

# **Dr Margaretha Brongersma-Sanders (1905-1996), Dutch scientist: an annotated bibliography of her work to celebrate 100 years since her birth**

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Dr Margaretha Brongersma-Sanders, palaeontologist, pioneer geochemist, geobiologist and oceanographer, Officer of the Order of Oranje Nassau was born 100 years ago (February 20th, 1905) in Kampen in The Netherlands. The fields of research that she covered during her lifetime include taxonomy of recent and fossil, principally freshwater fish; “fish kills” and mass mortality in the sea (especially of fish); taphonomy and preservation of fish; upwelling; anoxic conditions, linked to fish mortality and the origin of bituminous black shales and oil; red tides and harmful algal blooms; trace metal enrichment in recent and fossil sediments, especially the Kupferschiefer; the origin of evaporites; algal mats and stromatolites. She was the first to categorise fish mass mortality, emphasizing algal blooms (red tides) and their importance in forming fish-bonebeds and noting their input to oil production especially in open sea upwelling sites. On this basis she spent a decade or more in the 1950s and 60s as a consultant to Shell and became a member of the Dutch Academy of Science Commission on Sea Research. Her major 1957 review is a famous classic in this field. She managed to keep her scientific interests and intellectual life alive at a time when being married and having children and conducting scientific research were not the norm; she even maintained a reasonable scientific career of sorts for the next 50 years, even after official retirement publishing her last scientific paper in 1992. Despite these achievements, which she did on her own terms, when Brongersma-Sanders died in 1996 the fact was hardly mentioned in the scientific press or to the worldwide community.

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## **Brief biography**

‘Greet’ Sanders (fig. 1) was an exceptional and strong-willed woman who emerged from her early 20th century provincial and somewhat sleepy and strict, Dutch-reformed



Fig. 1, Portrait photo of Margaretha 'Greet' Brongersma-Sanders (1905-1996) in middle age; photo courtesy of the Van der Eb-Brongersma Family Archive.

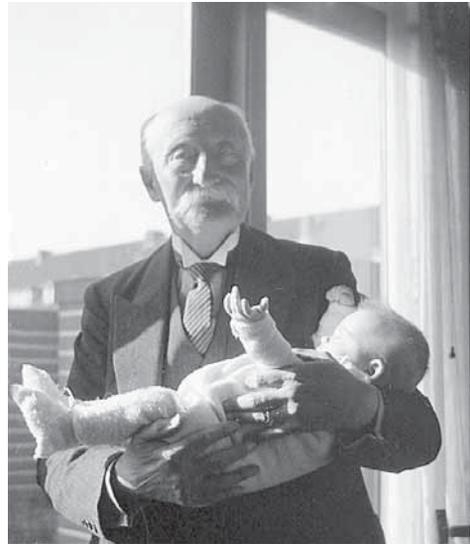


Fig. 2, Her father biology teacher, Herman Hendrik Sanders, 17 April 1862 (Kielwindeweer) - died 22 July 1937 (Bergen); photo courtesy of the Van der Eb-Brongersma Family Archive.

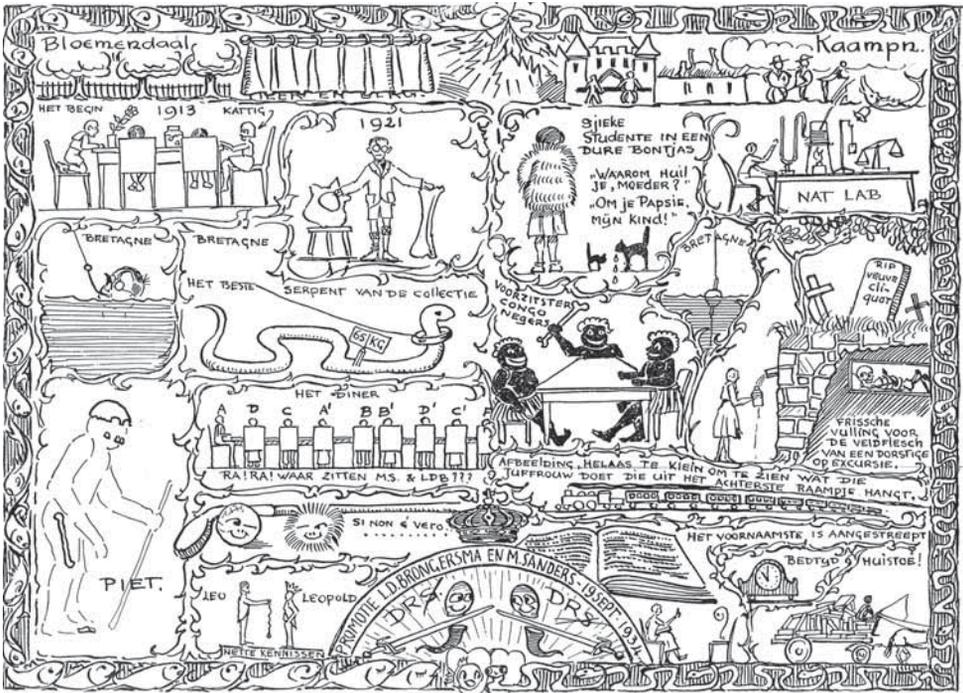


Fig. 3, Family cartoon accompanying theses defences of Greet Sanders and Leo Brongersma featuring 'Piet', an interpretation of Dubois' *Pithecanthropus*; photo courtesy of the Van der Eb-Brongersma Family Archive.

