable crystalline basalts occurred in an alternating sequence of deposition.[4]

VULCANISTIC AND PLUTONISTIC INTERPRETATIONS OF BASALT

The protagonists of vulcanism constituted a more or less assorted lot. Prominent vulcanists were John Whitehurst (1713-1788), Jean-Étienne Guettard (1715-1786), Nicolas Desmarest (1725-1815), Sir William Hamilton (1730-1803), Rudolph Erich Raspe (1739-1794), Barthélemy Faujas de St. Fond (1741-1819), Johann Jakob Ferber (1743-1790), Déodat Dolomieu (1750-1803), Jean-Louis Giraud Soulavie (1752-1813) and the Reverend William Hamilton (1755-1797). Although these naturalists shared a similar interpretation of basalt, they lacked a common theory of the earth. In fact many of them, especially Desmarest and Dolomieu, remained adherents of neptunism as a general theory.

James Hutton (1726-1794) added a new dimension to the problem of vulcanism's nature and origin with his cyclical theory of the earth,[5] in which a link was forged between the superficial basalt via his subterraneous whinstone (later to be called dolerite) with the fiery plutonic earth.

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3 O. Wagenbreth, 'Abraham Gottlob Werner und der Höhepunkt des Neptunistenstreits um 1790'. *Freiberger Forschungshefte,* series D, nr. 11 (1955) p. 183-241.
4 See J. Playfair, *Illustrations of the Huttonian theory of the earth* (Edinburgh, 1802) and E. den Tex, *Een voorspel van de moderne vulkaankunde in West-Europa. Met nadruk op de Republiek der Verenigde Nederlanden* (Amsterdam, 1998) p. 178.
5 J. Hutton. 1795. *Theory of the earth with proofs and illustrations*, 2 vols, (Edinburgh, 1795).

The weak spots in the neptunistic interpretation of basalt were only gradually recognised and an increasingly fierce controversy over the nature and origin of basalt developed in the last decades of the eighteenth and the first of the nineteenth century.[6]

In that period, the Republic of the United Netherlands was in deep conflict. Whereas the 'Stadhouder', Prince William V, and his Orangists sided with Britain, Russia and Prussia, the Dutch Patriots openly supported the philosophy of the French Revolution and initially hailed their 'liberation' by the French army. Many literary and scientific personalities were active in the patriotic movement and became strongly influenced by the French political reformation.

French naturalists discovered an increasing number of extinct volcanoes in Auvergne and the Vivarais in those days, while Desmarest, Soulavie and Faujas de St. Fond observed close relations between basalt and lava, in a vertical as well as in a lateral sense. In spite of political controversies and wartime enmities, their scientific communication with virtually all European naturalists remained unimpaired. Thus, two competent Dutch naturalists – Martinus van Marum (1750-1837) and Adriaan Gilles Camper (1759-1820) – freely visited colleagues in France, Germany and Italy, joined their field excursions and took part in unbiased discussions on geological topics.

Van Marum was an all-round naturalist. In his capacities as director of Teyler's Museum and secretary of the Hollandsche Maatschappij der Wetenschappen, he became a key figure in Dutch science.[7] Having read Thomas Burnet's highly speculative *Telluris theoria sacra* (1681), he exclaimed, 'It explains one miracle by introducing another and thus it explains nothing at all!'.[8]

Apart from his ardent promotion of new developments in physics and chemistry, Van Marum grew more and more interested in the geological aspects of nature. Owing to his studious and unassuming character, he befriended many outstanding scientists. His geological biographer, Willem Nieuwenkamp, summarises it as follows, 'Van Marum shows his gift of getting at the right side of eminent men'.[9]

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[6] Den Tex, *op. cit.* (note 1).
[7] Cf. R.J. Forbes et al. eds. 1970-1976. *Martinus van Marum. Life and work,* 6 vols (Haarlem, 1970-1976).
[8] Quotation from W. Nieuwenkamp, 'The geological sciences', in: Forbes, *op.cit.* vol. 3, p. 234.
[9] *Ibidem,* p. 231.

Van Marum undertook two journeys with a volcanic and basaltic interest. Since Forbes has described these trips in great detail,[10] I shall restrict my contribution to Van Marum's most important observations on the basalt controversy. The first journey took him to Hessia and Saxony in 1798. In Hessia, he visited the brown-coal and basalt exposure of Weissenstein in the Carlsgebirge. He found the brown coal covered by a layer of clay and pumice, separating it from the overlying brecciated basalt, which he called 'lava grit'. The 'Oberkammerrath' of the Margrave of Hessia told Van Marum an interesting anecdote relating to Werner's visit to the Weissenstein. According to him, the great master had admitted that this particular basalt should be of volcanic origin, in view of its close association with pumice. This story has never been confirmed. Possibly, it was a slip of the tongue of an obstinate but inwardly undecided neptunist. Characteristically, Van Marum failed to express himself either way on the issue concerned.

From the Weissenstein, he travelled on to the coal pit and its overlying basalt at Meissen in Saxony, an exposure famous since medieval times for its spontaneous coal fires. This sequence was 'gefundenes Fressen' for neptunists and other believers in the popular notion of a volcanic fire fed by combustion of vegetable matter. On the other hand, many a vulcanist would have hailed the increasing grade of metamorphism to bright coal and its development of a columnar structure towards the basalt as proof of combustion having been responsible for the baking of the overlying coal layers. Again, neither in speech nor in writing did Van Marum express an opinion on the matter.

His only outspoken opinion regards the cause of the columnar structure in basalt. As a thoroughly educated physicist and crystallographer, Van Marum dismissed the then popular interpretation of the columns as giant crystals precipitated from an aqueous solution. Instead, he attributed their origin to shrinkage during cooling of the lava and he substantiated his opinion with an up-to-date treatise on the physical process of differential cooling of lava underlain by cold solid rock.[11] Faujas drew a similar conclusion in 1778 in his book on the volcanic rocks in the south-eastern part of France.[12] Van Marum was probably influenced by Faujas, since he frequently cited Faujas's bookin the notes for the lectures that he delivered in Teyler's Museum in 1796-1797.[13]

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[10] R.J. Forbes, "Journey to Cassel, Göttingen, Gotha, Erfurt, Weimar and Jena in 1798', in: Forbes, *op.cit.* vol. 2, p. 273-311.

[11] Nieuwenkamp, *op. cit*, p. 231.

[12] B. Faujas de St.Fond. 1778. *Recherches sur les volcans éteints du Velay et du Vivarais*, (Grenoble, 1778).

[13] The syllabus of these lectures is preserved in the archives of the Hollandsche Maatschappij der Wetenschappen (Haarlem).

The second journey took place in 1802. As far as basalt was concerned, only his visit to Paris is of importance.[14] His main contact there was Faujas, the occupant of the first chair of geology in the Muséum d'Histoire Naturelle. As fate decided, the famous Werner was to arrive at the same time and with the same intention to purchase a copy of the highly sought-after set of René-Just Haüy's 500 crystal models. Although Van Marum had previously made an appointment with Haüy for the next day, the latter was so overwhelmed with Werner's wish to make an appointment for the same day that he tried to put Van Marum off his priority. The latter was not impressed by Haüy's awe for Werner and replied, 'Be his fame ever so great, that does not give his admirers the right to go back on their promises'. Neither Van Marum nor Werner appear to have been spiteful over the unfortunate event, for they gracefully dined together, by invitation of Faujas, and a week later, Werner received Van Marum in his lodgings and promised to send him rock samples from his cherished Saxonian Erzgebirge, the model outcrop for his 'Uranfängliches'. On that occasion, the rarely publishing Father of neptunism confided to Van Marum that his geognostic ideas were best presented in Robert Jameson's book *Journey through Scotland*!

ADRIAAN GILLES CAMPER

Of lesser status as a scientist than Van Marum, but earlier and more actively engaged in the study of basaltic and volcanic rocks, was his contemporary, Adriaan Gilles Camper (1759-1820),[15] third son of the famous physician and naturalist Petrus Camper. Camper junior received private tuition in mathematics, physics and natural history, as well as the classical and modern languages in his parental home at Franeker, under his father's supervision. Later, he enrolled at the Universities of Groningen and Leiden. Though only a student, he was allowed to accompany his father on some of his scientific travels to Germany and France where he became acquainted with eminent naturalists and physicists. In this way, Adriaan Gilles was rapidly brought to maturity as a naturalist, developing a special interest in geology and mineralogy.

Like Van Marum, Camper junior made two journeys with an interest in volcanism and basalts. The first, in 1784, took him along the eastern bank of the river Rhine.[16] His first object of study was the extinct volcanism of the

[14] R.J. Forbes, 'Journey to Switzerland and France in 1802', in: Forbes, *op.cit.* vol. 2, p. 312-377.
[15] For his biography see J.G.S. van Breda, *Levens-schets van Adriaan Gilles Camper*, (Gent, 1825).
[16] See A.G. Camper, *Voyage de Dusseldorp pour examiner les Volcans au bord du Rhijn, depuis Bonn jusqu'à Coblentz (1784)*, Ms. Amsterdam, University Library, G II 54.

Siebengebirge, which in those days belonged to the Electorate of Cologne. The 'Markwalter' of the Elector accompanied him on his seven-day tour of the most renowned hills in the area between Königswinter and Oberwinter. No fewer than sixteen volcanoes, among which several basalts, were visited on this tour. The first visit was to the Drachenfels, which was to gain repute in literary circles by romantic and naturalistic journeys, such as Goethe's. Sir William Hamilton had produced a more scientifically focussed report in 1779.[17] Camper did not agree with Hamilton's claim that three of the Siebengebirge volcanoes, namely Wolkenburg, Drachenfels and Stromberg, carried a crater on top of a cuniform base. He even declared not to have seen any craters at all. On the other hand, he followed the 'modern Pliny of Vesuvius' in his view that the ash or tuff of the Weilberg was a pozzolana or trass.

After brief visits to the remaining volcanoes of the Siebengebirge, he set out to cross the river in order to examine the graben of Niedermendig in the Eifel district. But before doing so, Camper decided to have a close look at the Unkelsteiner basalt, the regular columns of which descended into the Rhine. To the West of the river, Camper went to see the famous basalt quarry of Niedermendig, where the broad columns of the basalt had served as a source of millstone for ages, while the resulting caves provided ideal storage for the popular 'Niedermendiger Felsenbier'. On the spot, Camper came up with a distinction between three formations. From top to bottom of the quarry face he recognised:

- a cover of sand and volcanic material;
- a layer of sand and clay with mammalian and vegetable remains; and
- a coarsely columnar basalt, characterised by marks of burning and vulcanicity.

Herewith, he gave a very clear and modern description of the quarry profile.

In January 1787, signs of a serious (possibly venereal) disease became manifest and, in consultation with his father, Camper decided that he should go to south-eastern France and Italy on a journey of recuperation and geological collecting that lasted from the 20th of June 1787 to the 16th of October 1788.[18] He met Faujas in the Vivarais and together, they faithfully reiterated the latter's journey that is accounted for in Faujas's book on this volcanic

[17] W. Hamilton, 'An account of certain traces of volcanoes on the banks of the Rhine', *Philosophical Transactions of the Royal Society of London*, 68 (1777-1778) p. 1-16.

[18] A.G. Camper. 1787-1788. *Itinéraire de Paris par Lion, Grenoble, Montélimar, le Vivarais, Avignon, Aix, Marseille à Livorne par mer, Florence, Siene, Rome, Naples de 20 Juin à 16 Octobre 1788*. Ms. Amsterdam, University Library, II E 2.

area. Part of the way, they were accompanied by Faujas's friend, Madame Chenet, whose beauty and wit enchanted Adriaan Gilles. Via the basalt knolls of Rochemaure, Melas and Maillas, and the volcano of Montbrul, they arrived in Freissinet near Aubenas on the 19th of July, where Camper saw volcanoes perched on top of a granitic basement.

More interesting are the observations Camper made during his trip down the Volane valley between Antraigues and the Coupe d'Aisac, the notorious bone of contention between Faujas and the orthodox neptunist Johann Wilhelm Friedrich Widenmann.[19] The following is a paraphrase of Camper's statement regarding this controversy. On the one hand, he conceded to Widenmann that Faujas's draughtsman might have flattered the profile of the Coupe d'Aisac to clarify his master's interpretation (but not to falsify it, as Widenmann had claimed!).[20] On the other hand, he confirmed Faujas's opinion that the porous lava occurring in the ravine that led downward to the columnar basalt was similar to that in the crater. Camper also agreed with Faujas's observation that the basalt contained fragments of the underlying granite. Moreover, he recognised that the columnar basalt terraces that accompanied some of the torrent and river valleys around Antraigues had neither craters nor volcanic slags, and that they rested on granitic river banks. This confirmed the findings of the vicar of Antraigues, Jean-Louis Giraud Soulavie, published in 1780.[21]

Independently, Camper observed a basalt terrace in the Volane valley containing not only granite fragments but also boulders of the valley floor. He drew an informative sketch of the situation and concluded that a molten basalt had flowed over a boulder bed that had been derived from a granitic basement. With this purely inductive hypothesis explaining a complex geological scene, Adriaan Gilles Camper stands out as a remarkably modern geologist.

In Rome, he met two outstanding naturalists.[22] The first and foremost was the French Etna expert Déodat Dolomieu, who combined a thorough knowledge of nature with a broad interest in art. Camper must have had fruitful discussions with him, although no testimony of it has been found. It so happened that the famous author and naturalist Goethe kept residence in Rome.

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19 Faujas, *op.cit.* p. 267-288.

20 J.W.F. Widenmann, 'Was ist Basalt? Ist er vulkanisch oder ist er nicht vulkanisch?', *Höpfners Magazin für die Naturkunde Helvetiens*, 4 (1789) p. 172-176.

21 J-L. G. Soulavie. 1780-1784. *Histoire naturelle de la France méridionale…,* vol. 2 (Nimes, 1780) p. 180-204.

22 IJ. Botke, 'Je recueille toujours des pierres. Adriaan Gilles Camper in Italië', in: Y. Botke et al. eds, *Ziedaar Italië. Vijf eeuwen Friezen en Groningers in Italië* (Franeker, 1999) p. 66-103.

He received Camper junior at least twice. Initially, Goethe praised him for his explanation of his father's ideas on vertebrate typology. The latter had sharply criticised Goethe's attribution of the intermaxillary bone to man. Later on, Goethe's favour veered round after Adriaan Gilles had ridiculed the zoological knowledge of the romantic writer and naturalist. Indeed, in a letter to Johann Gottfried von Herder, Goethe referred to Camper junior as a 'Strudelkopf' (a hothead), who knew a lot, believed to understand too quickly and trifled with the facts. In one of his satirical 'Venetianische Epigramme', Goethe made fun of Adriaan Gilles Camper's dull-wittedness in respect of the ambiguous signification of the German word 'Vögeln' and suggested that the 'Strudelkopf' had been punished with syphilis for his high inflammability in erotic and scientific matters.

Adriaan Gilles Camper's many visits to Sir William Hamilton were clearly much more rewarding. Apart from his status as envoy extraordinary and minister plenipotentiary of his British Majesty George III to the Neapolitan Court of Ferdinand IV, King of the two Sicilies, Sir William was a widely recognised expert on objects of antique art as well as an eminent volcanologist. In his private observatory, the Villa Angelica at Portici, Hamilton kept the most modern apparatus for his research as well as an extensive and well-documented collection of rocks and minerals from the nearby Vesuvius. Adriaan Gilles must have felt like a fish in the water in the company of the friendly and communicative Sir William, for he wrote in his diary that he felt more like Hamilton's son than his pupil. On the subject of his future travelling arrangements Hamilton offered Camper a copy of his studies on the Ponza islands and their extinct volcanoes and expressly advised him to visit these. It is unknown what caused the latter to divert his interest to the equally volcanic islands Ischia and Procida.

Adriaan Gilles' highly inflammable state of mind was once more demonstrated, when he described his ardent admiration of the shapely and alluring mistress of Sir William, the youthful Emma Hart. She had just been admitted as a member of the household, albeit somewhat 'contre coeur', at the urgent request of his nephew Charles Greville in London, whose marriage plans were inconvenienced by her. Camper's evaluation of 'the nymph of the attitudes' was somewhat ingenuous – if not ironic– as he stated in a letter to his father, 'elle m'a fait mille gentillesses très innocentes'.[23]

Camper highly praised the cabinets of natural curiosities, shown to him by the abbots Mervini and Bottis. These cabinets contained unique specimens of volcanic products that had been collected by these early mineralogists in the immediate surroundings of Vesuvius. Despite his failing health, he did

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[23] *Ibidem,* p. 78, 79.

not hesitate to climb and sample the volcano himself, albeit under the leadership of that faithful guide of Hamilton, the one-eyed Bartolomeo Pumo, the cyclops of Vesuvius. Only a year before Camper's arrival in Naples, the volcano had suffered an eruption, but Adriaan Gilles' interest in Vesuvius was not simply scientific, the volcano clearly attracted him also in a romantic way. Notwithstanding Sir William's persuasion, a proposed visit to Sicily did not take place. Although Camper put the blame on his empty purse, his ill health was possibly the more important cause.[24]

CONCLUSION

I hope to have demonstrated that Martinus van Marum and Adriaan Gilles Camper contributed on an unbiased and expert level to the knowledge of basalt, especially about its columnar structure and geological setting. Between the two, Van Marum was less assertive and had a wider field of interest, whereas Camper Junior was focussed on basalt and was less reliable, but had the makings of what was to be called a geologist. They both made many relevant observations in the field and assembled collections of representative samples. All of Van Marum's specimens may still be inspected at Teyler's Museum at Haarlem, but only three of Camper remain, and can be found in Groningen's University Museum.

[24] *Ibidem,* p. 81, 82, 87.

Crystal models: milestone in the birth of crystallography and mineralogy as sciences

Lydie Touret

The geometrical shape of some natural crystals, as well as their transparency – and, for some of them, their bright colours – have always attracted the attention of mankind. In ancient Greece, the power of Athens relied for a significant part on the mines in the Laurium area, ideally located at a close distance to the city. These mines provided the silver and other base metals that played such a large role in the development of the Greek civilisation. Well known is for instance the fact that the boats involved in the Salamine victory over the Persian army were financed with silver extracted from Laurium mines.

Mineralogically speaking, the Laurium is a unique occurrence, in which hundreds of different mineral species have been found. Many occur in the form of well-developed crystals, solids limited by perfect planes: spectacular shapes that have undoubtedly attracted the attention of many philosophers and artists since ancient Greece. It has been postulated that the five Platonic solids (tetrahedron, octahedron, icosahedron, hexahedron, dodecahedron), which play such a great role in Greek philosophy, found their basis in crystal shapes. It is also reasonable to suppose that Archimedes' study of semi-regular solids was inspired by observation of natural crystals (Senechal, 1990). In the Renaissance, the famous engraving 'Melancholia' by Albrecht Dürer, created in 1514, gives a prominent place to a polyhedron that closely resembled (but not exactly matched) a natural crystal (calcite?). Might the difficult interpretation have partly caused the artist's melancholy?

A simple and natural way of making crystals is by freezing water – snow or ice – as regularly seen on the tops of high mountains in Greece every winter. It was soon inferred that all transparent crystals – notably of this very common variety of silicium oxide, quartz – are nothing but some variety of ice. This idea, part of Aristotle's philosophy and popularised by Claudius in a famous poem, persisted for ages, until the age of Enlightenment.

FROM NATURAL CRYSTALS TO MODELS

Even if some natural crystals, notably of quartz, can be quite spectacular, they are rarely complete. In most cases, they occur in groups of crystals, consisting of one or several mineral species and interpenetrating each other. Some faces may be broken, covered by other minerals or missing. Most important, a fundamental law in mineralogy and crystallography states that in a given crystal, only the angles between adjacent faces are constant. It was first discovered by the Danish monk Niels Stensen (Steno) (1638-1686) in the seventeenth century, later generalised by Jean Baptiste Louis de Romé de l'Isle (1736-1790), shortly before the French revolution. The development of the faces is variable, depending upon the modalities of the crystal's growth. Some faces may grow more rapidly along certain directions. This results in a 'distorted habit', which may give two crystals of the same mineral appearances that at first sight may look very different.

This law of constant angles was incidentally rediscovered by an assistant of Romé de l'Isle, Arnould Carangeot, who assisted his master with the description of his extensive mineral collection. He initially used copper gauges, which were practical for the verification of constant angles within a single mineral species but not adapted to the comparison of different minerals. He then had the idea to design a simple but highly efficient instrument, a protractor with a mobile limb, which could be applied on two adjacent faces. Under the name of 'application goniometer', this instrument rapidly became the most important tool used in mineralogical studies. Together with all other instruments – most of them also very simple: hammer, scales, magnifying-glass and so on – it was used for the determination of a mineral's physical and chemical properties (Fig. 1).

When it was realised that in natural crystals any face could be translated by an unknown distance, the idea to replace them by ideal models, in which each face would be equally developed, became almost mandatory. As a matter of fact, the idea was not new. The great naturalist Linnaeus had tried to classify minerals in the same way as he did for plants or animals and had already published projections of cubes or octahedrons that were supposed to represent ideal crystals. But these attempts were very limited and mostly intended to underline the striking similarities between some crystals and the mathematical forms defined by the ancient Greeks. Models of the five Platonic solids, mostly done in parchment or paper, were common objects in many 'cabinets de curiosité', e.g. in the 'Wunder und Kunstammer' of the Elector of Saxony in Dresden.

The first attempts: the terra cotta models of Romé de l'Isle

Besides Arnould Carangeot, Romé de l'Isle had a number of skilled and enthusiastic co-workers, such as Lhermina and Swebach-Defontaines, who assisted him in the study of his extensive mineral collection. Except for a few

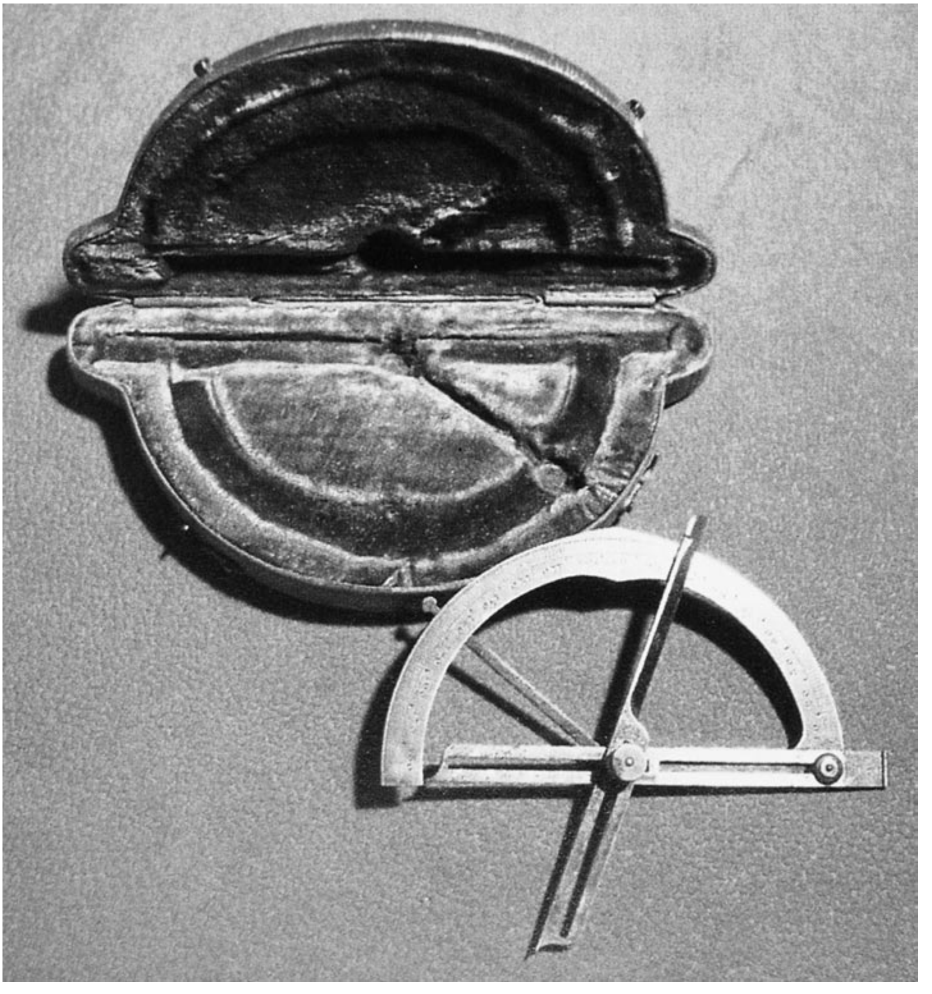


Figure 1 The application goniometer, designed by Arnould Carangeot. This silver model, an exact replica of Carangeot's 'mesure-angle', has been used by Haüy himself during the many years that he spent at the Museum d'Histoire Naturelle in Paris (Courtesy MHNP) (width: about 8 cm).

mineral species, like quartz or calcite, large natural crystals are either rare or incomplete. Romé de l'Isle and his assistants kept the small crystals in small paper boxes, very often cut from old playing cards (Fig. 2), but they soon felt the need to make artificial crystal models, somewhat larger and, above all, idealised, with all identical faces having the same development. In this respect, Romé de l'Isle went far beyond any of his predecessors. He rapidly established crystal models as an essential part of any mineral description. In his public lectures and demonstrations for his protector, the Count Michelet d'Enery, he used models in metal (copper, brass) (Fig. 3) that could be handled by inexperienced observers without causing any damage. However, these models were difficult to make, could be produced only in very small numbers and were not very precise. With the help of one of his friends, who had access to the Royal Porcelain Manufacture of Sèvres, he had the idea to make small models (about 3 cm high, 1 cm wide) sculpted in soft clay, then baked at high temperature in the porcelain stoves. This terra cotta technique is by no means easy, but Romé de l'Isle and his co-workers, notably Lhermina and Swebach-Desfontaines, succeeded so well in mastering it, that in a few years they were able to produce hundreds of crystal models, all with very precise and constant shapes and angles.

In 1783, Romé de l'Isle published his life's work, the *Cristallographie*, which contained hundreds of mineral descriptions and crystal drawings. It was a real scientific book but also a work in the tradition of artistic mineral books, such as the famous *Histoire Naturelle* (1781) by François Gautier D'Agoty. These books were very expensive and reserved for a small circle of

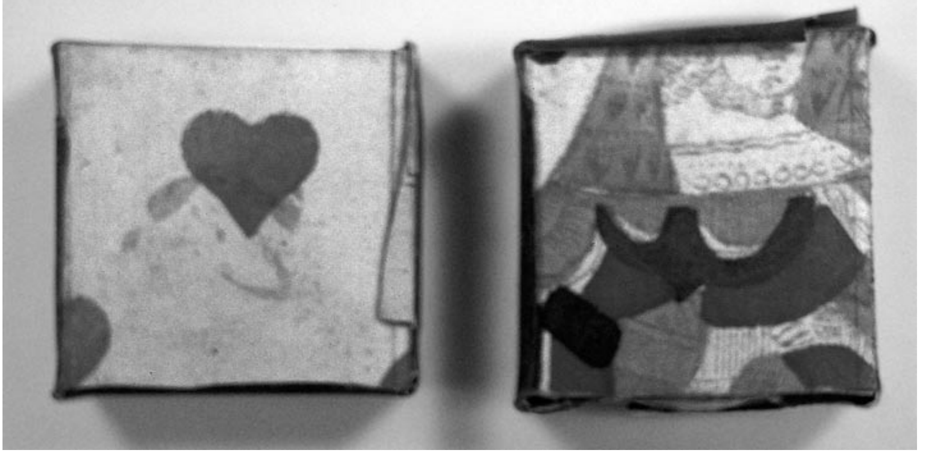


Figure 2 Carton boxes made from playing cards, used by Romé de l'Isle and his co-workers for storing his crystals.

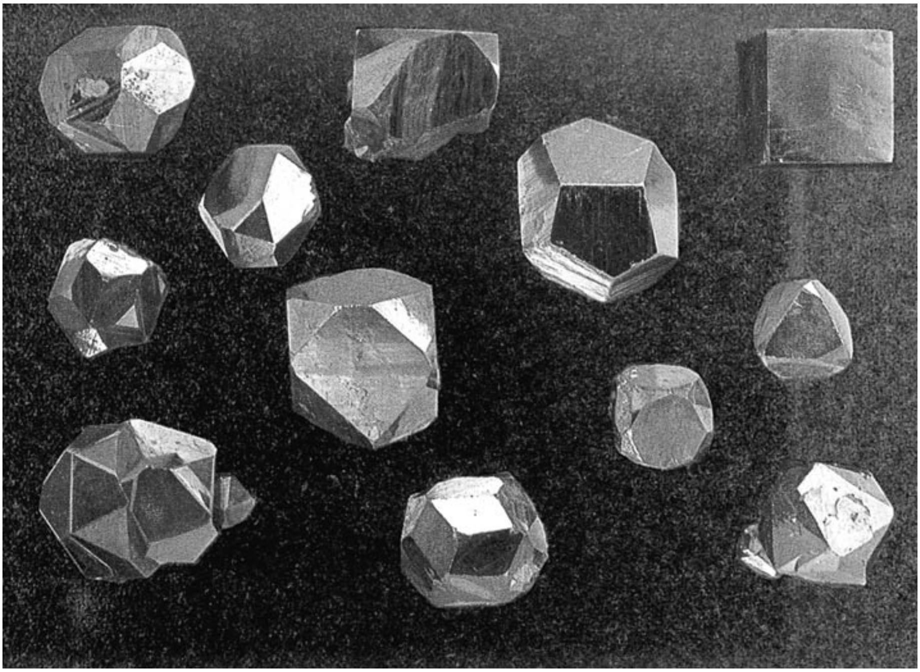


Figure 3 Brass models of crystals, used by Romé de l'Isle for the education of his rich protectors (average size: about 2 x 2 cm).

rich aristocrats. In order to boost the sales that, obviously, did start rather slowly, Romé de l'Isle decided to offer to each subscriber a complete collection of terra cotta models, representing all minerals described in his book. The complete collection counts 448 models and its success was such that, in less than ten years, many collections had been sold all over Europe. Other, smaller collections were presented in luxurious leather boxes and used by well-to-do amateurs to embellish their collections (Fig. 4). In contrast with later models, these small models were considered valuable objects and were never used for teaching purposes. As a consequence, many collections have been preserved and are now found in a number of European museums: the Museum d'Histoire Naturelle in Paris, Naturhistorisches Museum in Vienna, Teyler's Museum in Haarlem, the University Museum in Utrecht, the British Museum in London and so on.

At the end of his life Romé de l'Isle – simply born Romé in the small town of Gray, then changed his name to Romé Delille and finally to Romé de l'Isle, often hidden in his publications in the form of his initials (MDRDL= Monsieur de Romé De Lisle)- suffered from his close relations with the aristocratic circles and disappeared from the forefront of the scientific scene. He

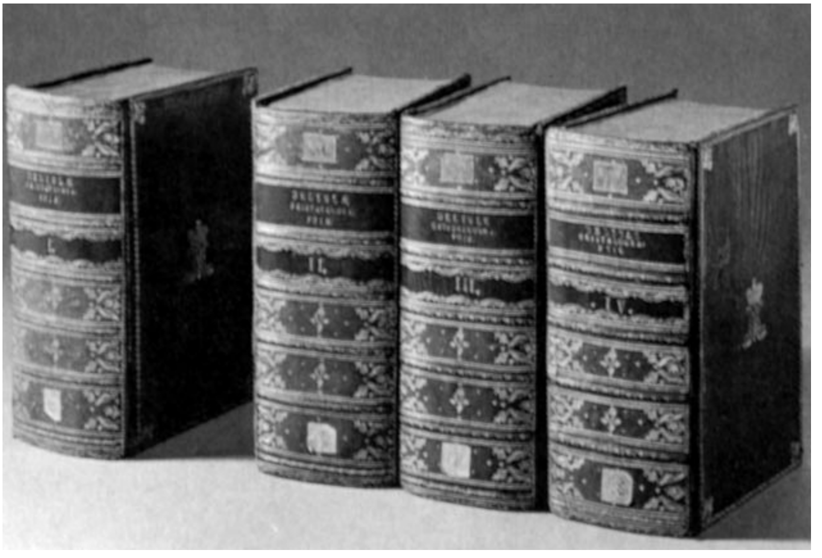


Figure 4 Box of biscuit models by Romé de l'Isle, in the form of richly decorated book cases, as 'aristocratic set'.

saw, with some frustration, the rise of a modest priest, René Just Haüy (1743-1822) (Fig. 5), instructor at the Collège de Navarre, who became so interested by a public lecture of Daubenton (Fig. 6) at the Museum that he decided to switch his major interests from botany to mineralogy. A few publications in the proceedings of the Académie des Sciences, as well as a good sense of communication, made him a direct competitor and, very soon the successor of Romé de l'Isle.

As early as 1784, Haüy claimed having had the flash of inspiration of his life after he accidentally broke a calcite crystal and realised that successive broken fragments had a similar rhomboidal shape until the final 'molécule intégrante', which would constitute the final building element of all crystallised matter. Haüy later worked out this theory in more detail (Haüy 1801, 1815), always recalling the anecdote of the broken calcite crystal. As discussed in detail by Hooykaas (1951), the reality was probably rather different. The idea of a scalenohedron built up by stacking rhombohedral nuclei, as well as the explanation of the calcite cleavage by the superposition of rhombic lamellae, had already been suggested in 1773 by the Swedish chemist and mineralogist Torbern Bergman (1735-1784). And Haüy, even if he did not recognize it openly, must have been aware of this work. He made a brief, rather negative reference to Bergman's contribution in his *Traité* of 1801, pretending having come across Bergman's work in 1779. This date was

Figure 5 Portrait of R.J. Haüy, Professor at the Museum d'Histoire Naturelle, by A. Tardieu.

for Haüy close enough to his two first communications to the Académie Royale des Sciences (1781, 1782) to suggest that his views owed nothing to Bergman. In fact, the exact date of Bergman's publication is 1773, and it is highly improbable that it would remain unnoticed for six years in the small circle of mineralogists of that time. Moreover, resemblance between both approaches is striking, evolving along a different line with time (lamels instead of molecules, choice of garnet besides calcite, twofold conception of the garnet of structure). We can only fully agree with Hooykaas that Haüy's initial ideas have been deeply influenced by Bergman, but that later on he tried to conceal this fact as much as possible (Hooykaas, 1951).

Original or not, Haüy's ideas were not readily accepted by Romé de l'Isle. He reacted rather bitterly, calling Haüy a 'cristalloclaste' (crystal smasher) and opposing violently to most of his publications. However, he was too old,

Figure 6 Portrait of Daubenton, the first Professor of Mineralogy at the Museum d'Histoire Naturelle, whose public lecture induced Haüy to shift his interests from botany to mineralogy (by A. Tardieu).

too much marked by the 'ancient régime', to hinder the triumphant rise of his rival to the top of the French scientific establishment: founding member of the Institut de France, then 'secrétaire perpétuel de l'Académie', professor at the Ecole des Mines, then at the Museum and at the Ecole Normale Supérieure, etc. Haüy always kept a very modest appearance, which did not prevent him from fiercely fighting his scientific opponents. He succeeded to remain 'en cour' under all political regimes: personal friend and collaborator of Lavoisier, with whom he worked on the 'système métrique', highly praised by Napoléon, and finally called to a chair at the Sorbonne university after the fall of Napoléon. A remarkable career, which denotes a strong political sense in a man apparently detached from all terrestrial contingencies.

FROM TERRA COTTA TO PEAR WOOD

Just like Romé de l'Isle had written the *Cristallographie*, Haüy wrote his *Traité de Minéralogie*, which was first published in 1801 and which for many years was to remain the worldwide basic text in systematic mineralogy. It carefully described more than 700 mineral species, with for each the drawing of its ideal crystal shape. Crystal drawings are compiled in the atlas (volume 5) of the *Traité*, together with representations of mineral assemblages (crystal twins) and theoretical representations of the 'figures de décroissement' (decrement figures) illustrating the notion of the 'molécule intégrante'. These figures are made according to elaborate projection techniques, derived from the principles of descriptive geometry, one of the great mathematical achievements of the time (with, as a major figure, Gaspard Monge, professor at the Ecole Polytechnique and close colleague of Haüy at the Académie des Sciences). This was obviously an immense work, for which Haüy, without acknowledging it very openly, had the help of many colleagues and students at the Ecole des Mines: F. Vauquelin, for the mineral analyses, Clouet, librarian at the Ecole des Mines, for drawing the atlas figures, and the students Trémery and Champeaux for the horizontal projections, under the supervision of Jérôme Tonnellier, priest like Clouet and Haüy and 'garde des collections' at the Ecole des Mines (Touret and Kohler, 2001). However, no matter how elaborate the method of projection or representation is, a drawing of a three-dimensional object is always difficult to visualise. Like Romé de l'Isle, Haüy felt the need to have crystal models to complement his drawings, but he switched from a small-scale, amateurish production to an almost industrial enterprise.

First of all, he saw, and discussed at length, the inconvenience of baked clays. Even when dealing with apparently simple forms, the making of crystal models requires a high precision. Angles must be defined within few minutes of a degree, if the edges are to intersect exactly into an apex. Not only is this precision extremely difficult to achieve in soft clay, so is avoiding deformation, notably shrinkage, during the baking process. When a model has been baked at a temperature of several hundred degrees, it becomes extremely hard, and any further modification is virtually impossible. As a matter of fact, the rare later attempts to reproduce Romé's models have all failed, and the exact procedure by which they were produced is still not yet completely understood.

On the other hand, carpenters were true artists in the eighteenth century, able to make some of the most beautiful pieces of furniture ever done at the time of Napoléon or his predecessors, the kings of France. Haüy used their skills and had his crystal models almost exclusively made in fine-grained pear wood, which turned out to be extremely convenient for this purpose. The size of the models is significantly larger than that of Romé's models, up to about 5 cm and larger for the 'modèles de décroissement', exquisitely carved and true masterpieces of ebenistery.

It took Haüy and his carpenters, first Gillot, then Claude Pleuvin, several years to master the technique of producing good crystal models. Claude Pleuvin, who was an extremely skilled worker, received a fee of 1900 livres (French pounds) from the Bureau de Consultation des Arts et Métiers in 1794, for having made wooden polyhedrons with indications of 'décroissement', for the demonstration of Haüy's crystallographic theory. The collection rapidly counted about 600 models (604 described in the *Traité de Minéralogie* of 1801), and counted about 700 models at the end of Haüy's life. After the death of Claude Pleuvin, the work was continued by his son, Pleuvin fils, assisted by Journy, only fifteen years old when he started, and by the newly hired Beloeuf. They initially all had to work at the Museum but when it became clear that model production was a commercial enterprise, the Museum directors requested them to leave the place. They moved to a small rented room at Rue Copeaux, n° 6 near the Museum. Making a single decrement model could take several days, but simpler models were produced much more rapidly, under the constant pressure of the boss. The workers occasionally complained that they had to work 'in candlelight' and that the working conditions, even by the rough standards of the time, were less than satisfactory. Until 1809, Pleuvin fils and Journy made collections that were sent throughout Europe: to the famous Werner in Freiberg, to Berzelius in Sweden, to De Saussure in Geneva, to Van Marum in Haarlem and so on. After 1809, the work was mostly done by Beloeuf, who made slightly larger, more modern-looking models, notably the magnificent series of about 1000 models presently kept at the Naturhistorisches Museum in Vienna.

These collections were expensive and must have been a significant source of income for Haüy. They were advertised by the faithful 'garde des collections' of Haüy at the Museum, J.A.H. Lucas, who had replaced Jérôme Tonnellier, who was still at the Ecole des Mines. Lucas admired his master so enormously, that each year, from 1801 to 1820, he was the first student to register for Haüy's yearly open course that any professor at the Museum had to offer to the public. He also assisted his master with his semi-commercial activities. In 1813, Haüy wrote (freely translated):

Monsieur Beloeuf, living at the Museum, executes with the highest possible precision a wide variety of wooden models of crystalline forms. The number of forms described in the *Traité* [by R.J. Haüy] is 535, to which 350 must be added, which have been determined since the printing of the *Traité*. Also made by him are twenty models representing decrements relative to various secondary forms. The price of each simple model is 1 franc; the price for all decrement models is 190 francs. It is possible to order any part of the whole collection.

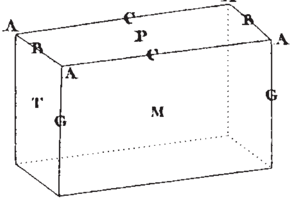
In fact, ordering a model collection was not that simple, especially during the first years. On 9 December 1799, Martinus van Marum, director of the Teyler's Museum in the Netherlands, ordered a complete series of 597 models, for the sum of 460 livres and 16 sols for the Hollandsche Maatschappij der Wetenschappen at Haarlem. Anecdotic is the fact that, in the bill, the model's labels were charged at one sol each, even when written in Haüy's own hand (Fig 7a p. 55). Van Marum had to pay in advance, but then had to wait for a long time. He was not too happy when he heard that 'his' models had been sent to Werner on December 26, 1802, as 'the famous Werner could not wait any longer'. The models finally reached Haarlem in 1804, just after Haüy had been made a member of the Hollandsche Maatschappij der Wetenschappen. Van Marum previously had had many relations with the French establishment. He was a great admirer of Lavoisier and in his extremely well equipped Teyler's Museum, which would remain an important centre of scientific research until the early twentieth century, he designed elegant and efficient instruments to reproduce, notably, the analysis of water. He also performed many experiments related to electricity. Napoléon, who visited him in Haarlem, considered him a major scientific figure and so did Napoléon's brother, Louis-Napoléon, who was king of Holland for a few years and resided at Haarlem as well. His close links with Haüy are attested by a number of letters, exchanged between 1794 and 1804. The preference given to Werner for delivering the crystal models, however, must have been rather painful. As soon as the crystals reached Haarlem – and Haüy had become a member of the Hollandsche Maatschappij – the correspondence ceased completely.

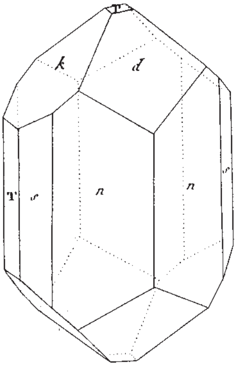
FROM MINERAL MODELS TO CRYSTAL CLASSES

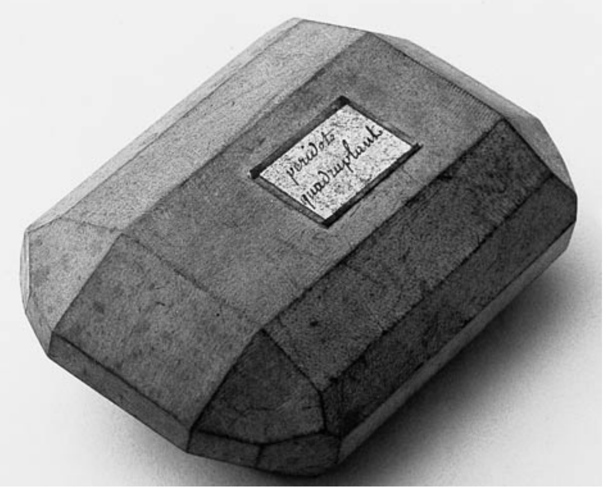
During France's Premier Empire, Häuy was at his peak. As 'secrétaire perpétuel' of the Académie des Sciences, he belonged to the establishment. He was a favourite of Napoléon, who asked him to write the *Traité de Physique* for the education of the imperial elite. Combining physics and chemistry (think of the docimacy of Vauquelin), mineralogy was indeed the most important natural science at the time. One of the major interests of Haüy was the determination of a mineral's electric properties. Crystal models became an essential tool for education both in the 'lycées'(secondary education) and the universities. For instance, Chaptal, Minister of Education implemented a recommendation from the Conseil des Mines and decreed that each student should acquire a simplified collection of Haüy's models, together with his book. This market was served by a number of opportunistic salesmen, notably Lambotin, who made reproductions in white porcelain, of great artistic quality. To my knowledge, only one complete case by Lambotin still exists today: in the collections of the Utrecht University Museum in the Netherlands.

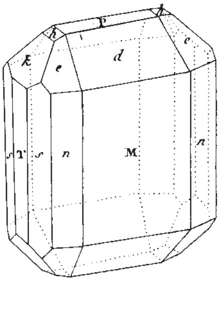
Interesting to note is that, during this entire period, no reference is made to the symmetry classes and systems (cubic, quadratic, orthorhombic and so on), the basis for modern structural mineral classifications. In the eyes of Haüy, crystal models represent idealised minerals, directly inferred from natural occurrences that illustrate the systematic descriptions of his *Traité de Minéralogie*. Above all, they illustrate the two theoretical entities that Haüy considered to be the fundaments of the crystal structure: the 'molécule intégrante' (limited to three solids, namely the tetrahedron, triangular prism and cube) and the 'forme primitive', from which all natural crystals are derived. The number of 'formes primitives' amounts to six (parallelepiped, octahedron, tetrahedron, hexagonal prism, rhombododecahedron, dipyramidal decahedron), from which three belong to the cubic, two to the heaxagonal and one to the orthorhombic system. Clearly, if Haüy had expressed correctly the most important crystal symmetry laws in his book of 1801, he had not seen how they can be logically combined in systems. He was close: the 'forme primitive' of the peridot (olivine), for instance, is exactly the reference frame of the orthorhombic system, incidentally the correct system for this mineral (Fig. 7a). Other naturally occurring mineral forms are derived from the 'PRIMITIF' (faces labelled P, M, T) by sections (troncatures) on edges and summits. The 'péridot continu', for instance, shows 20 faces (10 vertical, 8 obliques, 2 horizontal), including remnants of the primitive faces P and T (Fig. 7b). The more complicated 'péridot quadruplant' (Fig. 7c), 'qui réunit toutes les variétés précédentes' shows no less than 33 faces, among which the three primitive faces P,M and T are still present (Fig. 7c).

Figure 7 'Forme primitive' (above) and two varieties ('péridot continu' and 'péridot quadruplant') (below), pear wood crystal models from the collection acquired by M. Van Marum for Teyler's Museum, Haarlem. All labels, bordered by a characteristic red line, are from the hand of R.J. Haüy. (Courtesy Teylers Museum, Haarlem).
7 a (Top): 'Forme primitive', 7b (Middle): 'Péridot continu', 7c (Below): 'Péridot quadruplant'. To the right of each photo, drawing of the same crystals (letters= face notations) from the atlas (tome 5) of the *Traité* (1801)









Translating Haüy's rather obscure terminology into modern crystallographical langage, it is easy to identify four systems from the different 'formes primitives': cubic, orthorhombic, rhomboidal and hexagonal. This major step was done by C.S. Weiss (1815), clearly under the inspiration of Haüy's work (Weiss had translated in German most works from Haüy). But, among all primitive forms defined by Haüy, any reference to systems with oblique axes (monoclinic, triclinic) is missing. The precision of the application goniometer was not sufficient to identify the small angles typical for these systems, and in this respect the patient work of Haüy fails to reproduce correctly some of the most important mineral species occurring in nature (e. g. a great number of rock-forming silicates). The number of crystallographic systems defined by Weiss is thus only 4, and only seven years later (1822) F. Mohs introduced the two additional systems (monoclinic, triclinic), to reach a scheme that has not changed since.

The notion of symmetry systems has given to the crystal models a fundamentally different character: not a simple reproduction of a naturally occurring mineral, but an illustration of its symmetry element and a way to identify the different mineral faces. Haüy's method of face indexation, later extended by Michel-Lévy, remained in use in french-speaking countries for about a century but was soon superseded in other countries by other methods, which rely less on crystal faces than on crystallographic reference axes: the Weiss-Naumann notation in Germany and, above all, the Miller notation, nowadays universally employed. Haüy himself remained largely outside this evolution, which occurred at the end of his long life. He was at this time bitterly quarelling with Mitscherlich about the notion of isomorphism (Mitscherlich, 1820), and did not want to change anything to his own mineral classification nor to accept the new theories. He refused stubbornly to consider any other instrument for measuring angles than the contact goniometer, notably the reflexion goniometer which would give too much support to Mitscherlich's hated ideas.

Already in 1815, the fall of Napoléon had marked the decline of the French golden age in crystallography and mineralogy. The lead would pass to German scientists, who with their sense for compilation and systematics would lay the foundation for present-day systematic mineralogy. The number of identified crystal forms increased rapidly, all got their wooden models. The fabrication of these models also passed in German hands, commercialised, until to-day, by the company of Krantz in Bonn. It is interesting to note that since the years 1850, all Krantz models have been made in the same Black Forest factory, owned by the Piehl family which still to-day keeps the fabrication details secret. Wooden models have since been an essential part of crystallographic education, regrettably now disappearing from higher-education programmes due to the apparent ease of computer drawings.

Even though a large number of crystal models were made in the Museum enterprise, very few complete collections have been preserved. They were mainly sent to universities, educational centres where the original models were mixed with later (Krantz) models, lost, or damaged in the hands of successive student generations. Two notable exceptions are the collection of the Naturhistorisches Museum in Vienna and the collection of the Teyler's Museum in Haarlem (the one acquired by Van Marum for the Hollandsche Maatschappij der Wetenschappen). The latter one is the most interesting. It was made at an early stage, when Haüy was drawing up his theory and systematic classification. The models of Vienna, made by Beloeuf and bought in 1820, resemble and possibly have inspired the later Krantz models.

Of the 569 models ordered by Van Marum, 550 still remain, including 77 decrement models ('modèles de décroissement par une, deux, trois rangées ou d'avantage, ou encore décroissements sur les angles, sur les arêtes, intermédiaires ou mixtes'). The nineteen missing models correspond to simple forms (cube, tetrahedron), probably taken at some point by someone interested in crystallography. Decrement reproductions are essential for the understanding of Haüy's theories and would deserve a special study. The study of the crystals that represent the different mineral species is interesting as well for a full realisation of the enormous amount of measurements made by Haüy and by his co-workers and to see to what extent they closely reproduce reality. Mr Saeijs performed this work (see the next chapter). By using the same instruments that were available to Haüy (notably the application goniometer), he was able to measure the angles between model faces precisely. This allows the exact representation of the models on the now familiar stereographic projection. It would also permit the precise reproduction of the models by one of the many computer programmes (e.g. SHAPE) now available. It is also interesting, as carried out by Mr Saeys for a few selected examples, to compare Haüy's data with modern data. In many cases, the models are precise enough to identify accurately the mineral by reference to present-day crystallographic data. In other cases, however, this is not possible, due to incomplete mineral determination or mistaken reference specimen. Nevertheless, there are remarkably few errors, if we consider the simplicity of instrumentation and the poor quality of many natural crystals measured by Haüy and his co-workers. Contrary to damaged, distorted or deformed natural crystals, models are amenable to mathematical abstraction and geometrical analysis. They are at the basis of geometrical crystallography, which would ultimately lead to the atomic conception of the crystal structure. But more than a century would elapse before this theory could be physically demonstrated by X-ray analysis.

ACKNOWLEDGEMENTS

My work on crystal models, which was initiated by the discovery of Haüy's original models in the collection of the Teyler's Museum in Haarlem in 1981, could only be continued through a grant from the Pieter Langenhuizen Lambertuszoon Fonds (Hollandsche Maatschappij der Wetenschappen), which is gratefully acknowledged, as well as the friendly collaboration of some of my former colleagues at the Teyler's Museum, notably A. Wiechman.

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The suitability of Haüy's crystal models for identifying minerals

W. Saeijs

introduction

René-Just Haüy published the *Traité de Minéralogie*, which contains the first sound system for identifying and classifying minerals, in 1801. The classification of minerals was based on chemical analysis, but in those days, chemical analysis was still in its infancy and hence not really suitable for this purpose. Therefore, Haüy's mineralogy leaned predominantly on identification of mineral species through their crystal forms. The crystals of an unknown mineral could be compared with Haüy's crystal forms. These forms – although derived from usually inadequate mineral samples – were developed as idealised abstractions. As such, they were sketched in the fifth volume of the treatise. They were also crafted as wooden models under supervision of Haüy himself.

In Haüy's mineralogy, the idealised forms were of paramount importance. It seems worthwhile to determine if they can be used to identify mineral species accurately. The author's investigation was directed towards finding out if the idealised forms are in accordance with modern crystallographic data. The models were used because, contrary to the sketches, the models can be treated as if they were crystals. Hence, the crystallographic conventions as in choosing primary planes and axes can be used. The dihedral angles were measured and stereographic projections prepared. Section 2 summarises Haüy's crystallography and development of idealised forms. Section 3 shows the method proper for measuring and plotting the models. Section 4 is dedicated to identifying Haüy's minerals. Section 5 reports a few significant results of the investigation. There are four sheets with stereographic projections attached to this paper. They are meant to assist with the explanations in sections 3 and 4 and the presentation in section 5.

haüy's crystallography and idealised forms

In 1784, René-Juste Haüy showed the Académie Royale des Sciences his first results in analysing crystals through cleaving until a simple form emerged. At the same time, he presented a generalising theory to explain the build and exterior forms of crystals.[1] In the following years, he tried to apply his theory to an extending range of minerals. His studies progressed to a new level when he developed idealised forms of the crystals of these minerals.

Haüy's work on crystals

Haüy's theory of crystals originated in his work on calcite. When cleaving its crystals 'along their natural joints' he could always find a kernel with the simple shape of an Iceland spar crystal.[2] He then postulated that all crystals are built from a kernel and small building blocks of the same form. Stacked on the faces of the kernel, there are diminishing plates or layers, formed of those blocks, building up pyramidal and prismatic faces to give the crystal its exterior shape.

To apply this theory to another mineral, Haüy had to cleave its crystals till the kernel emerged and its dimensions could be estimated. Then he attributed to the diminishing plates of a face a ratio of small numbers, i.e. the number of rows of building blocks omitted in height and depth. From this ratio, he could calculate the face's slope, which he then checked by measuring the dihedral angle.

The method worked fine when applied to crystals of sufficient size and cleavage properties, but when tackling mineral samples with tiny and distorted crystals and without good cleavage, the method had to be reversed. The form and dimensions of the kernel were imagined 'in analogy' with other cases.[3] The measured dihedral angle gave the slope and from this slope, a ratio of small numbers could be estimated. Combined results from different slopes could lead to a convincing analysis. This way, Haüy's method became a method for which the dihedral angles were the primary data and in which geometric calculation became the most important tool.[4] Meanwhile, the exterior form gained importance and the primacy of the kernel diminished.

Haüy's creation of idealised forms

Haüy used the contact goniometer – invented by Carangeot and at that time the only instrument available for this purpose – to measure dihedral angles.

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[1] R.J. Haüy, *Essai d'une théorie sur la structure des crystaux, appliquée à plusieurs genres de substances cristallisées* (Paris, 1784).

[2] R.J. Haüy, *Traité de minéralogie*, vol. 1 (Paris, 1801) p. 21.

[3] *Ibidem,* p. 27.

[4] *Ibidem*, p. 41.

Its inaccuracy was at least 0.3 degree.[5] After measuring a certain angle several times, Haüy's results could have a spread of 0.5 degree or more. To overcome this uncertainty, he transferred one of his values to the angle of an orthogonal triangle and calculated the ratio of lengths of the triangle's sides, with the aid of a goniometric table. This ratio usually was made up of two high numbers. Using a universal law that he believed in, i.e. the law of simple numbers, he simplified this ratio to simple numbers or square roots of simple numbers. This 'true' ratio gave him, again by using the table, the 'true' value of the angle with a precision of 1 second of arc. This procedure he named 'finding the limit'.

He tackled the problem that parts of crystals were hidden in the ground mass with another universal law, i.e. the law of symmetry.[6] However, this idea of symmetry went not much farther than suggesting that the hidden part of a crystal should show the same set-up of faces as the visible part. Calculating and sketching, Haüy developed an image of an enlarged and idealised crystal. These images are drawn more or less in perspective in the fifth volume, the Atlas, of his *Traité*. For most minerals, there is a range of figures starting with a figure with a minimum of crystal forms and ending with figures with combinations of forms. There is no proof that Haüy saw all these single habits. Also, in a later defence of his method, he pointed out that he did not have complete or undistorted crystals.[7] Nevertheless, in applying these figures in his mineralogy, he suggested that all these figures were drawings of real crystals instead of being abstractions.

THE METHOD FOR MEASURING AND PLOTTING HAÜY'S MODELS

Simultaneously with the publication of his *Traité*, Haüy announced that there were also models of his crystal forms. In some way, Haüy had managed to convey the images and their dihedral angles to the cabinetmakers Pleuvin and Journy, who then succeeded in chiselling models of all habits.[8] Some sets of these models are still available. The models seem to be good three-dimensional realisations of the figures in the Atlas and were used in

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5 R.J. Haüy, 'Observations sur la mesure des angles des cristaux', *Annales des mines* 3 (1818) p. 413.

6 M. Blondel-Mégrelis, 'Le modèle et la théorie. Analyse d'un exemple de la cristallographie de Haüy', *Revue philosophique de la France et de l'Étranger* 171 (1981) p. 292-296.

7 Haüy, *op. cit.* (note 5) p. 411.

8 R. Hooykaas, 'La correspondance de Haüy et de van Marum', *Bulletin de la Société Fançaise de Minéralogie et de Cristallographie* 72 (1949) p. 412.

the present investigation to determine the minerals from which they were derived. For that purpose, their dihedral angles can be measured and their stereographic projections constructed.

The models

The models with their dimensions of 5 to 8 cm are made of pear wood. They have smooth faces, sharp edges and sharp solid angles. They carry small labels, measuring about 9 to 16 mm and cut by hand from circa 90 grams laid paper. These labels are rimmed in red ink. Haüy's names of the minerals and crystal forms are written in black, in a very fine, regular hand.

The models show the same faces as the figures in the Atlas although there are small deviations in the forms of faces. A close inspection reveals more serious imperfections, i.e. the faces are always slightly convex. Also, dihedral angles, that should be identical, are not: differences of several degrees occur. It is clear that the cabinetmakers could not instantly chisel the intended dihedral angles accurately and that, in trying to improve, they took off very fine chips near the edges. Of course, the smaller the face the greater the imperfections.

The sets of models were immediately sought after as a tremendous aid in teaching mineralogy. In the course of time, most sets became either depleted or got lost. To the author's knowledge, only two sets of the original Haüy models have been preserved. A quite extensive one is in Teyler's Museum in Haarlem and a smaller one is in the author's possession. Models from both sets have been used in this investigation.

A method for finding accurate dihedral angles on the models

The positions of the crystallographic axes and the principal faces in many figures of crystal forms in the Atlas can not be determined. All models, however, can be rotated until their orientation agrees with conventions used in crystallography so that they can be treated as if they were real crystals. A contact goniometer is good enough for finding dihedral angles on the models since its inaccuracy of 0.3 degree is far less than the errors caused by the imperfections mentioned in section 3. To reduce these errors, use is made of a peculiarity of crystals, i.e. the existence of zonal relationships between faces of a crystal. A zone on a crystal is a set of faces that are cutting one another along parallel lines, or would do so if larger. The common direction of those lines, when moved to the centre of the crystal, is the zone axis. All the normals on the faces of the zone, also moved to the centre, lie in one plane, the so-called zone plane. Each face or its extension cuts the zone plane along a straight line. These lines together form a polygon. The sum Σ of the values of the n angles of a polygon equals (n-2) 180°. In this investigation the zone is used as a sequence of dihedral angles of which the sum should be Σ. On the models, the faces belonging to a certain zone are, in general, recognisable. A model usually has several different zones, but may also have some similar zones. A certain zone may contain subsets of identical angles. In general, a single value of a measured dihedral angle may be quite inaccurate, due to the inaccuracy of the goniometer, the unintended error in crafting, and the error caused by applying the legs of the goniometer against two convex faces. However, after measuring successively all angles of a zone, the sum of the values compared with Σ shows that the errors cancel out somewhat.

Each zone is measured twice on a model in order to reduce accidental errors. To avoid bias, all similar zones are measured as well. The values of identical angles of a zone or of a set of similar zones are gathered. Their number is noted, their average is calculated and noted in tenths of degrees. Their standard deviation is noted as well. For each zone, the resulting averages are re-inserted in the zone sequence and their sum compared with Σ. Next, while keeping in mind the standard deviations, the averages are rounded to whole degrees so as to comply with Σ. The resulting values, with a 1-degree accuracy, are chosen as the dihedral angles between the faces. A list of the chosen values is always noted on the sheet on which the stereographic projection is made (see Figs. 2 and 3). Finally, the supplements of the chosen values are calculated because in a stereographic projection, the normals of the faces are plotted.

Plotting the models

Each model is plotted in a stereographic projection of 12.6 cm diameter by using a Wulff net. The accuracy is about one degree. In a stereographic projection, normals and axes are plotted as points, the so-called poles. Zone planes are projected as circles at 90 degrees from their zone axis poles. On the model, primary planes and axes are chosen in accord with crystallographic conventions. The model is placed upright, with the principal axis vertical. The pole of this axis coincides with the centre of the projection. Its zone, i.e. the set of vertical prism faces, is plotted first. Because these faces were easiest to chisel accurately, their positions are the bases for finding the other poles. Some poles are part of two zones going through different base poles. Their positions are found by using the two dihedral angles to these base poles. The appropriate zone circles are drawn and the other poles along these zones are plotted one by one.

Some faces, not belonging to zones, are plotted by triangulation, by using measurements against at least three surrounding faces that do belong to zones. When all the faces are plotted, the previously chosen primary planes are identified and connected with zone circles. The poles of these zones are the poles of the axes. The axial angles are the arcs between them. Their values, thus found, are more accurate than those measured directly on the model because the contact goniometer is not suited to measure angles between edges.

The symmetry elements in the projection are established and the face poles are recognised as parts of different forms, e.g. pyramids, horizontal prisms etc. The combination of these forms is also noted on the projection sheet (see Figs. 2 and 3).

A PROCEDURE FOR IDENTIFYING HAÜY'S MINERALS

After application of the procedure of measuring and plotting, the models must show their suitability in identifying minerals. Nowadays, minerals are characterised by their axial angles and axial ratio. In some cases, it is possible to derive such data directly from the plot of a model. In most cases, the model's mineral is traced back by comparing its plot with one derived from a mineral's modern data.

The accuracy of the method in its application to identify minerals

Mason and Berry published the values of six dihedral angles belonging to a common crystal of the feldspar orthoclase.[9] These modern data suffice to make a stereographic projection (see fig. 1). There are two sets of nearly coinciding poles, viz. (0 0 1) with (1 0 -1) and (0 0 -1) with (-1 0 1), and β equals 116°.

The same situation of nearly coinciding poles at the same positions is found in the projection of the model labelled 'Feldspath bibinaire' (see Fig. 2). Moreover, β is found as 117°, a difference of only one degree. All other models labelled 'Feldspath', not being kernel or twin, show the same characteristics. This case proves that Haüy's 'Feldspath' is the monoclinic feldspar. It also shows that the described method of measuring and plotting applied to the models is accurate enough to search for and identify Haüy's mineral.

Direct and indirect calculation of the axial ratio

Some models give the impression that a good parameter plane, i.e. a face cutting off unity from the three axes, is present. In such cases, a direct calculation

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9 B. Mason and L.G. Berry, *Elements of mineralogy* (San Francisco, 1968) p. 421.

of the axial ratio of the model's mineral is possible. This is done in the following manner. The designated pole in the stereographic projection of the model is connected with the poles of the axes a, b and c. The respective circle arcs ρ, σ, and τ from the pole to the axes are measured and inserted in the formula (a: b: c = sec ρ: sec σ: sec τ).[10] This axial ratio must agree with the modern value of the probable mineral. A drawback is that a 1-degree error in the position of the pole, even when the pole is located somewhere in the middle of the first quadrant, results in a 5% error in the axial ratio. Poles near the borders of the quadrant even give inaccuracies of 10 to 20%. Identification of a mineral is then uncertain.

When no suitable parameter plane seems to be present, a reversed procedure is useful. In this case, the indices (hkl) of some pole of the model can be calculated by using the known axial ratio of a probable mineral. The circle arcs ρ, σ, and τ are measured and, together with the known values a, b and c of the axial ratio of the probable mineral, they are inserted into the formula

$$(a/h:\ b/k:\ c/l = \sec\rho:\ \sec\sigma:\ \sec\tau).$$

A set of indices with values near whole numbers confirms the axial ratio, but a 1-degree error impairs this conclusion also.

A general method to identify the mineral

In many cases, there is no suitable face for direct calculation on any model of the particular Haüy mineral. The procedure can then be started with the tentative choice of a mineral. From the known modern data of this mineral, a stereographic projection is made, a so-called 'Reconstruction'. At least the normal pattern is plotted, i.e. the positions of the three axes, plus the primary poles (100), (010) and (001), plus the three secondary poles (110), (011) and (101), plus the parameter pole (111). This is executed as follows. The c-axis is placed in the centre (see Fig. 4). The b-axis is plotted at or near azimuth 0° at α degrees of the c-axis. The a-axis is plotted where the arcs with β degrees from the c-axis and γ degrees from the b-axis coincide near azimuth 90°. (in Fig. 4, the negative a-axis is shown.) The three zone circles of which the axes are poles are drawn. Their intersections near the a-, b- and c- axis are (100), (010) and (001) respectively. These three poles form a spherical triangle with inner angle values of (180-α), (180-β) and (180-γ) respectively.

[10] P. Terpstra and L.W. Codd, *Crystallometry* (London, 1961) p. 60.

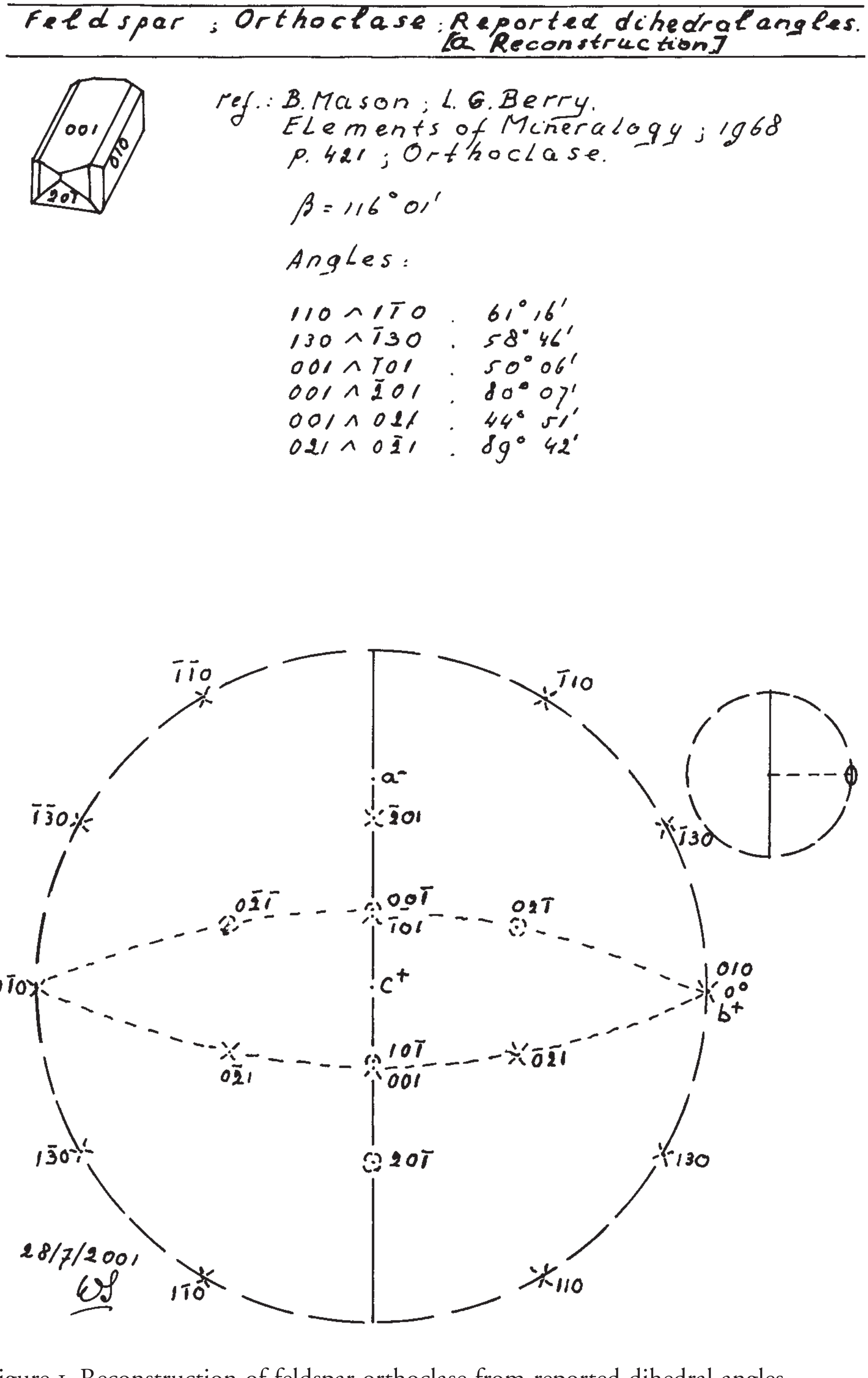

Figure 1 Reconstruction of feldspar orthoclase from reported dihedral angles.

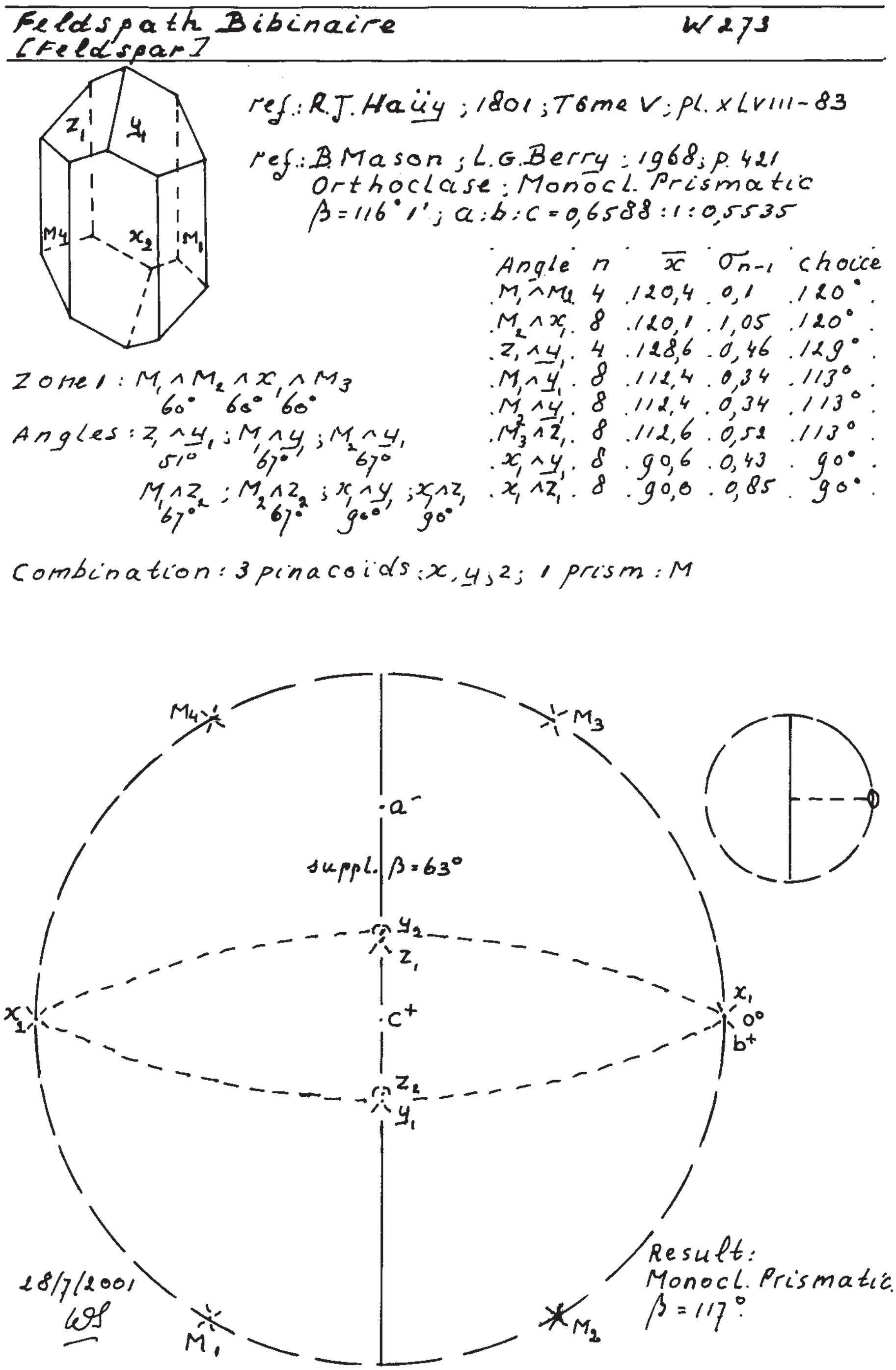

Figure 2 Construction of the author's model W 273, labelled 'Feldspar bibinaire'.

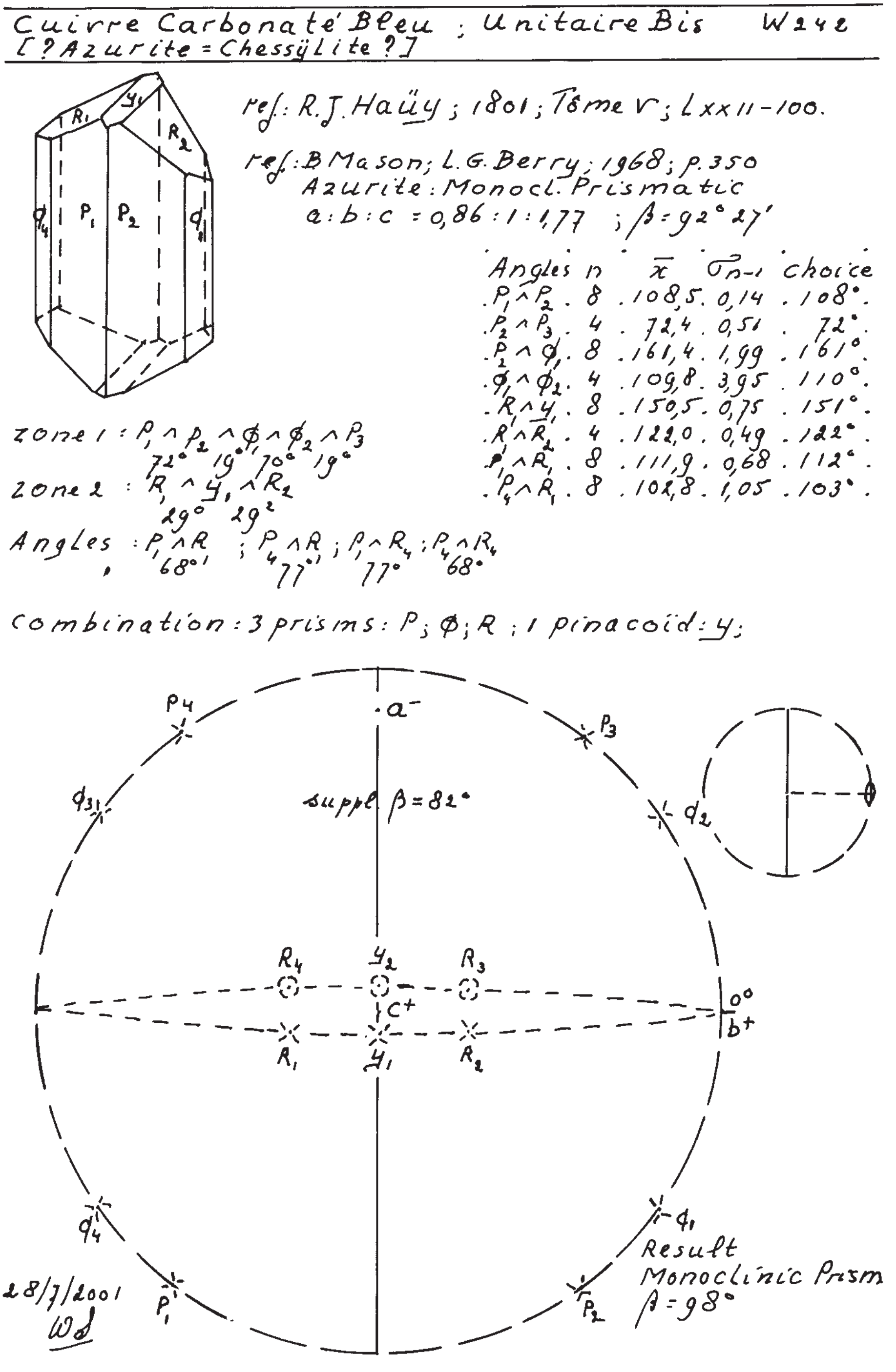

Figure 3 Construction of author’s model W 242, labelled ‘Cuivre carbonaté bleu unitaire bis’

Malachite ; Reconstruction from modern data.

ref: C. S. Hurlbut; C. Klein; Manual of Mineralogy; 1977; p309
Malachite; Monocl. Prismatic; $a:b:c = 0{,}788:1:0{,}267$; $\beta = 98{,}75°$

calculation of a (hkl) position.
$a' = a/h$; $b' = b/k$; $c' = c/l$.
$p' + q' = 180 - \gamma = 90°$: $\sin p' : \sin q' = a' : b'$
$r' + s' = 180 - \beta = 81{,}25°$; $\sin r' : \sin s' = c' : a'$
$t' + u' = 180 - \alpha = 90°$; $\sin t' : \sin u' = b' : c'$

$$\frac{\sin p' - \sin q'}{\sin p' + \sin q'} = \frac{1 - b'/a'}{1 + b'/a'} = \mathrm{ctg}\,\tfrac{1}{2}(p'+q').\mathrm{tg}\,\tfrac{1}{2}(p'-q') = \frac{\mathrm{tg}\,\tfrac{1}{2}(p'-q')}{\mathrm{tg}\,\tfrac{1}{2}(180-\gamma)}$$

the other divisions analogous.

Miller indic	Interceps axes a'	b'	c'	axial angles α	β	γ	division p'	r'	t'
111	0,788	1	0,267	90°	98,75°	90°	38,24	17,64	15,05
221	0,788	1	0,534	90°	98,75°	90°	38,24	31,27	61,90
331	0,788	1	0,801	90°	98,75°	90°	38,24	41,03	51,31

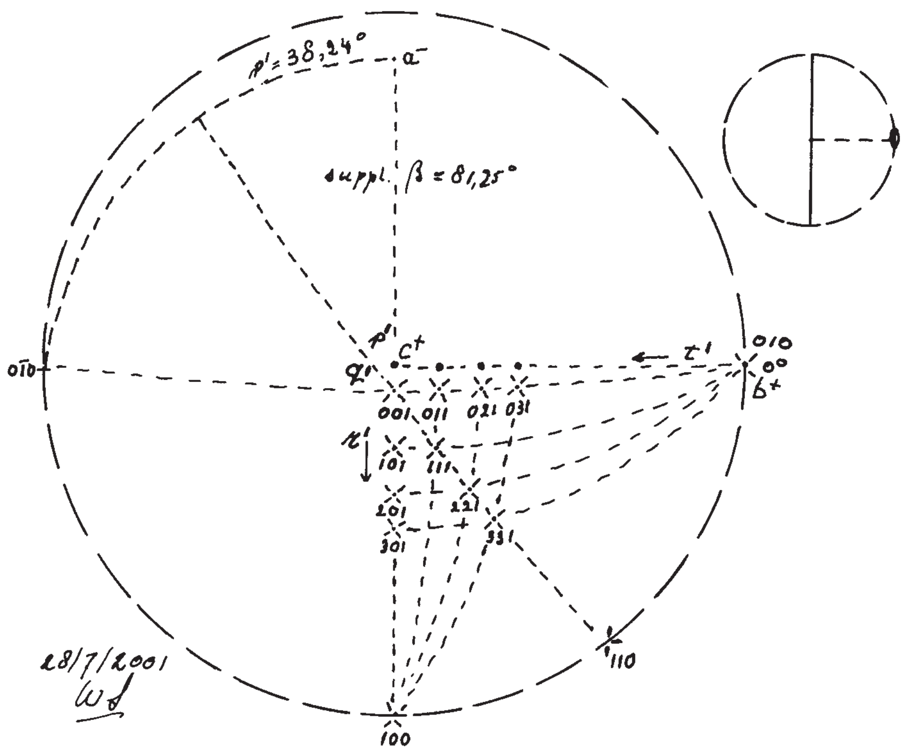

Figure 4 Reconstruction of malachite from modern mineralogical data.

The pole of the parameter plane is situated somewhere in the middle of the spherical triangle at the intersection of three dividing arcs of these inner angles. The division of these angles in respectively u and t, s and r and q and p (anti-clockwise) can be calculated.[11] (see the algorithm in Fig. 4). The division of the angles in the plot must be executed at 90° from the angle points. Then the dividing arcs are drawn and the parameter plane is found at their intersection. The secondary planes are found where the dividing arcs intersect the sides of the spherical triangle. If needed, the reconstruction can be extended in the same way with other poles. In Fig. 4, the plot is extended with (221) and (331) and their secondary poles.

The reconstruction is made on transparent paper. Other reconstructions may be made. Serving as overlays, they are used to find if any of them matches with the plots of the models.

SOME SPECIES IN HAÜY'S MINERALOGY

The accuracy of Haüy's work has already been demonstrated in the case of 'Feldspath bibinaire' (section 4), but this case also shows the restraint with which Haüy used his 'limit'. The small difference in the slope and also the identical form of the faces ij and z did not incite him to declare them equal (see Fig. 2).

Although described as a man of humble character, Haüy shows in the first volume of his *Traité* a profound confidence in the success of his method of finding and identifying species. In some cases, the models tell another story. For example, of the five models labelled as 'Stilbite' in the author's collection, three indeed represent stilbite, but two are actually heulandite. Of the four models labelled 'Mesotype', three can be attributed to mesolite, but the fourth is apophyllite. On the other hand, the minerals distinguished by Haüy as 'Sphène' (three models), 'Titane Silico Calcaire' (also three models) and 'Spinthère' (one model) are all sphene. Although Haüy had done 'limit' work on the 'Sphène' crystals, only 'Spinthère' matches the modern data.

Another example is the case of 'Cuivre carbonaté bleu' vs 'Cuivre carbonaté vert', tentatively translated as azurite and malachite. Haüy's description of the blue mineral is quite extensive, that of the green one scanty.[12] For the blue mineral, Haüy gives good pointers to follow the way to calculate his 'limit', meanwhile revealing flaws in this method. Nevertheless, one can surmise the extent of Haüy's work on the mineral and the availability of good crystal material. There are 7 models of the blue mineral and none of the

11 *Ibidem*, p. 58, 60.
12 Haüy, *op. cit* (note 2) vol. 3, p. 562-575.

green. fig. 3 shows the projection of one of the models, 'Cuivre carbonaté bleu unitaire bis'. Although tentatively identified as azurite, the projection does not match the projection for that blue mineral, but a good match can be made with fig. 4, the reconstruction of malachite. This is evident from the face R, IJ and P, which coincide with (021), (001), and (110) respectively. Moreover, the β's differ only 0.75 degree. The other models of Haüy's mineral are good matches with malachite as well. Mason and Berry give the key to this riddle, 'Azurite is less common than malachite, but it is often found as distinct crystals implanted on malachite or other secondary minerals, the crystals often altered to malachite pseudomorphs'.[13] The author therefore concludes that Haüy's blue mineral is the pseudomorph of malachite after azurite.

conclusions

This paper presented a method to measure the models crafted from Haüy's idealised crystal forms and to construct their stereographic projections with an accuracy of 1 degree. Also, a procedure was given to identify the mineral from which the idealised forms were derived. On the basis of some cases, the sufficiency of the models to identify Haüy's minerals was discussed.

[13] Mason and Berry, *op. cit.* p. 351.

Geology in the Belgian provinces during the reign of William I

Geert Vanpaemel

The short-lived union between the Netherlands and its southern neighbour Belgium lasted from 1815 until 1830, but has received only little attention from historians of science in both countries. In his superb review of the history of science in the Netherlands, Klaas van Berkel remarked that the union with the South had little significance for the practice of science in the northern Netherlands. 'A few Northerners found temporary employment at a southern university, but for the rest the universities in the two regions remained separate worlds.'[1] The recent two-volume work on the history of science in Belgium since 1815 does contain a few passing references to this so-called 'Dutch period', with some attention paid to its importance but still without taking its particular impact on Belgian science into serious consideration.[2]

Obviously, the importance of the union should not be overestimated. The fifteen-year interval between Napoleon's defeat at Waterloo and the Belgian Independence was much too short to realise all the projects for reform and renewal of scientific life. Its consequences were only to be seen in the next generation. Yet, when comparing the poor state of Belgian science during the period of French annexation with the high level of achievement reached around the middle of the nineteenth century, the crucial stimulus provided by the Dutch authorities cannot be overlooked.

When Belgian Independence was proclaimed in 1830, scientific life in the country immediately took off. The leading figure of this scientific movement was the mathematician Adolphe Quetelet (1796-1874), who became permanent secretary of the Brussels Academy of Science and

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[1] K. van Berkel, 'The Legacy of Stevin. A Chronological Narrative', in: K. van Berkel, A. van Helden and L. Palm eds, *A History of Science in the Netherlands* (Leiden etc., 1999) p. 3-235, quotation on p. 101.

[2] R. Halleux, J. Vandersmissen, A. Despy-Meyer, G. Vanpaemel eds, *Geschiedenis van de wetenschappen in België 1815-2000* (Brussel, 2001).

director of the Belgian Observatory. He was the best example of the benign Dutch influence during the preceding era. As a young mathematician, freshly graduated from the State University in Ghent, he received almost unconditional support from the Dutch government, enabling him to travel abroad and to meet the most famous scientists all over Europe. Quetelet always remained very aware of the unique opportunities offered to him by the Dutch officials. 'The love for the sciences,' he wrote in his history of Belgian science, 'which in Holland had remained a well preserved tradition, was of great advantage to us: we were in a position to ask rightfully for our provinces the same support that the northern provinces had always benefited from and we have to admit that the Dutch government did not recede before these legitimate requests.'[3] Only a few years after the formation of the United Kingdom, three state universities were established in the southern provinces, the Royal Academy of Science and Literature was reinstalled and the building of a Royal Observatory had begun. It was, as Quetelet said, an 'alliance between two nations, born to love one another'.

Quetelet may not have been a neutral witness in singing the praise of the Dutch government, but it cannot be denied that he, and Belgian science in general, fared very well during the years preceding Belgian Independence and that this beneficial impact was due to a conscious effort of Dutch officials to promote science in Belgium. This conclusion may sound very strange when we compare it with the judgement of Dutch historians of science concerning this same period. Klaas van Berkel describes the first half of the nineteenth century as a period of 'real decline of Dutch science', caused by a spirit of 'self-satisfied patriotism and the lack of critical perspective.' 'It is not difficult at all,' he observes, 'to ridicule the practice of science in the Netherlands at the time of William I'.[4] Although he acknowledges the fact that William I was 'always prepared to attack the reigning stick-in-the-mud attitude' of the Dutch scientific community, he still seems to agree with the nineteenth-century physiologist and philosopher Jacob Moleschott, who wrote a devastating article on the backwardness of Dutch science in 1848. Recovery in Holland only started around 1850.

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[3] 'L'amour des sciences, dont la Hollande avait conservé les traditions, fut pour nous d'un immense avantage: nous nous trouvâmes en droit de réclamer, pour nos provinces, les mêmes bienfaits dont elle jouissait depuis longtemps, et l'on doit convenir qu'elle ne recula pas devant des demandes aussi légitimes.' A. Quetelet, *Histoire des sciences mathématiques et physiques chez les Belges* (Brussels, 1864) p. 321.

[4] K. van Berkel, *op.cit.* p. 109-113.