hometown of Kampen to become a well-known scientist both in The Netherlands and internationally. Margaretha came from scientific stock with her grandfather Hieronymus Sanders and father Herman Hendrik Sanders (fig. 2) both graduates from the University of Groningen and thus she was raised in a scientific environment. Showing a certain assertiveness, and contrary to her parents' wishes for her to acquire a 'respectable' girl's education, without notifying her parents, in her twelfth year she cycled up and enrolled herself at Kampen Stedelijk Gymnasium. There, undoubtedly influenced to some extent by her father, who was the biology teacher, she gained her national level Gymnasium B examination certificate on June 9, 1923 (aged 18). This gave her requisite marks to enter the University of Amsterdam, which she did later that year, majoring in botany, zoology and palaeontology in 1929 (fig. 4).

Zoologist Lieven Ferdinand de Beaufort (1879-1968; Engel et al., 1969), expert on zoogeography especially of the Indonesian Archipelago became her supervisor for doctoral research. Through him Margaretha became involved in the study of zoogeography of the Indonesian Archipelago and the systematics of fossil and recent freshwater fishes from the East and West Indies. Her doctorate on Early Tertiary freshwater fishes from mid-Sumatra (Sanders, 1934) was awarded *Cum Laude* on 19th September 1934, one hour before, and dedicated to, her husband-to-be Leo Daniel Brongersma, later Professor of Systematic Zoology and Director of the National Natural History Museum at Leiden (now Leiden Naturalis) was awarded the doctors degree. She had met her fiancée during their undergraduate days and their relationship was fostered through the auspices of one of de Beaufort's teachers, Dutch palaeoanthropologist Eugène Dubois who had recommended Leo to her as a quiet, suitable husband when she took a 3-month cataloguing job on the Dubois collection in late 1932 (Shipman, 2001). They married once they had obtained their doctorates (figs 3, 5) and moved to Leiden, where Leo had a post as Assistant Curator at the National Natural History Museum (Holthuis, 1995). Their first child was born in October 1935. Although Greet was a very conscientious mother, motherhood did not stop her interest and activity in science.

Her Ph.D. on fossil fish from Indonesia is still a basic pioneer reference because this is a poorly understood part of the world geologically and palaeontologically and it prompted her to consider how the fish such as she had described could be so well preserved. In late 1938 Greet accompanied her husband and other Dutch scientists (e.g., Benthem-Jutting, 1968) on an official extended trip to South Africa to visit museums, laboratories and nature reserves. During an apparently serendipitous visit to Walvis Bay (also known as Walfish Bay, now in Namibia) on 24 November, she witnessed one of the regularly occurring fish mortalities in December – January caused by upwelling currents often at times of El-Niño-related climatic change. She was impressed by the huge walls of dead (and smelling) fish tossed on the beach (fig. 6). This experience gave her some answers to the taphonomical questions she had raised in her thesis and spurred her on to become a pioneer and world expert on mass mortality events (e.g., Richter, 1950; Brongersma-Sanders, 1957). Thus began the life-long study investigating the cause and effect of this phenomenon, the importance of upwelling water, the related biological and oceanographical factors, and the genesis of petroleum.

She was based in Leiden from 1934, first as wife and mother, later in 1947 gaining a position as an assistant in the University of Leiden Geological and Mineralogical Institute rising to a permanent position and finally a Senior Research Fellow by the time



she retired in 1970. Many of her papers give her institutional address as the “Geologisch en Mineralogisch Instituut, University of Leiden, then at Garenmarkt 1b”, to which the ‘Rijksmuseum van Geologie en Mineralogie’, now part of Leiden Naturalis (Winkler Prins, 2001), was closely linked. After a few shorter papers in Dutch and English on fish kills related to upwelling in open sea areas (Brongersma-Sanders, 1943, 1945, 1947b) in 1948 her first review of fish kills, “The importance of upwelling water to vertebrate paleontology and oil geology”, which dealt with the occurrence of upwelling water, red tides and mass mortality, was published in English in a journal of the Royal Netherlands Academy of Arts and Sciences. This would lead to her appointment as a scientific advisor or consultant to the Royal Dutch Shell Oil Company at their Exploration and Production Laboratory, at Rijswijk, during the fifties and sixties. In the following years her field of interest extended to studies to try and understand the relationship between the role of hydrogen sulphide and the accumulation of certain metals in bituminous shales and the origin of oil (e.g. Brongersma-Sanders, 1944, 1952, 1966a, b).

In 1962 she took the initiative for an interdisciplinary investigation of the Ria de Arosa marine embayment area in Galicia, north-western Spain, also an area with upwelling and red tides (Margalef, 1956), but on a much smaller scale than in Walvis Bay. A multidisciplinary team of students in oceanography, biology, geology, ecology and chemistry took part in this project (fig. 7), initiating several theses, including that of her unofficial student, Gerhard C. Cadée (1968), under the supervision of Professor Dr A. Brouwer (fig. 9); Wytze S. Koldijk (1968), supervisor Professor Dr A.J. Pannekoek; and Leonard Otto (1975), supervisors Professor Dr R. Dorrestein and Professor Dr P. Groen. This was the first such venture of its type in The Netherlands. Unfortunately, the general report given by her husband and colleague (Brongersma & Pannekoek, 1966) does not award her the position she deserved as she was neither co-author nor recognised for the role she played. She herself did not write formally on this work.