The contrast between North and South was in particular very striking in geology. Whereas geology in the North had not elicited much interest, the coal fields of the South had created a long-standing tradition of geological research. Although there actually were a few authors in Holland who wrote on geological subjects, this work remained academic and theoretical in nature. Mainly entrepreneurs from Liège or Germany carried out field exploration of the coal fields of southern Limburg.[5] Only in the northern region of Groningen did the local preoccupation with agriculture produce some studies on soil formation.[6]

Coal mines were to play an important role in the economic development of the United Kingdom of the Netherlands. The country had suffered much under the French regime and its industry could not compete with the cheaper manufactured products from England. King William concentrated his economic policy for recovery on an attempt to industrialise the country, which lead him to put large sums of money at the hands of Belgian entrepreneurs. The textile industry benefited most, but also the coal and iron industries of Hainaut, Liège and Limburg received substantial support. The Zuid-Willemsvaart, which was opened in 1826, connected the Liège coal fields with the Rotterdam port and was the first major transportation link between the South and the North.[7] This supportive policy of the Dutch government even went against the interest of the Dutch merchant class, which would rather buy cheaper coal and iron from abroad.[8]

One of the problems in developing the Belgian coal and iron industries was the backwardness of the entrepreneurs. Former naval officer Gerhard Moritz Roentgen, acting as an advisor to the Department for National Industry on the Belgian iron industry, observed in 1822 that no improvements had been made in the industry during the last 25 years. In his view,

[5] C.E.P.M. Raedts, *De opkomst, de ontwikkeling en de neergang van de steenkolenmijnbouw in Limburg* (Assen, 1974); Ben Gales, 'De mijnbouw', in: H. Lintsen ed., *Geschiedenis van de techniek in Nederland. De wording van een moderne samenleving 1800-1890*, deel IV (Zutphen, 1993) p. 13-35.

[6] E.W.A. Henssen, *Uit de geschiedenis der Nederlandse geologische wetenschappen* (Groningen, 1995) p. 3-6.

[7] In fact, the Vaart was not completed. It stopped in Maastricht. The connection with Liège was only constructed in 1850. According to Auke van der Woud, 'De Kanalenkoning en zijn reputatie', in: C.A. Tamse and E. Witte eds, *Staats- en natievorming in Willem I's koninkrijk (1815-1830)* (Brussels, 1992) p. 237-260, the building of the canals served a rhetorical rather than an economic discourse of national unification.

[8] H. Witlox, *Schets van de ontwikkeling van welvaart en bedrijvigheid in het Verenigd Koninkrijk der Nederlanden* (Nijmegen, 1956).

only three entrepreneurs were capable of running their factory according to modern standards. Omalius d'Halloy, the governor of the mining province of Namur, reached a similar judgement. He blamed, in particular, the backwardness of businessmen, who were not at the level of current knowledge. The Dutch king agreed with this analysis and promoted the organisation of public technical courses for businessmen and young students. These courses were quite successful in the South, though much less in the North.

The Namur governor, Jean-Baptiste-Julien d'Omalius d'Halloy (1783-1875), put a profound mark on the history of geology in Belgium.[9] During the first years of the nineteenth century, he went to Paris and took courses with the great French professors at the Muséum d'Histoire Naturelle: Cuvier, Haüy and Lamarck. From 1804 until 1813, Omalius travelled some 25.000 kilometres throughout the entire French empire (partly in French government service) to draw a detailed geological map, which was finally published in 1822 as *Essai d'une carte géologique de la France, des Pays-Bas et de quelques contrées voisines*. After the creation of the United Kingdom of the Netherlands, Omalius became governor of the province of Namur. He continued his geological work, yet his many official duties prevented him from doing any more field research and he gradually turned to more theoretical and didactical work. In 1831, he published the well known *Elements de géologie*, which was reedited no less than seven times. In his later years, his geological work became increasingly involved with ethnological and evolutionary themes and that made him an important advocate of transformism and a forerunner of Darwin.

The second important geologist in the southern Netherlands was the Dutchman Jacob G. S. van Breda (1788-1867), professor of botany, zoology and comparative anatomy at the University of Ghent since 1822. Van Breda had also studied in Paris, but his interests were much broader than geology. In Ghent, he served as the curator of the botanical garden, edited a book of Linnaeus and worked for some years at a description of a large number of plants sent from Batavia. After the Belgian Independence, Van Breda returned to Leyden, where he became extraordinary and later ordinary professor of zoology and geology, before taking up the position of secretary of the Hollandsche Maatschappij der Wetenschappen and director of Teyler's Museum. In 1852, he was appointed chairman of a committee charged with the preparation of a geological map of The Netherlands. This led him into

[9] E. Dupont, 'Notice sur la vie et les travaux de Jean-Baptiste-Julien d'Omalius d'Halloy', *Annuaire de l'Académie royale des Sciences, des Lettres et des Beaux-Arts de Belgique* (1873) p. 181-296; Y. Granville-Streel, P. Granville, J. Lenaerts et al., *Jean-Baptiste-Julien d'Omalius d'Halloy 1783-1875* (Ciney, 1984).

a controversy with his former student W.C.H. Staring, who finally produced a complete map of the Netherlands on his own.[10] In Dutch historiography, however, Van Breda remains the main inspirator of the development of geology in the Netherlands between 1840 and 1865. Van Breda 'takes his place in the series from Van Marum via Van Breda until Staring and Loiré, who marks the transition of the protohistoric into the historical times of our country, if we look at it from a geological perspective.'[11]

Although Van Breda's interest in geology mainly emerged during his Leyden years, he also did some geological work during his stay in Ghent. Van Breda showed a genuine interest in the geological sciences and published several studies on fossil plants found in the coal mines, on the dolomite rocks of Durbuy and on the vertebrate fossil remains of Maastricht. Whatever the merits of these short articles, his contemporaries recognised him as an able geologist. In 1825, he was appointed by Royal Decree as a member of the committee for the preparation of a Geological Description and Map of the Southern Netherlands. Other members of the committee included colonel J.E. Van Gorkum, Omalius d'Halloy, and the chief mining engineer in Liège, P.M. Bouesnel. Van Breda was to make the scientific descriptions of the mineral and geological condition of the country.

The project had a very utilitarian goal. 'This Royal Decree,' it said in the official declaration, 'will provide the Netherlands, as the first nation, with a map that in combination with a scientific description will give answers to anyone having an interest in the products of the soil; not only the miner and the farmer, but also anyone who has to make use of the products of the mines and of the soil will look forward to this map.' The map should have been completed by the end of 1829, but the work did not go beyond the first exploratory efforts. A technical committee, consisting of lieutenants Van Voorst and Van Panhuys, captains Prisse and Roloff, and major Van Swieten, crossed the country and made numerous notes. The Topographical Service in Delft still conserves a large number of documents with preliminary results of the geological mapping. These would be used in the search for coal in the Dutch province of Limburg in the 1850s. However, due to the Belgian Independence and the ensuing return of Dutch scientists to the North, the results of this large undertaking were completely lost for Belgian geologists.

Although the Dutch government made several efforts to promote geological research in the southern provinces, it always remained very well aware of its

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10 For Staring and his geological map see Faasse's contribution to this volume.

11 J.G. De Bruijn, 'Van Breda als geoloog', in: A.S.H. Breure and J.G. de Bruijn eds, *Leven en werken van J.G.S. van Breda (1788-1867)*, (Haarlem/Groningen, 1979) p. 227-234.

own utilitarian credo, making geology a matter of state interest. Geological surveying was carried out by army officials and mining engineers, while also Omalius and Van Breda both held official appointments. Official support for geology apparently could not exist outside the institutional setting provided and controlled by the state, which retained all the rights to use the results for its own benefit. This had important consequences for the development of science in Belgium. As a result of the centralist policies of the French regime, an independent scientific community, as existed in Holland, had not yet reached maturity in Belgium. There were hardly any scientific societies and no university tradition, since the University of Leuven had been closed in 1797. Belgian science, consisting of a few isolated individuals, completely depended on government support for its further growth.[12]

As an example of a similar but unsuccessful royal initiative, it is useful to look at the creation, in 1817, of a national central depot for mineralogical and geological objects found during public works. Some of these objects were to be transferred to the collections of the universities. A mining engineer called Dekin was appointed director of this depot, but for unknown reasons, it was already dissolved in 1825 and the depot's building was destroyed by a fire shortly after. Most of the fossil objects had then already been transferred to the Museum in Leyden, while the Belgian depot was being dismantled. Whatever geological objects remained were transferred to the newly founded engineering faculty in Liège in 1841, while pieces of historical interest were donated to the Museum in Brussels.[13]

The involvement of the Dutch government in matters of science is very clear and puts a different perspective on the rather weak impression it made in the North. At least in the field of geology (and a few other disciplines, such as statistics), the official initiatives laid a firm foundation for later developments and Belgian scientists were very eager to react positively to the offered opportunities.

THE ACADEMY

Undoubtedly, the most important scientific institution created in the southern provinces was the Royal Academy for Science and Literature. The Academy

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[12] Similar examples of this government policy were the establishment of a statistical bureau, where local administrators and scientists were enlisted, and the creation of public courses and museums. These government services stimulated science in Belgium and gave young scientists the opportunity to aim for a scientific career. Independent or private scientific societies only started taking off around the middle of the nineteenth century.

[13] E. Groesens and M.C. Groessens-Van Dyck, 'De geologie' in: R. Halleux, et al. eds, *op. cit.* p. 269-288.

was originally founded in 1772 under the Austrian regime, but had stopped all activities during the French occupation. In 1816, William I reinstalled it, bringing together the best scientists from the country. The history of this institution has long been regarded as the central focus of Belgian science during the nineteenth century. Strangely enough, it has never been studied in comparison with its twin institution, the Royal Dutch Institute for Sciences, Literature and Fine Arts, created by Royal Decree in the same year. The differences between the northern and southern part of the country are very well reflected in these two institutions. Whereas the Belgian Academy was to play a dominant part in the growth of Belgian science, the Dutch Academy had only 'a modest role in the world of science.'[14] This contrast can be explained by the fact that Belgian science had no other outlet for its creative work. There were no large scientific societies as in Holland and the newly founded universities had not yet reached full maturity. The Brussels Academy filled this intellectual void, carving out for itself a well-deserved place at the centre of Belgian science.

Although established by William I, the Academy was not a state enterprise. From the beginning, it considered itself – and was regarded as such by William – the continuation of the Austrian Academy. Its aim was to further the level of knowledge and to bring honour to the country. Besides the stipulation that the Academy would examine on demand of the government every project for the amelioration of industry and the practical arts, no particular task was set. The academicians were quite free to do whatever they pleased. On the other hand, they hardly received any financial means to work with and being a member of the Academy remained a position of honour for a long time.

Probably already at the very start of the Academy, the suggestion was made to execute a complete geological description of the kingdom. However, the main subjects at the Academy were physics and mathematics, ancient literature and national history, not geology. The suggestion must have come from Omalius d'Halloy, who was a member of the Academy and one of the few men in the country with any experience in geological surveying. Why he came up with this initiative is unclear since he could not possibly have expected a warm response from his colleagues. As it happened, though, this became the start of a dynamic and well-developed scientific community of geologists in Belgium.

The geological project was not to be executed by the academicians themselves. It became the subject of a series of prize competitions in the 1820s,

[14] K. van Berkel, *op.cit.* p. 101.

[15] The role of Omalius as the main promoter of the prize competitions is stated by Quetelet, *Sciences mathématiques et physiques au commencement du XIXe siècle* (Brussels, 1867) p. 34.

each time concentrating on a particular province.[15] The formulation always ran in the same words, 'To give a description of the geological structure of province N., the mineral rocks and the fossils that can be found in the region, with indication of their exact locations and their resemblance with the descriptions of authors who have already treated the same subject.' Prize competitions were opened for the provinces Hainaut, Namur, Luxemburg, Liège and Brabant. This was an obvious choice, since these hilly provinces held more geological interest and were the site of a prosperous mining industry. Still, this choice also reflected the nationalistic tendencies among Belgian scientists, who never really sought active co-operation with Dutch scientists.

A total of nine essays entered the various competitions. Five of them were rewarded with a first prize; two obtained a second prize. More importantly, all (awarded) essays were written by different authors, most of whom were residents of the province under study. This illustrates the widespread interest in the country for the work of the Academy, although most of the authors had some connections with the scientific establishment in Brussels. No Dutchman entered the competition, possibly because, as far as can be established, no great effort was made to make these questions known in the northern provinces. All essays were written in French although, in principle at least, the memoirs could also be written in Dutch.

THE GEOLOGICAL PRIZE ESSAYS

These geological memoirs were all composed in the same way. First, a general survey of the geological structure was given, followed by a more detailed description of minerals and fossils and concluding with an essay on the historical formation of the geological layers. The authors wrote from first-hand experience and had made extensive travels through the region. They had carefully jotted down their observations, sometimes even including little anecdotes from their travel experiences.

The first awarded memoir was written by Pierre Drapiez (1778-1856), a somewhat forgotten figure in the history of Belgian science. Drapiez was born in Lille and had studied at the Paris Ecole Polytechnique, but lived in Brussels for many years, where he was an active author of books on natural history.[16] He concentrated mainly on entomology and botany, and played a role in the creation of the Brussels botanical garden. In 1819, together with a chemist called Jan Baptist van Mons (1765-1842) and a French naturalist,

[16] P. Van Beneden, 'Pierre-Auguste-Joseph Drapiez', *Biographie Nationale* 6 (1878) col. 158-164.

J.B. Bory de St Vincent (1778-1846), he founded the *Annales générales des sciences physiques*, which, however, only briefly remained in existence. The city of Brussels appointed Drapiez as a member of a Committee for the conservation of a collection of scientific instruments that had been used at the Ecole centrale. Drapiez seized the opportunity to propose a series of public lectures on science – with the support of Quetelet. Drapiez himself was assigned the chemistry course.[17] In 1836, Drapiez published his magnum opus, a *Dictionnaire de chimie et de minéralogie*.

Notwithstanding all these achievements, Drapiez did not quite make it as a scientist in Belgium. His interests were possibly too wide-ranging and his work was quickly superseded by more specialist researchers. His geological memoir on the province of Hainaut, awarded in 1821 and published in 1823, lacks a systematic approach and easily drifts away into irrelevant details. Drapiez did not further aspire for a geological career and limited his interests to mineralogy.

The second memoir on the province of Namur is quite different. François-Philippe Cauchy (1795-1842), also a native of France, wrote it. Cauchy was born in Abbeville, but was sent to Brussels at an early age. Afterwards, he studied at the Paris Ecole Polytechnique, but returned to Belgium where the Ministry of Public Works appointed him as mining engineer and administrator for the provinces of Namur and Luxemburg in 1816.[18] The following year, he was made responsible for the courses mineralogy and metallurgy at the Atheneum in Namur, which was an institution for secondary education but part of the general higher-education system. Cauchy had a very successful professional career and became member of the Academy in 1825, where he would be the main promoter of geology at the side of Omalius. His awarded memoir of 1825 contained a wealth of precise information on local finds, and a good systematic study of the geological structure.

Three memoirs were sent in for the prize question on Luxemburg and two received an award. The first one was composed by a German teacher, Johannes Steininger (1794-1874), who taught physics and mathematics at Trier.[19] Steininger had studied philosophy and theology at Trier before going to Paris for a scientific education. Since 1819, he had published several works on the Eifel and Rhine region, as well as on parts of Belgium, Luxemburg and France. His interests were not confined to geology, but

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[17] Geert Vanpaemel, 'Onderwijs voor 'de meer beschaafde klasse'. Het Museum voor Wetenschappen en Letteren te Brussel (1826-1834)', *Scientiarum Historia* 23 (1997) p. 3-19.

[18] G. Dewalque, 'François-Philippe Cauchy', *Biographie Nationale* 3 (1872) col. 380-383.

[19] J.A. Massard, 'Les pionniers de la géologie Luxemburgeoise: Steininger, Engelspach-Larivière et les autres', in: J.A. Massard ed., *L'homme et la terre* (Luxemburg, 1996) p. 127-170.

touched just as well on archaeology and history. His prize-winning memoir of 1828 apparently served him as an introduction in the French geological society, since he published several articles in the *Bulletin de la société géologique de France* during the following years. He had no further influence on the geology in Belgium.

The other essay elicited much more controversy. Its author was Auguste Engelspach-Larivière (1799-1831), who had been born in Brussels although his father, a theatre performer, was from the Alsace region in France.[20] Engelspach studied at the Ecole des mines in Paris and then went on a long journey throughout Europe, from England all the way to Russia. To pay for his travel expenses, he published geological descriptions of the countries he passed through, but when he ran out of money, he also served as a waiter in a Saint Petersburg café. Upon his return to Brussels, his career took off very rapidly. He became a member of the Southern Brabant Statistical Committee and then won the award with his memoir on the province of Luxemburg. In the following years, he published a few other books on geology and was charged with teaching geology and mineralogy at the Museum for Science and Letters, founded by Drapiez and Quetelet, although this appointment was not made official by the Dutch government. Then political events took over: at the outbreak of the Belgian Revolution, Engelspach was one of the first to take up arms against the Dutch army. He was soon promoted to the position of military leader of the rebellious troops and became a member of the committee to take care of public order in Brussels. In the aftermath of the revolution, however, the promises made to him for public office did not materialise and he passed away suddenly in July 1831.

Engelspach's memoir on the province of Luxemburg created a minor controversy in Luxemburg itself. A local mining director accused Engelspach of being completely ignorant of geology and only having some knowledge in mineralogy. The controversy, which mostly centred around terminology, also took on a sharp personal turn, but died down very soon. It shows, nevertheless, how this geological research touched a very sensitive nerve in the local newspapers. The criticism Engelspach had uttered on the technical competence of the Luxemburg mining authorities was answered by pointing out that Engelspach had no profound knowledge of the Luxemburg mines (a point on which Engelspach agreed) and that he had used his title 'mining engineer' (justified by his studies at the Ecole des Mines) in a most

[20] L. Alvin, 'Auguste Engelspach, dit Larivière', *Biographie Nationale* 6 (1878) col. 589-600; J.A. Massard, *op.cit.*

misleading way, as he was not a member of the State Corps of engineers. Science and practice did not always go together well.

The most important of the geological memoirs was the one written on the province of Liège by the young André-Hubert Dumont (1809-1857), who was only nineteen at the time.[21] Dumont worked as a surveyor in the mines, but had not obtained any further knowledge of geology. Only after his essay had been awarded by the Academy did he take courses at the University of Liège, where he received a doctorate in mathematics and natural sciences in 1835. In the same year, he was appointed extraordinary professor of mineralogy and geology at the same university, where he would continue to teach and to do research until his early death in 1857.

Dumont's memoir was immediately recognised as being of exceptional value. Both Omalius and Cauchy, who acted as referees in the prize competition, lauded the exactness, precision and extent of the detailed observations, but also the novelty of the method used. Dumont had in fact initiated the stratigraphical method in geology, showing among other things how the different layers of chalk in the Condroz hills could be explained by the clines and anticlines of the soil. Dumont had further included a geological map of the province, which was considered by the referees to be 'the best ever made in our country.'

Dumont was to make a distinct mark on the history of geology in Belgium. Elected as a member of the Academy in 1836, he was assigned the preparation of a geological map of Belgium, of which he was able to present a manuscript copy to the Academy in 1849, made to scale 1:60,000. The map received high praise from geologists and was still republished in 1876. A new geological map on scale 1:40,000 was only made around the beginning of the twentieth century.

The prize competition for Liège resulted in three essays. Dumont's was placed above the others, but number two also deserved to be awarded. This memoir was written by Charles-Joseph Davreux (1800-1863), a Liège druggist, who taught chemistry and mineralogy at the local School for Industry.[22] He was cofounder of the Société des sciences naturelles de Liège in 1822 and participated actively in its scientific work with papers on chemistry, mineralogy and geology. Since 1830, he was curator of the mineralogical collections

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[21] A. Le Roy, *L'université de Liège depuis sa fondation. Liber Memorialis* (Liège, 1869) col. 216-255; G. Dewalque, 'André-Hubert Dumont', *Biographie Nationale* 6 (1878) col. 283-295; A. Renier, 'A propos du début des études géologiques en Belgique. B. L'oeuvre cartographique d'André-Hubert Dumont, 1808-1857', *Bulletin de la Classe des Sciences de l'Académie Royale de Belgique*, 5e série, 35 (1949) p. 143-156 and p. 709-729.

[22] G. Dewalque, 'Charles-Joseph Davreux', *Biographie Nationale* 5 (1876) col. 733-735.

of the university and he was even given the task of teaching, but after a few years he preferred to return to his drugstore. Davreux's memoir was particularly mentioned for its use of fossil studies. His further career directed him, however, towards medicine and he became a member of the Royal Academy of Medicine. Apart from his administrative duties in several committees for public medicine, he did some research in local history and archeology. Geology apparently disappeared from his work. The third memoir did not receive a prize, but the three referees still judged it good enough to conclude with satisfaction that scientific studies had made great progress in Belgium during the last decade.

The last of the prize competitions, and the first since Belgian Independence, concerned the province of Brabant. In 1835, the prize went to a memoir by Henri Galeotti (1814-1858), born in Paris as the son of a Milanese father. Galeotti had lived in Belgium since his early childhood years and obtained Belgian citizenship in 1843.[23] His interest in geology was only short-lived. He was much more an explorer who travelled in many countries. As a result of his winning the Academy prize, he became involved with the Etablissement Géographique of Philippe Vandermaelen (1795-1869). For the Etablissement, he made several expeditions to Mexico from 1835 and 1840, writing on the geological structure of the country and collecting some 8,000 exotic plants. Upon his return, he enlisted the help of several botanists to produce descriptions of his specimens. At some point, he started a commercial enterprise for exotic plants, but it failed. With the support of his fellow academicians (he was elected as a correspondent in 1841), he obtained the post of director of the botanical garden of the Brussels Société royale d'horticulture in 1853, which later became the National Botanical Garden.

BELGIAN GEOLOGY IN 1830

When reviewing the seven prize-winning essays of the Academy, it becomes clear that they had an enormous impact in stimulating scientific research in Belgium. Geology was not taught as a separate discipline at any university and there were no scientific societies that could or would publish geological papers. It was on, the other hand, a topic that occupied a number of talented mining engineers as well as young scientists with often broad interests but with sufficient enthusiasm for geology to carry out field trips and very laborious research. The initiative of the Academy came just at the right time to

[23] A. Quetelet, 'Notice sur Henri-Guillaume Galeotti', *Annuaire de l'Académie royale des Sciences, des Lettres et des Beaux-Arts de Belgique*, 25 (1859) p. 139-147; F. Crépin, 'Henri-Guillaume Galeotti', *Biographie Nationale* 7 (1880) col. 433-436.

support this widespread interest in geology. By rewarding the would-be geologists with a prestigious prize and by publishing their essays, the Academy provided Belgian geologists with a firm ground from which geology could grow. Three of the prize winners – Cauchy, Steininger and Dumont – indeed went on to make a career for themselves in geology. Drapiez, Davreux and Galeotti remained active in science, but turned away from their early interest in geology. The career of Engelspach was cut short by his premature death.

What was the involvement of the Dutch government in the Academy competitions? Although the Academy was a state organisation, with members being nominated by the government, the prize competitions were not inspired by any concern for state interests. Whereas the making of geological maps, ordained by the Royal Decree of 1825, had overtly utilitarian goals, the prize essays were evaluated for their scientific merits. Many of them carried mottoes stressing the utilitarian credo, such as 'Nisi utile est quod facimus, stulta est gloria' ('Unless what we do is useful, the glory is foolish'), but the essays were never considered for their practical utility. On the other hand, what the essays did do was confirm the local particularities of the Belgian provinces. If the national policy of William I was directed towards an integration of the two parts of his kingdom, the scientific policy of the Academy did the opposite. Exploring the geology of the Belgian provinces was not a topic to elicit much enthusiasm in the North. The geological essays emphasised the independent status of the southern provinces by singling out a feature that was not to be found in the North. Whether or not this was done on purpose is not clear. As explained in the beginning of this paper, Belgian scientists were not averse to the Dutch authorities and, in fact, were very successful in obtaining all kinds of support. Whatever their personal feelings towards the political situation of the Kingdom,[24] they appeared to have lived their own history, without much regard to what happened in the North. The beneficial support of the Dutch authorities was gratefully acknowledged, but the Belgian scientists did not consider themselves to be part of a kingdom that transcended the borders of what came to be the independent state of Belgium.

[24] Both Quetelet and Drapiez were members of the Société des Douze, a literary society of which some members were prosecuted by the Dutch government. On the other hand, after 1830, Omalius remained faithful to the oath sworn to William I and only returned to public life after Belgian Independence was officially recognised in 1839.

Hermann Vogelsang (1838-1874), 'Européen avant la lettre'.

Jacques L.R. Touret

The name of Hermann Vogelsang, the first professor of mineralogy and petrology at the Polytechnic School of Delft (Fig. 1), is only known to-day among fluid inclusion specialists. They recall that, with the help of his assistant, Theodore Geisler, he succeeded in analysing the strange fluid that Brewster had found in cavities within some topaz and quartz crystals (Vogelsang and Geisler, 1869). He did not write too many publications, but his major essays, notably the *Philosophie der Geologie*, published in Bonn in 1867, reach high prices in sales of ancient books, because of the spectacular colour plates and exquisite drawings (Fig. 2). Vogelsang was, however, an important figure of European mineralogy and petrology during the nineteenth century, together with recognised authorities like Ferdinand Zirkel and Harry Rosenbusch. From his country of adoption, the Netherlands, he established constant bridges between the two major schools of England and Germany, without forgetting the French, with whom he was in an almost open conflict (in the line of the French-Prussian war, which would mark the fall of Napoléon III). Vogelsang's short life (he died at the age of only 36) started as a dream and ended in a nightmare. His influence was, however, much greater than commonly realised and, as much as H. C. Sorby, who was his direct inspirator and mentor, he deserves to be recognised as one of the founders of modern microscopic mineralogy and petrology.

THE STUDENT YEARS IN BONN

Vogelsang was born in Minden near Hannover in 1838, but after the death of his father, his mother moved to Bonn, where his education was mainly supervised by one of his uncles. The family counted four children, one daughter and three sons, who all died at a relatively young age, even by the standard of the time: 13 years for the daughter and 17 and twice 36 for the sons. All died from lung infection, which might indicate some genetic weakness in the family.

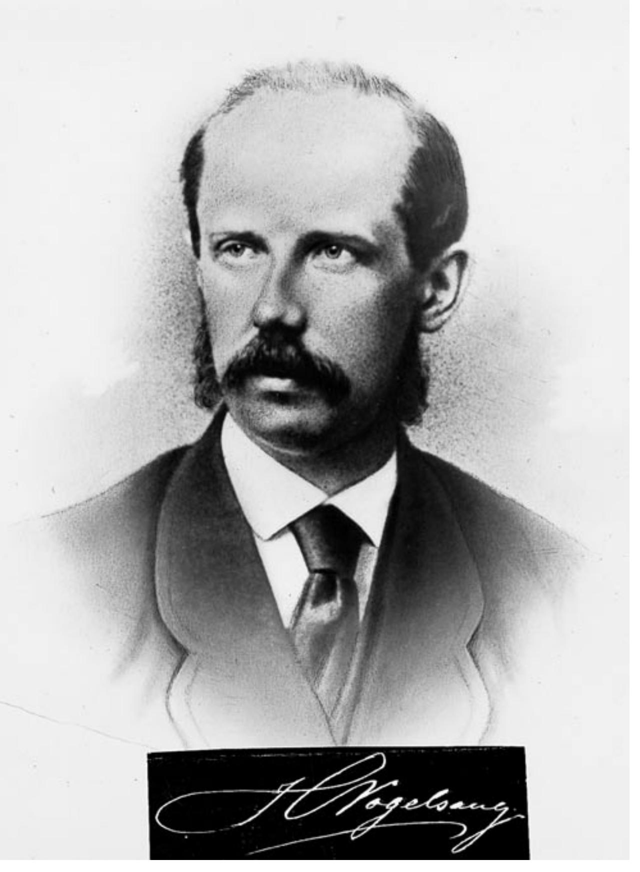


Figure 1 Official portrait of Hermann Vogelsang, about 1870 (Courtesy, Museum Technical University, Delft).

Hermann was a gifted, brilliant child and a successful student at the Bonn gymnasium, from which he obtained his 'Abitur' in 1856. The Bonn region counted a number of mines at the time, notably of iron and copper, and the young Hermann decided to choose the career of mining engineer. He became 'Bergbeflissen' immediately after his 'Abitur' and was rapidly promoted to 'Bergexpectant' in 1857, after having visited and worked in a number of mines, particularly in Saxony and at the famous locality of Freiberg. The influence of the old master of Freiberg, A.G. Werner, was still very important in Germany at this time, especially for practical mining purposes and the essence of the 'art of mining' was learned in the field, from experienced miners.

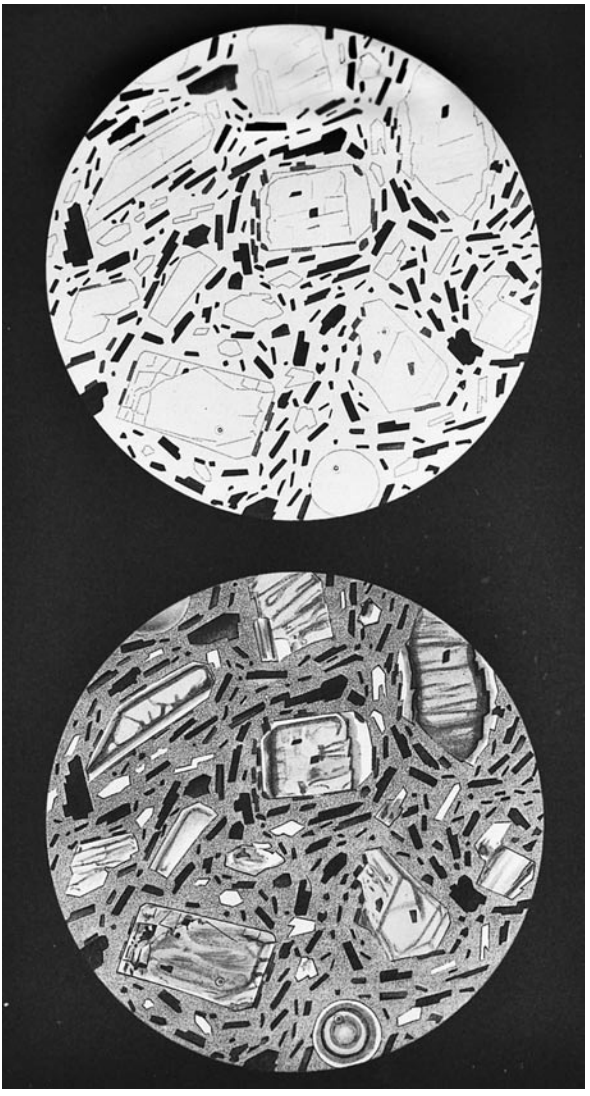


Figure 2 Colour plate (Tafel II) from the *Philosophie der Geologie*, (quartz-bearing trachyte from Campiglia). Polarised light, parallel (top) or crossed nicols (below).

In 1858, the political situation in Germany was not very stable and military forces were slowly building up. Vogelsang had to go into the army, which he could luckily do in his hometown, Bonn. Military duty in those days allowed a number of possibilities and the young Hermann was able to spend much time at the university, where he resumed his university education. He ended up deciding to quit mining, keeping, however, always a keen interest for mining geology, which proved to be helpful for the immediate follow-up of his career, but which should also lead to a real drama at the end of his life.

At the end of the two years that he had to serve in the army, Hermann, at the recommendation of his professors, chose science instead of mining. He engaged in the preparation of a thesis on the formation of metal-bearing veins, a subject typically in line with Werner's thinking. As with the mines, he could not consider geology without extensive travelling. He was sent to Corsica, in order to study the orbicular diorite recently discovered

Figure 3 The 'Allégorie de la Science', by Abel de Pujol (1846). This monumental painting, together with a number of spectacular geological landscapes (Mont-Blanc, Gavarnie, Etna, Giant causeway, and so on) decorates the ornamental staircase of the Ecole des Mines in its post-napoleontic location (Hôtel de Vendôme, near the Jardin du Luxembourg). All these paintings had just been completed when the young Hermann Vogelsang paid a visit to the School's director, Elie de Beaumont. (Musée de Minéralogie, ENSMP.)

on the island, a spectacular rock, which was the object of much discussion among the petrologists at the time.

Selecting this subject was probably not an innocent choice. The orbicular diorite of Corsica was then known in France – as it continues to be called by non-geologists today – under the name of 'napoléonite' and the local people consider it a symbol of the Napoleontic era.

We can surely assume that a part-time soldier of Bonn was already in a mood of revenge after the Napoleontic wars and preparing for the war that would burst out ten years later (1870). Scientifically speaking, the major question was to find out if the special features of the orbicular diorite deserved a special name – an idea favoured by the French – or if it was just a question of texture, not sufficient to justify a special name. On his way to Corsica, Vogelsang stopped in Paris to meet the great man of the time, Léonce Elie de Beaumont, newly installed in the brand new Hôtel de Vendôme, where the Ecole des Mines is still located today. Napoléon III was the new 'Empereur des Français' and France was then at the top of its industrial power, with a number of international exhibitions (1855, 1862 etc.) showing the world the beauties of science and the miracles of new techniques. In 1862, the monumental staircase of the Hôtel de Vendôme had just been decorated with magnificent paintings: the 'Allégorie de la Science' on the ceiling (Fig. 3), the 'Vue du Mont-Blanc' (first price at the 1855 International Exhibition) and other famous geological sites on the wall, together with magnificent panels of 'faux-bois' and 'faux-marbres', imitations of natural rocks slabs. Among these, the 'napoléonite' occupies a place of honour, painted from a sample exhibited at the International Exhibition of 1855 (Fig. 4).

Vogelsang must have seen then how important this rock was to the French. He was not impressed: neither by the dictatorial authority of Elie de Beaumont nor by the rock itself. Upon his return to Germany, he concluded that the special texture of the orbicular diorite was only a local phenomenon (very rightly, as it occurs only very sporadically in an otherwise homogeneous intrusion), and that it would by no means deserve a special name. This opinion has definitely prevailed in the international literature since then. It may not be a coincidence that, since the end of the nineteenth century, the Museum of the Paris Ecole des Mines has accumulated an amazing collection of rocks with orbicular textures, from a wide variety of rock types (granites to ultrabasic rocks) and provenances, which incidentally have never been the object of detailed studies.

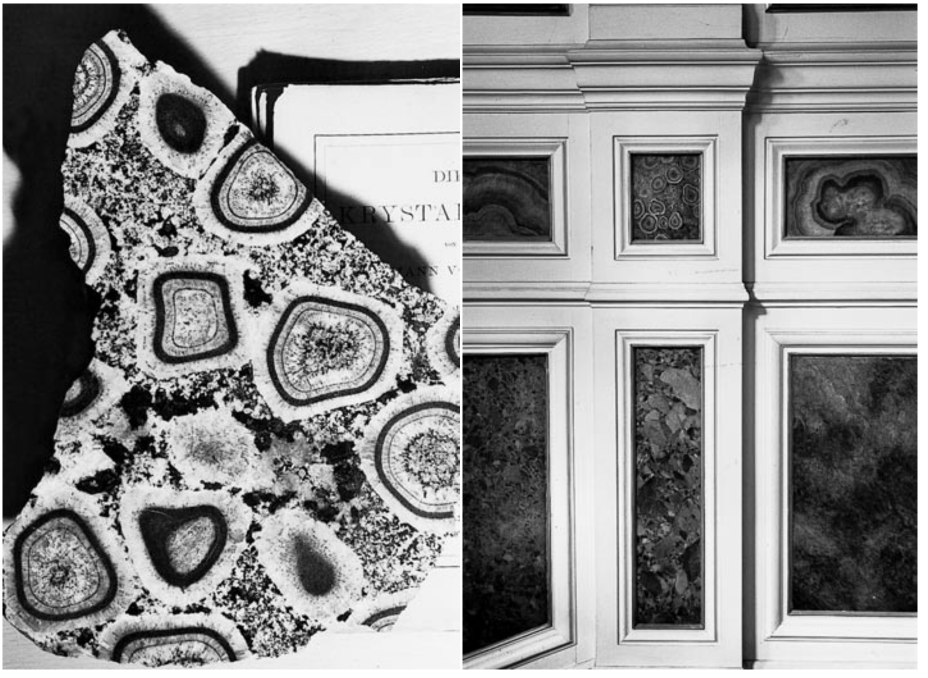


Figure 4 Sample of orbicular diorite ('Napoléonite'), exhibited at the International Exhibition of 1855 (first in Paris, second in the world) (left), which served as a model for the 'trompe l'oeil' wall painting in the staircase (right). (Collections Musée de Minéralogie, ENSMP.)

ZIRKEL AND SORBY, THE GREAT INSPIRATORS

The year 1862 would definitely become important in the life of Vogelsang. At Bonn University, he became a close friend of Zirkel who, together with H. Rosenbusch, would become a major figure of the golden era of the German descriptive mineralogy and petrography. Vogelsang married Zirkel's sister and he remained extremely close to him during all his life. Zirkel took care of the publication of his major work on crystallites after his death (Vogelsang, 1875). During their university years, both friends used to travel the countryside around Bonn to make geological observations and one day, by chance, they met Henry Clifton Sorby, who was travelling through the Rhine valley with his mother.

Sorby was a typical example of a British aristocrat, rich enough to carry out his scientific activities in his own office, but without any formal link to an established university or research centre. This position of distinguished amateur caused him immense resentment when, at the end of his life, he was denied the presidency of Sheffield College, which was, however, only known internationally because of him. As President of the British Geological Society, member of a number of academies and learned societies, he was well known for having introduced the microscope in mineralogical studies, as well as for having developed the technique of thin-section preparation.

This was a major technological breakthrough, which makes Sorby the founder and now recognised inventor of a number of scientific disciplines, such as microscopic petrology and structural geology, metallurgy and meteorite science. At the time, however, the idea of 'looking at mountains with a microscope' was received with much condescension and mockery by many of his established colleagues, notably Honorace Bénédict de Saussure. In the current petrographical literature, Sorby is dubbed as the father of inclusion studies (e.g. Roedder, 1984), but it must be recognised that his work was much more devoted to melt inclusions than to fluid inclusions (Fig. 4). A few drawings of fluid inclusions appear here and there, but – in marked contrast with his treatment of melt inclusions – without any attempt of explanation or interpretation. We might add 'fortunately', as the blind application of Sorby's principles of melt inclusion interpretation to fluid inclusions would later have dramatic effects on the development of fluid inclusion studies, leading in fact to their almost complete disappearance from petrology in the middle of the twentieth century (see discussion in Touret, 1984). With all his merits, Sorby is thus less the real 'father' of fluid inclusion studies than some of his contemporaries, among which, as argued hereafter, Vogelsang stands out as a most serious candidate.

Luckily, the young Zirkel and Vogelsang had a more open mind than De Saussure and both were impressed by Sorby to the point that this encounter had a decisive influence on the rest of their careers. Vogelsang would become an ardent defender of microscopic studies for the rest of his life, as illustrated by his detailed and magnificent drawings. He visited Sorby at Sheffield to learn how to make thin sections and later developed this technique at Delft so well that, at the time of his death, the thin-section collection at his university amounted to several thousand specimens, by far the most important collection worldwide in those days.

THE PRIZE COMPETITION OF THE HOLLANDSCHE MAATSCHAPPIJ DER WETENSCHAPPEN

In 1863, Vogelsang successfully defended his thesis at Bonn University (*Quomodo venarum spatia primum formata atque deinde mutata sint*, freely translated: How the space of the veins is first formed, then transformed). This work has not left much of a trace in the later literature, but was obviously found very satisfactory by his professors. In the same period, he travelled extensively through the Eifel, in order to answer a question posed in a prize competition organised by the Hollandsche Maatschappij der Wetenschappen in Haarlem. This society was a typical example of the learned societies, which flourished in the Netherlands during the eighteenth century, founded and supported by the establishment of wealthy bourgeois who had a marked interest in science and the arts. The Hollandsche Maatschappij, closely associated with Teyler's Museum, was established in a superb monumental building in the heart of the historical city of Haarlem (Wiechmann, 1987). The society still exists today, keeping the same tradition of collegial membership and complete independence of any form of state administration. During the short reign of Napoléon's brother, Louis-Napoléon, the society had superbly refused the offer of the king to become a national academy. Besides regular meetings and discussions among the members, one of the most important activities of the Maatschappij was the yearly 'prijsvraag', presenting an, at the time, important question to the whole international community.

In the framework of the great debate between followers of neptunism and plutonism, which would last during the major part of the nineteenth century, questions on the origin of volcanoes had a central role. Leopold von Buch, a former student of Werner, was convinced of the igneous origin of the volcanoes in Auvergne and became an ardent propagandist of the new theories. On May 28th, 1817, he presented before the Academy of Berlin a communication entitled *Ueber die Zusammensetzung der basaltischen Inseln und über Erhebungskratere*.

Under the name of 'Erhebungskratere', the idea that volcanic cones were uplifted by the rise of underlying magmas was enthusiastically adopted by some great geologists of the time, notably Alexander von Humboldt and Léonce Elie de Beaumont. If, to a point that today may sound rather strange, this theory was almost unanimously accepted for ancient volcanoes, critical comments were immediately issued concerning the formation of recent volcanoes. Especially Sir William Hamilton had made a number of precise observations in southern Italy, leading to the obvious conclusion that falling debris after an eruption caused the conic structure of a volcano.

In 1864, the question was still much debated and it was proposed for that year's 'prijsvraag'. Written in French, the language commonly spoken by educated people in Holland at the time, it read, 'Dans la contrée montagneuse de la rive gauche du Rhin, connue sous le nom de l'Eifel, on remarque plusieurs montagnes côniques. – La société désire voir décider par des recherches exactes faites sur les lieux mêmes, si l'on y trouve des traces de soulèvement des roches anciennes, ou bien si ces montagnes ne sont que des cônes d'éruptions'.

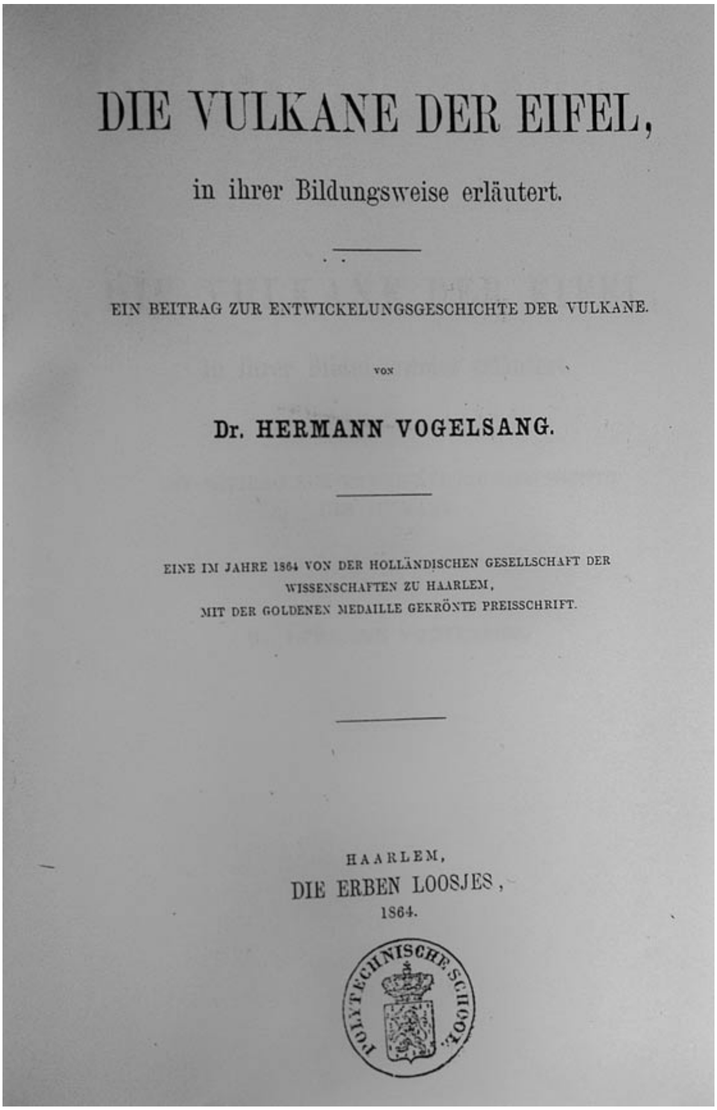
Vogelsang took the challenge very seriously and in few months' time made extremely detailed field studies, precisely mapping the most important volcanoes and, especially, the 'maars', which are so typical of the Eifel. His answer was very elaborate, in the form of a 76-page book divided into three parts: more than ten pages of historical introduction, which prefigures the later first part of his *Philosophie* and in which his preference for the British school is clear, followed by the description of the various volcanoes with associated sketch maps (about 30 pages), and a long conclusion, which constituted almost half of the entire book. This conclusion was written 'au fil de la plume', without any interruption and, to tell the truth, with a rather confusing internal organisation. However, the first statement is very clear, and it does directly respond to the 'prijsvraag', 'Erhebungskratere und Erhebungskegel gibt es in der Eifel nicht.' But might volcanoes indeed be eruption cones, corresponding to the alternative hypothesis proposed by the Society? Vogelsang, again after a long historical introduction, discussed in detail the mechanism of a volcanic eruption, relying extensively on his experience in underground mining. He showed that the fractures around a volcanic cone do not match the pattern found in underground blasting, and he concluded, very rightly, that most craters couldn't be due to simple explosions. This idea was commonly accepted as an alternative to uplift craters, but Vogelsang rather attributed the crater depression to the sinking of solidified lava in the void provoked by the eruption ('Einsenkungs-Kratere'). This interpretation later proved to be correct and it is evidence of a rare maturity and sense of observation for such a young man (Vogelsang wrote the essay at the age of 25).