Again, in 1968 she used her growing influence with Shell to set up a field research programme this time returning to Walvis Bay after 30 years to sample the sediments and test her hypothesis regarding the relationship of upwelling sites, the “azoic zone”, and oil production. Combining with Dr Doeke Eisma, then of the Netherlands Institute

Fig. 4. University of Amsterdam student excursions with biologist/lecturer Prof. Theo J. Stomps. All from the archives kept in the library of the Biology Department, University of Amsterdam, courtesy Dr Marga Coesèl.

- a: Switzerland-Italy 1928, at Diavolezza, Greet Sanders is 4th on the right.
- b: Piz Alf in the Alps, 1928; Greet is on the right side.
- c: Excursion to France, 1929, picture taken near the Eiffel Tower, Paris. Greet Sanders is standing on the left. Leo Brongersma 7<sup>th</sup> from left. Prof. Stomps 5<sup>th</sup> from right. 1 M. (Greet) Sanders, 2 J.A. (Fientje) Leliveld, 3 H.W. Doornink ???, 4 A.E. (Liesje) van Bremen, 5 G. van der Torren, 6 W.F.H. Stroer, 7 L.D. Brongersma, 8 J.H. van Meer, 9 A. van der Werff, 10 F.J. Waage, 11 Prof. Dr Th.J. Stomps, 12 C.O. van Regteren Altena, 13 W.J. Lütjeharms, 14 J.D. Vis, 15 E.M. van Zinderen Bakker.
- d: At a French (?) railwaystation during Normandy-Brittany excursion, 1929; Greet Sanders is 8<sup>th</sup> from left, Leo Brongersma 3<sup>rd</sup> from left. 1. J.H. van der Meer, 2. W.F.H. Stroer, 3 L.D. Brongersma, 4 A.E. (Liesje) van Bremen, 5 G. van der Torren, 6 C.O. van Regteren Altena?, 7 W.J. Lütjeharms, 8 M. (Greet) Sanders, 9 A. van der Werff, 10 Prof. Dr Th.J. Stomps, 11 H.W. Doornink, 12 E.M. van Zinderen Bakker, 13 F.J. Waage, 14 J.A. (Fientje) Leliveld, 15 J.D. Vis?
- e: Jena (Germany) 1930 ‘On the Inselberg’, Greet Sanders in the middle with black cap.



Fig. 5. Margaretha and Leo Daniel Brongersma on their wedding day in Amsterdam (30th October 1934); photo courtesy of the Van der Eb-Brongersma Family Archive.



Fig. 6. The shoreline at Walvis Bay, Namibia, after a mass-death of fishes pre-1931 modified from Richter (1950).

for Sea Research (NIOZ), and with financial and technical support from The Netherlands Organization for the Advancement of Pure Research, The University of Leiden and Shell, she went from December 22, 1968 to January 31, 1969 to S.W. Africa (Namibia). The expedition had at its disposal a brand new oceanographic vessel, the R.S. "Benguela" of the Marine Research Laboratory at Walvis Bay. Numerous cores were taken from the boat of the sediment on the sea bottom by Eisma and the Shell technician L. Spaans and Eisma made a large number of observations on seawater, sediment etc. (Brongersma-Sanders, 1969d, e; Eisma, 1969). The core material taken, stored deep frozen at a temperature around  $-20^{\circ}\text{C}$ , became the basis for a completely new field of research into organic geochemical compounds undertaken by the Delft University unit set up under Professor Pieter Schenck, her former colleague at Shell, Rijswijk. The outcomes identifying important organic compounds included part of a doctoral thesis (Boon, 1978) and a major innovative body of work (e.g., Boon et al., 1975, J.W. de Leeuw, pers. comm., 2004), as well as geochemical results on trace elements (e.g., Brongersma-Sanders et al., 1980).

At this time she became more widely accepted as a scientist in her own right both nationally and internationally gaining membership of the Academy-based Commission for Netherlands Sea Research. She was also a foundation member of the Geochemical Group of the Royal Netherlands Chemical Society. As Pieter Schenck, who held the first official chair in organic geochemistry at Utrecht University from 1977 till 1992, reminisced of Brongersma-Sanders' geochemical work (pers. comm., Sept. 2004):

"organic geochemistry in the late fifties of the 20th century was relatively unknown and in many circles (geologists!) an unappreciated field of research. As a result the number of scientists in the field was small; they were mainly found in institutes related to the oil industry or to coal and in universities there was no interest from the chemists. Interest did exist, among others at Shell, in organic matter in sediments; those with high contents of organic carbon ( $> 0.5\%$ ) were considered oil source rocks in a number of cases; this high organic carbon content was a minimum requirement for being a potential source rock. For organic matter to survive in a sediment, an anoxic environment is required; many starving organisms in excess to the available oxygen. Mrs Brongersma was interested in the origin of these types of sediments (Black Sea; Walvis Bay). It was to this end that she was invited by the Exploration and Production Laboratory of Royal Dutch/Shell in Rijswijk (the predecessor of the present SIEP in Rijswijk) to act as a consultant for research in this field, a formal relationship which perhaps lasted until the late 1960s. To my memory, she was also involved in discussions (and reports?) on the trace elements Vanadium and Nickel. These elements were often found bound to porphyrins, which may occur in sediments and in oils. This offers a possibility to relate oils and their source rocks. The determinations even on a semi-quantitative basis could be easily made by simple spectroscopy. It is important to realize in the context of the above that many results now well established, were not available at that time, could not even be dreamt of! Organic geochemistry has developed strongly since, has helped a lot in oil exploration and is now a recognized specialism in geology, oceanography and biology."