The Maatschappij received three answers, but the quality of H. Vogelsang's work was so much above that of his two competitors that his was the only one taken into consideration. Understandably, the members of the Society must have been satisfied, as by the end of the same year (1864), his essay received the gold medal and was published in Haarlem by the house of Loosjes, the usual printers of the Hollandsche Maatschappij (Fig. 5).

A gold medal, a book printed: Vogelsang must have been happy. Nevertheless, the most important was still to come: in July 1864, at the age of 26 – as a matter of fact before having officially received his price – he was appointed as the first professor of mineralogy and petrology at the newly created Polytechnic School of Delft.

A BRIEF BUT BRIGHT CAREER IN THE NETHERLANDS

Hermann Vogelsang moved to Holland with his family and, even though he always kept in close contact with his home country, assimilated very rapidly in his new position. He quickly mastered the Dutch language and was obviously



DIE VULKANE DER EIFEL,

in ihrer Bildungsweise erläutert.

EIN BEITRAG ZUR ENTWICKELUNGSGESCHICHTE DER VULKANE.

VON

Dr. HERMANN VOGELSANG.

EINE IM JAHRE 1864 VON DER HOLLÄNDISCHEN GESELLSCHAFT DER
WISSENSCHAFTEN ZU HAARLEM,
MIT DER GOLDENEN MEDAILLE GEKRÖNTE PREISSCHRIFT.

HAARLEM,
DIE ERBEN LOOSJES,
1864.

POLYTECHNISCHE SCHOOL

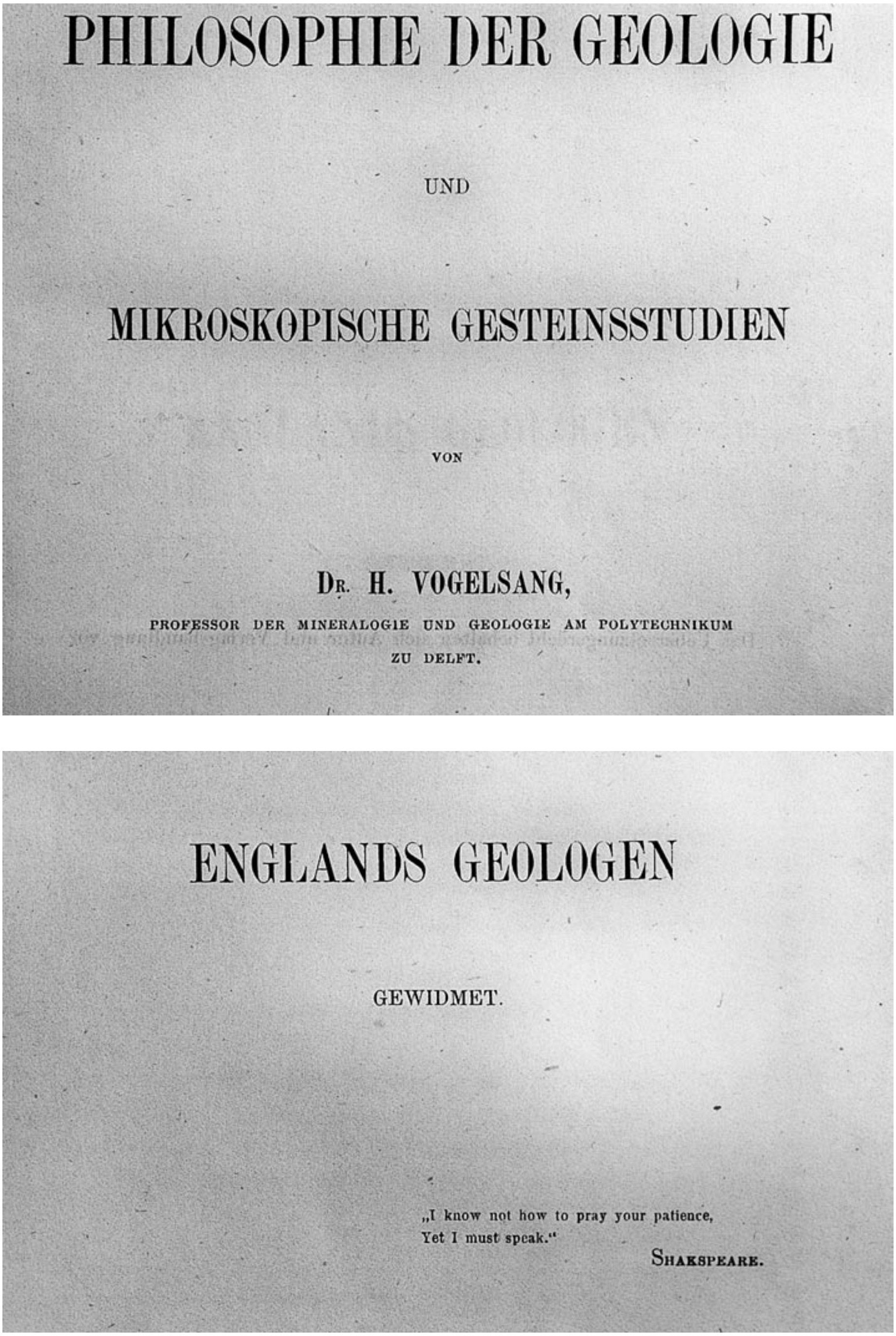
Figure 5 Front page of *Die Vulkane der Eifel*, the printed answer of H. Vogelsang to the 'Prijsvraag' of the 'Hollandsche Maatschappij der Wetenschappen' in Haarlem.

an extremely good teacher, praised and admired by students who were only few years younger than he. He could also count on dedicated technical staff, who helped him develop his extensive collection of rock thin sections. Most of his work was related to microscopic studies, but he also tried to analyse some of the objects that he saw under the microscope, notably fluid inclusions (see hereafter) – and succeeded. His skillful technician Theodore Geisler assisted him with this and he had the integrity to include Geisler in his publications systematically. These intense teaching and organisational activities did not delay the writing of a major book, the *Philosophie der Geologie*, which was published in Bonn in 1867, the year of his election as member of the Hollandsche Maatschappij. One year later, he became a member of the Koninklijke Nederlandsche Academie van Wetenschappen in Amsterdam.

PHILOSOPHIE DER GEOLOGIE

The *Philosophie* is a very interesting book and still very readable today. The front page (Fig. 6), with a quotation from Shakspeare (sic) 'I know not how to pray your patience, Yet I must speak', is a clear homage to Sorby and his countrymen, 'Englands Geologen gewidmet' (Dedicated to the geologists of England). The book is divided in two parts, of which the first one is an historical account of the development of geology as a science, whereas the second one ('Moderne Geologie-Mikroskopische Gesteinstudien') is entirely devoted to microscopical description of rock thin sections. Polarised light was known, particularly through the work of Brewster and Nicol, but not the power of this mode of observation in the interpretation of the mineral structure. At that time, the observers were mostly impressed by the vivid polarisation colours that Vogelsang reproduced superbly in a number of colour plates (not less than twenty in total for the whole book) (Fig. 2).

The scientific content is more difficult to grasp. The book was written during the last phase of the Werner-Hutton controversy and Vogelsang, educated in the Werner system but converted to the Huttonian views, was only interested in volcanic rocks, a direct continuation of his field experience in the Eifel. His major interests focussed on two subjects: the small elongated crystals that he called 'Mikroliten' and that indicated a fluidal texture in solidified magmas, and – in the direct continuation of Sorby's famous paper of 1858 – the melt and fluid inclusions contained in some rock-forming minerals, notably quartz and feldspar (Fig. 7). These two topics would continue to dominate his research activities for the rest of his life: the inclusions, for which he would soon develop extremely effective analytical instruments, and the 'Kristalliten', were the subject of his second (and last) book (Fig. 8 and 9).



PHILOSOPHIE DER GEOLOGIE

UND

MIKROSKOPISCHE GESTEINSSTUDIEN

VON

DR. H. VOGELSANG,

PROFESSOR DER MINERALOGIE UND GEOLOGIE AM POLYTECHNIKUM
ZU DELFT.

ENGLANDS GEOLOGEN

GEWIDMET.

„I know not how to pray your patience,
Yet I must speak.“

SHAKSPEARE.

Figure 6 Title page of the *Philosophie der Geologie*. Below the back of this page with the dedication to England's geologists.

Figure 7 Drawings of melt inclusions from the *Philosophie der Geologie* (Tafel X). Left, porphyry (quartz trachyte?) from Cima di Potosi in Bolivia. Right, red porphyry from Halle, Germany. The different magnifications (left 300, right 100) have been chosen to illustrate the shape of individual inclusions (negative crystals, left) and right the relationships between the inclusions and their quartz crystal host.

However, the first part of the *Philosophie*, on the definition and historical development of geology, is not less interesting. Devoted to an elaborate discussion of the historical development of the geological sciences, it displays a rare maturity and freedom of style for a young man of 26 years. It should be acknowledged that, by today's standards, the text is often too compact, badly organised, with diversions that may hinder the prime objectives of the author. Vogelsang wrote from the heart, and his heart could be quite tough. His opinions are direct, straightforward, with strong words against dogmatism and the suffocating influence of some grand old men of the time. Most of the discussions relate to the disputes between neptunism and plutonism, with a clear preference for the second theory, even if the historical importance of Werner and the validity of some of his conceptions for the art of mining are fully recognised. The most acute criticisms are against the French authority figures of the time, notably Elie de Beaumont, as well as some of his German countrymen, especially A. von Humboldt, who was far too 'francophile' in his eyes. A few excerpts of the book may give an idea of the tone.

About Elie de Beaumont and the theory of 'Erhebungskratere':

p. 88: 'Endlich wird jede Insel, jeder Berg zum mehr or minder Hebungskrater, und schliesslich thut Elie de Beaumont seinem Freunde den Gefallen, den Gedanken zu einem geologisch-mathematischen Chaos zu verarbeiten, vor welchem sich die ganze Welt bekreuzte,- ob der grossen Gelehrsamkeit. Die französische Schule is aus Bewunderung ernstlich krank davon geworden'. (At the end, every island and every mountain becomes an uplift crater to some degree and finally, Elie de Beaumont does his friends the pleasure of working out this idea into a geological-mathematical chaos, for which the entire world should cross itself, in view of its great knowledgeability. As a result of admiration, the French school has become seriously ill.)

About A. Von Humboldt ('ein hochgebildeter, vielvermögender und vielbewirkender Dilettant, viel weniger Geologe als L. von Buch') (a highly educated, very competent and accomplished dillettante, much less of a geologist than L. von Buch):

p. 91: 'So lange der unwürdige, frasenhafte Humboldtcultus fortdauert, wirdt man erwarten müssen dass von böswillige Händen diesem wahrhaft grossen Menschen der reich verdiente Lorbeer frevelhaft entrissen und zertreten werde. Die Naturwissenschaft fordert nun einmal demokratische Institutionen. Keine Monarchen, keine Thronreden, keine gesetzgebende Körper, aber auch keine bombastischen Huldigungadressen. Die absichtliche Verkleinerung is schändlich, die maasslose Vergötterung ist gemein'.
(As long as the unworthy, bombastic Humboldt cult continues, one will have to wait until malevolent hands will grab away and trample the well-deserved laurels of this truly great man. Science needs, after all, democratic institutions. No kings, no inaugural speeches, yet neither bombastic honorary speeches. The horrible diminution is a disgrace, the unlimited idolisation is mean.)

p. 93: 'Was soll man aber zu solchen Grundzügen sagen, die bereits nach 43 Jahren von keinem verständigen Geologen mehr zu Ende gelesen werden können? So oft ich daran denke, freue ich mich, dass das Buch französisch geschrieben ist. Schwülstige Sprache und nebliche Begriffe, aber kein einziger verständiger Gedanken'.
(However, what should one say about such principles, which already after 43 years no geologist can read to the end. Each time I think of this, I am pleased that the book was written in French. Bombastic language and vague ideas, yet not a single sensible thought.)

The same type of discussion continues for at least ten pages. Vogelsang especially addresses his criticisms at some views defended by Elie de Beaumont, particularly his theory of a universal 'réseau pentagonal'. The idea was that contraction of the earth upon secular cooling would result in mountain chains oriented along certain directions, forming a pentagonal grid on the surface of the globe. During his many travels through many countries, Elie de Beaumont had claimed to have actually measured these orientations, transposed on elaborate models of the Earth by his disciples, such as Béguyer de Chamcourtois. A number of geologists knew that these data did not reflect reality, but very few had the courage to say it openly as long as the powerful secrétaire perpétuel of the Académie des Sciences (Elie de Beaumont) remained active.

THE DISCOVERY OF CO_2 IN FLUID INCLUSIONS

Besides his *Philosophie*, the great achievement of Vogelsang during his Delft period was the identification of a mysterious fluid 'with remarkable physical properties' found by D. Brewster in 1823. One year earlier, Davy (1822) had identified 'water and aeriform matter in cavities of certain crystals', but the nature of this aeriform matter, was to remain a mystery for almost half a century. Brewster, with remarkable technical skills, refined the determination of the physical properties of the mysterious fluid: a refractive index found to be significantly lower than that for pure water, and especially, an expansion coefficient of the liquid at moderate temperatures, found to be equal to 0,01497 / °C in the temperature interval of 10.6 to 26.7ºC (Brewster, 1826) (This amazing precision, as well as for the refractive index, is correct to the second decimal!). In 1835, a French physicist, J. Thilorier, investigated physical phase changes in pure CO_2, and found the expansion coefficient of liquid CO_2 to be equal to 0.015 / °C in the temperature interval of 0 to 30°C. More than twenty years would elapse before R.T. Simler (1858) noted the very close match between the values found by Brewster and Thilorier and proposed that the 'fluide aeriforme' of Davy might be CO_2. But he did not provide any confirmation and most scientists remained extremely sceptical.

Upon his arrival in Delft, Vogelsang re-attacked the problem in a systematic manner. With the technical help of T. Geisler, he imagined a very simple and effective model of heating stage, a simple thermometer with an annullar reservoir, heated by an electric resistance. Basically, the same set-up is still used today in microthermometry, which allowed much more precise and systematic measurements than done by Sorby and Brewster. In quartz of unknown origin (most probably Madagascar), he discovered a large amount of relatively small (a few tens of micrometers in diameter) and relatively dark inclusions, each showing spectacular 'negative crystal' shapes, and a gas bubble ('libelle'), the size of which rapidly decreased until it disappeared upon heating to 30-32°C. The expansion coefficients were of the same order of magnitude as those measured by Brewster and Thilorier, with, however, significant differences that Vogelsang attributed to measurement errors. In fact, we now know that another factor intervened, the fluid density, which might explain these differences and which is far more important than Vogelsang had supposed: very dense CO_2 may homogenise at as low temperatures as about -70°C (Touret and Bottinga, 1979).

In any case, the similarities between the fluid in quartz and CO_2 were such, that Vogelsang thought that the hypothesis of Simler might well be correct. But proof needed to be found, and again it relied on the construction of a simple, ingenious and efficient instrumental device: a small glass vessel, connected to a vacuum pump by a tube traversed by two electrical conductive wires, in turn connected to an electric generator.

A few fragments of quartz containing inclusions were placed in the glass vessel and the air was evacuated. The vessel was then heated by a gas flame, provoking the explosion (decrepitation) of inclusions and the expansion of the gas contained in inclusions in the glass tube. A high-intensity electric current in the tube would cause an electric arc, the light of which could be analysed spectrographically. Vogelsang found a very strong line corresponding to pure CO_2, together with a weak line for hydrogen (known now to be due to a small quantity of water, decomposed by the electric arc). In any case, the proof was there: the mysterious fluid of Davy and Brewster is dense CO_2.

The experimental setting conceived by Vogelsang and Geisler looks surprisingly modern, and as a matter of fact could be used today without major modifications. Only, today, most 'decrepitation lines' combine stepwise heating and crushing under vacuum. The results (including a few erroneous interpretations, notably on the complicated 'three-fluid phase' inclusions found in certain topaz crystals) were published simultaneously (1869) in German ('Über die Natur der Flüssigkeitseinschlüsse in gewissen Mineralien') in *Poggendorff's Annalen*, and in French ('Sur la nature des liquides renfermés dans certains minéraux') in the *Archives Néerlandaises des Sciences exactes & naturelles*, the scientific journal of the Hollandsche Maatschappij. As it happened, the German publication, the only one that survived in the international literature, was divided into two parts, published in the same issue of the *Annalen*. The second part was omitted in further references, and remained ignored until a few years ago (Touret, 1982, 1984). Only then it was discovered that Vogelsang had already described CO_2 inclusions in Saxonian granulites, rediscovered at a global scale more than hundred years later (Touret, 1971).

Unfortunately, the premature death of Vogelsang did not leave him time to elaborate on his important discovery, and his 1858 publication remained the only one of its kind. It must also be recognised that Vogelsang's further interests went into other directions, particularly concerning the systematic

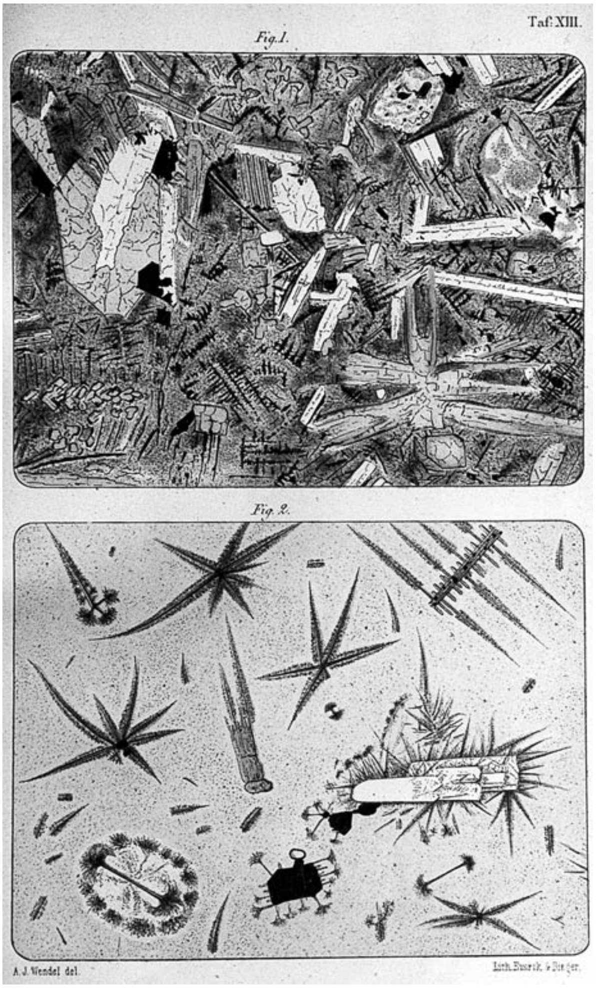


Figure 8: Examples of crystallites in natural rocks (Vogelsang 1875, Tafel XIII). As Sorby did for melt inclusions, Vogelsang interpreted the crystallites in effusive lavas by comparison with metallurgical slags. The drawings refer to the basalt of Podlie-Craig near North-Berwick, Scotland (above) and to the pechstein of Tormore on Aran, Ireland (below).

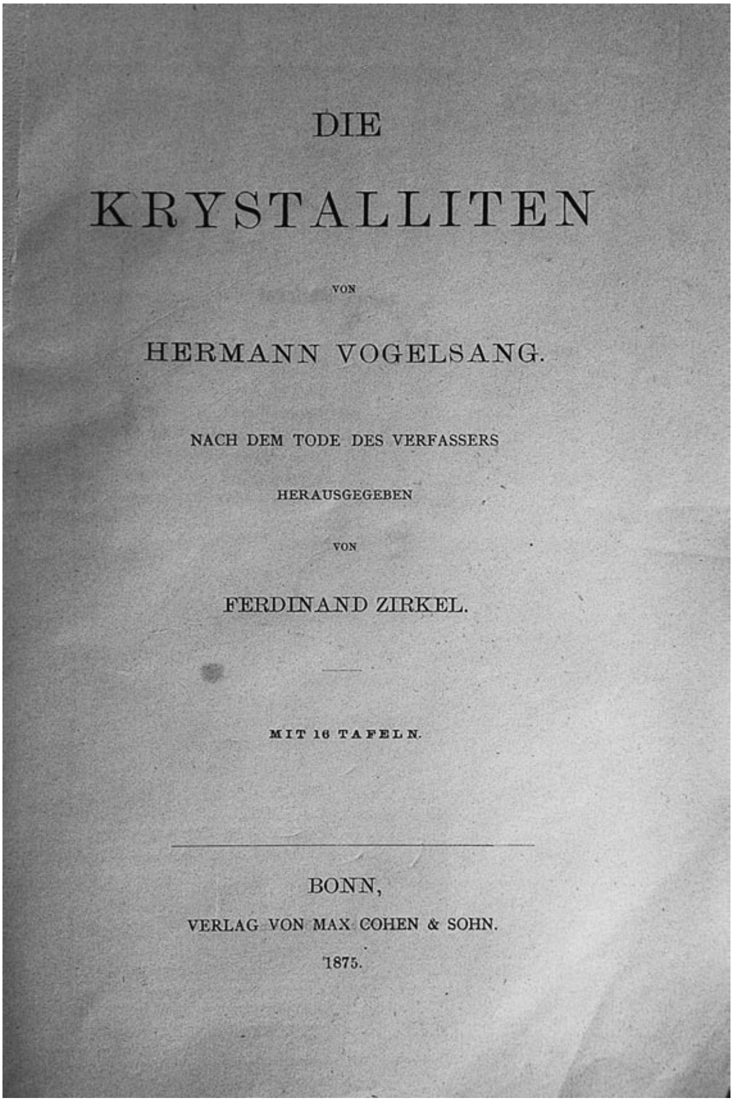
study of the shapes and mode of formation of crystallites, as well as on the iridescence effects shown by certain minerals, notably plagioclase. These works, partly published after his death (Vogelsang, 1875), are interesting, but as a whole less significant than his work on fluid inclusions. For this latter achievement, Vogelsang deserves to be recognised as the modern initiator of fluid inclusion studies, at the same level as H.C. Sorby for melt inclusions.

A DRAMATIC END

Vogelsang had only a few years of happiness in Delft. The French-Prussian war took place in 1870, and it is possible that the former soldier at Bonn derived some satisfaction from the fall of Napoléon III, even though there is no indication of this. He soon ran into a number of problems, which ended in a real drama. During the first half of the nineteenth century, the gold rush in California had led to intense speculation in precious metals. The gold rush ceased rapidly, but was followed by a silver rush where lucky strikes were much more rare than great losses. An American adventurer came to the Netherlands, and he was convincing enough to persuade a number of Dutch investors to create a mining company ('Nederland'), which first bought a small silver mine in California, and then the larger Cariboo mine in Canada. In both cases, Vogelsang was taken aboard as the national expert and, remembering his former experience of 'Bergexpectant' in the region of Bonn, he gave the green light for buying the mines. However, the profits were much less than expected, covering only one tenth of the huge investment during the first year of exploitation. By present-day mining standards, this would probably be considered acceptable, but it was far below the expectations of the investors. The relationship of Vogelsang with the group of investors deteriorated, and he had to resign abruptly. In addition to these professional problems, he had to face the tragic and premature death of his only child. This was too much for his fragile constitution and the recurrent lung problems of his family. After a short illness, he died of pleuritis in the winter of 1874. Very shortly after his death, his book on 'Krystallite' (crystallites) was published, again in Bonn, thanks to the efforts of his brother in law, Zirkel (Fig. 9).

VOGELSANG'S HERITAGE

The tragic and premature death of Vogelsang severely affected the young school of Delft. In a few years, he had succeeded in creating a major research centre and in building a thin-section collection that, as said before, had no equivalent in the world. The tone of his obituaries, notably those written in the local student journals, shows how much he had been appreciated and how much his death was regretted. His reputation, at least at his university, had not been affected by the Cariboo affair. Unfortunately, his successors failed to maintain his standard and the Delft Polytechnic slowly lost its reputation in geology. When some twenty years later, the future founder of the Dutch Geological Survey, Willem van Waterschoot van der Gracht – born in 1873, one year before Vogelsang's death – decided to study mining geology, he


DIE

KRYSTALLITEN

VON

HERMANN VOGELSANG.

NACH DEM TODE DES VERFASSERS

HERAUSGEGEBEN

VON

FERDINAND ZIRKEL.

MIT 16 TAFELN.

BONN,

VERLAG VON MAX COHEN & SOHN.

1875.

Figure 9 Title page of the posthumously published *Die Krystalliten* (1875).

had to go to Freiberg, where he obtained his title of 'Diplom Ingenieur mit Auszeichnung' in 1903. Only after the First World War would the Polytechnic, later University of Delft, again reached the level of excellence that it still has today.

The influence of Vogelsang on science continued, especially within the monumental works written by the two great men of the German descriptive petrography, F. Zirkel and H. Rosenbusch. Both were esteemed colleagues but also direct competitors and their paths would soon diverge. Zirkel, who succeeded Carl Friedrich Naumann in 1870 in the chair of Leipzig, concentrated on the crystallography and the description of mineral species (Zirkel, 1873). Rosenbusch was more of a petrologist, and highly interested in mineral microscopical investigations for the determination of rocks. In this respect, he appears to be have been closer to Vogelsang, whose influence can be traced easily in his works. Rosenbusch's major book, still a reference work in descriptive magmatic petrology today, is the *Mikroskopische Physiographie der Mineralien und Gesteine*, which counted five editions between 1873 and 1924, almost quadrupling in size and number of pages between the first and the last edition.

In the first edition (1873), the first part (Band 1), devoted to the general properties of rock-forming minerals, contained three parts: Morphological (I), Physical (II) and Chemical (III) properties. In the later editions, Parts I and III remained roughly unchanged, but Part II, which includes the whole theory of polarised light, evolved from less than 50 pages in the first edition to 122 pages in editions 2 and 3 (1885-1887), 309 pages in edition 4 (1905, with E.A. Wulfing) and 728 pages in the last edition (1924, E.A. Wulfing-O. Mugge). At the same time, the general organisation changed. The second part (in the first editions) became the first part in editions 4 and 5, whereas the former part I is rejected at the end of the volume. Still, it remained practically unchanged through the different versions, dealing only with two topics, 'Kristallite und Einschlüsse' (crystallites and inclusions), which came almost word for word from Vogelsang's work. Each of the various aspects, namely the crystallite classification, the principles and methods of inclusion study, examples and case studies can be found in one of the two Vogelsang books. Rosenbusch's successors would not maintain this tradition. They would go a step further, not pushing this aspect of petrological studies to the very end of their introductory text, but ignoring it completely. A long 'traversée du désert' for inclusion studies, which would last for almost half a century. Nowadays, with the endless analytical possibilities of modern instruments, melt and fluid inclusion studies are among the most rapidly developing fields of mineralogy, petrology and geochemistry. From his central position in the Netherlands, Vogelsang succeeded masterly in bridging two schools: the highly specialised, technically inspired English (and Scottish) geologists, such as Sorby, Brewster and Nicol, and the encyclopaedic German masters of descriptive mineralogy and petrology. In this sense, he was a real European, a good century ahead of his time.

ACKNOWLEDGEMENTS

Upon my arrival in The Netherlands in 1980, my interest for the work of Vogelsang was raised by M. de Bruin, then librarian at the Teyler's Museum in Haarlem. I have also benefited from a number of documents provided by many friends and colleagues: Professors F. van Veen and W. Uytenbogaardt, both successors of H. Vogelsang at Delft, W. van Tellingen, and especially Maaike van Tooren, curator of the Mineralogisch Geologisch Museum in Delft.

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Staring and his geology lectures at Delft in 1863

F.R. van Veen

introduction

Winand Carel Hugo Staring (1808-1877), generally considered to be the father of Dutch geology, completed the first geological map of the Netherlands in 1860. He achieved an international reputation with this map because he was the first who had mapped a detailed subdivision of both the diluvial and alluvial soils, an example that was later followed by German geologists. After completion of the map, Thorbecke, the minister of the interior who had commissioned the map, was not prepared to provide funds for continued geological activities. As a result, while waiting for his new post as inspector of secondary education, Staring had to look for a new job. It is not generally known that he was appointed professor in geology and mineralogy for mining engineering students during the academic year 1862-63 at the Koninklijke Akademie ter vorming van Ingenieurs, the precursor of the Delft University of Technology. Staring is not even mentioned in the official list of professors and lecturers in Baudet's history of that university.[1]

The manuscript of Staring's notes for his lectures at the Delft Polytechnic School has been preserved in the family archives. It offers a fascinating insight into the state of geology in the Netherlands at the time. This contribution aims at giving an idea of the contents of Staring's teaching.

staring archive

The Staring family archive at the Wildenborch (Vorden, province of Gelderland) contains forty-six voluminous files of Winand Staring. They contain many interesting items such as his Leyden University notes, in Latin, of the geology lectures by J.G.S van Breda and on the lectures *Botania et*

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[1] H. Baudet, *De lange weg naar de Technische Universiteit Delft,* vol. 2 (Den Haag, 1992).

Mineralogia and *Chemia organica* by Reinwardt;[2] a collection of letters written to his father during the ten days' campaign against the Belgians in 1831 in which Staring participated as a member of the Leyden Students Voluntary Riflemen Corps; and his Leyden PhD certificate with its wax seal (1833).[3] Besides there is a notebook with excerpts from geological literature (1834-38), mainly from articles of Leonhard published in his *Jahrbuch für Geologie* e.g. on theories of erratic blocks and the criticisms of these theories, a hotly debated subject at the time and on the maximum slope that still allows sedimentation in water, an early experimental sedimentology paper. His diaries from 1834-1852 and a vast correspondence, written in a meticulous hand, provide a detailed account of his early professional life. The manuscript of the Delft lectures[4] is in a leather-bound volume and consists of some 300 A5-size pages.

Staring's youth and education

Winand Staring was born on 5 October 1808 at the Wildenborch as the third son and fifth child of the well-known romantic poet Anthonie Christiaan Winand Staring (1767-1840). His grandfather Damiaan had been in the service of the Dutch East India Company at Cape Town and had purchased the country estate De Wildenborch in 1781.

In Winand's obituary (1877)[5], it is stated that:

> 'From childhood he greatly enjoyed outdoor life and it was difficult to keep the boy at the writing desk and make him adhere to regular time schedules of the day, when he wanted to accompany the farm hand or the gaggle of geese, barefooted, in their rambles through puddles and pools… Through this way of life, Winand developed a strong leaning towards investigating the nature of things that surrounded him. He enthusiastically read, studied, and copied whatever he could get hold of from books and illustrations of natural history. When he was eight years old, he embarked on a large manuscript (100 pages) with illustrations entitled *Nuttig leerboek voor de jeugd* ('Useful textbook for young people').'

Until they reached the age of twelve, Winand and his siblings were taught by their father. Winand continued his studies at the French boarding school of Mr Ducommun at Nijmegen. Here, he evidently missed the rural environment. In a letter to his parents, he asked to make sure that his garden would

[2] Staring Family Archive, box 92, 93.
[3] Ibidem, box 98.
[4] *Lessen aan de aanstaande mijningenieur, gegeven in 1863.*
[5] Staring Family Archive. box 63.

not be neglected, how the fox hunting went and how many braces of partridges had been taken.

Following his father's wishes, Staring started law studies at Leyden University, where he moved into a room at the Rapenburg. Soon it became clear that these studies did not appeal to him and after six months, his father agreed that he switched to natural history. In 1830, Winand entered a prize-competition of the University of Ghent with a study on *De reuk-, oog- en oorzenuwen van den mol (*on the olfactory, optical and auricular nerves of the mole), based on anatomical research of six moles that had been shipped from De Wildenborch. To his great surprise, he obtained the first prize and a gold medal. In a letter to his younger brother, he wrote, 'I assume that my curious *ad naturas* drawn illustrations dumbfounded the Flemings; the work itself can hardly deserve the award, in my opinion.'

The Ghent professor of natural history Van Breda invited Winand to visit the academy on its founding day, 4 October 1830, to receive the medal. However, the outbreak of the Belgian uprising on 24 August 1830 prevented this.

THE TEN DAYS' CAMPAIGN

The Leyden students offered their voluntary service to the King on 5 October 1830 to crush the Belgian uprising. Of the 750 students, 280 came forward. The Voluntary Riflemen Corps left by canal boat by way of Rotterdam to the Moerdijk on 13 November. In Brabant, they went into billets with private persons, mostly farmers, in "straw quarters' with a goat or cow, with food: potatoes and oil. But with some luck, in the town of Breda, in 'napkin quarters' or 'silver quarters' (with silver cutlery) or even 'wine quarters', but that only by intrigue or good fortune.'[6]

On 3 August 1831, King William III gave orders to cross the border and begin the attack. Staring participated in the battles of Hasselt and Leuven. Due to the arrival of a French army, the King's army soon had to retreat to Eindhoven. On 17 September, the students were able to return to Leyden, after almost a year of service, but only after a bombastic speech by their commander Stoecker on 'the glorious August days, which will always belong to the most beautiful of my life'. Staring, in a letter to his father, wrote that *he* definitely did not consider these days the most beautiful of his life.

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[6] J.G. Veldink, *W.C.H. Staring 1808-1877 geoloog en landbouwkundige* (Wageningen, 1970) p. 32.

After Belgium became independent, Van Breda moved to Leyden where Staring finally met him. Van Breda had participated in the first geological mapping of Belgium, which was initiated in 1825. In 1831 he was appointed to a temporary professorship in zoology, geology and mineralogy at Leyden University. Staring enjoyed Van Breda's lectures. He wrote to his father, 'Both lessons by Van Breda are excellent. He does have, though, a curious manner of moving wildly while speaking, but otherwise he talks rapidly but clearly and without repetitions and drivel, like two thirds of our professors do.' After consultation with Van Breda, it was decided that Staring should write a thesis on the geology of the Netherlands, the chances of obtaining a post in geology being considered better than in zoology. On 6 december 1833, Staring obtained his PhD degree with a thesis entitled *Specimen de geologia patriae,* which for the first time reviewed the geology of the Netherlands and neighbouring districts.[7]

A position of curator of the Leyden Museum of Natural History did not materialise, contrary to what Van Breda had foreseen, due to budgetary restraints resulting from the poor situation of the country's finances after the Belgian upheaval and subsequent independence. Staring returned to the Wildenborch to assist in managing his father's estate. In his diary he remarked,

> 'Upon my return home, I found all lights on … and a quiet, comfortable room prepared for my coming stay. The loss of my beloved studies will be bearable only by the thought that I will repay with some interest the trouble and costs that my parents have undergone for me till now.'

On 5 January 1834, Staring wrote a long letter to his friend H. Bake at Gendringen about his plan to write a Dutch geological glossary to provide unity and understanding in the many terms and geological descriptions. This *Proef eener Nederlandsche kunstspraak voor de aardkunde of geologie* (Netherlands nomenclature for earth science or geology) was published at Deventer in 1844. It provided an extensive description of stratigraphy and rock types and a list of geological terms in German, English and French with Dutch equivalents. In the introduction, he wrote:

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[7] W.C.H. Staring, S*pecimen academicum inaugurale de geologia patriae* (Leiden, 1833). A facsimile edition of the original Latin text with Dutch translation and English summary was published in *Grondboor en Hamer* 55, nr. 5a (2001).

‘Not a few subjects of science still need a Dutch terminology, in order to become rooted in our native soil and to become ‘vernederlandscht’ (dutchified). Some sciences have reached the stage that his fellow countrymen can understand a Dutch author. Many, however, still require many Greek, Latin, French, High German and English terms to express a large amount of everyday matters. Geology, amongst other subjects suffers from this defect and to this, in my opinion, it owes its cool reception in our country’.

Staring continued by mentioning his efforts to obtain:

‘… at least some mineralogical knowledge to enable me to identify our diluvial boulders by the study of my small rock and mineral collection by means of the blowpipe… I want to dedicate my life wholly or partly to disseminating an understanding of this wonderful science of the geology of the Dutch soils.’

Here, Staring had applied geology in mind for the first time. He wrote, ‘That this is very imperative does not need to be proven. All published papers, in which only modest geological knowledge would come in handy, constantly reveal the great ignorance in this science – yet it is not very difficult to learn’. He carried on, ‘To cite an example: if the gentlemen of the Land Registry had only the faintest idea of what geology is about, then they would surely not, at great cost, have developed artificial meadows on poor, sandy diluvial soil, but instead on alluvial soils which receive their fertility from the nearby rivers and brooks’.

Staring finished his letter as follows:

‘You will laugh at my lofty plans, dear friend, the study demon has suddenly possessed me. Whatever will happen, I must continue studying, and is it not much better to let others share the results of my research, rather than carrying out these studies only for one’s own enjoyment and occupation during empty hours? My first endeavour towards this goal will be the writing of a *Geology of the Netherlands*.’

Staring realised this objective in 1856, with the publication of his two-volume standard work *De bodem van Nederland*[8], which remained the only available geological textbook for many years.[9] A popular version was published in 1858 under the title *Voormaals en thans* (Before and after the flood).[10]

[8] *De bodem van Nederland. De samenstelling en het ontstaan der gronden van Nederland, ten behoeve van het algemeen beschreven*, 2 vols (Haarlem, 1856-1860).

[9] At the centenary of his birth in 1908, the first installment of an updated version of *De Bodem van Nederland* was prepared by J. van Baren. The full text was published in two volumes in 1920-1927.

[10] *Voormaals en thans. Opstellen over Neerlands grondgesteldheid* (Haarlem, 1858).

In 1852, the minister of the interior, Thorbecke, reluctantly approved a post of Dfl 10,000 on the state's budget to prepare a geological map of the Netherlands. Van Breda was appointed chairman of the commission charged with this task. The other members of this commission were Staring, who acted as secretary, and the natural history professors Friedrich Miquel and Pieter Harting. Van Breda formulated an overloaded work programme, which was to be carried out as quickly and cheaply as possible. Staring commented on the prevailing mentality in the country:

> 'Many still believe that the Netherlands has no geology and that it is not worthwhile to occupy oneself with the origin of our soil, using as the only argument that 'we have no mountains'. Others, amongst which many housewives, even see something impious in scientific knowledge of our soil.'

For his new appointment, Staring and his family had to move from his estate De Boekhorst near De Wildenborch, which he had purchased in 1838, to Paviljoen Welgelegen at Haarlem. With the co-operation of a large number of correspondents all over the country, a large collection of rock specimens, minerals, and fossils was soon assembled. In 1853, the exhibition that was to show the formation of the Dutch soils already contained 4,758 specimens. It was opened to the public on Tuesdays and Saturdays, from noon till 4 p.m. An extensive guidebook of 142 pages was offered to the public, with the entry ticket, for half a guilder.[11]

The production of the map, was not achieved without a lot of friction.[12] The minister disbanded the commission already in 1855 after heavy clashes between the authoritarian Van Breda and the quick-tempered and independently operating, but industrious, Staring. Staring accused Van Breda of having no first-hand knowledge of the Netherlands' soils apart from what he had tried to learn from a few sightseeing trips, which had led to nothing. He was unable to make useful observations in the field and had contributed little more to the commission than submitting his expense accounts.[13] The governor of the province of North Holland meanwhile put the collection at the Pavilion under seal. After this fiasco, Staring would have loved to return to his beloved estate De Boekhorst, as is revealed in a letter to his brother, in which he laments, 'Ah, should I only not be prevented by wife and children

[11] *De geologie van Nederland. Handleiding voor de bezigtigers der verzameling welke op het Paviljoen te Haarlem bijeengebracht is* (Haarlem, 1853).

[12] For the conflicts in the commission see also Faasse's article in this volume.

[13] Letter from Staring to Thorbecke 8 Aug. 1855, quoted by Veldink *op. cit.* p. 74.

to leave the geological mess to the D[evil] and return to my pigs and oxen.'

Two years later, after lengthy deliberations and lots of bickering, Staring was commissioned to complete the geological map at his own discretion. It was published on a scale of 1:200,000 in 28 sheets between 1860 and 1867. It was internationally acclaimed and honoured at the 1862 World Exhibition in London with a gold medal because, for the first time, a subdivision of the Alluvium and Diluvium had been presented on a geological map. With twenty-one units within the Quaternary, thirteen in the Alluvium and eight in the Diluvium, the map was far ahead of its time. At the request of the Dutch Teachers' Association, Staring also prepared a geological and agricultural map for schools,[14] which was in use well into the twentieth century. The last reprint was published in 1973.

After completion of the map in 1860, Staring wrote a memorandum[15] in which he presented recommendations for the future practise of geology in the Netherlands. He emphasised the importance of regular revision and updating of the map to prevent its becoming outdated. Minister Thorbecke, however, was not prepared to provide funds for an extension of the geological studies and consequently, Staring had to start looking for a new job.

APPOINTMENT AT DELFT

Staring's older brother was a senior civil servant at Thorbecke's ministry and drew Winand's attention to the vacancy that existed at Delft after the decease of Salomon Bleekrode, the geology and mineralogy professor, early in 1862. Staring would seem to be the right person for this post, but he was disappointed about the offered salary. This amounted to Dfl. 1,500 yearly, the same salary he had received for working on the geological map. The current salary of a professor was Dfl. 2,300 which could be supplemented by examination and lecture fees, which were paid in cash to the professor, so that the total salary could amount to about Dfl. 2,600. Staring meanwhile had to educate six adolescent children and was constantly short of money. He even had the gold medal, that he had received from the Royal Institute of Engineers, melted down to help support his large family. He therefore showed little enthusiasm for a position at the Delft Polytechnic School. Moreover, both he and his wife considered moving to Delft a rather uninviting prospect and more so, because Thorbecke had promised an appointment as inspector of secondary agricultural education, with a salary of Dfl. 3,000, as soon as the

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[14] *Schoolkaart voor de natuurkunde en de volksvlijt van Nederland* (Haarlem, 1860).

[15] *Overzigt van hetgeen er voor de geologie van Nederland verrigt is en wat er nog te verrigten valt* (Haarlem, 1860).

new law on secondary education would pass parliament. Staring eventually wrote to Thorbecke, 'Reluctantly I accept the task, even if it only were for one semester, because I would not like to be considered a sound mineralogist and I feel unattracted to teaching.' Subsequently, with a sense of duty, and probably even with some enthusiasm, he started to prepare his lecture notes.

LECTURE NOTES: TOPICS AND SEQUENCE

In the introductory remarks, Staring wrote in telegraphic style:

> 'Requested to assist in teaching g. and m. Willingly taken on only because in our country great lack of geol. and min. knowledge. But not without hesitancy. Never taught, nor thought about doing so. Only expertise on Netherl. Geol; little general geol., not sufficient mineralogy, even less metallurgy. Shall try whilst continuing learning myself. Be not surprised if I make a mistake, nor if occasionally I contradict myself.'

The lecture notes clearly show that Staring, who till then had mainly studied the geology of the Netherlands, had kept himself up-to-date with the foreign geological literature. He commanded a wide range of subjects on general geology, palaeontology and mineralogy. Half of his lectures dealt with the geology of the East Indian Archipelago, where the majority of the Delft mining students would find their future jobs. Staring himself once said that he would have liked to work in the colonies after completing his studies at Leyden, but due to the poor health of his father he had to assist him in managing De Wildenborch. However, he had kept abreast of developments in the colonies by avidly studying the relevant literature such as the proceedings of the Bataviaasch Genootschap[16] and possibly also the reports of the Mining Survey, which had been established at Buitenzorg (Bogor) in 1850.[17]

Between December 1862 and April 1863, Staring gave thirty-three lectures and after the April break, another twenty-one. In the first lecture, he described geology as a:

> '… vast, extensive science, which deals with the components of the Earth's crust and their origin. It is supported by other disciplines like physics, which explains the mechanical forces that are active during transport of material by rivers, but also vol-

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[16] Batavian Society of Arts and Sciences, founded in 1778. Up to 1860, it was the centre of all scientific activity in the Netherlands East Indies.