Nevertheless, despite this important contribution to the history of organic geochemistry, principally her peers thought of Brongersma-Sanders as an oceanographer, which is the style awarded to her sometimes on her papers and to some extent in the

final memorials that she received. This fact notwithstanding, she is also entirely missing from histories of oceanography (e.g. Schlee, 1973; Mills, 1989; Postma, 1990).

During the Second World War and the period of invasion of The Netherlands (1940-1945), she undoubtedly used the library of the Natural History Museum for her work (then in the Raamsteeg, Holthuis, 1995, 2001) as the university was closed and analysis of the literature was principally her main research tool. She managed to produce three papers and was working on others during this time. At least five of her papers including her most cited work on mass mortality in the sea (Brongersma-Sanders, 1957, e.g., Wilby et al., 2004), and her last, give her institutional address as “Rijksmuseum van Natuurlijke Historie” or The Natural History Museum, Leiden, The Netherlands (National Museum of Natural History). While she was never regarded as an honorary member of the staff of the museum, RMNH was pleased with her work and on a purely practical level she needed an address where people could write for reprints and so this institutional affiliation may have been purely arbitrary. Early on Prof. Dr H. Boschma, Director from 1933-1958 (Holthuis, 1995), was supportive giving advice, presenting for her when necessary and in proofreading. Later, her husband attained the Directorship (e.g., Hoogmoed, 1995a; Holthuis, 1995) and she was often in the museum for official as well as social events (fig. 9).

The whole oeuvre of Dr Margaretha Brongersma-Sanders was influenced by her interest in mass mortality events beginning in her Ph.D. research (Sanders, 1934, e.g., p. 130) and the visit she paid to Walvis Bay; from these come her contributions to oil exploration, organic geochemistry, metal enrichment as well as fundamental knowledge in



Fig. 7. Brongersma-Sanders during the summer of 1964 at the Ria de Arosa in Spain. She discusses the oceanographic work with Joop Rommets (NIOZ, to left of picture) and Henk Sweers (physicist, Leiden Univ.). Photo taken by and courtesy of Hidde Brongersma.

geology and oceanography. Remarkably she worked consistently to build up her own career but not at the expense of family and household; she was totally self-motivated and enjoyed being entirely self-supporting. Nevertheless she is almost universally acknowledged in The Netherlands as having “fallen between the cracks” and is not easy therefore to categorize as a scientist. This may explain the lack of formal recognition she received in her lifetime and when she died. At the end of her life she summarized her thoughts and her own contributions (according to her own words, MB-S Archive, Final Statement 1996, numbers as in the brackets below) as follows:

“Q1. If Red Tide and mass mortality at the Namibian coast is the result of the abundance of nutrition minerals as a consequence of Upwelling; then Red Tide and mass mortality will occur in other areas with Upwelling as well.

The answer was Yes, indeed (publ. 8, 13, a.o.).

Q2. About the origin of salt basins, answer in (publ. 22, 23)

Q3. The high percentages of Cu, Pb, and Zn, etc. in the Kupfer Schiefer are due to the high concentrations of plankton in places where upwelling occurred. This turned out not to be true for Walfish Bay. So there must be something else, perhaps the presence of stromatolites (publ. 31). This is still an open question and has to be investigated I believe.”

This paper lists all her major and minor publications and seeks to show her unpublished record of work especially for Shell. English translations of her brief contemporary memorials are given for the first time thus avoiding the vagaries of history for women scientists (see Falk, 2000). This is seen as a first step in making her work and its significance for the history of Dutch science better known in The Netherlands and internationally. Interestingly, her classic paper is still cited and interest in her pioneering work on mass mortalities continues (e.g. Okaichi, 2004; Turner, 2004). The citations are annotated as to her base at the time and any remaining questions regarding their derivation. Further aspects of her life and work will be dealt with elsewhere.

### Contemporary memorials

There were only two short obituaries written in Dutch when she died in 1996; here they are given in English for the first time. One was by her former head of department and old friend, Professor Dr A. (Ton) J. Pannekoek and written for the Dutch geological community newsletter. The second was by her colleague in the Geological Institute, Professor Dr Aart Brouwer, palaeontologist and historical geologist. Brouwer’s notice complements that of Pannekoek and he (pers. comm., Sept. 2004) felt the need to emphasize her scientific importance and achievements to the Dutch biological community.