[17] The first director of the Survey, Thomas de Groot van Embden, was one of the first class of the Delft mining engineers. See: J.Ph. Poley, *Eroica, The Quest for Oil in Indonesia (1850-1898)* (Dordrecht, 2000) p. 36.

canic activity. Chemistry explains the formation of soils, the origin of ores, of recent materials like bog iron, and even of granites. Natural history is also important for the study of the antediluvian world. Knowledge of composition, living environment and habitats of contemporary fauna and flora can assist to identify the primeval climatic zones, sea or fresh-water environment and water depth'. [an indication of determining ancient depositional environments 'avant la lettre'!]

A sound knowledge of general geological principles was said to be required for those who wanted to study nature and concern themselves with the earth:

'In fact, every well-educated person should possess such knowledge – which especially in Germany, everyone really has – so that one does not confound flint with fossil bone, no footprints of hoofed animals should be imagined from a time when no such animals yet existed.' [Staring possibly referred to fossil 'footprints', which could be seen in the sandstones of the Isterberg, a popular field trip site, just across the Dutch-German border. These footprints were thought to be from Noah and his animals, which had landed here after the Flood, when the surface was still soft.[18]] 'When one knows geology, it is more or less known which raw materials like coal and ores can be expected and what they can yield'.

Staring did not propose to treat the various subjects 'systematically', because everything had to be seen as interconnected:

'I will not start with A and end with Z, first mineralogy, then palaeontology, then geology. Rather, I shall try, which will be more satisfactory both to you and to me, to start off immediately with the observation of nature and subsequently when required, introduce scientific elements.'

Judging by many deletions and corrections on the contents page, Staring had some difficulty settling on the topics and the sequence of his lectures. However, when surveying the complete lecture notes, the final contents and sequence can be reconstructed as follows:

I. Alluvium and the Netherlands (peats, river and stream formations, marine deposits, dunes, sand drifts (4 lessons);[19] coral reefs, mountain ice and icebergs (lessons 5, 6).
II. Intermediate lessons: Neptunic and Plutonic formations; uplift and subsidence; dykes and veins, ores, mines (lessons 7-15); Fossils, illustrated by numerous sketches and with ten stratigraphic tables with distribution ranges of fauna and flora; Evolution and origin of mankind (lessons 16-23).

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18 See for this popular view C. te Lintum, *Bad Bentheim, Eene Nederlandsche zomerkolonie over de grens* (Hengelo, 1897).

19 It is remarkable that Staring nowhere in his lessons specifically referred to his geological map (though he uses the subdivisions that he introduced for the map).

III. Diluvium. Scandinavian Diluvium, Meuse Diluvium, mixed Diluvium, sand Diluvium (transition to Alluvium). Buckland's bone caves (lessons 24-26). Diamonds, gold and tin (lessons 27-28).
IV. Volcanoes (lessons 29-35).
V. East Indian Archipelago. Alluvium, Diluvium, Tertiary, coal (lessons 36-41)
VI. Tertiary and Secondary formations, Primary terrains, Groundrock (lessons 42-46).
VII. 'Fire formations', Plutonic rocks. Occurrence of main ores (lessons 47-50)

Appendix of eighteen systematic tables of minerals, metals, and rock types (Groundrocks and metamorphosed Neptunic rocks, Plutonic rocks).

LECTURE NOTES: CONTENTS

The introductory lesson started with an explanation of geological methodology on the basis of six questions:

1. Where does the formation occur, and what is its thickness?
2. Of which rock types does the formation consist?
3. What do they contain: fossil flora and fauna?
4. What are the overlying and underlying formations?
5. How did they originate?
6. What are the raw materials and what may be their use?

In the margin of the first lesson Staring wrote:

'Start with the territory of the Netherlands, ('*Het beste van huis uit')* not with volcanoes or extinct animals, but with alluvial soils, which always cover the gravel hills or the clay with sea-shells from Eibergen[20] and the Limburg chalks. They can contain human remains and relics. They originated by causes that still operate today.'

With this last remark, Staring showed himself to have adopted Lyell's actualism. He seems to have been one of the few to do so. The Noachian flood theory or the catastrophism of Cuvier, which inspired the first geology text published in Dutch by Bilderdijk in 1813,[21] had many adherents throughout the first half of the nineteenth century.

Staring then stressed the uncertainty of all classifications of nature, 'Nature does not make jumps (clear-cut divisions) neither in the animal and plant kingdoms, nor in geology.'

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[20] Staring was probably referring to a sandpit along the road Eibergen-Winterswijk (province of Gelderland) where Miocene shells were found.
[21] W. Bilderdijk, *Geologie of verhandeling over de vorming en vervorming van de aarde* (Groningen, 11813).

A classification of various alluvial soils followed. The first was peat, 'a spongy, water-absorbing substance, which can flow and which shrinks from dehydration. Its chemical composition is that of plants. When dry, it becomes productive soil; when wet it does not decompose.' Peat was the most important energy source in the Netherlands at the time and the students were given an example, to compare the heat values of peat and coal, '5 baskets of peat have a weight equal to that of 1 basket of coal and 10 baskets of peat give an equal amount of heat as 1 basket of coal.'

Various classes of iron, red iron ore, bog iron, magnetite iron, hematite and siderite, were listed under 'brook deposits'. In those days, bog iron was processed at the blast furnaces of Deventer, Doesburg and Ulft. The ore of Wanroy was exported to the Ruhr region.

In the sixth lesson, glaciers and icebergs were discussed. Glaciers consisted of plastic material, which descended by its own weight ('not sticky like bird lime'). Darwin described glaciers from Tierra del Fuego that reached the sea. In Baffin Bay, glaciers become drift ice, which could transport large boulders. Later, Staring returned to this subject when discussing the boulders in the Dutch Diluvium, 'The gravel Diluvium comes from the Northeast… transported by drift ice, possibly by glaciers.' [He may have been familiar with the Swedish geologist Torell's new continental ice theory as a transport medium for the erratic boulders from Scandinavia but in his lessons, he still adhered to Lyell's drift theory].[22]

Coral reefs were 'most important for geologists because they explain the origin of most calcareous rocks.' Various theories were presented: *'Bronn Thierreich* II, 'very good', De la Beche p. 155, 'rather tedious, long',[23] Darwin in his *Voyage with the Beagle* and Dana's theory in: *Jahrbuch Geol. Reichsanst, 1852'.*

Staring distinguished coastal reef, dyke or barrier reef, lagoon reef and atoll. 'Atolls were originally explained by building on volcanic ring craters, but this theory does not explain the often elongated shape of atolls, and the great thickness of the very steep coral wall. A better explanation is Darwin's idea of a sinking base. De Rochas, however, is against Darwin, and proposes rising of reefs. (*Album der Natuur*, Wetenschappelijk bijblad, p. 11, 1863)'.[24]

'Florida seems to be entirely a coastal reef; Agassiz calculated that 200,000 years were necessary to build this reef. The Torres Strait had 26 reef islands in 1606, now 150. These dyke reefs may be connected in 20 years. Junghuhn reports uplifted reefs from Timor and the South coast of Java.'

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[22] Cf. E. Oele, 'Ontwikkelingen in de Kwartair-geologische opvattingen over ons land na Starings proefschrift van 1833', *Grondboor en Hamer* 55, nr. 1 (2001) p. 16-21.

[23] Staring often refers to De la Beche, but without further specification. Possibly to *Handbuch der Geognosie von H.T. de la Beche. Nach der zweite Auflage des Engl. Originals bearbeitet von H. von Dechen* (Berlin, 1832). This reference is listed in Staring's PhD thesis.

[24] *Album der Natuur* was a widely read magazine for popular science.

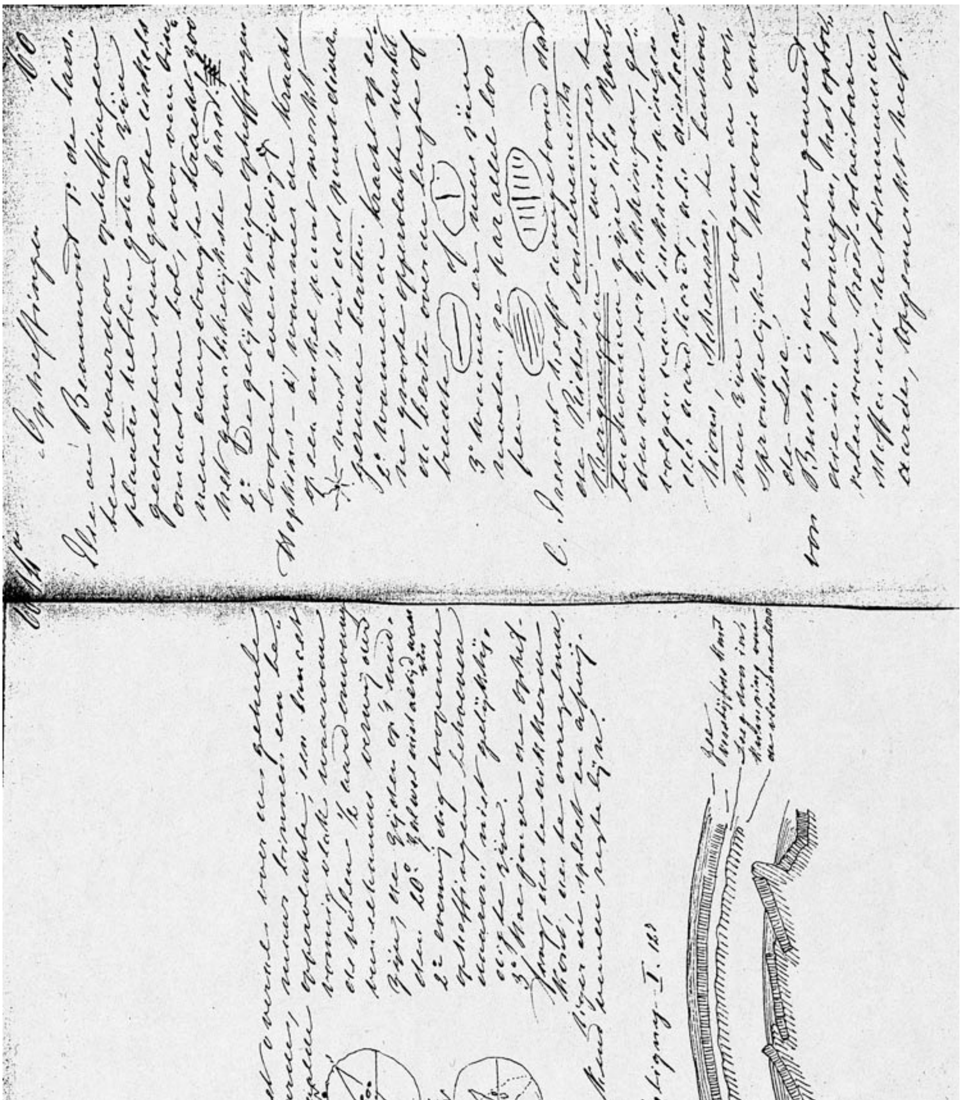

Figure 1 Staring also illustrated mountain forming with a sketch that reminds one of Descartes' model of concentric spheres.

Staring was obviously bewildered by the many theories, but from an educational point of view, he rightly drew the students' attention to the many different ideas on coral formations. Rising and sinking of the land was already accepted but sea level movements were apparently not.

Nine lessons were devoted to the subject of fossils. The necessity of at least a superficial knowledge of fossil plants and animals was explained. Staring recommended, 'Don't look for land animals in a marine formation. Know what to collect. It is not necessary to be a paleontologist, but observe carefully and leave the identification to the specialist. Fossils are indispensable when distinguishing various formations.'

On *verheffingen*[25] (uplift): the causes of elevation and subsidence were thought to be the expansion or contraction due to heating or cooling of the Earth's crust in the subsurface. Staring placed these movements in a geological perspective, emphasising the great age of the earth:

> 'These recent changes of the surface are, however, negligible compared to those of the ante-diluvial world… One should ascribe the uneven surface of the earth to elevation and subsidence, not to the lowering of the sea.'[But in the margin, a reference was given to an article of Delesse in: *Jahrbuch Geol. Reichsanstalt,* 1862, p. 605, 'On the possibility that the water, due to cooling of the Earth will penetrate deeper, and decrease at the surface.'

This shows that Staring was well aware of the recent geological literature. Staring also illustrated mountain forming with a sketch that reminds one of Descartes' model of concentric spheres.[26] He drew a rigid crust covered by the sea. Under this crust, there was an empty 'sphere' supposedly caused by contraction of the fluid core. Subsequently, the crust collapsed and the broken pieces were tilted to form mountains.[27] He referred to Elie de Beaumont who proposed cyclical episodes of mountain building in a cooling and contracting earth. Fissures, along which the crust breaks, lie on great circles because a sphere fractures that way in response to the force of contraction. Leopold von Buch was mentioned as having observed bubbling up of hot fluids from the interior of the earth in Norway. In his opinion, this indicated the presence of internal forces that could lead to the fracture of the crust resulting in sudden upheaval.[28] Staring presented a model of the earth's interior:

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25 *Lessen*, p. 43.
26 See for this model F. Ellenberger, *History of Geology*, vol. 1 (Rotterdam, 1996) p. 179.
27 *Lessen*, p. 60.
28 Von Buch speculated that parts of the exploding mountains could make an air voyage and subsequently descend far from the mountains. In this way, he tried to explain the diluvial boulders in the North German plain. Most contemporaries, however, considered his theory too fantastic.

‘The interior of the earth will have to be solid, but while cooling there must always have been liquid between the core and the crust. This liquid *could* be the origin of lava. Everything else we cannot judge, we can only hypothesise. The liquid masses are not in communication and can be present temporarily only. Different eruptions from the same volcano can derive from different depths.’[next he put the question] ‘But how can we explain the continually changing loss of heat that comes to the surface while the earth is cooling?’

Sketches of anticlines and synclines were given and the measurement of dips and strikes of layers with the compass was taught. The rocks producing elevation are granites, not greenstones or porphyries. Crystallised Neptunic rocks usually surround the granites. Mountain ranges are always ‘roof-shaped’ and elongated. Entire uplifted regions are being denudated, ‘How this happens is simply due to an amazingly long period of time.’ Elongated valleys, like the Rhine valley, are due to fissures in the crust. Numerous examples of Earth movements, both uplift and subsidence, were presented, accompanied by sketches for example of the ‘temple’ of Serapis,[29] which was also described by Lyell to illustrate the elevation and subsidence of the land. Cicero’s villa was shown, high and dry above the ancient shore, below which stands the temple, excavated in 1750. Scotland has been rising. Above the high water line of the Clyde, canoes had been found buried in the mud. Also, skeletons of whales and a harpoon were found in the Firth of Forth, seven yards above the water level. In New Zealand, an entire plain ’as large as the province of Gelderland’ has risen nine feet.[30] Subsidence in the Netherlands was also a subject of debate:

‘Some waver, declare the matter as highly debatable, sometimes saying ‘yes’, then again ‘no’, and thus remain hovering like bats between mammals and birds without reaching a conclusion. Others, on the other hand, deny subsidence; it is a local phenomenon, a theory ‘plucked from the air’, unfortunately not supported by any proven fact, but still useful to explain phenomena which are difficult to understand.’

Much attention was paid to hot mineral-water springs in volcanic areas and to mineralised dykes and ore veins. The construction and terminology of mines was treated only briefly.[31] Technical mining engineering subjects were not taught at Delft in Staring’s time; students had to spend at least one year at one of the German mining academies to get acquainted with mining practise, before receiving their diploma.

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29 Now interpreted as a market place. Personal communication D. Oldroyd.
30 *Lessen*, p. 42.
31 *Ibidem*, p. 57.

Neptunists and Plutonists were also mentioned. Staring remarked, 'Werner was a good observer but a poor reasoner'. In his lessons, Staring still used some of the Wernerian classification like 'Groundrock' and 'Neptunic' rock, next to Plutonic rock, amongst which volcanic rocks.'Groundrocks (gneiss, slate and quartz rock) were initially considered to represent the earliest cooled and solidified crust, now preferably as metamorphosed Neptunic rocks'.Four reasons were listed. 'Metamorphosed rocks are characterised by:

1. Transition to overlying Neptunic rocks.
2. Regular layering as in the oldest Neptunic rocks.
3. Alternation with clear layers of different rocks as is the case with Neptunic formations.
4. Intercalation of calcareous rocks (marble) and dolomites. Obviously these could not have originated from the same solution as the gneiss and slates.'

Extensive attention was given to Darwinism. The *Origin of Species* was published in 1859, three years before Staring's Delft lectures. As Staring, who was fluent in French and German, claimed not to read English, he probably used the Dutch translation by T.C. Winkler, which appeared in 1860.

Staring illustrated his explanation of evolution by a curious, but imprecise, calculation:

'… if we accept that the earth has been populated during one billion years (1,000,000,000,000) and every forty million years a new population emerged, than 12,500,000 animal species and two million plants would have lived in the ancient world. Though large numbers of fossils have already been found, we only know the elevated areas. In the *Losser* quarry[32] alone, seventeen animal species were encountered to a depth of 9.5 yards. But our knowledge of fossils is still very limited. It is as if we know only one word of a library with which we try to judge the entire collection of books… But despite this minimal knowledge we have been able to draw beautiful conclusions.'[33]

Next, the importance of zoogeography was stressed, 'one is forced to assume in many cases that regions that are now separated by seas or high mountains were united in the past.' On climate changes he stated, 'We know that more tropical flora and fauna occurred in the past than today, so the earth must have been warmer.'

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[32] The Losser Cretaceous sandstone in the province of Overijssel was investigated as part of Staring's first geological survey in 1843. See: F.R. van Veen, 'Staring en de steen van Losser', *Grondboor en Hamer* 53, nr. 2 (1999) p. 28-32.
[33] *Lessen*, p. 90, 91.

The big question of how the earth was populated with living beings was addressed:

‘d’Orbigny believes that species repeatedly become extinct and are then replaced by new creations. Lyell, on the other hand, assumes that existing species are gradually replaced by new species. The only intelligible theory is that of Darwin, who assumes that new species originate when the environment changes. The apparent constancy of species and the diversity in nature merely proves that man is unable to observe species changing during the few thousands years during which he has been observing them. Man has never witnessed a major change of climate and its influence on animals.’

‘The repeated creations of new species out of nothing went against everything that we know of natural laws and therefore Darwin’s theory is much more plausible. The very first creation cannot be explained by this theory. But we will never be able to solve this mystery, 1° because we cannot grasp infinity, or ‘no beginning and no end’; 2° because life is a mystery, we have no concept of immaterial elements. We do not want to contemplate, and cannot admit, the development of men from animals, because we cannot separate physical man from moral man. Even if the soul is nothing but the highest developed instinct of the animal, it remains a soul. God’s majesty does not manifest itself through miracles, but through the incomprehensible wisdom by which the laws of nature have been established, and in the amazing variety together with the greatest unity.’[34]

On diluvial man, Staring wrote:

‘The simultaneity of men and prehistoric animals is far from being proven. Most ‘proofs’ are false, only very few are so far difficult to contradict. In the Netherlands no human remains have been found in the Diluvial hills and sandy soils, but mammoth bones have been discovered at thirteen locations. The age of the human race based on tools, pottery and time calculations of Egyptians, Babylonians and Chinese reach to 15,000 or 16,000 years BC’.

The students were once again provided with some interesting statistics:

‘A certain scientist has calculated that since the creation 36,621,813,235,075,855 men (36 thousand billion) have lived on earth. Currently, the earth has a population of 1,283 million, of which 272 million in Europe, 720 million in Asia, 89 million in Africa, 200 million in America and 2 million in Polynesia. Each year, 32 million people die and 90,000 each day’.

Only very few organic remains were preserved:

‘What remains does one find of plants and animals, what of deceased human beings? If one accepts that humanity started with the Adam of the Jewish writers

[34] *Ibidem*, p. 101-103.

4,000 BC and those people had multiplied in the usual way and their bones had all been preserved, the entire earth would be covered with a layer of half a yard thickness. And what remains of all this? Not even a millionth part of that which dies leaves anything behind in the present world, and even less remains of the prehistoric animals.'[35]

After the philosophical remarks on the origin of man, the economic geology of the colonies received full attention. Publications of the Bataviaasch Genootschap and the Tijdschrift voor Nijverheid were frequently referred to. The expeditions of Horner to the Merapi and to Sumatra in 1838, of Maks (governor of the Greater and Lesser Dayak) and of the mining engineer R. Everwijn in 1859 to Borneo were reviewed.[36] Near Samarinda, coal had been found cropping out at twelve localities and, 'A six day- journey up the river Mahakkam from Tengarong, where the Sultan of Kutei resides, there seems to be a permanently burning coal seam'.[37]

The coal fields Riam and Oranje Nassau of Borneo, which had been exploited since 1849, were discussed. Production figures from the tin mining of Singkep and Karimon from 1828 till closure in 1831 were given as well as from the tin sluicing enterprise Prins Hendrik, active since 1852 (annual production 187,500 kg). Tin mining at Billiton, which started in 1857, was discussed in detail.

The work of the naturalist Junghuhn was frequently quoted, for example, his classification of volcanoes. Staring knew how to keep students' attention by occasionally spicing his lessons with horror stories, such as Junghuhn's description of the Valley of Death in the Diëng volcanic mountains of Java, where poisonous volcanic gases are emitted from the ground.'[38]

'The temple ruins in the crater show that the volcano has been extinct for more than 1,000 years. In 1838, a corpse was sniffed at for a quarter of an hour by a dog. We have to conclude that in this case death was not caused by poisonous gas. But in 1840, a dog suffocated; therefore the poisonous gas layer must then have measured 3 – 4 palms. [one palm = 1 dm] On a small, densely overgrown area of 3 yards diameter, Junghuhn found many wild boars, devoured by raven. In 1859 a dead cat and a porcupine were encountered'

Junghuhn[39] also described eight localities on Java where mud volcanoes and petroleum seepages had been observed; these were thought to be related to

[35] *Lessen*, p. 89.
[36] A sketch map and geological section are provided on p. 236 of the *Lessen.*
[37] *Ibidem*, p. 242.
[38] *Ibidem*, p. 213.
[39] *Ibidem*, p. 163, 164.

volcanism. According to Junghuhn oil originates from brown coal, which is heated by volcanoes. Staring also quoted a publication of Delesse in the *Revue de Géologie*, which states that asphalt is of vegetable origin.

A large number of less well-known islands in the Indonesian archipelago with their deposits of diamonds, gold, silver, copper, tin, lead, iron, mercury, and brown coal were mentioned. Important paleontological locations were those of Timor, where fossil brachiopod and crinoid faunas occur. Even fossil finds from the virtually unexplored island of New Guinea were mentioned.

An interesting note on gold comes from the West Indies,[40] 'the gold nugget from Aruba, which is kept at Leyden, is valued at Dfl. 10,000'. Gold in alluvial quartz gravels at the foot of the mountain near Post Gelderland at the river Surinam was found in 1862. The small gold chips are kept in the Colonial Ministry.

The experiment to detect gold in pyrite is of interest, 'Take a teacup with mercury at the bottom. Place a piece of pyrite in a folded card with a hole in the middle. Place the card close to the surface of mercury and put the cup on a hot plate. After half an hour the gold will turn dull white like silver.'[41]

Leaving Delft

Staring's teaching assignment was terminated in June 1863, when Thorbecke succeeded in passing his secondary education bill through parliament and he then redeemed his promise to appoint Staring as one of the three inspectors.

It is a pity that Staring gave his well-prepared course only once. His performance was judged favourably by the students, 'the handful of mining engineers who attended the course, can testify that he took his task seriously and presented his lectures *con amore*, as is also proven by the available compendium of these lessons.'

Staring definitely treated more interesting and useful geological subjects than his predecessor Bleekrode. This medical doctor and gynaecologist, who also had a doctorate in natural history from Groningen University, was the first Delft professor in earth science and mineralogy, from 1846 to 1862. The only publications known from him are on windmills and general industrial subjects. He was co-founder of a madder factory and handled the technical aspect of a bread and flour-mill at Amsterdam. One must wonder how much practical geological knowledge he imparted to his students.

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40 *Ibidem*, p. 127.
41 *Ibidem*, p. 282.

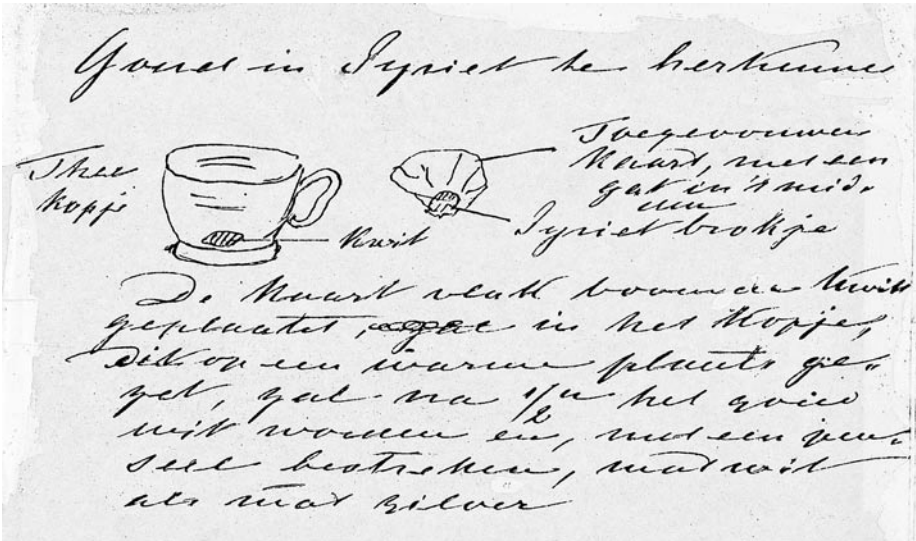

Figure 2 experiment to detect gold in pyrite

The last visit Staring paid to Delft was at the 'Solemn Opening' of the Polytechnic on 26 September 1864. Staring could now finally return to his beloved Boekhorst estate, where he devoted the next fifteen years to running his affairs but also found time to publish no less than one hundred and fifty papers on a wide variety of topics. A small selection shows Staring's wide-ranging interests: artificial insemination, diamond finds, the planting of pines in the dunes (all in 1864), diluvial grounds of Java, the age of mankind, reading by farmers (1865) rinderpest (1866), drinking water in the Netherlands, soil- subsidence (1867), the listing of all mammals, birds, reptiles, and fishes of the Netherlands (1868), the future of madder growing, draining of the Zuiderzee (1874), bird protection, drilling for coal in Limburg (1875), the Colorado beetle (1876), the proper and improper protection of animals, and his last publication: iron ore in the Netherlands (1877).

His main contribution to the geology of the Netherlands remained, however, his map and the accompanying textbook *Bodem van Nederland.* In 1873, two German geology professors, who were preparing a new geological map of their country, visited Staring. They consulted him in order to use his subdivision of the diluvial and alluvial grounds for their map.[42] Staring's

[42] Veldink, *op.cit.* p. 164.

contributions to geology and agriculture were recognised by a knighthood in the Order of the Netherlands Lion in 1870.

Winand Staring died on 4 June 1877. He was buried at the old cemetery at Lochem. Honouring the 'Father of Dutch geology', his friends fittingly placed a large Scandinavian boulder, recovered from a sandpit at Markelo – with a bronze medallion showing his geological map of the Netherlands – on his grave.

ACKNOWLEDGEMENT

The permission of Staring's great grandson, Ir Damiaan Staring, the present resident of the Wildenborch, to copy the manuscript is gratefully acknowledged. Copies are now available at several libraries, including those of Delft University, Naturalis (Leiden) and Teyler's Museum (Haarlem).

W.C.H. Staring's geological map of the Netherlands

Patricia E. Faasse

introduction

The story of how the first geological map of the Netherlands was generated has been told frequently and with remarkable little variation.[1] The man whose name is linked to the map is W.C.H. Staring and the period in which it was printed lies between 1858 and 1867. Staring, so the story goes, was the first true geologist of the Netherlands. He literally put the Netherlands on the geological map, thereby demonstrating that even a country lacking hills and mountains can yield new and interesting insights into geological science.

The Dutch government only appointed Staring to complete the geological map of the Netherlands after a commission of three men had failed to do so. Divergent opinions between Staring, initially the secretary of this commission, and its two other members, J.G.S. van Breda and F.A.W. Miquel, led to the premature resignation of this commission in 1855, only three years after its institution. Staring was subsequently appointed to complete the task. Especially the differences in character between Staring and Van Breda are held responsible for the commission's failure. Both are said to have been men with outspoken characters. Van Breda is usually seen as a somewhat old-fashioned and authoritative man, whereas Staring is attributed qualities as stubbornness and a quick temper.

Besides this '*incompabilité des humeurs*', another reason has been given for the failure of the three. The Netherlands had never before been surveyed geologically and a task thus complicated would have been better assigned to a single person instead of to a commission, some argue. The rationale of this argument appears to be that commissions intrinsically contain the potential for conflict and, indeed, case studies often do confirm this logic.

[1] See e.g.: A.S.H.Breure and J.G. de Bruijn eds, *Leven en werken van J.G.S. van Breda (1788-1867)* (Haarlem/Groningen, 1979) and J.G. Veldink, *W.C.H. Staring (1808-1877) geoloog en landbouwkundige* (Wageningen, 1970). For Staring see also Van Veen's contribution to this volume.

As an exhaustive explanation for the failure of the three, however, both arguments seem insufficient. Van Breda and Staring had already been working together before they met in the commission. In the 1830s, Staring had completed his PhD thesis under the supervision of Van Breda. This project had led to fully satisfactory results on the part of Staring, and on Van Breda's too. Besides, precisely the difficulty of surveying a country for the first time had been one of the reasons to install a commission instead of giving one person all responsibility. Blaming the commission with hindsight seems, therefore, to be begging the question: what exactly was the difficulty in surveying the Netherlands?

In what follows, I will try to answer this question. I will investigate what it is a geological map represents, why Staring is known as the 'Father of Dutch geology' and what was behind the quarrels that led to the resignation of the commission. I will demonstrate that there was more at stake than matters of personal conflict or complications resulting from the organisation of the work. The three members of the commission severely differed in opinion on the question of *how* the survey was to be done, and on *what* should be surveyed. These differences would therefore relate to diverging views on the scientific status of geology, its aims and its methods.

STARING

Especially for laymen, it is hard to understand why geological maps repeatedly need revisions. After all, a country's geological constitution does not change so rapidly – why then is a map that was printed, say, no more than ten years ago, no longer satisfactory?

In general, the answer relates to several points. Take, for instance, the way in which the Dutch geologist J.L.C. Schroeder van der Kolk answered this question in 1893.[2] At that time, Staring's map, completed some 25 years before, was considered fully out of date. A new one was needed, Van der Kolk argued, first of all, because several more practical aids had become available. Topographical maps on the scale of 1:50,000 were now at hand, whereas Staring could only use a map on a scale of 1:200,000. These new topographical maps offered the possibility of delimiting formation boundaries more precisely, and thus allowed

[2] J.L.C. Schroeder van der Kolk, ' Een en ander over een toekomstige kaart van Nederland', *Album der Natuur*, (1893) p. 353-368. Schroeder van der Kolk received a doctorate from the University of Leiden in 1891. During the academic year 1891-1892, he taught mineralogy and geology as a honorary lecturer in Leyden, before accepting a post as a teacher in physics and natural history at a girls' college in Deventer. He was appointed to the chair in mineralogy and geology at the Delft Polytechnic School in 1898. He passed away in 1905.

the incorporation of more petrographical details. Consequently, a new map would be more precise. Secondly, the use of shallow borings led to improved observations. A new map, therefore, would be more reliable.

Thirdly, as more investigators were available, mutual control would increase and thus, the chance of errors would diminish. This again would increase the new map's reliability. And a final justification for the surveying of a new map was the fact that the theories on the history of the earth's crust had changed profoundly since the days of Staring.

The latter remark is of crucial importance. Implicitly, Van der Kolk argues that a geological map not only depicts the underground of a country, but also reflects the state of its geological knowledge. When the knowledge changes, so does the map. In other words, the map not just reflects the geology of the Netherlands, but also what geologists know of it.

Three years later, Van der Kolk's colleague, the Utrecht professor A. Wichmann, literally wrote about that knowledge in the well known monthly *De Gids*: 'Geology is not an exact science; it is dominated by theories and hypotheses the correctness of which can not always be proven (...) Not quite unjustified, it is sometimes said, that where three geologists meet, they adhere to four different opinions.'[3] The conclusion is obvious: if a geological map reflects the state of geological knowledge, then the development of that knowledge can be read from the successive editions of the map. Those interested in the development of geological knowledge, therefore, need only arrange the different geological maps chronologically. Assuming that the earth's crust itself has not changed essentially in the meantime, the maps depict the changes of geological knowledge in the course of time.

The historically interesting questions then arise which maps should be used for such a series, and, if we picture them on a desk, which one should take the left-hand position and indicate the beginning of geological surveying. Despite the fact that the latter question has never been a matter of geological debate, Dutch geologists answer it remarkably unanimously. According to the general opinion, Staring's map should have the left-hand position. The history of the geological map of the Netherlands herewith begins with this map, the first sheets of which appeared in 1858.

This choice is remarkable, since Staring's map was not the first one on which the territory of the Netherlands is geologically depicted. Belgian and French geologists had already included the Netherlands on their geological maps as early as in the beginning of the nineteenth century. In addition, a Royal Commission[3], installed in 1825 had already surveyed the southern

[3] A. Wichmann, 'De geologische kaart van Nederland', *De Gids* (1896) p. 533-548.

Netherlands.

The choice for Staring's map then means something else than the choice for the *first* map: rather it is a choice for the *first* map *based on a certain geological way of thinking*. To his successors, Staring's map represents the crucial elements of a completely new way of thinking. Those who put Staring's map on the left-hand side of the series marked a new era in the history of the geological sciences in doing so and, at the same time, paid tribute to the particular way of thinking that Staring's map represents.

Characteristic for this new era is primarily the introduction of the Quaternary, the present geological period. Before 1800, neither the term nor its concepts of time and space existed. Whoever wondered what the subsurface of Holland was like was confronted with an enigma. The name Holland offered support to those who dared to take the name literally: derived from *Holt-land*, it suggested the presence of large forests in earlier days. Just as well, a corruption of '*hol-land*' suggested that the subsurface was bottomless, or filled with water.[4] For most of the population, however, the question was pointless and the answer to it eternally hidden in the omniscience of the Creator.

Around 1800, the static concepts on the origin of the earth were replaced by ideas that included processes of change. Studies of fossils and minerals had created space for the concept that the earth was much older than Genesis allowed. Yet the general consensus of granite being the oldest, primary rock certainly did nothing to stimulate research in the Netherlands. Rocks of granite did simply not occur here and mud, sand and peat were, geologically speaking, not of interest.

The new concepts about the age of the earth were helpful only in order to explain the occurrence of erratics. If they were not *in situ* phenomena, then they had been transported one way or another. But that was it. Apart from the popular view that the stones were growing in the soil, the transport hypothesis offered sufficient explanation for their presence. Since the country lacked mountains and mines, many geologically interested scholars were soon inclined to satisfy their curiosity elsewhere.

This changed only when, around 1825, a Government Commission was charged with surveying part of the Kingdom of the Netherlands. Although the prospect of economic profit was the most important motive for this survey, it was the discovery that the southern Netherlands were richly fossiliferous and exposed different formations and kinds of rocks, which eventually

4 This reconstruction of earlier thinking about the geology of the Netherlands is derived from Auke van der Woud, *De Bataafse hut: denken over het oudste Nederland (1750-1850)* (Amsterdam/Antwerpen, 1998) p. 63-101.

contributed to the intellectual linkage of geologists in the entire kingdom, among whom the Dutch professor Van Breda, to international research.

In the meantime, stratigraphy had become an instrument for distinguishing different epochs internationally. Starting from the proposition that the history of the earth could be read from the characteristics of mineralogically different formations, namely their succession, superposition and specific guide fossils, geologists in Britain and France had distinguished the eras Primary, Secondary and Tertiary. This classification provided the international geological community not only with a frame in which previously entirely local investigations could be correlated, but opened also new fields for research directed towards refining this classification.

This enabled the British geologist and stratigrapher Buckland, in 1823, to identify two formations younger than Tertiary. Evidently, the first ensued from a large flood and was consequently called Diluvium and the second resulted from alluvial depositions in the most recent past and was therefore called Alluvium. Together, they constituted the Quaternary. Precisely this demarcation of the Quaternary was of special relevance to the Netherlands. Apart from the most southern region, the Netherlands originated in this epoch and thus the country could now claim its own place in geological science. It no longer had to figure in one colour on geological maps, but as youngest member in the geological family, merited different colour shades of its own.

STARING'S MAP

Establishing these colour shades was all Staring had to do. Starting from the concept that the forces that operate in the earth's crust are the same now as in earlier times – the theory of uniformitarianism – Staring claimed that his study of the country's unconsolidated deposits could even give an extra contribution to the science of geology: for the processes, of which elsewhere only the results could be observed, were still visible here to anyone willing to observe them. In order to make essential contributions to the earth sciences and to see the effects of erosion, sedimentation, subsidence and sea level rise, there was no need to travel far and to foreign countries. To look under one's own feet sufficed.

The implications of the awareness that the Netherlands, small as they were, were part of that immense history in which the earth got its structure and most important features were far-reaching.

In the first place, it made the country much larger. When mud and peat are seen as geologically of no importance, the survey of a country largely covered with these deposits is a childishly simple matter. Everything within its borders will get one single colour, there being no difference between the various soft deposits. But as soon as it becomes clear that the recent geological past shows quite different sediments, when even clays can differ from one another, the country becomes a large and unexplored wilderness and the task of surveying it nearly as impossible as counting of the number of sand grains on the beach.

At the same time, the awareness that the superficial deposits of the Netherlands have their own place in geological history makes the task of surveying lighter. The remarkable feature of Staring's map, and one of the reasons for its 'left-hand position', is that its colouring is limited to geology only. Whereas the other two members of the commission, professors J.G.S. van Breda and F.A.W. Miquel, considered the survey as a vehicle to carry out further investigations in the fields of botany, zoology, mineralogy, paleontology, physics and chemistry of the subsurface in order to represent the results on the map, Staring restricted his work largely to the boundaries and subdivisions of the Alluvium, the Diluvium, the Tertiary and the Cretaceous. Although it was often difficult for Staring's successors to distinguish the agronomist from the geologist, Staring wanted to separate geology from its 'auxiliary sciences'.

On the one hand, Staring thus narrowed the survey by limiting his work to the different types of sediment; on the other hand, he broadened his work by wanting to look for them everywhere. These differences of opinion between Staring and the two other members of the Commission led to many misunderstandings, mutual grumbling and resentment, and eventually, three years after its establishment, to the dissolution of the Commission for the Geological Map of the Netherlands in 1855.

In their respective reproaches, the different views can be clearly heard. The angry ex-chairman of the Commission – Van Breda – said in 1856, with respect to the question if and how the map should now be completed, that 'to produce a good geological map, I stress the word a *good* geological map, a combination of capabilities, not to be found in a single person, is needed (…). We are completely and positively convinced, yes, we can assure without any reservation, that in the Netherlands no such person can be found, who combines the necessary knowledge and the further suitability to fulfill such a task.'[5] Staring characterised his former teacher Van Breda as a man who had only hindered Staring's own work by his 'highly superficial knowledge (…) properly speaking only gathered in conversations with scholars in earlier

[5] Van Breda, undated, probably written between February 25th and March 25th. Rijksarchief Noord-Holland, 64-nr. 213.

years; his complete lack of studies especially in recent years and his unfamiliarity with the present state of science; his total inexperience in carrying out field observations and the use of maps; his unfamiliarity with the Netherlands' terrains, only known to him from a few efforts during some pleasure trips to no avail.'[6] About the third commission member – Miquel – Staring only wrote that he 'was an excellent Botanist, nobody doubts this, but more and more I got convinced that he is neither a Geologist nor a Mineralogist, certainly not a field-Geologist, and never will be one.'[7]

The scientific aims of the learned commission members Van Breda and Miquel, on the one hand, and Staring indeed with a doctorate but without a university position, on the other hand, differed as day and night. In many respects, Van Breda and Miquel were typical representatives of an early nineteenth-century scientific ideal, when science was scholarship and its source the written text. They focussed on gathering and studying collections of natural objects, publishing and studying voluminous, nearly encyclopaedic scientific works, and preparing well-to-do young man for their admission to the upper class. Their knowledge was universal, accumulated continuously, was stored, and could be consulted in libraries and cabinets. They were the guardians of the revealed secrets of the book of nature: reliable, virtuous, and treated with respect and awe. Only at the end of the nineteenth century, these scholars were gradually replaced by scientists, and their cabinets and books by laboratories, experiments and active intervention in nature.

Staring, in his approach as secretary of the Commission for the Geological Map of the Netherlands, but earlier as well, as investigator for the Provincial Board of Guelre or for the Overijssel Society for the development of Provincial Prosperity – showed himself primarily a *practical* geologist, a man in the field, with mud on his boots, and hail and rain falling on his meditating head.

Without this fieldwork, this day-after-day walking or horse riding in the field, a geological description of the Netherlands was – in his view – simply not possible. As a practical geologist, Staring felt far more familiar with the farmer daily handling his own land than with the scholars usually getting acquainted with the earth's exotic minerals and fossils in the warm silence of their comfortable studies. *Listen! Ye countrymen all, to me* is the significant motto he gave to his 1858 book *Voormaals en thans, opstellen over Neerlands grondsgesteldheid* (Past and present, essays on the Netherlands' natural terrains).

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[6] Quoted by J.G.Veldink, *op.cit.* p. 74
[7] *Ibidem.*

The extent of the contrast between Staring – practical geologist and in his forties – and Van Breda – universal scholar and in his late-sixties – is perhaps best illustrated by the importance that each of them attached to the study of fossils and rocks. Van Breda considered it necessary that the geologist surveying the Netherlands should not only be acquainted with 'the various geologic formations abroad' – even if they were present only to a limited extent in the Netherlands – but should not less be capable 'of indicating of every erratic in the Netherlands' Diluvium, the locality from where it was derived.'[8] The man who himself had published on magnetism, electricity, after-images, the pile worm, lightning conductors, the distribution of 'granite and other primeval rocks', Tertiary formations in Guelre and 'a new species of Dolphin', this man demanded universal knowledge.[9] After all, he had occupied several university chairs: in botany, chemistry, pharmacy at Franeker, in botany, zoology and comparative anatomy at Ghent afterwards, and finally in zoology and geology in Leyden. In his opinion, only a person acquainted with all of these branches of science could be charged with the country's survey.

Staring was the first person to admit that the specific determination of erratics should be the work of specialists and should be trusted to foreign investigators. Yet, he was no less convinced that the study of the erratics constituted only a minor part of the work. Much more extensive, challenging and significant – in his eyes – were the demarcation of the Alluvium and the subdivision of the diluvial terrains: work that could not be carried out at the desk in the study, but needed physical presence in the field. Thus, Staring not only disagreed with his co-members on the committee *in what* he considered his task but also *in the way* the work should be carried out. So it is particularly *his method* for which his successors praise him and see his map as the first geological map: anyone willing to survey the Netherlands does so in the open air, looks at the landscape with his own eyes, and crosses it on his own feet.

Eventually, in 1857, Staring alone was assigned the task of completing the geological map of the Netherlands. The fact that his map received a special prize at the world exhibition in London in 1862, particularly for the 'detailed subdivisions of the formations younger than the Tertiary',[10] illustrates the public recognition of the originality of the man and his opinions. His map not only showed that the Netherlands were the product of wind,

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8 Van Breda, see note 5.
9 From Breure, *op.cit.* p. 31-37.
10 Veldink, *op.cit.* p. 80.

rivers and sea but also of the new geological insights of the nineteenth century itself.[11]

Staring's map showed a country never seen before by anybody: so rich in colour shades, so full of recent history and so breathtaking with new questions. Particularly in that respect, the map opened a new era and Staring was the first to emphasise that the work was not finished, that still much remained to be investigated, that it was only a beginning, and certainly not an end.

As early as 1860, still before the map was completely printed and published, Staring reviewed what had been accomplished and what remained to be done for the geology of the Netherlands.[12] He put his ideas on paper and, seven years later, presented them in a section meeting to the members of the Koninklijke Akademie van Wetenschappen, the only influential advisory body to the government at that time.