Prof. Dr A.J. Pannekoek “*KNGMG nieuwsbrief*” (Newsletter of the Royal Netherlands Geology and Mining Society), 6, September 1996

Translated by Dr J.M.J. Vergoossen Sept. 2004

### In Memoriam Dr Margaretha Brongersma-Sanders

On June 3, 1996, dr Margaretha Brongersma-Sanders died at Leyden [NB. *Leiden is the proper Dutch spelling*] at the age of 91. Her scientific work lay at the crossroads of three



sciences: biology, geology and oceanography, and in this borderland she has achieved remarkable results. She started her study of biology at the University of Amsterdam in 1923. Her doctoral thesis on fossil fishes already got her into contact with geology and the causes of mass mortality of water organisms. Soon after the war, in 1948, her study "The importance of upwelling water to vertebrate paleontology and oil geology" was published in the "Verhandelingen van de Koninklijke Nederlandse Akademie van Wetenschappen" (Proceedings of the Royal Netherlands Academy of Arts and Sciences). The importance of her work to oil geology was evident from the courses she gave to oil geologists in

Fig. 8a. Greet at the height of her work; b, attending the Gordon Conference 1963; photos courtesy of Hidde Brongersma.



the Koninklijke Shell Exploration and Production Laboratory in Rijswijk. Another bulky study, with a reference list of approximately 500 titles, was "Mass Mortality in the Sea", published in 1957 as a chapter of the compilation on marine ecology in the Memoirs of the Geological Society of America. Later she extended her work to studies on the relation between cyclic evaporite deposits and stratified ore deposits with bituminous sediments. She also brought her oceanographic work into practice: in 1962-64 with a group of students and staff members from Leiden in N.W. Spain, and in 1965 on the coast of S.W. Africa. At the former Geological Institute at Leiden she lectured in oceanography, but in addition she prepared the students for congresses and colloquia.

Prof. Dr A. Brouwer 1996. *Bionieuws* vol. 6: page 3 (12 October 1996)  
Translated by Dr Gerhard C. Cadée Sept. 2004

### **In Memoriam Margaretha Brongersma-Sanders.**

With the death of Margaretha Brongersma-Sanders, who died on the 3<sup>rd</sup> of June 1996 at the age of 91, science has lost a very original scientist as well as a remarkable woman.

She terminated her studies in Biology in Amsterdam in 1934 with a Ph.D. (doctoral) thesis on an Eocene fish fauna of Sumatra. The choice of this subject was probably by chance, however, this rich and excellently preserved fish fauna preserved in bituminous shales put her on a trail she would follow for a long time. "Für eine gute Erhaltung der toten Organismen ist es erstens von Wichtigkeit dass diese massal umkommen" [translated: for good preservation of the dead organisms it is firstly of importance that they should die en masse] she writes in the last chapter. Two pages later she asks herself whether there is a relation between the sedimentation and the death of the fishes. These were two elements leading her later research: mass mortality and sedimentary environment. A visit in 1938 to Walvis Bay (Namibia) with its annually recurring fish mortality formed an excellent stimulus at the start.

With her solid biological background she went into geology and chemistry and developed herself into a true oceanographer. With her critical mind she tackled problems others had avoided up to then: What is the significance of the thin fossil rich layer "Kupferschiefer" at the base of Permian salt deposits in Europe? What exactly was going on in that sometimes closed sometimes semiclosed [Permian] basin? So often the next question resulted from the answer to a former question. She buried herself in the origin of salt basins [how did they form] and of petroleum and in the role of metals.

Seeing her list of publications one is impressed by the natural line in the subjects dealt with. Her last paper – based on her last lecture given at the Maria Laach symposium in 1988, she was then aged 83 – deals with most of the aspects of her lifelong interests: "On the association of ore deposits with stromatolites" (Published in *Early Organic Evolution* M. Schidlowski et al. Editors p. 478-482, Springer Verlag 1992).

After being attached to the Zoological Museum in Amsterdam before the war [WW II 1940-45] she was admitted (permitted to enter) to Leiden University as a 'privaat docent' [unsalaried university lecturer] in zoogeography. Her further career was at Leiden: Lecturer in oceanography 1956, Staff member (Wetenschappelijk ambtenaar - Research fellow) in the geology department in 1958 until she retired in 1970 as a Senior



Fig. 9a. Brongersma-Sanders in the Academy building University of Leiden, with Prof. Dr A. Brouwer (in robes at a doctoral ceremony); photo courtesy of Prof. Dr W. Vervoort; b-c, Brongersma-Sanders at the Leiden Natural History Museum, meeting and greeting and enjoying the social life; photo from the Leiden Naturalis archive.

staff member (Hoofdmedewerker - Senior Research fellow). At her retirement colloquium\* she lectured on "Azoic basins in an extremely dry climate". Even after her retirement she remained a highly esteemed and consulted visitor of the Geological Institute, where she continued to give generous advice. Many of her pupils, biologists and geologists, will think with thankfulness of the support they got from 'mevrouw Brongersma' during their first steps on the slippery path of lecturing and writing papers.

\* Brongersma-Sanders (1970) in our bibliography presented here.

There were brief mentions of her elsewhere in English but mainly as an adjunct to her husband (e.g., Hoogmoed, 1995a, b). One further biographical piece appeared in 1971 when she retired and was awarded the medal of Officer of the Order of Oranje Nassau, officially given by the Queen of The Netherlands, for her contribution to science and the work in the Institute of Geology (fig. 10).

Anon. (1971), Acta & Agenda, 1971 Note on: Mrs Dr M. Brongersma-Sanders appointed Officer in the Order of Oranje Nassau at her retirement.

Translated by Dr J.M.J. Vergoossen Sept. 2004

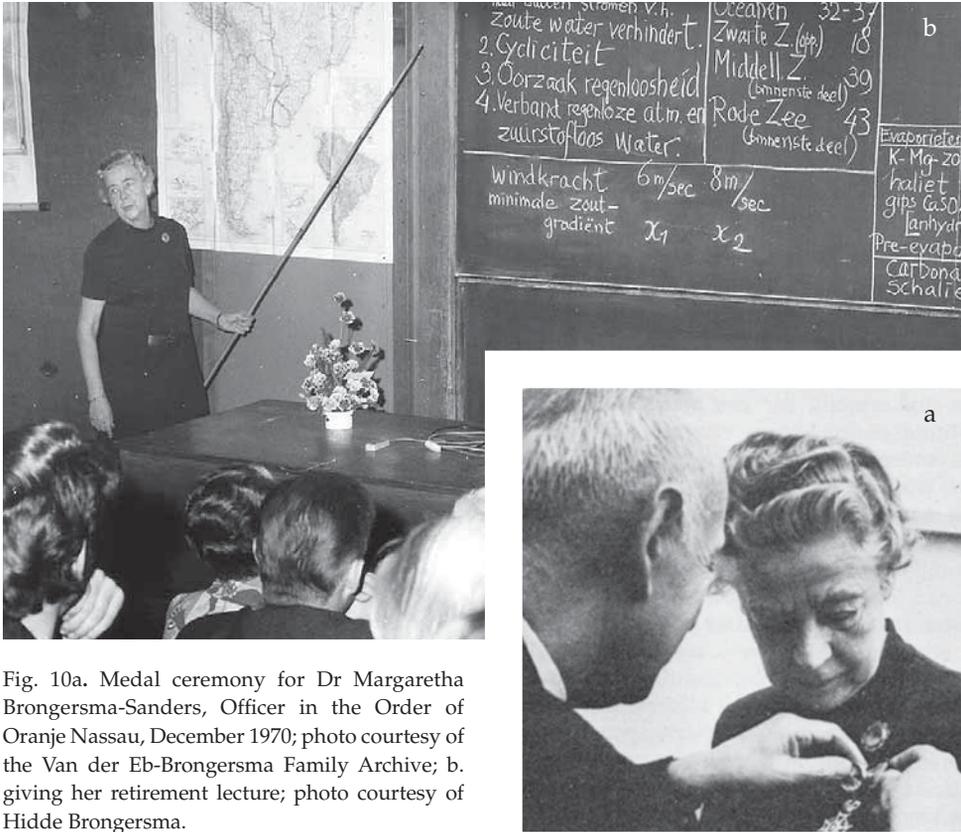


Fig. 10a. Medal ceremony for Dr Margaretha Brongersma-Sanders, Officer in the Order of Oranje Nassau, December 1970; photo courtesy of the Van der Eb-Brongersma Family Archive; b. giving her retirement lecture; photo courtesy of Hidde Brongersma.

The news of the appointment was announced by the President-Curator Prof. Dr P. Muntendam, who also pinned the insignia on her during the reception given in her honour in the Geological and Mineralogical Institute. This reception followed Mrs Brongersma's retirement colloquium[\*] devoted to anoxic basins in an extremely arid climate. Next Mrs Brongersma was addressed by Prof. Dr A.J. Pannekoek, head of the department of general geology of the institute, who offered her a voucher for stereo records on behalf of the personnel.

Mrs Brongersma, who is a member of the Committee for Sea Research of the Royal Netherlands Academy of Arts and Sciences and closely involved in the founding of the Geochemical Circle, was part of a Dutch delegation to the international oceanographic conferences in New York, Moscow and Tokyo in 1959, 1966 and 1970 respectively.

\* Afscheidcollege on December 18th, 1970.

### Bibliographic notes

This new compilation is based on study of the books, reprints and typed notes left by Margaretha Brongersma-Sanders with her daughter Titia as well as on other sources such as documents and reprints held by her colleagues and students. The object of this



Fig. 11a. From right to left Dr L.D. Brongersma, Dr M. Brongersma Sanders, Prof Dr J.T. Wiebes and his wife; b, Brongersma-Sanders at the retirement of her husband Leo Daniel Brongersma from the Directorship of Leiden Natural History Museum in October 1972; photos courtesy of Prof. Dr W. Vervoort.

bibliography is to make the work of Brongersma-Sanders better known and available again to the oceanographic, life- and geoscience communities because of the relevance of her pioneer work to many current problems.

Her first publication was at the age of 26 as a young postgraduate at Amsterdam Municipal University. Included here for interest are the 'Stellingen' (Statements) from her thesis (Sanders, 1934) because they show a little of her grasp of the subject and interests and because such provocative sentences which accompany a Dutch Ph.D. thesis doctoral defence as a loose sheet are not usual in scientific life elsewhere. She mostly wrote as a single author in her nearly 40 publications and reports. Her vehicle for publication was mainly European journals with later in life invited chapters and reviews in conference proceedings or to a wider audience through American-published encyclopaedias. Her final publication came out when she was 87.

There are a series of unpublished Reports, included here – at least five, and possibly eight – that are apparently still regarded as confidential even though the topics of most were published. She prepared these in her role as a consultant or advisor to the Royal Dutch/Shell Group Exploration and Research laboratories at Rijswijk. Efforts are now being made to access those reports.