True enough, the fieldwork needed for the map had been finished in that year, but Staring insisted that the task itself was not yet finished. Just as with foreign maps, this map too should be accompanied by vertical and horizontal geological sections, useful for public works and military engineering. Also, a description of the map should be written, the entire body of correspondents kept on (in order to maintain continuity and uniformity), the delimitations of the 'antediluvial terrains' with, possibly, fossil remains of extinct marine animals should be traced more precisely, the collections of rock samples and foreign maps should be continued; in short 'appreciable progress had been made in the knowledge of the geology of our country, so the Netherlands were no longer a white spot on the geological map of Europe (....) but, at the same time, it became evident that the country's geology could not be considered as a finished and closed book.'[13] Whereas Van Breda and Miquel aimed at the production of a map as a model of universal knowledge of the earth's crust, as a *monument* of science, eternally and timeless, Staring considered the map as a starting point for investigation and discussion, as a fallible *moment* in the history of science. Thus the 'archfather of geology in the Netherlands', paved the way for his successors and it was up to them to decide upon the fate of his map.

That was exactly what they did. Ten years after the first sheet of the map had been printed, in 1873, nearly the entire edition of 250 copies of the map

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11 This observation is derived from Jan Buursink, *Nederland in Geografische Handen, honderd jaar regionale geografie van Nederland* (Utrecht, 1998) p. 13

12 W.C.H. Staring, *Overzicht van hetgeen er voor de geologie van Nederland verrigt is en nog te verrigten valt*, drafted in October 1860, Brochure, Library TNO-NITG (Utrecht)

13 *Ibidem,* p. 10.

had sold out. With Staring's argument in mind, the Koninklijke Akademie van Wetenschappen addressed the government in 1874 and recommended the survey for a new geological map.

> 'Wondering what had been the outcome of Staring's recommendations, the answer is: completely nothing. The systematic collection of objects failed; the study of the already present objects was not furthered; the catalogue was not revised. Of the map, many copies of all kinds, sometimes with so-called minor corrections, appeared, but the map itself was left to become *obsolete.* Only one new edition appeared, in 1889, and it was new only in so far as canals and railway tracks constructed and completed since 1867 had been added: "*Otherwise everything remained unchanged.*"'[14]

In the current historical view, an intense silence fell after the first publication of Staring's map and an unchanged reprint in 1889. It lasted until 1918 before the government became once more convinced of the usefulness of a new geological map, and before geology received general recognition. With Staring's death in 1877, however, his lifework seemed to end too.

CONCLUSIONS

Staring wanted to make a geological map according to the standards of geological science, as he saw them. To this end, fieldwork was one absolute prerequisite in his eyes, the delineation of the boundaries and subdivisions between Diluvium, Alluvium, Tertiary and Cretaceous another. To Staring, geology primarily was a field science, and desperately in need of further research, too. By leaving a map, surveyed according to these standards, Staring has demarcated both the *object* of Dutch geology and its main *method*. Given the prominent place he took in the history of geological science, his successors have granted Staring's views priority over others. Since Staring, Dutch geological science has moved within the boundaries demarcated by him, as is testified by the various new editions of the geological map of the Netherlands, published since.

ACKNOWLEDGEMENT

I wish to express my gratitude to Prof. Dr. A. Brouwer for translating the text into English.

[14] Quoted by Veldink, *op. cit.* p. 81. Italics in original.

From speculation to science: the founding of groundwater hydrology in the Netherlands

Jacobus J. de Vries

Introduction

A major part of the Netherlands can be considered as manmade in the sense that a substantial component of the country has been made habitable by reclamation of marshland, lakes, lagoons and estuarine areas. As a consequence, water management has always been an integral part of life in this coastal lowland. Protection against floods, disposal of surplus water and the struggle against encroaching seawater have been a continuous focus of care and attention for more than thousand years. In fact, the problems have aggravated in the course of time due to land subsidence by drainage and the creation of low-level areas by reclamation of lakes and marine embayments. More than 25% of the country now lies below sea level and 65% of the land surface would be flooded if not protected by coastal dunes and dikes (Fig. 1).

Concerns about water and the study of its behaviour was directed at surface water for a long time. Subterranean water with its remarkable appearance in springs and free flowing artesian wells remained a mysterious phenomenon of obscure origin and destiny and the domain of water diviners. Scientific interest in groundwater emerged when problems with the supply of clean drinking water became manifest in the early nineteenth century with the expansion of the cities and the outbreak of waterborne epidemic diseases, notably cholera. Water in the canals and shallow wells used to be contaminated because of a lack of adequate sewage disposal whereas deep wells often produced brackish water. Successful drillings for artesian water in France and England in the first half of the nineteenth century – featuring the famous 548 m deep artesian well at Grenelle (Paris) in 1841 – drew the attention of scientists as well as the government. Might fresh artesian water also be a solution for public and industrial water supply in the Netherlands? Several attempts were subsequently made in the period between 1830 and 1850 to reach this intriguing resource – without success. Illustrative is the drilling at the Nieuwmarkt in Amsterdam: this work

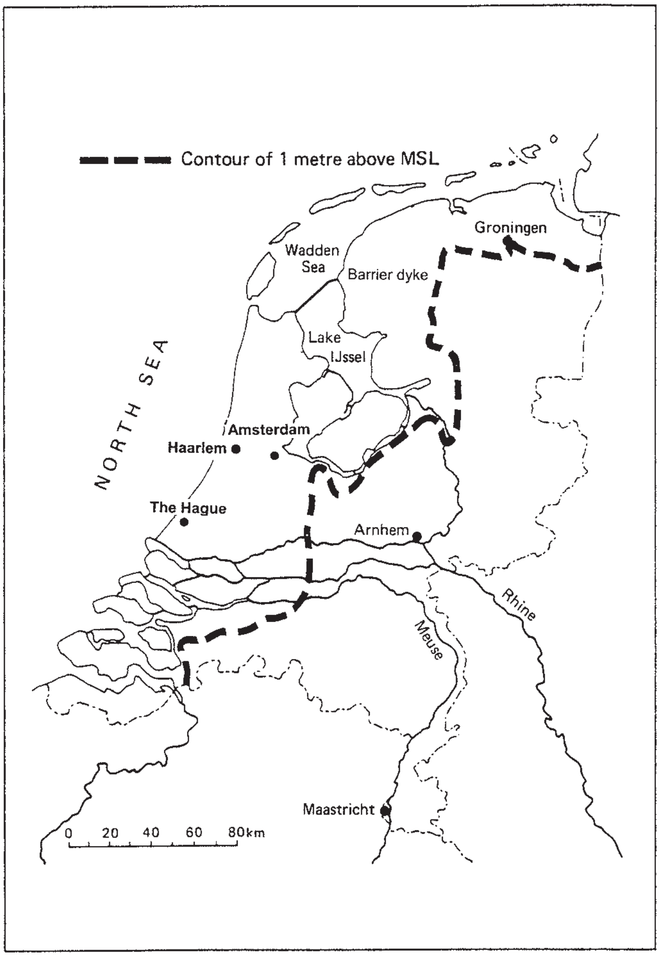


Figure 1 Physiographic conditions of the Netherlands; the 1-m elevation contour forms the approximate boundary between the sandy Pleistocene and the Holocene clayey and peat deposits of the coastal plain. Several polders in the latter area are situated more than 6 m below mean sea level.

started in 1836 and was terminated in 1843 after reaching a depth of 172 m without obtaining any indication of artesian pressure. Although not successful for water supply, these well-sampled boreholes provided important information on the subsurface – particularly through the able lithological and paleontological descriptions of the samples by Pieter Harting (Fig. 2a; see Harting, 1852).

Theoretical understanding of groundwater movement remained very poor until the mid-nineteenth century and it would take another 70 years to develop a clear idea of the origin of groundwater, and to formulate and apply the basic laws of groundwater flow towards a proper understanding of actual field conditions. The present paper shows how the exploration for clean drinking water stimulated the development of conceptual ideas on the origin and dynamics of groundwater and how these concepts eventually merged with the mainstream of physics into a comprehensive theory in the period between the mid-nineteenth century and World War I. It further elucidates the role of the various pioneers and shows how disputes on the origin and behaviour of groundwater repeatedly provoked strong personal controversies, and how the societal relevance of the subject led to political implications. A more elaborated and complete overview of the evolution of scientific groundwater hydrology in the Netherlands is given in De Vries (1982).

EARLY CONCEPTS AND DEVELOPMENTS

Drainage and the origin of groundwater

Although land drainage by ditches had been practised for hundreds of years, a clear perception of the actual flow processes involved did not emerge before the end of the nineteenth century. In 1857, a committee of the Royal Agriculture Society published a discussion on suggestions for the proper application of tile drainage based on the 'rules of science' (see De Zeeuw, 1960). Evaluation by the chairman, the noted soil scientist and geologist W.C.H. Staring, gives a good insight into the prevailing 'rules of science' at that time. A proposal for a drain depth between 130 and 150 cm was rejected with the argument that in such a case the drain would lie below the groundwater table permanently and therefore hardly participate in the drainage process. Apparently, the general perception was that infiltrating rainwater would move vertically through the unsaturated zone until it reached the area of influence of the drain. Substantial participation of the saturated zone in the groundwater discharge process was obviously not considered. The committee therefore – not surprisingly – categorically refuted the recommendation by certain experts (notably from Great Britain) to increase drain spacing with an increase in drain depth.

The doctrine that the volume below the groundwater table would only play a minor role in groundwater circulation was also manifest in discussions about recharge of the saturated zone. The idea prevailed that at least part of the groundwater originated from condensation of water vapour. This hypothesis was undoubtedly inspired by ideas of philosophers of antiquity, who based their opinions on the existence of wells and springs in arid areas without evident recharge by rainfall. The belief in a substantial contribution to the water balance by condensation was supported in the second half of the nineteenth century by observations on evaporation by way of inadequate evaporation pans and lysimeters. Over-estimation of the evapotranspiration component on several experimental sites suggested an excess of annual evapotranspiration over annual rainfall. The physicist and meteorologist C.H.D. Buys Ballot (1879) therefore assumed that a substantial part of the water consumption by vegetation originated from condensation.

The German geologist Otto Volger (1877) took an extreme view by categorically denying any relation between rainfall and groundwater. He even argued that concern for contamination of groundwater was a fear of phantoms, which would lead to unnecessary costs in the construction of extraction wells for public water supply outside urban areas. The geologist and paleontologist T.C. Winkler, who distrusted the self-purifying capacity of the soil, proposed an opposing idea. He calculated the accumulated numbers of buried dead bodies since creation and concluded that groundwater could be nothing more than diluted dissection poison. He therefore propagated the use of water from the coastal dunes, which he rightly considered as originating from local rainwater that had infiltrated in pure and uncontaminated sand (Winkler, 1867).

Percolation experiments and Darcy's Law

Physician, geologist and professor of natural history Pieter Harting (Fig. 2a) performed the first systematic studies in the Netherlands on the behaviour of groundwater flow. Harting carried out percolation experiments on soil samples from Amsterdam's subsurface, in the framework of his geological studies of this area, and concluded (Harting, 1852; Fig. 2b), 'that the quantity of water percolating through a clay layer in a time unit increases or decreases at the same rate with increase or decrease of the length of the water column resting upon this layer'.

Harting was evidently aware of the basic principles that would lead to Darcy's law (1856; Fig. 2b), but since he was working with an outflow under atmospheric pressure, he wrongly neglected an elevation head term. Subsequent experiments with sieve fractions led Harting to the relation between pore diameter and permeability and he recognised the analogy between groundwater percolation through a porous medium and the flow through a capillary tube, thus satisfying the Hagen-Poisseuille law.

Harting (1877, 1878) extended his percolation experiments in relation to proposals for large reclamation works in the Zuiderzee – an inland extension

Figure 2a Pieter Harting (1812-1885). Harting was educated as a medical doctor; after several years as a general practitioner, he became professor of natural history at the University of Utrecht. He is considered one of the founders of the geology of the Netherlands. His interest in the subsurface most probably originated from his concern for social hygienic conditions, recognising the importance of groundwater for healthy drinking water.

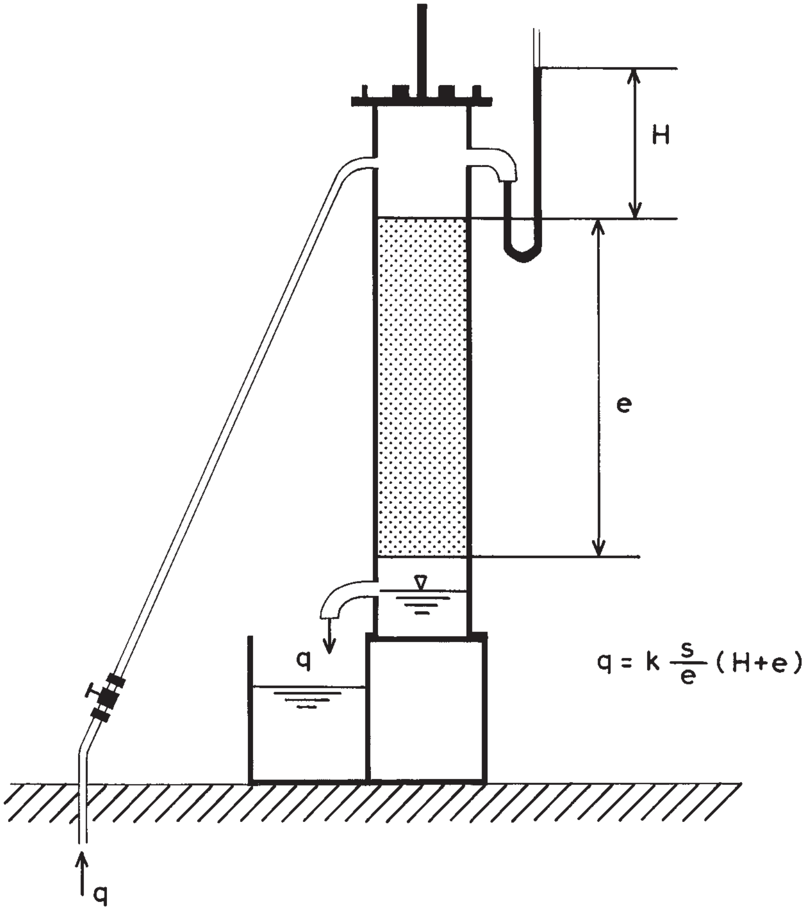


Figure 2b Principle of percolation experiments by Harting (1852) and Darcy (1856). Pieter Harting (1852) wrongly deduced from his percolation experiments that the amount of water flowing through a soil column would be proportional to the length of the water column resting upon this column. For the depicted experiment this would mean:

$$q = ks \frac{H}{e}$$

The right relationship was deduced by Henri Darcy (1856); his formula is considered to present the general law for groundwater flow through a porous medium, which for the depicted set up reads:

$$q = k \frac{s}{e} (H+e)$$

Where q is the amount of water per time unit that flows through a soil column with horizontal area s, due to the gradient in hydraulic head between top and bottom of that soil column. If the elevation head at the bottom is chosen zero (reference level)

◁ and the pressure head at that level is also taken zero (atmospheric pressure), then the hydraulic head at the top equals pressure head *H* plus elevation head *e*. Thus the hydraulic gradient equals *(H+e)/e*. The proportionality factor *k* is the permeability factor which depends on the soil material.
It eventually took more than 50 years before the concept of hydraulic head was properly applied under field conditions to relate flow pattern and hydraulic head distribution, especially where a vertical flow component caused a change in the elevation head along the flow line. Johan M.K. Pennink (1905) was probably the first to draw a two-dimensional flow pattern as function of a measured hydraulic head distribution under field conditions (see Fig. 8).

of the North Sea. This work, which eventually started after World War I, included enclosure of this inland sea by a dike of 30 km and the reclamation of part of the newly formed freshwater lake (Lake IJssel) behind a barrier dam. Soil samples were obtained by drilling in the bottom of the Zuiderzee as early as 1875 and their permeability was investigated to assess the rate of upward seepage (leakage) that could be expected in the projected deep polders. The fear of project failure due to excessive seepage was real and based on bad experience with the previous reclamation of the Naardermeer and Béthune polders. These had to be turned into lakes again because seepage rates of more than 20 mm per day could not be coped with. Harting was aware of the important role of the Holocene confining layer against upward seepage and advised to leave this bed as undisturbed as possible. He further applied sandbox models to simulate the reduction in pressure and seepage from the fringe towards the centre of the polders. The results were reassuring.

State of knowledge in the late nineteenth century

One can conclude that Darcy's law was properly understood and applied in laboratory experiments at the end of the nineteenth century. Extrapolation of this knowledge to field conditions, however, was hindered by lack of a clear perception of the actual flow pattern and the concept of hydraulic head in the sense of pressure head and elevation head. This can be illustrated by the view of a committee of scientists and engineers, as expressed in their report on problems associated with the exploitation of the coastal dunes for Amsterdam's public water supply (Rutgers van Rozenburg et al., 1891). They rightly argued that recharge of the dune area originated from rainfall minus evapotranspiration and arrived at a replenishment of 40% of the precipitation. This, to our present knowledge, good assessment was based on a study of rainfall, evaporation and groundwater level fluctuations.

Groundwater was extracted from the dunes by a series of drainage canals at that time and the committee assumed horizontal flow through the section between the groundwater table and a horizon through the bottom of the canal (Fig. 3). The committee was rather vague about the area below the canal bottom and believed that, in general, groundwater flow would not extend more than a few meters in depth. Its perception was that flow would normally be restricted by a less pervious layer or that it, in the absence of such a horizon, would abate due to cohesion of the water particles and their adhesion to the soil. Flow at greater depth would therefore change into 'trembling' of the water particles. This concept was derived from the authoritative book by the German Otto Lueger (1883, 1895). Lueger's ideas were based on the wrong doctrine that groundwater under free water table conditions could never flow in an upward direction.

Similar obscure ideas existed concerning the extension of freshwater reserves below the dune area. The committee knew that the subsurface consisted predominantly of sand to at least a depth of 100 m and assumed that fresh water in the upper layers had removed the original salt water to greater depth by hydrostatic pressure during formation of the dunes. A gradual change from fresh to brackish water was supposed and the committee pleaded

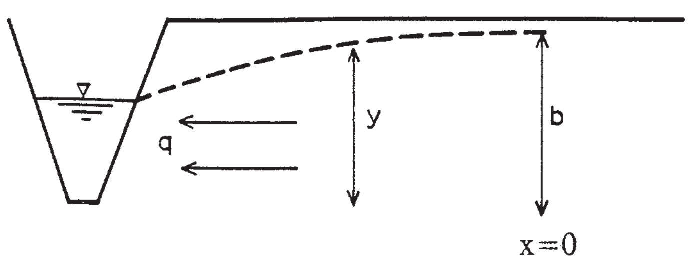


Figure 3 Horizontal flow to a drainage canal. The Committee of 1891 that investigated the groundwater situation in the Amsterdam dune water catchment presented the following formula for its flow case:

$$\frac{qx^2}{kcb^2} + \frac{y^2}{b^2} = 1$$

where k = the quotient of hydraulic conductivity and porosity c; q = discharge per time unit; y = thickness of that part of the subsurface that participates in the discharge process at distance x from the canal; $y=b$ if $x=0$. This formula is similar to the well known Dupuit equation, which applies to a situation where the flow to the canal originates from another, more elevated, canal at $x=0$ (Dupuit, 1863).

for a systematic exploration to determine the depth of this interface. No reference was made to Badon Ghijben's principle, published in 1889 (see Fig. 5).

The committee followed Lueger's ideas of horizontal flow and produced an early drainage formula (Fig. 3). Discrepancy between calculated groundwater flux to the canals and the measured much higher discharge by the canals subsequently inspired an engineer with the Amsterdam Dune Water Supply Company, J.M.K. Pennink, to postulate a much larger part of the subsurface participating in the groundwater drainage process (see Fig. 8).

DAWN OF SCIENTIFIC HYDROGEOLOGY

Dune water research

In the middle of the nineteenth century, after endless problems with polluted and brackish water and many plans to improve the situation, Amsterdam went to the coastal dunes for its principal drinking water supply; 1853 marked the first groundwater extraction from dunes near Haarlem, 30 km West of Amsterdam. Lack of insight into the vertical extent of fresh water occurrence in the dunes and the fear of salinisation initially led to a groundwater production system with drainage canals. The dune water was piped to Amsterdam, which led to a further concern, namely that in the event of war an enemy might cut off the town from its water supply. Consequently, the officer of the Army Corps of Engineers, Captain W. Badon Ghijben (Fig. 4) was commissioned to explore the Amsterdam subsurface for an emergency source of fresh water. Badon Ghijben indeed discovered a number of suitable fresh water pockets surrounded by salty water and advised drilling near the north-west fringe of the town. Amsterdam was at that time situated along the Zuiderzee and its surface was more or less level with this inland sea, which was then still open to the North Sea. In relation to possible encroachment of Zuiderzee water, Badon Ghijben stated (Drabbe and Badon Ghijben, 1888/1889):

> 'The pressure head on the groundwater column inside the coast is lower than outside at any place where the water level inland is below sea level, and thus sea water must intrude. Equilibrium is only reached if the lighter inland water is a little above sea level. The situation is quite different, however, along the North Sea, where the groundwater in the coastal dunes always shows a higher level than the sea. Assuming a difference = *a*, and considering a specific density of North Sea water of 1.0238, there will be an equilibrium between saline water in the outer area and fresh water in the inner area at a depth of $a/0.0238 = 42\ a$.'

He thus claimed that the interface between fresh and salt water under the dune area would be found at a depth of not less than 42 times the elevation

Figure 4 Willem Badon Ghijben (1845-1907). Badon Ghijben (Badon is part of the family name) joined the army in 1862 and became a member of the Army Corps of Engineers. He worked on several defence constructions and was a specialist in the typical Dutch water fortress system in which forced inundations formed the most important part of the defence (the 'flooded earth strategy'). He wrote an authoritative book on the extensive water and fortress defence line that protected Holland until World War I and, among others, was a lecturer at the Royal Military Academy. His early retirement because of ill health, with the rank of colonel following in 1902. Badon Ghijben was not aware of the earlier formulation of the fresh-salt water interface equilibrium by Joseph DuCommun in the USA in 1818; he was even not aware of having presented a new idea at all, as he later stated.

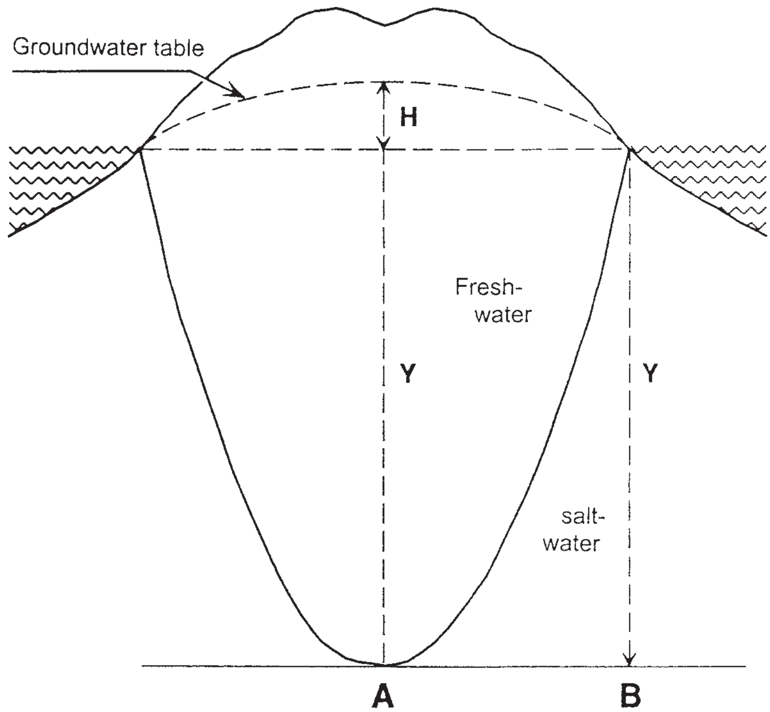


Figure 5 The position of the fresh-salt water interface according to the Ghijben-Herzberg principle. The weight of the colum of fresh water at A: $(y+H)\gamma_f$, equals the weight of the column of salt water at B: $y.\gamma_s$, where γ_f and γ_s are the specific weight of fresh water (1 g/cm^3) and salt water (1.0238 g/cm^3) respectively, so that $y = 42\ H$. The average maximum height of the water table H in the Netherlands coastal dune area is of the order of 5 m.

of the groundwater table above sea level (Fig. 5). Badon Ghijben's ideas did not receive proper recognition until the German engineer A. Herzberg (1901) independently reached the same conclusions, after discovering freshwater extending to a depth of 60 m under the North Sea island of Norderney. Subsequent drilling in the Amsterdam Waterworks dune catchment revealed a freshwater lens with a thickness of more than 150 m and in 1903 the extraction of groundwater by deep wells began.

The Ghijben-Herzberg principle is based on the assumption of hydrostatic conditions, which actually cannot exist. Deviations from the theoretical model therefore increase with complexity of the dune structure and the associated groundwater flow pattern. Engineer C.P.E. Ribbius, director of the Delft Water

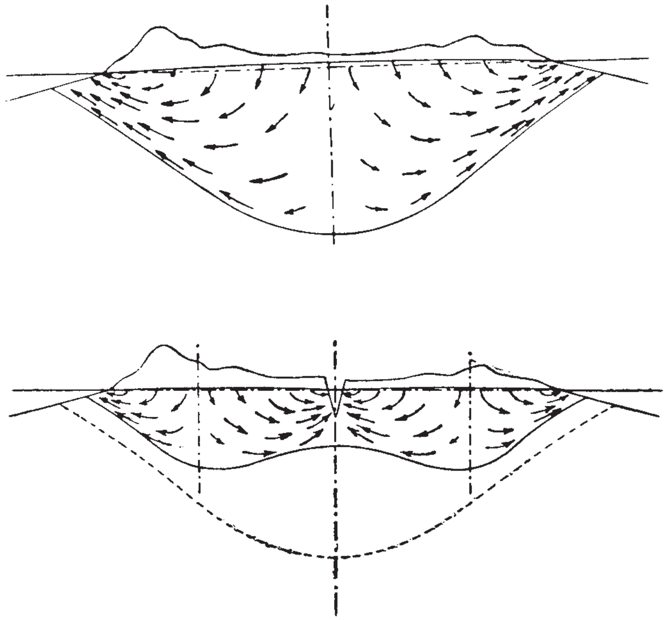
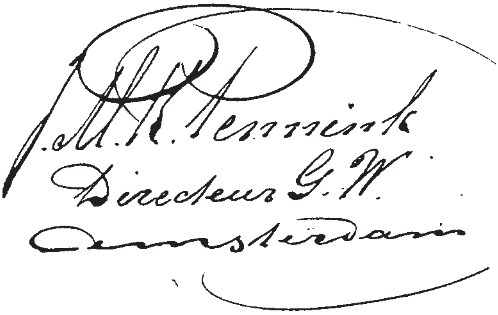


Figure 6 Groundwater flow pattern in the dune area according to Ribbius (1903/1904).

Supply Company, was the first to suggest the dynamic character of a fresh groundwater lens (Ribbius, 1903/1904). He showed a clear conceptual insight into the groundwater flow pattern, including the occurrence of upward-bending flow lines under free water table conditions (Fig. 6). Ribbius realised that this was not in accordance with Lueger's theory as laid down in his authoritative book on public water supply (Lueger, 1895; see previous section).

Figure 7 Johan M.K. Pennink (1851-1936). Pennink was an engineer with the Amsterdam Dune Water Company from 1890-1900 and subsequently director of its successor, the Amsterdam Municipal Waterworks. He not only combined management with scientific and experimental work, but also developed technical schemes for safeguarding of the increasing water demand for the town. His most important design was a system for artificial recharge of the dunes with water from the river Rhine, only executed half a century later after serious salinisation problems. Pennink experienced a long-lasting conflict with the Amsterdam municipality, because he stubbornly refused to extract more water from the dunes than a percentage of the quantity he rightly assumed to be the rainfall replenishment. Council members blamed him for being more interested in scientific research than in water supply and he was finally dismissed as director in 1916, but stayed on as an advisor. Pennink received the highest award by the Royal Institute of Engineers for his scientific and technical work.


J.M.K. Pennink
Directeur G.W.
Amsterdam

He therefore cautiously stated that he did not want to challenge Lueger's theory in general, but that the very special conditions of the dune area did allow for this deviation.

More rigorous in his opinion of Lueger's doctrine was Director J.M.K. Pennink of the Amsterdam Waterworks (which evolved from the private Dune Water Company in 1896). As mentioned in the previous section, Pennink (Fig. 7) noticed that measured flow through the drainage canals was a factor three higher than the groundwater flux calculated on the basis of horizontal flow, as depicted in Fig. 3. This gave him the idea that the thickness of the subsurface participating in the groundwater discharge was possibly underestimated in the then current theory. He therefore postulated radial and upward bending flow lines in a vertical section perpendicular to the channels. Pennink beautifully demonstrated the flow pattern below partially penetrating channels from both field evidence and experiments with viscous parallel-plate models (Pennink, 1904, 1905). His models consisted of parallel glass plates, initially filled with liquids and in later experiments filled with sand. His field experiments were carried out using rows of piezometers to measure water pressure at different distances from the canals and at various depths. From these observations, he constructed the spatial pattern of hydraulic head and the connected flow lines (Fig. 8), then proving his principle of radial flow. Pennink thus understood that the driving force in a point of the flow field is formed by the gradient of the sum of the elevation head and the pressure head (see Fig. 2b).

Pennink's experiment also clearly explained the increase in hydraulic head with depth under areas of discharge. This phenomenon, as well as strong upwelling of water in excavations at the foot of dunes, had often been misinterpreted as an indication of the occurrence of artesian water veins beneath the dunes. The artesian water hypothesis formed an alternative explanation for the existence of the large freshwater pocket. Not everybody at that time accepted the Ghijben-Herzberg principle and the autochthonous origin of the freshwater lens (from infiltrating rainwater). The origin of the postulated artesian water was sought in higher ground of the eastern ice-pushed ridges or even further to the east in Germany and Belgium. Pennink fiercely rejected an alien origin of the dune water (from artesian veins) and simulated the formation of freshwater lenses beneath coastal dunes with his parallel-plate analogue with fluids of different density, to verify the Ghijben-Herzberg principle (Fig. 9).

He further demonstrated with this model the risk of overproduction and the up-welling of salt water, and stubbornly refused to extract more water from the dunes than 70% of the replenishment by rainfall, which he rightly assumed to be in the order of 250 mm per year. This policy caused a water

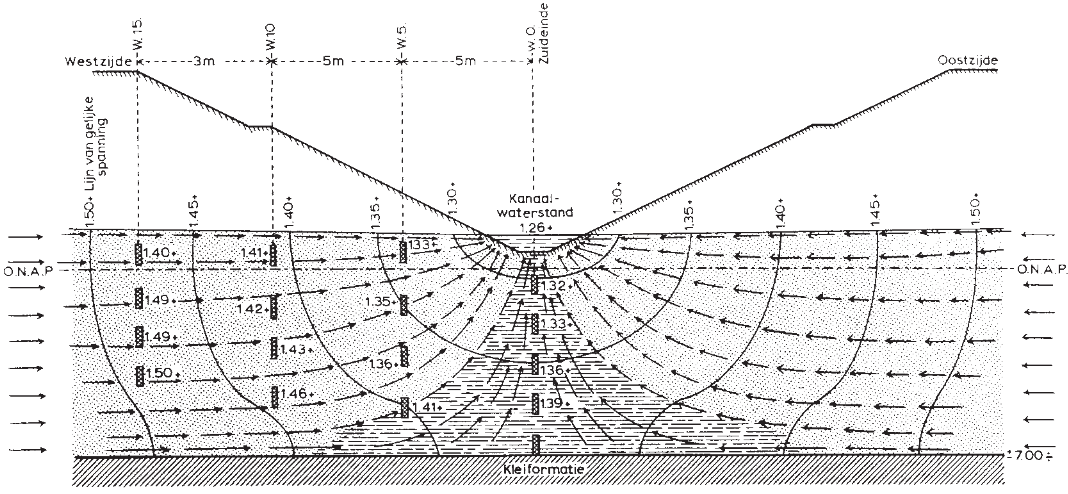


Figure 8 Flow net around a drainage canal based on hydraulic head observations; redrawn from Pennink, 1905.

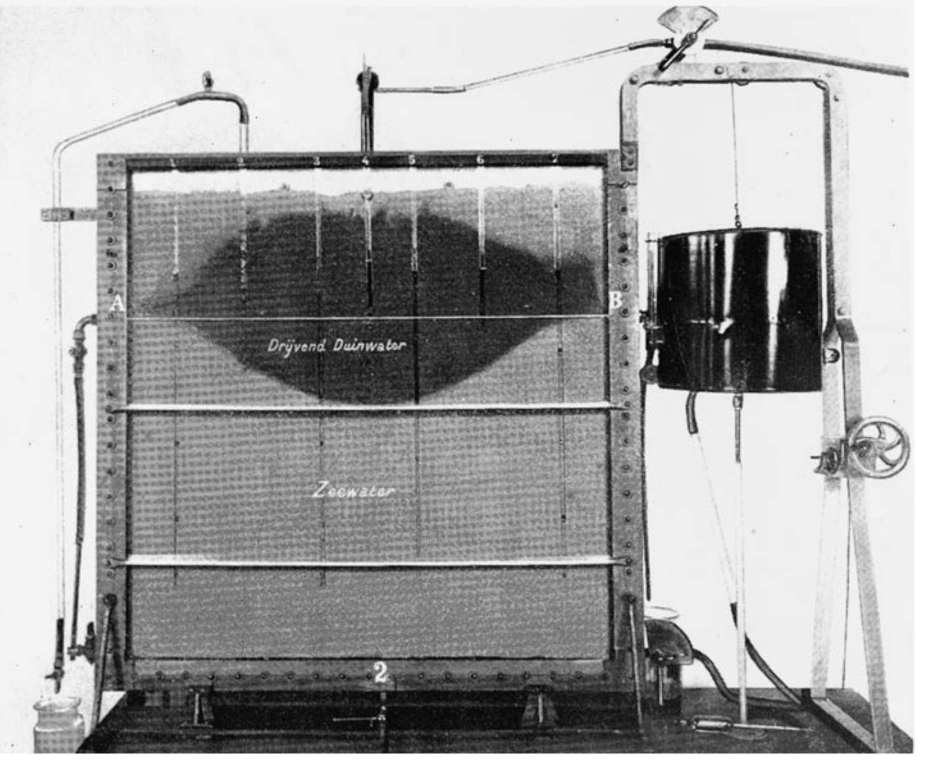


Figure 9 Experiment on the Ghijben-Herzberg principle with a parallel-plate model with fluids of different density; according to Pennink, 1905.

shortage in Amsterdam and a long-lasting conflict with the municipality. Pennink therefore proposed – as early as 1901 – artificial recharge of the dune catchment with water from the river Rhine, for which he designed a detailed scheme. The municipality, however, was confused and considered his plans too expensive and perhaps unnecessary, should the inexhaustible artesian water source indeed exist. It would eventually take more than fifteen years before Pennink's view became generally accepted and artificial recharge of the dune catchment with river water started only in the 1950s after severe salinisation problems.

One of Pennink's opponents was the director of the Water Supply Company of The Hague, engineer Th. Stang. The Hague extracted much more dune water from a smaller catchment than Amsterdam, sanctioned by Stang's belief in considerable extra replenishment by condensation and a postulated clay layer that would separate and definitely protect the fresh water from salt water intrusion. Director Stang, who also refuted the Ghijben-Herzberg principle, argued that when abstraction is lower than the replenishment – which he estimated at 750 mm – salinisation is 'a physical impossibility and in the next centuries not to be expected' (Stang, 1903). The Amsterdam municipality was impressed by Stang's performance and invited him to act as reporter on one of the many committees that were formed to propose a solution for Amsterdam's drinking water problems. Pennink reacted fiercely to Stang's unsound analysis in a counter report in which he also ventilated his personal opinion of him in an annihilating – not to say insulting – way. He characterised his opponent, in fact, as a self-conceited charlatan and finally advised the municipality 'not to take the responsibility to base any decision whatever, on such rotten grounds' (Pennink, 1907).

Another antagonist was the geologist Reinier D. Verbeek,[1] who – for more than 25 years – defended the idea of an inexhaustible artesian groundwater resource below the dunes and based this on his misinterpretation of the occurrence of groundwater with an upward flow component in the vicinity of the drainage canals. Verbeek exerted considerable influence on politicians and the general public with brochures and letters to newspaper editors (e.g. Verbeek, 1905). In fact, as late as 1921, the Minister of Works asked the Royal Netherlands Academy of Arts and Sciences for advice with respect to the origin of fresh groundwater in the dune area. This was due to an action by landowners, who argued that expansion of the dune catchment and expropriation of their estates for The Hague's water supply would

[1] Not to be mistaken for his geologist cousin, R.D.M. Verbeek, who was, among others, renowned for his analysis and description of the Krakatau volcanic explosion in 1883.

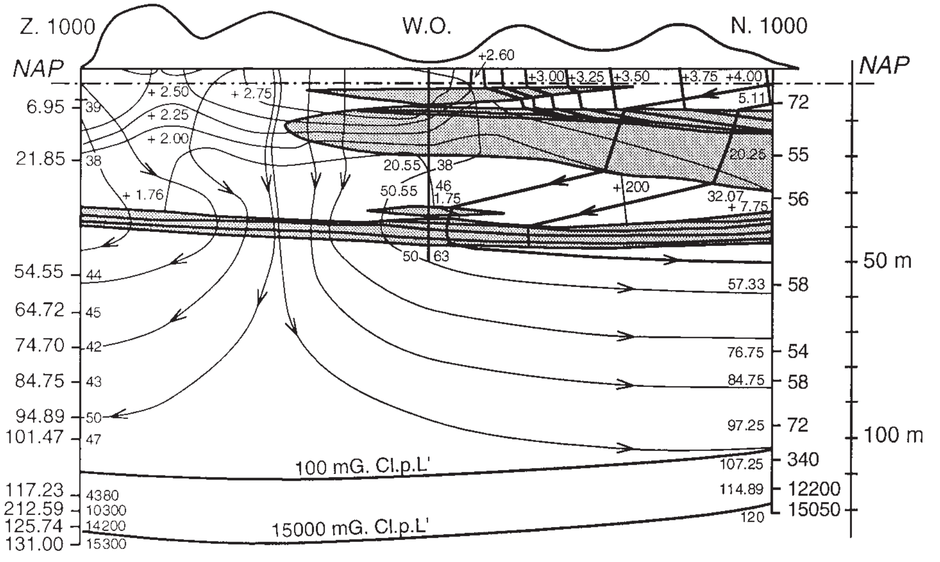


Figure 10 Geo-hydrological section through the dune area near Castricum. Fig. 10 exemplifies one of the geohydrological sections through the coastal dune area, according to a report from the Government Bureau for Drinking Water Supply, published in 1916 by its director J. van Oldenborgh. It shows the chloride content, hydraulic head distribution (corrected for density) and flow lines. These profiles and a regional 'finite difference' numerical model to assess the influence of groundwater extraction depth on the lowering of groundwater head and the associated threat of salinisation, were most probably established by the engineer with the Bureau, J. Kooper. Van Oldenborgh and Kooper were both educated as officers in the Army Corps of Engineers.

be unnecessary if subterranean recharge by artesian water would prove to be a reality. At that time, overwhelming evidence for an autochthonous formation of dune water from extensive exploration of the whole coastal dune area had already become available (Fig. 10) and the Academy, through its members the professors of geology Eug. Dubois and G.A.F Molengraaff, refuted the artesian water hypothesis (Molengraaff and Dubois, 1921). Parliament subsequently criticised the minister for having become involved in a scientific discussion.

Water balance and recharge mechanisms

The previous section notes that inadequate evaporation measurements led to confusion about the water balance. A. Elink Sterk, chief engineer with the Haarlemmermeer polder, was the first to indicate the conceptual problems and data inaccuracies of evaporation pans and lysimeters. From comprehensive water balance studies of the Haarlemmermeer polder, he derived an annual evapotranspiration of 481 mm, with a rainfall of 784 mm and a subsurface inflow of 150 mm (Elink Sterk, 1897/1898). This, to our present knowledge, rather good approximation was in contrast with the results of systematic lysimeter experiments carried out at the Oudewetering Observatory of the Rijnland Water Authority since 1876. Unlikely results were obtained from these instruments, particularly when water had to be supplied in dry seasons to keep the vegetation alive. Evapotranspiration, for example, exceeded precipitation with 496 mm during the dry year of 1893. These data caused Elink Sterk to turn fiercely against these Oudewetering experiments and to have them terminated in 1901. He showed his aversion with the comment that he 'hoped the instruments would soon disappear from man's memory'.

Another engineer, H.E. de Bruyn (1903), carried out lysimeter experiments and analyses of groundwater level fluctuations in the dune area for a period of eight years. He arrived at an acceptable annual figure of 350 mm for annual average groundwater recharge. Meanwhile, the hypothesis of groundwater recharge by water vapour condensation remained a matter of controversy. In addition to the confusing results from evaporation studies, the fact that even during and after heavy rainfall, no groundwater was observed to flow into an open pit above the groundwater table, led to denial by some investigators of the reality of infiltrating rainwater as a means of recharge. Geologist and mining engineer J. Versluys (Fig. 11) gave a clear explanation for this observation and refutation of the condensation concept as theory for water in the unsaturated zone in his 1916 PhD thesis on capillary phenomena. He made clear that water in the unsaturated zone exerted a negative pressure relative to atmospheric pressure and thus could not flow out at the surface in an excavation above the groundwater table.

The work of Versluys forms one of the first comprehensive treatises on water in the unsaturated zone. Although his approach was of a qualitative nature, it was based on sound physical principles and extensive observational work produced by the US Department of Agriculture (Versluys, 1916a). In the same year, Versluys also correctly explained the origin of sodium bicarbonate in coastal groundwater areas, through his hypothesis on cation exchange in the zone in which saline groundwater has been flushed by fresh water (Versluys, 1916b; Fig. 11). The sodium bicarbonate type of groundwater

Figure 11 Jan Versluys (1880-1935) Versluys was educated as a mining engineer and was the first ‘all-round’ hydrologist in The Netherlands. He was familiar with the work of well-known contemporary scientists such as King, Slichter, Boussinesque and Forchheimer. His 1916 PhD thesis on capillary phenomena in the soil forms one of the first systematic treatises on this subject. In the same year, he presented the correct explanation for the occurrence of sodium bicarbonate in groundwater in the coastal area, according to the process of cation exchange by flushing of saline water by fresh water:

Na clay + $Ca(HCO_3)$ water —> Ca clay + $NaHCO_3$ water

After several positions in drinking water supply and mining in The Netherlands, the Dutch East Indies and Surinam, Versluys joined the Bataafsche Oil Company in 1927 and lifted oil and gas exploration and exploitation to a scientific level. In 1918, he became the first lecturer in hydrology in the Netherlands, at the Delft Technical University; his appointment as professor of economic geology at the University of Amsterdam followed in 1932.

subsequently became an important tracer in reconstructing the evolution of fresh-saltwater distribution in coastal areas.

The emergence of a basic physical theory

The physicist A.H. Borgesius (1912) generalised Pennink's empirical work by referring to the mathematical analogy between a groundwater flow field and an electromagnetic field. He simulated a number of analogous flow patterns based on such methods as superposition, imaging and refraction. However, Borgesius showed poor perception of the reality of groundwater hydrology by arguing that the flow-line pattern around drainage galleries, as applied in The Hague's dune water extraction, would make salinisation almost impossible.[2] The noted physicist H.A. Lorentz showed – in a companion paper – that a combination of Darcy's flow equation with the continuity equation results in the general differential equation that governs groundwater flow. This equation is an expression of the well-known Laplace equation that also holds for electromagnetic fields and for heat conduction (Lorentz, 1913). He further presented a treatise on the lowering of groundwater level around drains and up-coning of the fresh-salt water interface, and added the comment that overexploitation of the catchment would – in any case – eventually lead to salinisation. In the following year, Pennink published his well known Salinisation Report, in which he convincingly demonstrated that the boundary between fresh and salt water was slowly moving up and that several deep wells had already been affected by salinisation (Pennink, 1914).