One further paper is included in her list (1950b) because, although written by Prof.

Dr Rudolf Richter (1881-1957), it was mainly based on her results and written to bring these to the attention of a wider German-reading public through the medium of the popular scientific magazine produced by the Senckenberg Museum. In addition, it was enclosed in Dr Brongersma-Sanders' own collection of papers.

The full reference is given and a translation of the title if the original is in Dutch. Relevant notes are made including where known the address of her institution where given. Given in brackets [x] are the numbers from the list compiled previously by her daughter, Titia van der Eb-Brongersma, based on MB-S's own compilation made before she died.

If any reader is aware of any omissions, please contact the first author. Copies of all documents and papers are at present in an archive residing with her daughter (please contact through Leiden Naturalis).

### Annotated list of work including publications

1. Sanders, G.A. (in err.) (crossed out and replaced with 'M' on her copy.) 1931. *Echte of valse parels. Natuur en Techniek*, Oct.: 257-260, [The truth about artificial pearls.] New process in 1921 - debate at the time on how to tell real from artificial pearls. Reference to Indonesia, real pearls in Celebes. This may have been the result of an honours project or some find in the Zoological Museum, Amsterdam, where she was working; possibly written to earn some money. No address given. [1a]
2. Sanders, M. 1934. Die fossilen Fische der alttertiären Süßwasserablagerungen aus Mittel-Sumatra. [The fossil fishes of early Tertiary fresh water deposits from central Sumatra]. *Verhandelingen van het Geologisch-Mijnbouwkundig Genootschap voor Nederland en Koloniën*, Geologische Serie, 11, pt. 1: 1-144, pls I-IX (Doctoral Thesis, Amsterdam Municipal University. In German with Dutch summary and preface and loose Stellingen I-VII); (NB. here written as printed) [1]
 

The 'Stellingen' (Statements to be defended; translated by Dr J.M.J. Vergoossen)

  - I. The arguments on which GILL and EASTMAN assume that *Toxotes antiquus* Ag. should be removed from the genus *Toxotes*, are not valid.
  - II. The distribution of the *Dipnoi* and *Osteoglossidae* has not been parallel from the beginning of the Tertiary, as assumed by GÜNTHER.
  - III. The fishes of the Siwalik deposits do not represent a purely freshwater fauna.
  - IV. The conclusion by HILLS that the presence of a form closely related to *Sclerophages* would indicate that the Redbank Plains-layers from South Queensland are of post-Eocene age, is unfounded.
  - V. The humerus of the tetrapods is homologous with a part of the shoulder girdle in fishes.
  - VI. From the ichthyological point of view, WERNER'S opinion that Aruba and Curaçao were linked longer to the continent of South-America, cannot be supported.
  - VII. For COCKERELL'S opinion that the genus *Lycoptera* should be considered a predecessor of the *Cyprinidae* insufficient reasons have been stated.
  - VIII. The daily periodicity in the movements of *Phaseolus* leaves is hereditary.
  - IX. The "kayoids" found by PALLA in the cells of the Conjugales do not contain nucleus substance.

- X. For our region it makes no sense to distinguish a “subboreal” period among the postglacial periods.
  - XI. A persistently high percentage of *Pinus* pollen in a deposit need not indicate that forests were impoverished.
3. Brongersma-Sanders, M. 1936. Nichtmarine Fische von Bonaire, Curaçao und Aruba. [Non-marine fishes from Bonaire, Curaçao and Aruba.] *Zoologische Jahrbücher* (Systematik), Jena, **67**, h. 5/6: 447-454. In: *Zoologische Ergebnisse einer Reise nach Bonaire, Curaçao und Aruba in Jahre 1930*, no. 22, [Abteilung für Systematik, Ökologie und Geographie der Tiere, Gustav Fischer Verlag]. In German, submitted January 1933, published 15.I.1936. Address: Zoological Museum, Amsterdam. Her only paper on Recent fishes. [2]

### **7-year gap, children (Titia born 1935, Hidde born 1940), war, occupation 1940-45**

4. Brongersma-Sanders, M. 1943. De jaarlijksche visschensterfte bij Walvisbaai (Zuidwest-Afrika) en haar beteekenis voor de palaeontologie. [The annual fish mortality near Walvisbaai (South West Africa), and its significance for palaeontology]. *Vakblad voor Biologen*, jaargang **24**, No. 2, Feb.: 13-18. [pages in reprint numbered 1-6] Address: Leiden. [3]
5. Brongersma-Sanders, M. 1944. Een H<sub>2</sub>S-bevattend sediment met een hoog organisch gehalte uit open zee. [A sediment containing H<sub>2</sub>S and with a high organic content from the open sea] *Geologie en Mijnbouw* (Nieuwe serie), **6**, nos 7-8: 57-63. Cites “Brongersma 1943” (sic). Much longer set of literature developing her ‘themes’ including phytoplankton. This paper draws attention to and tries to explain the high H<sub>2</sub>S contents of the Walvisbaai sediments and goes into the differences between gyttja and sapropel while explaining how sapropel might be formed in open sea. Address: Leiden. [4]
6. Brongersma-Sanders, M. 1945. The annual fish mortality near Walvis Bay (South West Africa), and its significance for palaeontology. *Archives Néerlandaises de Zoologie*, (Arch. Néerland. Zool.), **7**: 291-294. *Comptes rendues de la Société néerlandaise de Zoologie*, August 1942-July 1943; a summary of the 1943 paper, on importance of catastrophes; talk given at a Séance (meeting) on 23rd January 1943 at Amsterdam but not published until October 1945 after the war had ended. Address: Leyde. [5]