The Frenchman Joseph Boussinesq (1877) and the Austrian Philipp Forchheimer (1886) were probably the first to combine the continuity condition with a flow equation for the general differential equation for steady groundwater flow. The transient variety appeared for the first time in the work of Boussinesq in 1904. Forchheimer derived several solutions of flow cases around extraction wells, generalising the pumping well formulae developed by Adolph Thiem (1870). Charles S. Slichter (1899) – in the USA – arrived at the same results and extended Forchheimer's approach by including a vertical flow component. Although he did not mention Forchheimer, he referred to the German authors Thiem, Volger and Lueger. F.H. King (1899), who – in a companion paper – gave a general description of groundwater flow under the influence of topography, presented a sketch for the flow pattern near

[2] This misconception and his playing down on Pennink by pretending surprise that Pennink had seriously reasoned against the odd and unmatched concepts of Lueger obviously reflects Borgesius's earlier involvement in a study that was prepared in support of the practise of The Hague's Water Supply and the ideas of its director Stang (see De Vries, 1982).

a stream, similar to Pennink's case (Fig. 8). King correctly argued that the flow of water beneath a channel or depression is forced upward under hydrostatic pressure developed by the inflow and accumulation of water percolating downward through the surrounding higher land. In contrast to Pennink however, King did not verify his ideas by field experiments.

Slichter (1902) applied King's sketch to discuss the flow pattern in a framework of general theory. He emphasised that it would be misleading to compare groundwater flow with pipe flow and stream flow because the frictional resistance in groundwater is not transmitted by the fluid layers. In this connection, he considered the influence of an undulating impervious base for the flow pattern in an aquifer and stated:

> 'The contention of some German hydrographers [he was referring to Lueger, de V.] that there can be no motion in a region like ASB [referring to a figure with a concavity ASB in the impervious base of the aquifer; de V.] must be entirely abandoned. Water must circulate in all parts of the enlargements in the porous medium, for the same reason that heat would be conducted over similar enlargements in a conductor.'[He further specified]'If it were not for the ever present controlling influence of gravity the motion would be entirely analogous to the flow of heat or electricity in a conductive medium.'

Pennink was obviously not familiar with these theoretical approaches, or at least did not know how to apply this knowledge. In 1914, however, Forchheimer's comprehensive volume *Hydraulik* appeared and this book, which contains a chapter on groundwater hydraulics, became widely used in the Netherlands.

An era of speculation and scientific controversies had come to an end in the period around World War I, through development of a sound theoretical basis for groundwater hydrology and an adequate dissemination of this knowledge. Groundwater hydrology subsequently evolved by way of interaction between field observations and mathematical analysis, by solving the general differential equation of groundwater flow for appropriate schematisations and boundary conditions. This approach produced several original Dutch contributions to groundwater hydrology, particularly in connection with the typical Dutch conditions pertaining to leakage of water from/into aquifers through the semi-pervious Holocene confining layers. This problem became notably manifest after World War I in connection to large-scale land reclamation works in the Zuiderzee area, including the drainage of excavations for large hydraulic structures, upward seepage of brackish groundwater in deep polders and seepage through and below dikes.

The first original Dutch contribution in this field of groundwater hydraulics was a theoretical study of steady flow around a well or circular polder in a leaky aquifer by J. Kooper in 1914. Kooper already arrived at a

Figure 12 G.J. de Glee (1897-1975). De Glee began his career as engineer with the water supply company of the town of Tilburg in 1920. He joined the Government Bureau for Drinking Water Supply in 1925 and published his well-known formula for steady flow to a well in a leaky aquifer as part of his PhD thesis in 1930. In the same year, he became the first director of the Water Works of the Province of Groningen. His formula, which in fact was based on earlier work by J. Kooper (1914), reads:

$$s = \frac{Q}{2\pi T} K_o\left[\frac{r}{\lambda}\right]$$

where s is lowering of hydraulic head at distance r from the well through a groundwater extraction Q; T and λ are transmissivity and leakage factor of the aquifer respectively; K_o is a modified Bessel Function of zero order. This equation – and its variety for flow around a large diameter excavation or polder – have been widely used for pumping test analysis and for determination of groundwater inflow into deep polders and excavations.

mathematical solution with Bessel functions, which proved to be very useful in groundwater exploration and management. The solution for this flow case was subsequently elaborated by G.J. de Glee in his 1930 PhD thesis and is generally referred to as the 'De Glee Formula' (Fig. 12). Kooper and De Glee were both engineers with the Government Bureau for Drinking Water Supply, which had been founded in 1913. Another outstanding piece of work was delivered by C.G.J. Vreedenburgh, at that time professor at the Technical University of Bandung, who was the first to derive the exact mathematical solution for the flow through a dam under free water table conditions (in De Vos, 1929). He, moreover, solved the problem of flow through an anisotropic medium and simulated two-dimensional groundwater flow in an electrolyte tank on the basis of the analogy between Darcy's law and Ohm's law (Vreedenburgh, 1935; Vreedenburgh and Stevens, 1933, 1936).

Further mention should be made of J.H. Steggewentz's 1933 PhD thesis on the propagation of ocean tides in coastal aquifers, which included an early solution for the so called 'delayed' vertical flow near the oscillating free water table. It was only in the 1960's that the concept of 'delayed yield' appeared in the international literature in connection with transient well flow.

CONCLUDING REMARKS

Scientific groundwater hydrology in the Netherlands emerged around the turn of the nineteenth century in close connection with the growing demand of groundwater for public water supply. Suitable fresh groundwater resources in the western part of the country were mainly restricted to the belt of coastal dunes and were accordingly prone to depletion and salinisation. Proper and sustainable exploitation thus required a sound knowledge of the origin and replenishment of the fresh water reserves as well as understanding of the dynamics of the fresh/salt water interface and the flow towards the extraction means. It took more than 50 years of speculation, observation and theoretical consideration before a proper understanding on the basis of an adequate physical theory surfaced. The scientific debates often led to strong personal controversies with, sometimes, political implications because of the societal relevance of the subject. Several Dutch pioneers performed trailblazing and outstanding work during the inception period before World War I.

The basic theory enabled considering a groundwater flow case as a boundary value problem that can be solved as a mathematical equation. The Dutch hydrogeological conditions, which are characterised by relatively homogeneous aquifers and simple and artificially maintained boundary conditions, proved very suitable for this theoretical approach. A number of problems related to groundwater extraction, land reclamation and civil engineering works were subsequently solved. This has led to several original Dutch contributions to the theory of groundwater flow in situations were groundwater and surface water are closely related under leaky aquifer conditions. This development mainly took place after World War I.

Until World War II, most groundwater research was carried out by engineers rather than by geologists. This can be explained by the fact that engineers had a better background for the aforementioned quantitative approach and, moreover, most groundwater problems were related to soil and water engineering. The Government Bureau for Drinking Water Supply has played a major role in this development. It used to be the central organisation for groundwater exploration and research for both drinking water supply and infrastructure works, for more than half a century. The situation changed after World War II when water was increasingly considered as an environmental component, requiring an integrated approach of quantity and quality of surface water and groundwater and their interaction with the geological environment. This resulted in increasing involvement of earth scientists in hydrogeological research and exploration.

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Maastricht Cretaceous finds and Dutch pioneers in vertebrate palaeontology

Eric W.A. Mulder

INTRODUCTION

The foundations for the development of modern palaeontology were laid in the eighteenth century. In terms of the number of seminal publications Dutch scientists played only a minor role in this process. A century before, king Louis XIV had declared that the Netherlands were 'just an accumulation of silt, deposited by French rivers'. Although the sovereign spoke, of course, with political motives, geologically speaking he had hit the nail on the head, quite surprisingly. At first glance, major Dutch contributions to the establishment of scientific palaeontology thus did not seem to be the obvious thing to expect.

Nevertheless, the St. Pietersberg near Maastricht and its vicinity, became an important exception to this overall picture. During the second half of the eighteenth century, the Cretaceous marine sediments in that area yielded the fossil remains of several large vertebrates. Some of them were recognizable at once, such as sea turtles. Others appeared to be more puzzling than they had seemed at first sight. These creatures were neither crocodiles nor whales as had been thought initially: they were mosasaurs.

This chapter presents a closer look at how Dutch scientists interpreted these finds. Besides, the importance of these discoveries for the development of fossil studies will be emphasized. The mosasaur fossils played an important role in the emergence of modern palaeontology, since they paved the way to the understanding of the phenomenon of extinct life forms. The early investigations did not establish a lasting tradition of Dutch palaeontology. Due to political and, later, to apparent personal or institutional circumstances that arose at the end of the eighteenth and in the second half of the nineteenth century, scientifically important fossils were sent or sold to other countries.

In recent years, the geology and palaeontology of the Maastricht area have become the focus of a renewed interest.[1] The limestone formations in this

[1] See e.g. H. Brinkhuis and J. Smit eds., 'The Geulhemmerberg Cretaceous/Tertiary boundary section…', *Geologie en Mijnbouw* 75, nrs. 2-3 (1996) p. 101-293.

area document a shallow marine environment near the close of the Cretaceous period, some 65 million years ago. The youngest stage of the Cretaceous is named after the capital of the Dutch province of Limburg and is worldwide known as Maastrichtian. The end of the Maastrichtian is marked by one of the most dramatic events in the earth's history, highlighted by the flashlike extinction of numerous marine and terrestrial organisms.

The renewed interest among earth scientists in the Maastricht area did not only coincide with the 150th anniversary of the introduction of the Maastrichtian stage. Recently, evidence has been put forward that proves that the top of the Limburg limestone formation contains signals from the Chicxulub meteorite impact, which was at least partly responsible for the Late Cretaceous mass extinction.[2] Moreover, Rudi W. Dortangs discovered in 1998 a partial skeleton of a new type of mosasaur in the quarry of ENCI – Maastricht BV, at the St. Pietersberg.[3]

Mosasaurs are extinct squamate reptiles that populated the earth's oceans and epicontinental seas during the Late Cretaceous.[4] Several species in at least thirteen genera existed, amongst them specialists in a whole range of catches. All mosasaurs had elongated, snake-like bodies with paddle-like limbs and flattened tails and were thus remarkably well adapted to the marine carnivorous life. One of the largest representatives was *Mosasaurus hoffmanni*, an ambush predator with a total length of about 17 m.

MOSASAUR DISCOVERIES IN THE EIGHTEENTH CENTURY

Two centuries ago, the southern part of what is now Dutch Limburg and the adjacent Belgian areas raised scientific attention because of discoveries of mosasaur bones. The friable limestone at the St. Pietersberg had been exploited since, at least, late medieval times, in an ever-expanding system of underground galleries. During subterranean excavation, fossil mosasaur remains were discovered and it is plausible that this actually already happened prior to the second half of the eighteenth century. However, the first recorded find dates from 1766; it was described and illustrated by Van Marum.[5] The skull, with only portions of the lower and upper jaws preserved, was originally in

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2 *Ibidem.*

3 R.W. Dortangs et al., '*Prognathodon saturator*, a large new mosasaur from the Upper Cretaceous of the Netherlands', *Netherlands Journal of Geosciences (Geologie en Mijnbouw)* 81, nr. 1 (2002) p. 1-8.

4 G.L.Bell, 'Mosasauridae. Introduction', in: J. Callaway and E.L. Nicholls eds, *Ancient marine reptiles* (New York/London, 1997) p. 281-292.

5 M. van Marum, 'Beschrijving der beenderen van den kop van eenen visch,…', *Verhandelingen Teylers Tweede Genootschap* 8 (1790) p. 383-389.

the possession of the Maastricht collector J.B. Drouin.[6] Later, Van Marum, first director and founder of Teyler's museum in Haarlem, purchased the skull for the palaeontological cabinet of that museum. This mosasaur skull still is on exhibit there (Fig. 1).

Between 1770 and 1774, not in 1780 as often stated,[7] another skull was discovered. Compared to the 1766 find, this second specimen, although incomplete as well, would become more renowned. The romanticised and often retold history of its discovery (Fig. 2) has recently been scrutinised in detail by Bardet and Jagt[8] and analysed critically by Rompen[9] who showed that this second skull never was owned by the Maastricht collector and city surgeon J.L. Hoffmann, as suggested by Faujas de Saint-Fond. Its first legal owner was Canon Godding, who discussed the nature of the fossil with interested contemporaries.

In view of the fame of this second skull, which was to become the type specimen of *Mosasaurus hoffmanni*, southern Limburg takes a prominent position at the roots of vertebrate palaeontology. In discussions and formulation of concepts, Dutch pioneer paleontologists presented major contributions regarding the nature of this skull. Ultimately, a major role was reserved for Georges Cuvier. In 1795, the fossil was transported to the Muséum d'Histoire Naturelle in Paris, where it contributed to Cuvier's thinking about the concept of extinction.

EIGHTEENTH-CENTURY MOSASAUR INTERPRETATIONS

The discoveries of the mosasaur skulls – and other skeletal remains – drew the attention of intellectuals, amongst whom J.L. Hoffmann, who had an extensive collection. Hoffmann took up the study of the mosasaur remains and corresponded about his findings with European scientists, including Petrus Camper.[10]

Hoffmann, Drouin, Godding, and also Faujas de Saint-Fond, who became professor of geology in Paris, and many others were convinced that the skulls

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6 C.O. van Regteren Altena, ' Achttiende-eeuwse verzamelaars van fossielen te Maastricht en het lot hunner collecties', *Publicaties van het Natuurhistorisch Genootschap in Limburg* 9 (1956) p. 83-112.

7 See e.g. Bell, *op. cit*.

8 N. Bardet and J.W.M. Jagt,' Mosasaurus hoffmanni, le 'Grand Animal fossile des Carrières de Maestricht. deux siècles d'histoire', *Bulletin du Muséum Nationale d'Histoire Naturelle* 18 (1996) p. 569-593.

9 P. Rompen, *Mosasaurus hoffmanni: De lotgevallen van een type-exemplaar* (Unpublished master's thesis University of Maastricht, 1995).

10 See Van Regteren Altena, *op. cit.*

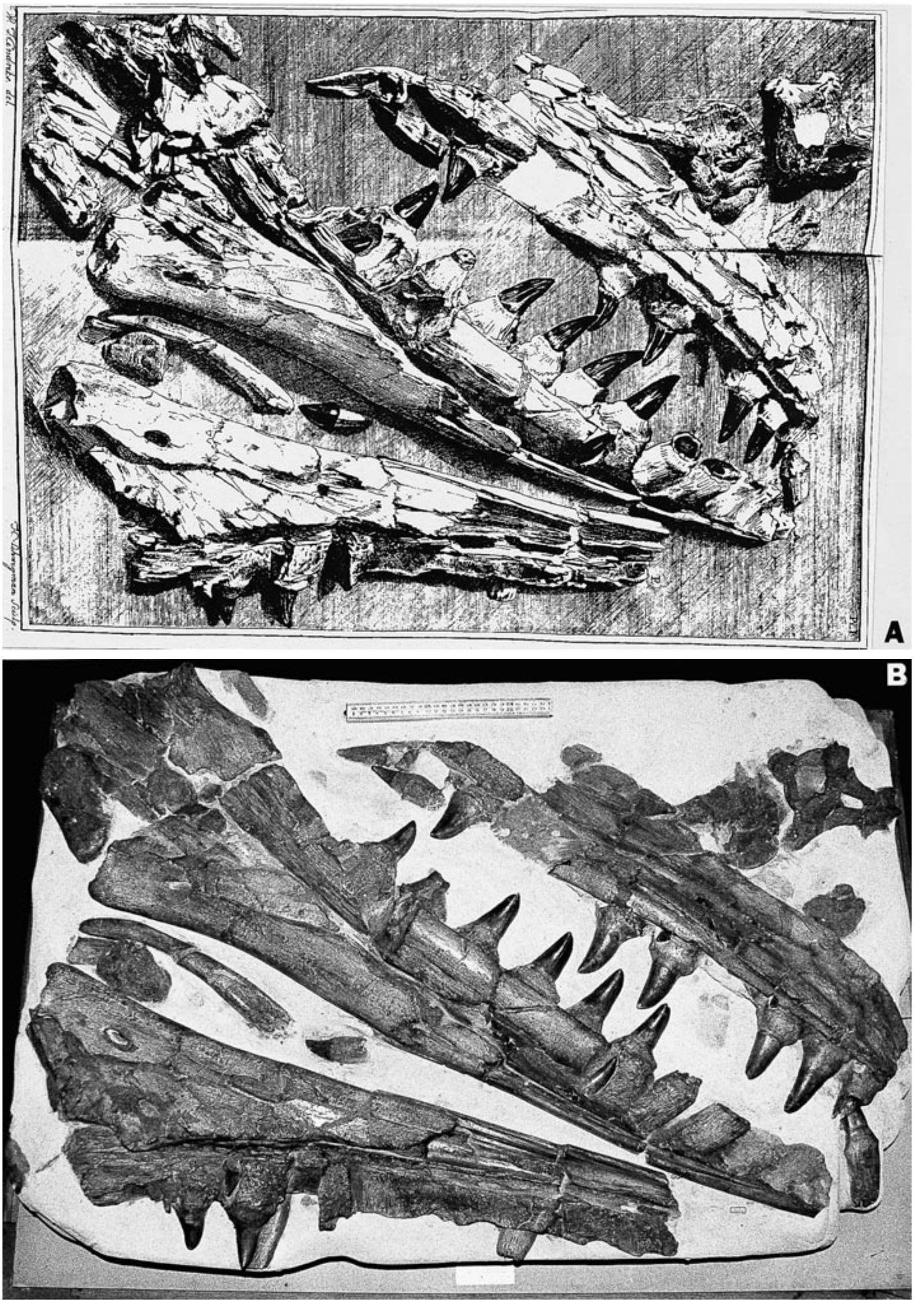

Figure 1 The first documented mosasaur find of 1766, St. Pietersberg, Maastricht. The specimen is preserved in Teylers Museum, Haarlem (no. TM 7424, *ex* Drouin Colln). **A.** Illustration by Van Marum (1790, pl. 1); **B.** of the specimen's skull notably the upper left jaw and rami of the lower jaw are disarticulated.

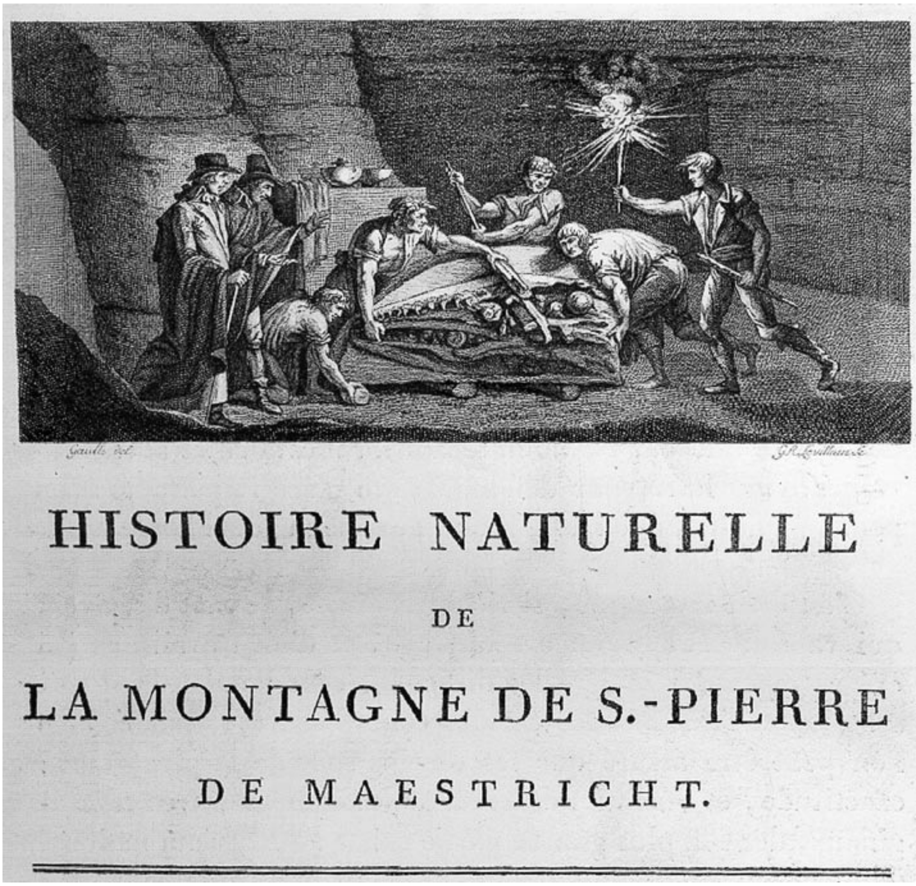

Figure 2 The discovery of the 'second' mosasaur skull in St. Pietersberg, Maastricht, as imagined by Faujas de Saint-Fond (1799).

were the remains of some kind of crocodile. At that time, this was an obvious interpretation since there were no widespread ideas on evolution yet. Furthermore, the Maastricht deposits were replete with remains of recognisable marine animals: corals, oysters, sea urchins, fishes, turtles and so on.

However, Petrus Camper, who studied mosasaur remains from the collections of Drouin, Hoffmann, Godding, and himself, concluded that these fossils were cetacean and belonged to an unknown sperm whale, a 'Physeteris incogniti ex Monte S(ancti) Petri'. He based his interpretation on comparative anatomical research.[11]

[11] P. Camper, 'Conjectures relative to the petrifactions found in St. Peter's Mountain near Maestricht', *Philosophical Transactions* 76 (1786) p. 443-456.

Petrus Camper was professor of medicine at the Universities of Franeker and Groningen and was generally considered as one of the foremost comparative anatomists of his time. How then was he able to interpret reptilian mosasaur fossils as mammal relics?

Camper noted that all other fossils from Maastricht clearly were remains of marine life. This incognitum thus had to be a marine animal as well. However, according to his (incorrect) view, crocodiles were restricted to freshwater environments.[12] Amongst the fossils he examined, Camper discovered phalanges in which he observed notable differences with crocodile digits.[13] Although he did not state this explicitly, he may have concluded that the enigmatic object of his study had paddle-shaped limbs and thus displayed a similarity to cetaceans. Camper erred in his assumption that the edges of the anterior and posterior surfaces of mosasaur vertebrae were comparable to the epiphyseal discs of cetacean vertebrae.

Camper saw similarities in the position of the nerve canals in the lower jaw of a sperm whale and in the jaws from the St. Pietersberg.[14] Also, the smooth-surfaced fossil jaws were (according to his observations) quite different from crocodile jawbones with their rough surface full of foraminae. Moreover, the unknown animal possessed teeth with solid roots, as do extant whales and dolphins. However, 'the crocodile has the teeth intirely [*sic*] hollow'.[15] Also, the incognitum had a set of teeth in the roof of the mouth. These pterygoid teeth are especially well preserved in the Godding skull. This observation is correct and for Camper it was an important clue. It is quite possible that Camper thought the sperm whale's rudimentary teeth of the upper jaw to correspond to pterygoid teeth. Remarkably, he reported that numerous fishes have pterygoid teeth as well. It appears that Camper was not fully aware of the fact that whales are not fishes, but mammals. In his paper, he did not distinguish clearly between fishes and whales and he used the confusing term 'cetaceous fishes'.[16]

Also, Camper ignored a fundamental difference between reptilians (including the mosasaur) and mammals (including the sperm whale). As in fishes, the reptilian lower jaw is composed of several elements. This feature is also visible in the skulls studied by Camper. However, in mammals, each half of the lower jaw consists of a single element only: the teeth-bearing dental bone.

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12 *Ibidem*, p. 445.
13 *Ibidem*, p. 450.
14 *Ibidem*, p. 446.
15 *Ibidem*, p. 455.
16 *Ibidem*, p. 444.

It is tempting to assume that Camper put forward his arguments to classify the object of his research within the cetaceans because such a huge marine vertebrate couldn't be anything else; there was simply no alternative. Ultimately, only Van Marum subscribed to Camper's views, using the same arguments (teeth with solid roots, presence of pterygoid teeth, surface structure of the jaws, position of nerve canals). Van Marum referring to 'Pisces cetacei',[17] shared Camper's concept of whales.

Like Petrus Camper, those that interpreted mosasaurs as crocodiles did not note the profound difference in jaw anatomy between reptiles and mammals. One of them was B. Faujas de Saint-Fond. In his *Histoire naturelle de la Montagne de Saint-Pierre de Maëstricht* (1799) he described the Godding skull.

Thus, at the end of the eighteenth century, there were two conflicting views concerning the nature of the incognitum of Maastricht. Adriaan Gilles Camper, Petrus' son, felt the need to defend his father and took up the study of the disputed fossils. He was the first to understand that actually both views were erroneous. He discovered that the incognitum had to be a giant marine squamate reptile with varanoid affinities.[18] Furthermore, Camper jr. noted that, in fact, a second species was represented in his father's collection.[19]

Prior to publication of Camper's conclusions, the skull from Godding's collection had been transported to Paris by the French revolutionary army. Georges Cuvier studied it there. In 1799, Adriaan Gilles began his correspondence on palaeontology with Cuvier. Of course, ideas on the Maastricht incognitum were exchanged.[20] Cuvier rejected Camper's views on a second species, but subscribed to the idea of a marine squamate reptile with varanoid affinities. He adopted this concept in his opus magnum *Recherches sur les ossemens fossiles* (1812) and identified the animal from the St. Pietersberg as an extinct species.

Eventually, the French palaeontologist Louis Dollo described the second mosasaur species, which A.G. Camper had recognised much earlier.[21] The discovery that mosasaurs had paddle-like limbs was made by the Dutch zoologist Hermann Schlegel. He was director of the Rijksmuseum van Natuurlijke Historie in Leyden between 1858 and 1884 and correspondent of the Committee for the Geological Map and Description of the Netherlands

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[17] Van Marum, *op. cit.* p. 388.

[18] A.G. Camper, 'Lettre de A.G. Camper à G. Cuvier sur les ossemens fossiles de la montagne de St. Pierre, à Maëstricht', *Journal de Physique* 51 (1800) p. 278-291.

[19] A.G. Camper, 'Mémoire sur quelques parties moins connues du squelette des sauriens fossiles de Maëstricht', *Annales du Muséum d'Histoire Naturelle* 19 (1812) p. 215-241.

[20] See B. Theunissen, 'De briefwisseling tussen A.G. Camper en G. Cuvier', *Tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 3 (1980) p. 155-170.

[21] L. Dollo, 'Note sur l'ostéologie des *Mosasauridae*', *Bulletin du Musée royale d'historie naturelle de Belgique* 1 (1852) p. 55-74.

between 1852 and 1855. Schlegel published his preliminary findings in 1854, but his contribution sank into oblivion.[22] Only, Van der Lijn and Bernink rightly pointed out Schlegel's merit.[23]

The existence of the Committee for the Geological Map and Description of the Netherlands ended prematurely in 1855. Internal conflicts between its chairman J.G.S. van Breda and its secretary W.C.H. Staring escalated when the former denied Schlegel the study of the fossil remains of the mosasaurs and turtles from Van Breda's private collection, contrary to earlier promises.[24]

The Geological Department of the British Museum acquired the Van Breda Collection at an auction, held in Haarlem in 1871. It appears that Schlegel did not bother to buy it for his musem probably because he still felt frustrated about the discourteous treatment that he had experienced. Also during Schlegel's directorate, and officially due to limited financial means, other valuable Maastricht collections assembled by J.A.H. Bosquet, C. Ubaghs and J.T. Binckhorst van den Binckhorst were sold to foreign institutions and collectors.

Figure 3 **A.** The sea turtle *Allopleuron hofmanni* (Gray, 1831), specimen NHMM 000001, on exhibit at the Natuurhistorisch Museum Maastricht, described by Winkler (1869, pp. 43-49). Width of the mounted dorsal shell: 109 cm. Copyright Centraal Archief DSM Heerlen.

[22] For Schlegel see E.W.A. Mulder and B. Theunissen, 'Hermann Schlegel als paleontoloog', *Natuurhistorisch Maandblad* 71 (1982) 163-171.
[23] P. van der Lijn and J.B. Bernink, *Geologie van Nederland* (Hengelo, 1918) p. 199.
[24] For the conflicts in the committee see Faasse's article in this volume.

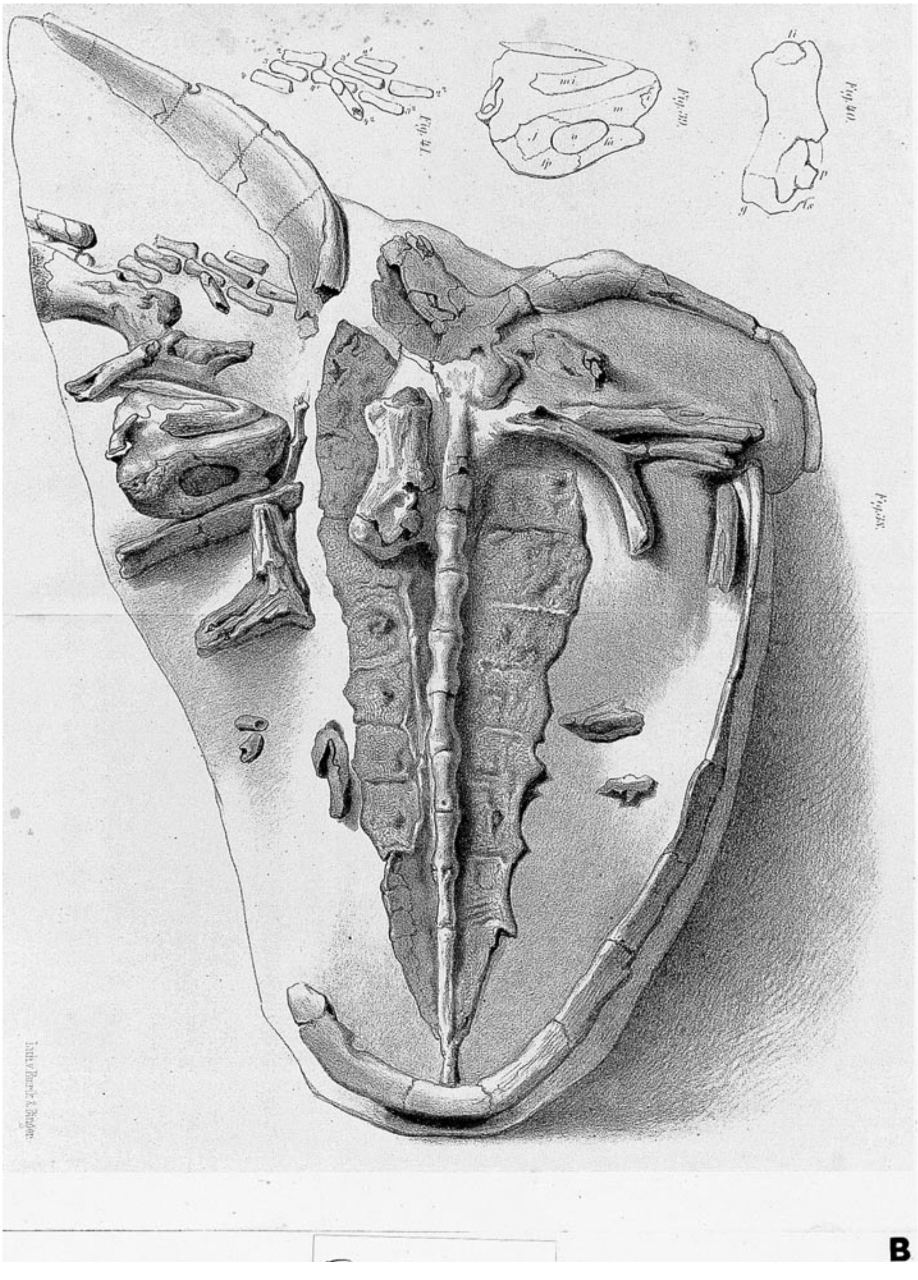


Figure 3 **B.** The specimen's state of preservation in earlier days, as pictured by Winkler (1869, pl. 12, figs 38-41).

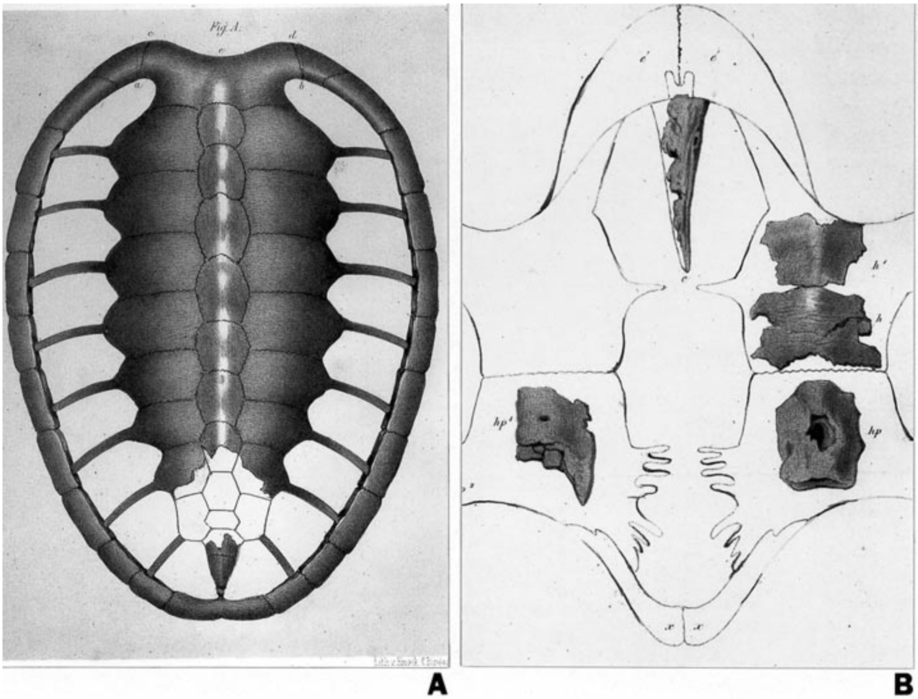


Figure 4 Reconstruction of the dorsal (**A**) and ventral (**B**) shell of *Allopleuron hofmanni* by Winkler (1869, pls 7 and 8)

TURTLES

Not only were the Maastricht discoveries of mosasaur bones documented, those of sea turtle remains as well. However, these fossils, amongst them the commonest and best known species *Allopleuron hofmanni,* could not rival the mosasaurs in fame. Eighteenth-century scientists immediately identified a number of turtle elements as such.[25]

In 1869, Tiberius C. Winkler published a detailed description of *A. hofmanni*. Originally a businessman, the gifted Winkler was not only interested in foreign languages, but also became a 'self-made' zoologist. His brother-in-law stimulated him to study Latin and become a physician. In Haarlem, he obtained the diploma of 'general practitioner'. His very first patient had handled a Weever (*Trachinus*), a poisonous North Sea fish. Winkler became

[25] See E.W.A. Mulder, 'Comparative osteology, palaeo-ecology and systematics of the Late Cretaceous turtle *Allopleuron hofmanni* (Gray 1831) from the Maastrichtian type area, *Publicaties van het Natuurhistorisch Genootschap in Limburg I* (2003) p. 23-92.

fascinated by this animal and took up the study of its anatomy. This ultimately resulted in his first scientific paper. Because of his investigations, he frequently visited the collections and library of Teyler's museum. This became the start of a scientific career, which led to several publications on ichthyology, geology and palaeontology. Winkler succeeded in 1864 Van Breda as curator of the geological and paleontological cabinets of Teyler's museum.

One of Winkler's major works is the book published in 1869 on the fossil turtles including *A. hofmanni*. This species is characterised by a very strong reduction of shell elements (see figs 3 and 4). At first sight, early students may have associated it with the shell of the extant Leatherback Turtle, *Dermochelys coriacea*. By pointing out profound differences between skulls and carapaces of these two species, Winkler demonstrated that *Allopleuron* is not an ancient Leatherback but a cheloniid turtle, 'une tortue de mer véritable, une *Chelonia* proprement dite'.[26]

Winkler, who had the opportunity to include the turtles in the Van Breda Collection in his studies, was also the first to present a reconstruction (Fig. 4: A and B) of the dorsal shell (carapace) and attempted to do the same for the ventral shell (plastron). Winkler's reconstructions are erroneous in the number and place of shell elements. He mistook the posterior part of a skull of the mosasaur *Plioplatecarpus marshi* for sacral vertebrae of *Allopleuron* (Fig. 5: A, B, C and D).

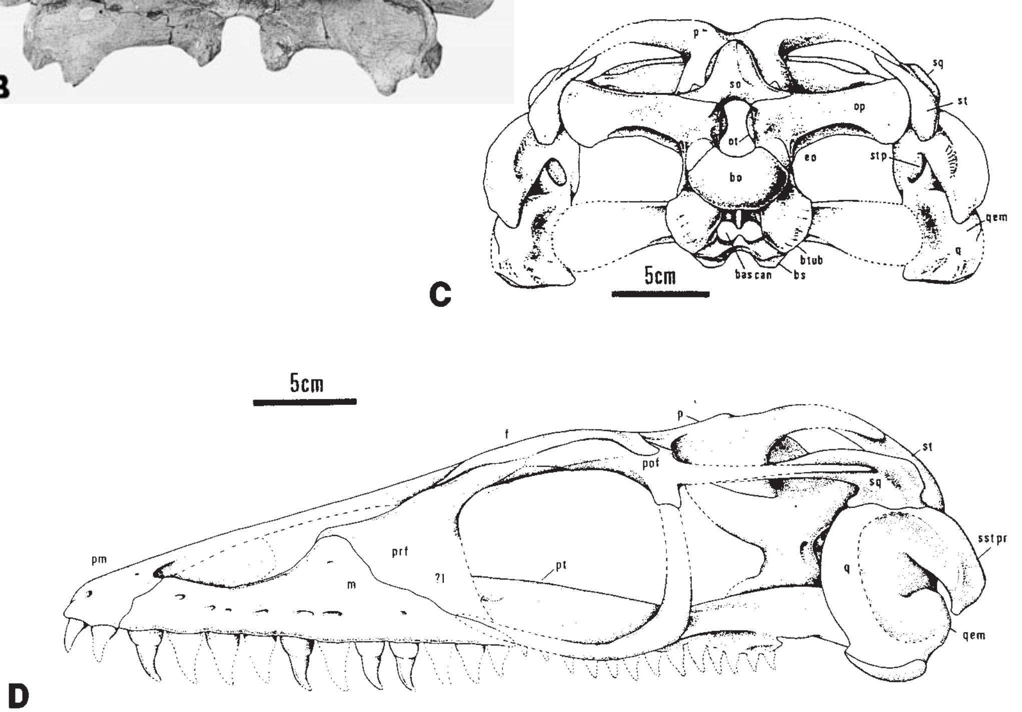
Yet Winkler's effort is indeed an achievement, when one considers the limitations of the material that Winkler had at his disposal (not a single complete element of the ventral shell was available). Also, the state of preservation of specimens precluded certain observations that would have been necessary, to come up with a proper reconstruction of the dorsal shell (Fig. 4: A and B). Winkler certainly deserves his place amongst the Dutch pioneers of vertebrate palaeontology. These early workers faced the problems of recognising similarities of fundamental characters amongst the species compared and distinguishing those from superficial resemblances. It is noteworthy that the higher systematic position of the turtle *A. hofmanni* remained unclear until very recently.[27]

Acknowledgements

I wish to thank Professor G.J. Boekschoten and Dr. J.W.M. Jagt who critically read the typescript and made useful suggestions. Furthermore, I extend my best thanks to: S. Chapman (Natural History Museum London), J.C. van Veen (Teyler's Museum Haarlem) and Dr. R.B. Holmes (Canadian Museum of Nature, Ottawa) for the permission to use figs. 5B and 5C.

[26] T.C. Winkler, *Des tortues fossiles conservées dans le Musée Teyler et dans quelques autres musées* (Haarlem, 1869) p. 60-63.
[27] See E.L. Nicholls, 'Testudines. Introduction', In. Callaway and Nicolls, *op. cit.* p. 281-292.

Figure 5 Matrix block with posterior part of a skull of *Plioplatecarpus marshi* Dollo, 1882, now in the Department of Palaeontology of the Natural History Museum, London (no. BM(NH) PD 42895, *ex* Van Breda Colln.). **A:** label with Winkler's handwriting saying: 'Apophyses des Vertèbres du Bassin de la Chelonée de Maestricht *Chelonia Hoffmanni*'. **B:** Ventroposterior view of BM(NH) PD 42895. **C** and **D:** posterior and lateral view of the skull of *Plioplatecarpus primaevus* Russell, 1967, for comparison [Reprinted from Holmes (1996, figs 2: C and 3) with permission][28]. See also for comparison: Winkler (1869, pl. 14, Fig. 49)



[28] *Journal of Vertebrate Paleontology* 16, nr. 4 (1996) p. 673-687.

An unpublished manuscript by C.E.A. Wichmann

Diederik Visser

INTRODUCTION

In 1990, a large box containing documentation from the Institute of Earth Sciences of the University of Utrecht was salvaged from the building 'Payenborgh' at Oudegracht 320 in Utrecht, which the Institute had occupied from 1929 until 1979. The box was put in storage at the University Museum Utrecht. It was only recently rediscovered during the summer of 2000 and this led to the investigation of its contents.

Apart from some financial records of the Institute of Earth Sciences,[1] the box contained personal notes and various versions of published scientific manuscripts by Carl Ernst Arthur Wichmann. One manuscript was different in that it was finished but not published. This manuscript on the mineral chloromelanite (an iron-rich variety of jadeite) from New Guinea dates from September 1901 and is accompanied by a detailed summary of available literature on the subject up to 1924 and by several separate notes and newspaper articles dated 1919, 1924 and 1926.

In this paper, the unabbreviated contents of Wichmann's manuscript are published in the original German language. Footnotes and comments in the text by Wichmann are rendered as found in the original document.

In 1879, at the age of 28, Wichmann (1851-1927) was appointed as the first professor of mineralogy and geology at the University of Utrecht. As he was a former student and assistant of the well known mineralogist and petrologist Ferdinand Zirkel (1838-1912), it was no great surprise that the main focus of Wichmann's scientific work during the first twenty years of his career was on mineralogy, petrology and the very new discipline of experimental petrology (Wichmann, 1885). On two occasions, Wichmann took part in a scientific expedition to the Dutch East Indies (now Indonesia). The first took place in 1888-1889 and was to Sulawesi (Celebes), Flores, Rotti and Timor and the

[1] Now stored at the Centrale Archief Bewaarplaats of the University of Utrecht.

second went to Ternate and Dutch New Guinea in 1903. During the last twenty years in Utrecht, Wichmann's studies were of a historical-geographical and polemic nature and mainly focussed on New Guinea and the individual volcanoes in the Indonesian archipelago. In 1917, he published his most important scientific contribution, viz. the results of the 1903 expedition to New Guinea. He was succeeded at Utrecht University in 1921 by L.M.R. Rutten.

In 1893, Wichmann received a small collection of rocks from the Humboldt Bay in New Guinea from missionary G.L. Bink. Wichmann subsequently described most of this collection in a paper published in 1901. One large block of chloromelanite from the same collection – of which a small piece[2] is still present in the mineralogical collection at the Faculty of Earth Sciences at the University of Utrecht (Fig. 1) – was investigated separately during the same period.

Wichmann's investigation of the chloromelanite rock is straightforward and very characteristic for mineralogical and petrological research at that time. It starts with a thorough account of the literature available on chloromelanite

Figure 1 Chloromelanite sample M.111.1898. Mineralogical collection of the Institute of Earth Sciences, University of Utrecht.

[2] Sample M.111.1898; thin section numbers D.2075-2077.

and its use as raw material for axes. Subsequently, the rock is described both macroscopically and with the aid of a petrographic microscope. The descriptions, as the reader will notice, are detailed and accurate. A whole-rock analysis enabled Wichmann to calculate roughly the chemical composition of the chloromelanite. When trying to integrate his data with those published previously by others, in order to provide a new and improved mineralogical composition of chloromelanite, Wichmann clearly was not pleased by the difference in quality of the analyses and the microscopic descriptions given in literature. This was probably one of the reasons why Wichmann did not submit his otherwise finished manuscript for publication.

A second reason came just after finishing the manuscript during the autumn of 1901 when Wichmann received word of approval from the Maatschappij ter Bevordering van het Natuurkundig Onderzoek der Nederlandsche Koloniën for a scientific expedition to New Guinea in 1903. The expedition to New Guinea provided Wichmann with the opportunity of a lifetime and enabled him to locate the chloromelanite rock in the field and study its genetic relationship with other rock types.

On the 22nd and 23rd of May 1903, Wichmann visited the area near Sageisara at the foot of the Cycloop Mountain Ranges, between the Sentani Lake and Jautefa Bay, west of the Humboldt Bay. He was able to collect a number of chloromelanite adzes (Figs. 2-4), made by the local Papua tribe, and several large blocks (Fig. 5) from the upper course of the small river Torare, which according to the tribe was the only source of chloromelanite. The large blocks appeared to be unaffected by transport as exemplified by

Figure 2 Unpolished chloromelanite adze. Found near Sageisara between the Sentani Lake and Jautefa Bay, west of the Humboldt Bay, Nieuw Guinea Expeditie 1903, No. 803. Geological collection of Naturalis. Copyright Photograph, Naturalis 2001.

Figure 3 Very large ceremonial unpolished chloromelanite adze weighing 2.88 Kg. Found near Sageisara between the Sentani Lake and Jautefa Bay, west of the Humboldt Bay, Nieuw Guinea Expeditie 1903, No 843. Geological collection of Naturalis. According to Galis (1955) these were no longer in use when he visited the same area early 1950's. Copyright Photograph, Naturalis 2001.

Figure 4 Fragment of a chloromelanite adze, note that is partly polished. Found in the fields near Sageisara between the Sentani Lake and Jautefa Bay, west of the Humboldt Bay, Nieuw Guinea Expeditie 1903, No 805a. Geological collection of Naturalis. Copyright Photograph, Naturalis 2001.

Figure 5 Chloromelanite block found in the Torare-river, south of Sageisara, between the Sentani Lake and Jautefa Bay, west of the Humboldt Bay, Nieuw Guinea Expeditie 1903, No. 814. Geological collection of Naturalis. Copyright Photograph, Naturalis 2001.

the rough edges. From the other rock types present in the same river bed, Wichmann (1917) inferred that the chloromelanite rock occurred intercalated with amphibolites[3] probably representing metamorphosed gabbroic rocks.

According to a note dating from 1919 and found with the manuscript, Wichmann intended to incorporate the results[4] and conclusions of melting experiments with the chloromelanite rock, but never did. The results of the experiments, which were carried out during the summer of 1900, were probably too inconclusive to use as evidence for or against the interpretation of chloromelanite rock as a representative of a bisilicate magma (see manuscript).

Publication of Wichmann's manuscript after more than 100 years, despite Wichmann's reasons for not publishing it, is not only valid from a historical point of view but also from a geological one. The knowledge of chloromelanite rocks in this part of New Guinea is at best fragmentary. In the detailed studies of the basement rocks in the Cycloop Mountain

[3] Notably albite-amphibolite, albite-crossiterock and albite-epidote-crossite rock.

[4] Thin sections D.2075 and D.2077 are made from a molten chloromelanite sample.

Ranges by Gisolf (1921), Zwierzycki (1921) and Baker (1955, 1956), chloromelanite is not mentioned. And apart from a description of the journey to the chloromelanite locality by Wichmann (1917), the only other documented occurrence of chloromelanite is in heavy-mineral concentrates from upper Tertiary sediments in southern West New Guinea (Schürmann, 1951). Finally, Van der Wegen (1971) described a chloromelanite adze from the collection of the Rijksmuseum van Geologie en Mineralogie in Leiden (now Naturalis).

ACKNOWLEDGEMENTS

Hanco Zwaan, Museum of Natural History, Naturalis, Leiden and André van Schie, University Museum Utrecht, are thanked for taking the photographs of the chloromelanite adzes and samples.

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Ueber den Chloromelanit von der Humboldt-Bai auf Neu-Guinea

Von Arthur Wichmann in Utrecht

Der Chloromelanit wurde zuerst von A. Damour als ein dem Jadeit verwandtes Mineral erkannt. Obwohl dasselbe bis vor ganz kurzer Zeit weder an ursprünglicher Lagerstätte, noch überhaupt als Rohmaterial nachgewiesen werden konnte,[1] stellte sich im Laufe der Jahre heraus, dass den aus diesem Mineral oder besser gesagt, Gestein hergestellten Gegenständen, hauptsächlich Beilen, eine weite Verbreitung zukommt. Damour führte zunächst die folgenden Fundorte an: Exideuil, Dep. Dordogne; Quiberon und Carnac, Dep. Morbihan; Cussac, Dep. Haute-Loire; Meudon, Dep. Seine et Oise; Chaumont, Dep. Yonne.[2] In einer zweiten Abhandlung wurde über Funde aus dem Thale von Mexico und der Umgegend von Oajaca berichtet,[3] und endlich auch noch derartig beschaffene Beile von Lyon; von Carcassonne, Dep. Aude, sowie von Antiochia beschrieben.[4]

H. Fischer zählte Chloromelanit-Beile auf von Schwetzingen bei Mannheim, Wehen bei Wiesbaden, Wesselingen zwischen Bonn und Köln, Monakam unweit Calw, Busseley Matt bei Niederried, unweit Aarberg, Oefeliplätze bei Geralfingen im Canton Bern.[5] Er erwähnt Scarabäen vom derselben Substanz aus Aegypten[6] und ist der Erste,[7] der ein Beil 'sogar' von Neu-Guinea anführt.[8] Als muthmassliche Heimath alle Vorkommen wird Hinter-Indien bezeichnet.

R. Virchow beschreibt ein Chloromelanit-Beil von Kloppenburg in Oldenburg.[9] Eine grosse Anzahl Fundorte bearbeiteten Chloromelanite führte O. Schoetensack an. Ausser den bereits erwähnten, werden die folgenden Vorkommen genannt:

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1 S. Franchi: Sopra alcuni giacimenti di roccie giadeitiche nelle Alpi occidentali da nell'Appennino ligure. Bolletin R. Comitato geologico (4) I. Roma 1900. p. 141 Chloromelanitit von Mocchie (Val di Susa) und p. 151 vom Wasserfall Visone bei Grognardo.

2 Sur la composition de haches et pierre trouvées dans les monuments celtiques en chez les tribus sauvages. C.R. LXI, Paris, 1865, p. 364.

3 Nouvelles analyses sur la jadéite et sur quelques autres roches sodifères. Bull. Soc. Min. IV, Paris 1881, p. 157.

4 Nouveaux essais sur la chlorомélanite. Bull. Soc. Min. XVI, Paris 1893, p. 57.

5 Nephrit und Jadeit nach ihren mineralogischen Eigenschaften etc. 2te Aus?, Stuttgart 1880, p. 376.

6 Ueber die mineralogisch-archäologische Beziehungen zwischen Asien, Europa und Amerika. Neues Jahrb. f. Min. 1881, II, p. 199.

7 Vergleichende Beobachtungen über die Form der Steinbeile auf der ganzen Erde. Kosmos. Zeitschr. f. Entwickelungsgeschichte X, 1881, p. 123.

8 Mineralogisch-archaeologische Beobachtungen. Corresp. Blatt d. Gesellsch. f. Anthropologie, Ethnologie und Urgeschichte XII. München 1881, N. 5, p. 35.

9 Das Vorkommen der flachen Jadeitbeile, namentlich in Deutschland. Verhandl. der Berliner Gesellsch. f. Anthopologie, Ethnographie und Urgeschichte, 1881 Berlin, p. 285.

Wangen (Württemberg), Edingen (Baden), Trier, Bieler-See, besonders bei Lattrigen, Robenhausen am Pfäffliker See, Neufchatel, Catanzaro (Calabrien), Athen, Delphi und Patras (Griechenland), Ephesus und Hierapolis (Klein-Asien).[10,11] Ueber einen Chloromelanit aus China hatte A.B. Meyer berichtet[12] und neuerdings wurde von F. Berwerth ein Beilchen von Cernikal im oesterreichischen Küstenland beschrieben.[13]

Da die Bewohner von Neu-Guinea zum grossen Theile noch heutigen Tages in der Steinzeit leben, darf es nicht Wunder nehmen, wenn ihre Geräthe und Waffen von Zeiten der meisten Reisenden und auch anderer Forscher Beachtung gefunden haben. Hinsichtlich der Deutung des Materiales gehen die Ansichten vielfach aus einander. Die Bestimmungen sind einestheils in der Regel vom Laien ausgeführt worden, anderentheils dürfte es aber kaum einem Zweifel unterliegen, dass auf der ausgedehnten Insel, sowie den ihr benachbarten Inselgruppen verschiedenartige Gesteine Verwendung gefunden haben.

Die ersten Steinäxte von Neu-Guinea wurden Ende des 17 Jahrhunderts von G.E. Rumphius beschrieben: 'een harde blaauwe steen als arduinsteen, gefatsoeneerd als een donderkeil, te weten beide einden toegespitst, in het midden een gat, daarin ze een houten steel steken'.[14] Salomon Müller erwähnt vom Utanata-Fluss, an der Südwestküste, eine Keule, die aus einem harten, feinkörnigem 'Hornstein' von graublauer Farbe verfertigt worden war.[15]

G.Royer hät das Material der Beile von der Humboldt-Bai für Serpentin oder Nephrit,[16] während dasselbe von J.H. Croockewit als 'amorphen Grünstein'[17] und von H. von Rosenberg sogar als Melaphyr bezeichnet wird.[18] In dem Berichte der Challenger-Expedition heisst es von demselben Vorkommen, dass die Beile aus Nephrit oder Grünstein oder aus einem Schiefer angefertigt würden.[19] H.N. Moseley

[10] Die Nephritoide des mineralogischen und des Ethnographisch-Prähistorischen Museums der Universität Freiburg im Breisgau. Zeitschrift für Ethnologie, XVII, Berlin 1885, p. 182-189 (auch Inaug. Diss. Freiburg im Breisgau, 1885, p. 27, 33.

[11] Nephritoid-Beile des Britischen Museums. Zeitschr. f. Ethnologie, XIX, Berlin 1887, p. 124, 128, 134.

[12] Jadeit- und Nephrit-Objecte. B. Asien, Oceanien und Afrika. Publicationen des K. Ethnogr. Museums zu Dresden III, Leipzig 1883, p. 46-48.

[13] Mittheilungen aus dem naturhistorischen Hofmuseum. Tschermak's Mineralog. und Petrogr. Mitthlg. XX, 1901, p. 358.

[14] Antwoord en rapport op eenige pointen uit name van zeker heer in 't vaderland, voorgesteld door den Edelen Heer Anthony Hurt, Directeur-Generaal van Nederlandsch Indië. Tijdschrift voor Staatshuishoudkunde en Statistiek XIII, Zwolle 1856, p. 129.

[15] Verhandelingen over de Natuurlijke Geschiedenis der Nederlandsche Overzeesche Bezittingen. Land- en Volkenkunde, Leiden 1839-1844, p. 18.

[16] Reis naar Nieuw-Guinea. Verhandelingen en berigten betrekkelijk het Zeewezen XXII, Amsterdam 1862, p. 75.

[17] Nieuw-Guinea, ethnographisch en natuurkundig onderzocht in 1858. Bijdr. tot de. Taal-, Land- en Volkenkunde (2)V, Amsterdam 1862, p. 142, 180.

[18] Der Malayische Archipel, Leipzig 1878, p. 478.

[19] Report on the Results of the Voyage of H.M.S. Challenger during the years 1873-76. Narrative I, pt. 2. London 1885, p. 684.

spricht von Jade, Grünstein oder Schiefer.[20] Zufolge R. von Willimoes-Suhm sollen die Steinhammer[21] aus einem serpentinartigen Gestein, die Beile dagegen aus Melaphyr bestehen.[22]

Ein ebenfalls von der Humboldt-Bai stammendes Beil wurde von A.B. Meyer beschrieben und in Uebereinstimmung mit der von A.Frenzel ausgeführten Analyse als Chlormelanit erkannt.[23] In Anschluss hieran möge noch erwähnt werden, dass aus Niederländisch-Neu-Guinea noch eine Reihe von Gerähten und Waffen beschrieben worden sind, ohne dass dabei eine Bestimmung ihres Materiales stattgefunden hätte.[24,25]

Was Deutsch-Neu-Guinea anbetrifft, so berichtet N. von Miklucho-Maclay, dass die Eingeborenen von der Maclay-Küste (östlich von der Astrolabe-Bai) die zur Anfertigung der Aexte erfordelichen Steine ('eine Art Achat') von den Bergbewohnern erhalten.[26]

Die Steinäxte der Eingeborenen am Angriffshafen bestehen, nach den Mittheilungen von M. Krieger aus Nephrit. Am Caprivi-Fluss, im Sechstrohfluss,[27] am Dallman-Hafen, auf der Insel Guap, sowie am Ramu-Fluss wurden ebenfalls derartige Waffen vorgefunden. Dagegen sollen die Aexte in der Gegend des Finsch-Hafens aus einem harten dioritischen Gestein verfertigt werden.[28] O. Finsch sagt, dass besonders Geschiebe von Diorit, Kieselschiefer, Basalt und amorphen Grünstein zu den Klingen Verwendung finden.[29]

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[20] Notes by a Naturalist of the 'Challenger'. London 1879, p. 439.

[21] Damit waren die Sagoklopfer gemeint, die in der Tat aus Serpentin und niemals aus Chloromelanit verfertigt werden. Steinhammer gibt es an der Humboldt-Bai nicht.

[22] Die Papuas der Humboldtsbai (Neu Guinea). Zeitschrift f. wissensch. Zoologie XXVI, Leipzig 1876, P.L XXXIX, auch Archiv für Anthropologie IX, Braunschweig 1876, p. 101 und Challenger-Briefe, Leipzig 1877, p. 162. O. Schoetensack hat dieses Material richtig als Chloromelanit bestimmt. Zeitsch. f. Ethnologie XIX, Berlin 1887, p. 134.

[23] Publicationen des K. Ethnogr. Museums zu Dresden III, Leipzig 1883, p. 51.

[24] C.M. Pleyte. De Praehistorische wapenen en werktuigen uit den Oost-Indischen Archipel, beschouwd uit een archaeologisch en ethnographisch standpunt. Bijdragen tot de Taal-, Land- en Volkenkunde (5)II. 's Gravenhage 1887, p. 596.

[25] F.S.A. de Clercq. Ethnographische beschrijving van de West- en Noordkust van Nederlandsch Nieuw Guinea, Leiden 1893, p. 225.

[26] Ethnologische Bemerkungen über die Papuas der Maclay-Küste in Neu-Guinea. Natuurk. Tijdschr. voor Nederl. Indië XXXV, Batavia 1875, p. 74; siehe ferner Beschreibender Catalog der Ethnographischen Sammlung Ludwig Biro's aus Deutsch-Neu-Guinea. Ethnographische Sammlungen des Ungarischen Nationalmuseums III, Budapest 1901.

[27] Dieser östlich von der Humboldt-Bai an der Nordküste mündende Fluss liegt, wie die Aufnahme der Kaiserl. Marine ergeben hat, bereits auf niederländischen Gebiet. Sein wirklicher Name ist Tami.

[28] Neu-Guinea, Berlin 1899, p. 154.

[29] Typen aus der Steinzeit Neu-Guineas. Ethnographischen Atlas zu den Samoa-Fahrten, Leipzig 1888. Auch Globus LIV, 1888, p. 371 und Mittheilungen der anthropologischen Gesellsch. XVII, Wien 1887, P. 14.

Aus Britisch-Neu-Guinea nennt L.M. d'Albertis Aexte, bezw. Keulen aus 'Grünstein' von Robert Hall's Sound,[30] sowie aus einem Dorfe am Fly-River.[31] Georg Seelhorst erwähnt Nephritbeile, die von der Süd-ostküste stammen.[32] An demselben Material sollen diejenigen von der Collingwood-[33] und von der Clowdybucht bestehen, während an der Holnicote-Bai aus Basalt verfertigte Klingen angetroffen wurden.[34] J.Chalmers und Wyatt Gill fanden am Laroki-fluss aus 'Jade' bestehende Beile.[35] Steinkeulen von der Südküste, besonders von Port Moresby stammend, bestehen, der Untersuchung von G.Linck zufolge, aus uralitisirten Diabas, bezw. Diabastuff.[36]Eine Reihe von Fundorten gibt O. Finsch an.[37]

In Betreff des Materiales der Steinwaffen auf den Neu-Guinea benachbarten Inseln, notiren wir die folgenden Angaben: Die Aexte auf der Hayter-Insel (Moresby-Archipel) bestehen nach J. Moresby aus einer Art Grünstein.[38] Die Aexte von der Dufaure-Insel sind laut der Mittheilung von d'Albertis aus einem harten, serpentinähnlichen Grünstein verfertigt.[39] Als Material der Steinklingen von Neu-Hannover, das mit demjenigen von Neu-Britannien übereinstimmt, nennt Finsch harten schwärzlichen Diabas und grünen Quarzit.[40] H.H. Giglioli beschreibt eine Axt von Kapsu, Neu-Mecklenburg (Neu-Irland) 'a hard dioritic Chloromelanite very like that of the axis of Dentrecasteaux-Island'.[41]

Vor einigen Jahren erhielt unser Museum von dem Utrechter Missionsverein einige Gesteine zum Geschenk, die der Missionar G.L. Bink in Jahre 1893, bei Gelegenheit eines dreimonatlichen Aufenthaltes an der Humboldt Bai, gesammelt hatte. Unter diesen Stücken befand sich ein kleiner Block, den der Reisende in dem am Santani-See gelegenen Dorfe Ajapo,[42] dessen Bewohner sich mit der Anfertigung

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[30] Dieser Fundort war bereits John Moresby bekannt. (Discoveries and Survey in New Guinea and the D'Entrecasteaux Islands, London, 1876, p. 176).
[31] New-Guinea I, London 1880, p. 407; II, p. 86.
[32] Australien in seinen Weltausstellungsjahren 1879-1881. Augsburg 1882, p. 396.
[33] Annual Report on British New Guinea 1 July 1890 – 30 June 1891. Brisbane, 1892, p. xxv. J.P. Thomson in British New Guinea, London 1892 p. 176 nennt die 'similar in colour to jade'.
[34] M. Krieger l.c. pag. 287, 288.
[35] Works and Adventures in New-Guinea, London 1885, p. 315.
[36] R. Semon. Im Australischen Busch und an den Küsten des Korallenmeeres. Leipzig, 1896, p. 368.
[37] Ethnologische Erfahrungen und Belegstücke aus der Südsee. Annalen des naturhistorischen Hofmuseums III. Wien 1888, p. 327.
[38] l.c. pag. 203.
[39] New Guinea I, London 1880, p. 194, 195.
[40] Ethnologischen Erfahrungen und Belegstücke aus der Südsee. Annalen des naturhistorischen Hofmuseums. III. Wien 1888, p. 103.
[41] Notes on a remarkable and very beautiful ceremonial Stone Adze from Kapsu, New-Ireland. Internat. Archiv f. Ethnographie III, Leiden, 1890, p. 183. Mit der obengenannte Dentrecasteaux-Insel dürfte wohl Morotau-Ferguson Island gemeint sein.
[42] Die ungefähre Lage dieser Ortschaft ist aus dem Kärtchen im Centrallblatt für Mineralogie etc. 1900, p. 649 zu ersehen.

von Steinäxten beschäftigen, erhalten hatte. Als Fundort wurde eine im Südosten des Sees gelegene Stelle namens Busnar genannt[43]

Aus der Form, sowie aus der oberflächlich rothen Färbung liess sich entnehmen, dass das Stück lose im Lateritboden gefunden worden war. Reste des Laterits stekkten noch in den kleine Höhlungen. Das Gestein ist so zähe, dass selbst ein kräftiger Stahlhammer wirkungslos an demselben abprallt. Nur durch Schrecken gelang eine Zertheilung in kleinere Stücke.[44]

Im frischen Bruche ist die Farbe durchaus keine schwärzliche- oder dunkelspinatgrüne, wie man dies allgemein an den bearbeiteten Objecten gewahrt, sondern vielmehr eine apfel- bis graungrüne.[45] Dabei ist das Gestein dicht und nur in dünnere Splittern kantendurchscheinend. Bemerkenswerther Weise treten in dem Grundteige zahlreiche kleine, kaum einen Duchmesser von 1.5 mm überschreitende glänzende, farblose Individuen von Albit auf. Ausserdem rlassen sich mit Hilfe der Lupe hier und da einige Granaten unterscheiden. Das spec. Gew., wurde zu 3,32 bestimmt, H = 6.

Unter dem Microscop gewahrt man eine schwach lichtgrünliche bis farblose Substanz von ziemlich gleichmässiger Beschaffenheit, In Folge der starken Brechungsvermögens erscheint die Oberfläche rauh; regellose spalten durchziehen Masse nach den verschiedensten Richtungen. Bei Anwendung polarisirten Lichtes beobachtet man ohne weiteres, dass ein Aggregat unzähliger und innig mit einander verfilzter Indviduen, die bald grösser, bald kleiner, aber stets unregelmässig begrenzt sind, vorliegt. In Folge der ausserordentlichen Zähigkeit des Materiales kann die gerade hier so erwünschte Dünne der Schliffe nicht erreicht werden, so dass die vielfach über einander gelagerten Individuen ihre optischen und morphologischen Eigenschaften nicht mit genügender Schärfe erkennen lassen. Indessen finden sich lokal Anhäufungen die

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[43] G.L. Bink. Drie maanden aan de Humboldtsbaai. Tijdschrift voor Ind. Taal-, Land- en Volkenk. XXXIX. 1896, p. 205. Leider wird in den verschiedenen Veröffentlichungen der Name jedesmal anders geschrieben. In den 'Berichten van de Utrechtsche Zendingsvereeniging voor het jaar 1894, VIII, p. 75', steht Rusmar und in 'Tijdschr. v.h. Kon. Nederl. Aardr. Genootsch. (2) XI, 1894, p. 331', wird die Stätte Rusman genannt.
Einen anderen Fundort giebt F.S.A. de Clercq an. In der Wiedergabe des Namens hat jedoch der Druckfehlerteufel abermals sein Unwesen getrieben. Einmal heisst derselbe Kajo (De Indische Gids XI, 2, 1889, p. 1266.), ein anderer Mal aber Kabo (Tijdschr. v.h. Kon. Nederl. Aardrijksk. Genootsch. (2) X., 1893, p. 994).
In einem am 22 Octb. 1902 in Amsterdam gehaltenen Vortrage theilte Baron van Asbeck mit, dass hinter Ormu, über einen Tagesmarsch entfernt, zwischen Humboldt- und Tanah-Mera-Bai, sich Steinbrüche befinden, in welchen das zu den Beilen dienende Material gewonnen wird. (Algemeen Handelsblad Amsterdam, 22 octb. 1902. Avond-uitgave, eerste blad.).

[44] Bink erwähnt (l.c. pag. 205), dass die Aexte von Seiten der Eingeborenen durch Klauben, spalten und Schleifen hergestellt werden. Leider wird der ganze Vorgang nicht näher beschrieben, denn es wäre wohl der Mühe werth gewesen zu erfahren, welche Kunstgriffe angewendet werden, um des so ungefügen Materials Herr zu werden.

[45] Bereits beim Netzen mit Wasser nimmt das Gestein eine dunklere Färbung an und noch mehr ist dieses beim Anschleifen der Fall. Augenscheinlich ist er das Eindringen fettiger Substanzen, welches diesen Beilen den dunklen Farbenton verleiht.

aus grösseren Körnchen bestehen, und welchen Gestalt durchweg eine unregelmässige ist, so lassen doch Spaltungsrichtungen und Auslöschungsschiefen (32-38°) deutlich erkennen, dass hier ein Pyroxen vorliegt. Der Durchmesser der einzelnen Körnchen schwankt zwischen 0,08 und 0,25 mm. Ein Pleochroismus war nicht wahrnehmbar. Der optische Charakter ist derselbe wie der des Jadeit, nämlich + gegen die Optische Mittellinie. Die Individuen erweisen sich im Bezug auf die Optische Verhältnisse als monoklin. Querschnitte gegen die Längenrichtung zeigen die Auslössung symmetrisch zu den Spaltungrichtungen im spitzen Winkel, nämlich 42-44°.

Als zweiter Gemengtheil ist der Albit hervorzuheben, dessen wasserklare Durchschnitte sich bereits im Folge den weit niedrigeren Brechungsexponenten von dem umgebenden Pyroxen abheben. So scharf sich auch die Individuen makroskopisch hervorheben, so wenig ist dies bei mikroscopischer Betrachtung der Fall. So dringen nämlich von allen Seiten die Pyroxene randlich in die Albitmasse ein. Dieselben sind als Einschlüsse überhaupt in grosser Zahl vorhanden und weisen auch zuweilen eine zonenförmige Anordnung auf. Diese Individuen, welche bis zu grosser Kleinheit herabsinken, besitzen meistens gerundete Contouren, wobei die Säulenform jedoch vielfach deutlich erkennbar ist. Die kleineren Gestalten erinneren vielfach an diejenigen des Salits. Ausser wenigen braunlichgrünen Säulchen werden im Albit nur noch hier und da ausserordentlich winzige Flüssigkeitseinschlüsse angetroffen.

Der Albit erscheint fast ausschlieslich in Gestalt einfacher Individuen, doch fehlen polysynthetische Zwillinge nicht ganz.

Als einen ferneren Gemengtheil erkennt man in den verschiedenen Präparaten, in wechselnden Mengenverhältnissen, den Granat, der im Gegensatz zu den beiden vorhergehenden, stets in wohlbegrenzten, meist sechszeitigen, Durchschnitten erscheint. Dieselben besitzen eine schwache, etwas röthlichgelbliche Färbung und sind durchaus optisch-isotrop. Gleich wie die Albit beherbergt er zahllose Einschlüsse, die parallel dem ausseren Rande eingelagert, aber von demselben durch eine fast einschlussfreie Zone getrennt sind. Die Interpositionen bilden auch hier wieder den oben beschriebenen Pyroxen.

Endlich findet man hier und da ein vereinzeltes Individuum von Titanit, sehr klein und von keilförmiger Gestalt.

Herr Dr. Krug in Berlin hatte die Güte eine Analyse des von makroscopischen Einsprenglingen moglichst befreiten Gesteines durchzuführen (I), unter II findet sich das Resultat derjenigen van A. Frenzel.

	I.	II.
SiO^2	57,06	56,80
Al^2O^3	19,22	16,25
Fe^2O^3	7,69	—-
FeO	0,34	7,53
MnO	0,18	Spur
CaO	0,94	5,60
MgO	0,14	3,13
Na^2O	13,66	12,06
K^2O	0,44	—
H^2O	—	0,25
	99,67	101,62

Es wurde nun versucht auf Grund des mikroscopischen Befundes eine Berechnung der zuerst angeführten Analyse vorzunehmen. Dabei wurden zunächst die geringen Mengen von FeO, CaO, MgO und MnO dem Granat zugewiesen, die in isomorphen Mischungen eines Thonerdegranats vorhanden angenommen wurden. Das gesammte Eisenoxyd gelangte als einer dem Jadeit isomorphen Mischung zur Berechnung. Schwieriger war es dagegen den Jadeitantheil zu ermitteln, da ja auch der Albit ein Natrium-Aluminiumsilicat darstellt. Unter Berücksichtigung der Resultate anderer Analysen musste angenommen werden, dass der Zusammensetzung des *Minerals* Chloromelanit am meisten entsprechen würde die Annahme[46] einer Verbindung bestehend aus 3 Mol. des Jadeit $Na^2Al^2Si^4O^{12}$ und 1 Mol des analogen Eisensilicats $Na^2Fe^2Si^4O.^{12}$ Der Rest wurde auf Feldspath berechnet unter Zugrundelegung des noch Berechnung verfügbaren Antheils an Thonerde. Das Ergebniss war, dass sich dabei ein Ueberschuss von 0,72 % SiO^2 und ein Deficit von 0,07 % Na^2O herausstellte.

Eine übersichtliche Darstellung der Berechnung findet sich auf der nebenstehenden Tabelle [see Fig. 6]. Man darf wohl behaupten, dass die Uebereinstimmung zwischen dem mineralogischen Befunde und dem Analysenresultat eine sehr zufriedenstellende ist.

Für den idealen Chloromelanit würde sich also die folgende Zusammensetzung ergeben:

SiO^2	57,53
Al^2O^3	18,95
Fe^2O^3	8,65
Na^2O	14,87
	100,00

entsprechend $3Na^2Al^2Si^4O^{12} + Na^2Fe^2Si^4O^{12}$

Die von P. Groth vorgeschlagene Formel[47] $(Na,^2\ Fe,Ca,Mg)^6(Al^2)^2Si^{15}O^{42}$ hat jedenfalls ihre Berechtigung eingebüsst, da es keinem Zweifel mehr unterliegt, dass die übrigen unter dem Namen Chloromelanit beschriebenen Mineralien grösstentheils mechanische Gemenge darstellen.

Damour hatte bereits in seiner ersten Abhandlung hervorgehoben, dass mehreren der von ihm untersuchten Vorkommen Granat beigemengt waren.[48] In seiner letzten Arbeit ging er sogar soweit, wie ich glaube mit Unrecht, in dem Chloromelanit ein dem Eklogit verwandtes Gestein zu erblicken.[49]

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[46] C. Hintze (Handbuch der Mineralogie II, Leipzig 1897, p. 1175) giebt in Folge eines Druckfehlers 25,56 statt 25,26 % Al^2O^3 an.

[47] Tabellarische Uebersicht der Mineralien. 3 aufl. Braunschweig 1889, p. 131; NB! 4 aufl. 1898, p. 147. Chlormelanit ein Jadeït in dem ein Theil des Al durch Fe ersetzt und ausserdem etweas Ca und Mg enthaltend.

[48] l.c. pag. 366.

[49] l.c. pag. 57.

	SiO^2	Al^2O^3	Fe^2O^3	FeO	MnO	CaO	MgO	Na^2O	K^2O	
Chloromelanit	39,70	16,85	—	—	—	—	—	10,47	—	88,94
	11,55	—	7,69	—	—	—	—	2,98	—	
Albit	3,35	0,95	—	—	—	—	—	0,58	—	5,97
Orthoklas ...	0,17	0,48	—	—	—	—	—	—	0,44	
Granat	1,01	0,57	—	—	—	0,94	—	—	—	4,11
	0,28	0,16	—	0,34	—	—	—	—	—	
	0,16	0,12	—	—	—	—	0,14	—	—	
	0,12	0,09	—	—	0,18	—	—	—	—	
Rest	÷0,72	—	—	—	—	—	—	÷0,07	—	0,65
Summe	57,06	19,22	7,69	0,34	0,18	0,94	0,14	13,66	0,44	99,67

Figure 6 Calculation of the chloromelanite composition and formula using the whole rock analysis I and the major mineral phases present in the rock. Original table made by C.E.A. Wichmann.

Es läge ausserordentlich nahe eine Berechnung aller Chloromelanitanalysen durchzuführen,[50] um auf diesem Wege ihre mineralogische Zusammensetzung zu ermitteln. Wenn ich hierauf Verzicht leisten muss, so liegt daran, dass die Ergebnisse im Einzelnen doch zu sehr von einander differiren. Auch ist er sehr wahrscheinlich, dass die mineralogische Zusammensetzung der verschiedenen Funde auch nicht einmal qualitativ diegleiche ist. Eine Berechnung ist daher mit Aussicht auf Erfolg nur dann möglich, wenn zugleich brauchbare mikroscopische Analyse vorliegt.[51] In dieser Hinsicht gewähren aber die bisherigen Untersuchungen geringe Befriedigung.

H. Fischer wollte aus dem Umstande dass er in den ihm vorliegenden Präparaten 'schon mikroskopische dieselben winzigen, gelblichen, mineralogische im Dünnschliff nicht näher bestimmbaren Flitterchen wie im Jadeit beobachtete und unter

[50] Eine vollständige Uebersicht derselben gab C. Hintze (Handbuch der Mineralogie II. 1897, p. 1176), weshalb darauf verwiesen werden kann. Seitdem hat S. Franchi noch die Analyse des Chloromelanitgesteins vom Mocchie im Sasathal veröffentlicht (l.c. pag. 143).

[51] Aus diesem Grunde habe ich es auch unterlassen in eine Discussion der Frenzel'schen Analyse zu treten. Ein Irrthum liegt insofern hier vor, als das Eisen als FeO und nicht als Fe^2O^3 eingesetzt worden war.

dem Mikroskop ausserdem im Dünnschliff allerlei andere Interpositionen wahrnahm, welche kleine Modificationen in den Analysen leicht herbeiführen können' den Chloromelanit mit dem Jadeit geradezu identificiren und den ersteren nur als Varietäten namen gelten lassen.[52] Wenige Seiten weiter[53] wird jedoch ein Chloromelanit von unbekannter Herkunft mit nur 5,9 % Na^2O+K^2O beschrieben, der mikroscopisch durch das Auftreten 4- und 6-seitiger Durchschnitte (Granat?), sowie vieler ziemlich grosse Körner und Striemen von Magnetit karakterisirt ist. 'Das Gewebe der Grundmassa ist verschindend fein, kurzfaserig?.'

Ein mexikanischer Beil liess in einer licht olivengrünen Grundmasse 'mit nicht erkennbarer Textur' eine unzählige Menge feiner Strichelchen und dann vereinzelte farblose, stets mit dunkleren Kern versunkene Krystalldurchschnitte von hexagonalem, selten quadratischen Umriss wahrnehmen. Die Letztgenannten wurden, wohl mit Recht, für Granat angesehen.

Im Schliffe eines Beiles von Schwetzingen wurde eine 'schmutzig hellgrüne, grob- und verwarren fasrige Grundmasse, worin eine Menge kurzen, dicker oft zugespitzter Strängelchen einzeln eingestreut sind…, winzige Magnetitkörnchen sind dazwischen streifenweise eingelagert.'

Auch in zwei mexicanischen Beilen erwies sich die 'tiefgrüne, äusserst feinfasrige Grundmasse ganz erfüllt mit streifenweise vertheilten Magnetitkörnchen.'

In einer weiteren Mittheilung bemerkt derselbe Autor, dass er von dem Jadeit so nahestehenden Chlormelanit viele Schliffe angefertigt habe, 'es ist aber dessen Textur so fein und verworren faserig, dass es nur bis jetzt nicht gelang, seine optischen Eigenschaften, die sich zunächst als Aggregatpolarisation manifestiren, näher zu prüfen'.[54]

P. Lohmann glaubte Beziehungen zum Omphacit erkannt zu haben. 'Er (der Omphacit) ist auch wieder ganz eigenthümlich; er zeigt selten Sprünge, eine Spaltungsrichtung ist gar nicht festzustellen, er kommt des gleichmässingen Grundmasse der Chloromelanits nahe'.[55]

F.H. Hatch meint bei Gelegenheit der Beschreibung eines Aktinolithgesteines, dass dasselbe sich durch den Gehalt an Magnetit denjenigen Jadeitvarietäten(Pyroxennephrit) nähere, welche man als Chloromelanit bezeichnet habe.[56]

A.Lacroix bekundet, dass der Chloromelanit dieselben optischen Eigenschaften besitze, wie der Jadeit[57] und A. Arzruni sagt endlich, dass ein Gleiches hinsichtlich der Struktur bei der Mineralien der Fall sei.[58] F. Berwerth sagt, dass die Körner des von ihm untersuchten Vorkommen 'vollständig mit dem Verhalten des Chloromelanit'

[52] Nephrit und Jadeit etc, p. 376.
[53] l.c. pag. 394.
[54] Mikroskopisch-mineralogische Miscellen. Zeitschr. f. Krystallogr. IV. Leipzig, 1880, p. 372.
[55] Neue Beiträge zur Kenntnis des Eklogits vom Mikroskopisch-mineralogischen und Archaelogischen Standpunkte. N. Jahrb. f. Min. 1884. I, p. 108.
[56] Ueber den Gabbro vom Wildschönau in Tirol und die aus demselben hervorgegangenen schiefrigen Gesteine. Tschermak's Min. und Petrogr. Mitthlg. VII. 1886, p. 81.
[57] C. Hintze. Handbuch der Mineralogie II, p. 1176.
[58] Minéralogie de la France. I Paris. 1893-1895, p. 616.

(Welches?) übereinstimmen. Ausser Rutilstaub in dem Kern vieler Körner, auch sonst sehr viel gelblich gefärbter Rutil, einige wenige gerundete Körner von Granat und einmal ein Blatt eind Glimmerminerals.[59]

In Betreff der Beziehungen des Chloromelanits zu anderen Gesteinen anbetrifft, haben H. Fischer, P. Lohmann, A. Damour und S. Franchi[60] auf eine Verwandschaftr mit den Eklogiten hingewiesen und zwar wegen des häufigen Granatgehaltes, sowie wegen der vermeintlichen Aehnlichkeit zwischen *Omphacit* und Chloromelanit. A. Lacroix gab darauf hin geradezu dem Gedanken Ausdruck, dass mit Bezug auf die Herkunft der in Frankreich gefundenen Steinbeile, der Chlormelanit (wie der Jadeit) in Gneissgebiet dieses Landes gesucht werden müsse.[61]

Von den vielen Hunderten und aber Hunderten von Nephrit-, Jadeit-, und Chlormelanitgegenständen hat man, soweit Europa in Betracht kommt, noch niemals das dazu gehörige Gestein im Anstehenden gefunden, wohl aber sind, wenigstens Nephrite und Jadeite wiederholt als Geschiebe erkannt worden. Er kommt mir vor, als ob die Menschen zur Steinzeit das zur Anfertigung ihrer Gerähte benöthigte Material auch Geröllablagerungen entnommen haben. Der Zwang der Verhältnisse schärfte ihren Blick und befähigte sie das geeignetste Material leicht zu erkennen. Diese Fähigkeit ging den Nachkommen, die er nicht mehr nöthig hatten, verloren. Wer sich heutzutage aber die Kenntniss erwirbt über das Material aus dem Steinwaffen angefertigt wurden, von anderem leicht zu unterscheiden, der wird wichtigere Ziele ins Auge fassen, als eine unter *allen* Umständen doch recht ergebnissarme Durchforschung der unendlich vielen Schotterablagerungen vorzunehmen. Durchaus unthunlich erscheint auch eine Herkunft der Geräthe aus entfernten Gegenden anzunehmen. Derartige Gebrauchsgegenstände konnten nicht einmal während einer Generation vorhalten, so dass ein häufig Ersatz unvermeidlich war. Die Verkehrsmittel waren zu jener Zeit aber doch viel zu mangelhaft, um derartige Gegenstände, deren die *ganze* Bevölkerung bedurfte, auf weite Strecken zu transportieren. *Verte*!

Da es F. Nötling geglückt ist den Jadeit im Anstehenden und zwar in Birma zu finden, so sind dessen Mittheilungen auch in Bezug auf die Chloromelanitfrage von Wichtigkeit.[62] Es wurde zunächst festgestellt, dass der Jadeit im innigen Verbande met Serpentin auftritt. Beide Gesteine werden auf allen Seiten von tertiären Sandsteinen umgeben, welches Verhältniss, zufolge Nötling, zweierlei Deutung zulässt. Entweder halten Serpentin und Jadeit zur Zeit des Absatzes der Tertiären Schichten bereits eine Kuppe gebildet, um welche herum die miocänen Sandsteine sich ablagerten oder aber der Serpentin ist eruptiven Ursprungs und dann müsste der Durchbruch in tertiären Zeit erfolgt sein und wäre der Jadeit als eine aus grössere Tiefe mit gerissenen Scholle zu betrachten. An späterer Stelle wird noch gesagt, dass die intrusive Natur aller der

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59 l.c. Pag. 359.
60 S. Franchi: Sopra alcuni giacimenti di roccie giadeitiche nelle Alpi occidentali da nell'Appennino ligure. Bolletin R. Comitato geologico (4) 1. Roma 1900. p. 130.
61 l.c. pag. 615.
62 Ueber das Vorkommen von Jadeit in Ober-Birma. N. Jahrb. f. Min. 1896. I, p. 15.

Serpentinvorkommen durch schwerwiegende Gründe gestützt werde und knüpft daran anschliesend die Frage ob der Jadeit vieleicht nicht als eine unter besonderen Umständen erfolgte Abkühlungsmodification des Serpentins darstelle.

Zu einem ganz entgegensetzten Resultat gelangte Max Bauer durch die Untersuchung der von Nötling gesammelten Gesteine. Er erkannte, dass neben dem Serpentin auch ein Albit-Horblende-gestein und ein Hornblende(Glaukophan)-schiefer als Begleiter des Jadeit auftreten.[63] Bauer möchte er für das naturgemässeste halten, 'dass die ganze Jadeitführende Gesteinsreihe eine von Tertiärschichten mantelförmig umgelagerte… Kuppe eines Systems krystallinischer Schiefer zu halten'.[64] Den Ausgangspunkt dieser Betrachtungen hatte der Glaukophan gebildet, von dem vorausgesetzt was, dass immer im Gneiss und Glimmerschiefer eingelagert gefunden worden sei. Diese Annahme kann heutzutage nicht mehr aufrecht erhalten werden, da geradezu im Laufe des letzten Jahre Beispiele bekannt geworden sind, welche eine Glaukophanisirung in Serpentin und Gabbrogesteinen darzu thun vermochten.

Was nun das Vorkommen des Chloromelanits betrifft, so ist von den in seiner unmittelbaren Nachbarschaft vorkommenden Gesteinen nichts bekannt. Wir wissen aber, dass in der Nähe nämlich zwischen dem Santani-See und der Humboldt-Bai Olivingesteine und damit zugleich Serpentin, Diabas und wahrscheinlich auch Olivingabbro auftreten.[65] Es erscheint nicht allzu gewagt die Vermuthung auszusprechen, dass die erwähnten Olivingesteine sich in das im Süden anschliessende Hügelland fortsetzen, so dass das Auftreten des Chloromelanit dem des Jadeit in Birma entspräche. Freilich sind die Serpentine von Neu-Guinea, wie auch von übrigen Theilen des Indischen Archipels sicher praetertiär, wie schon aus den wiederholten beobachteten Zusammenvorkommen mit Diabasen hervorgeht.

Was die genetischen Beziehungen des Chloromelanits zu den genannten Gesteinen anbetrifft, so hat Nötling bereits für den Jadeit zwei Möglichkeiten in Betracht gezogen. Für die Annahme, dass Jadeit (und Chloromelanit) eine aus grösserer Tiefe emporgerissenen und metamorphosirte Scholle darstelle, würde wenigstens bei dem letztgenannten das Auftreten des Granats, sowie das ausserordentlich beschränkte Vorkommen dieser Gesteine sprechen. Aber noch ein anderes Moment tritt hinzu. Es ist eine auffällige Erscheinung, dass auch der harte und zähe, den Jadeiten, in seiner aüsseren Erscheinungsform, so sehr gleichende Nephrit – wo anstehend gefunden – im Contact oder als Einschluss der Serpentin gefunden wird.[66]

Dass der Jadeit bezw. der Chloromelanit 'eine Abkühlungsmodification des Septentins' nicht ohne Weiteres repräsentieren kann, erhellt bereits aus der gänzlich

[63] Der Jadeit vom Tammaw. N. Jahrb. f. Min. 1896. I. p. 18.
[64] l.c. pag. 50.
[65] Ueber einige Gesteine der Humboldt-Bai, in. litt.
[66] H. Traube. Ueber deb Nephrit von Jordanemühl in Schlesien. N. Jahrb. f. Min. Beil. Bd. III. 1884, p. 142.; A. Diesseldorff. Ueber Nephrit, darunter in situ von Neu-Seeland. Sitzgber.d.Ges. 2. Bef. d. Ges.Naturw. Marburg 1901. p. 50; Centralblatt f. Min. 1901. p. 357, wo auch noch weitere Beispiele angeführt werden.

abweichenden chemischen Zusammensetzung derselben. Wohl aber könnten sie verschiedene Spaltungsproducte des Gabbromagma's darstellen.[67]

Aber ein dritte Möglichkeit ist nicht ganz von der Hand zu weisen, nämlich wenn man die Jadeit-Pyroxeniten als Vertreter bisilicatischer Magmen,[68] die aus alkalischen Pyroxenen oder Amphibolen bestehen, eine Selbständigkeitzuerkannt. Auf diesen Punkt hat kürzlich F. Von Loewinson-Lessing in jüngster Zeit hingewiesen.[69]

Wie dem auch sein möge, das Wichtigste bleibt die Ermittelung eines Vorkommens des Chloromelanits, womit die Möglichkeit gegeben ist, in absehbaren Zeit, eine Reihe wichtiger Fragen der Beantwortung zuzuführen. [This last sentence was crossed out by Wichmann].

1 septh. 1901.

[67] Ich schliesse mich durchaus der von W.S. Bayley (The Basic Massive Rocks of the Lake Superior Region. Journ. of Geology. ii. Chicago 1894, p. 814) ausgesprochenen Ansicht an, dass bei Olivingesteine durch Differentiation des Gabbromagma's entstanden seien. Dieselbe bietet die beste Erklärung für das so ausserordentlich verbreitete Zusammenvorkommen des Gabbro und Serpentine.

[68] Gegen die Existenz 'mono-tektischer Magmen' könnten mancherlei Einwande erhoben werden.

[69] Kritische Beiträge zur Systematik der Eruptivgesteine. Tschermak's Mineralog. Petrogr. Mitthlg. xx. Wien 1901, p. 115.

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