### **2-year gap**

7. Brongersma-Sanders, M. “D.Sc.” 1947a. *Het belang van de Antarctische Convergentie voor de Zoögeographie en voor de Geologie van den Zeebodem*. [The importance of the Antarctic convergence to the zoogeography and for the geology of the seabottom]. Openbare les gegeven bij den aanvang van haar colleges als privaatsdocent in de Zoögeographie aan de Rijksuniversiteit te Leiden, op Dinsdag 29 April 1947. E.J. Brill, Leiden, 13 pp. NB. No references and no illustrations, privately printed text of inaugural lecture at the start of her job at the university as an unsalaried university lecturer (privaatsdocent) in zoogeography. No address given. [7]

8. Brongersma-Sanders, M. 1947b. On the desirability of a research into certain phenomena in the region of upwelling water along the coast of South West Africa. *Proceedings of the Koninklijke Nederlandsche Akademie van Wetenschappen*, 50, no. 6: 659-665. North Holland Publishing Company (N.V. Noord-Hollandsche Uitgevers Mij.), Amsterdam. Communicated at a meeting on May 31 1947 by Professor Dr H. Boschma; extends the 1945 paper. No address given. [6]
9. Brongersma-Sanders, M. 1948. The importance of upwelling water to vertebrate palaeontology and oil geology. *Verhandelingen Koninklijke Nederlandsche Akademie van Wetenschappen*, Afd. Natuurkunde, 45, sect. 2, no. 4: 1-112. [Verh. Kon. Ned. Ak. Wet., afd. Natuurk.] N.V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam. "D.Sc." Extends the 1945 paper with extensive 14 pages of literature (362 titles). Address: Leiden, Netherlands with Rijksmuseum van Natuurlijke Historie added on final page. [8]
10. Brongersma-Sanders, M. 1949. On the occurrence of fish remains in fossil and recent marine deposits. *Bijdragen tot de Dierkunde*, 28: 65-76. E.J. Brill, Leiden. Journal translation is "Contributions to Zoology" of The Royal Zoological Society (Artis Natura Magistra, based in Amsterdam and also linked to the Amsterdam Zoological Garden, 'Artis'. Address: Leiden. [9]
11. Brongersma-Sanders, M. 1950. Verzoek om inlichtingen over het voorkomen van rood water en massale sterfte. [Request for information on the occurrence of red water and mass mortality]. *De Zee*, no. 3, jaargang 1950: 115-117. Address: Rijksmuseum van Natuurlijke Historie, Leiden. [10]
12. Richter, R. nach den Forschungen von Brongersma-Sanders, M. 1950. Massensterben im Meere, Auftriebwasser und Erdöl-Bildung. [Mass mortality in the Sea, upwelling and origin of oil]. *Natur und Volk* [Berichte der Senckenbergischen Naturforschenden Gesellschaft], 80, h. 1/2: 21-28 with 3 figs. Frankfurt am Main 15.2.1950 Address given as 'Rijksmuseum Leiden'.
13. Brongersma-Sanders, M. 1951. On conditions favouring the preservation of chlorophyll in marine sediments. With an appendix by W.G. Aldershoff and discussion with Krecji-Graf, K., Gubler, Y. & Louis, M. *In: Proceedings of the Third World Petroleum Congress, The Hague*, sect. 1, 410-413, E.J. Brill, Leiden. Address: Lecturer, Leiden University, Netherlands. [11]
14. Brongersma-Sanders, M. 1952. On the origin and environment of marine sapropelium. *Assoc. Océanogr. Phys., Procès-Verbaux*, no. 5: 139-140. Un. Géod. Géophys. Internat., General Assembly Brussels, August 1951, Abstract. Address: Leiden University. [12]

### 5-year gap

15. Brongersma-Sanders, M. 1957. Mass mortality in the sea. Shell report QH-AB-1 1C, HSE documents, unpublished. [Requested but not seen] This was probably as published in 16.
16. Brongersma-Sanders, M. 1957. Mass mortality in the sea. *In: Hedgpeth, J.W. (ed.), Treatise on Marine Ecology and Paleocology*, 1. Geological Society of America Memoir, 67: 941-1010, with 7 figs. The citation list has extended to 543 references. Address: Oceanographer, Rijksmuseum van Natuurlijke Historie, Leiden. [13]

**5-year gap: During this time she was lecturing in oceanography and one of her sets of lecture notes has survived. This item is not numbered, as it was a recurrent lecture; she did apparently recycle parts of it for her retirement lecture (see no. 30).**

Brongersma-Sanders, M. 1959. Convectiestromen in de zee. [Convection currents in the sea] Unpublished lecture note 11<sup>th</sup> December 1959 pages numbered 10-16 + 6 pages figures; mimeographed and distributed to her students together with "Zuurstoftoevoer en verbruik in zee" (Supply and consumption of oxygen in the sea) forming pages 1-8 – p. 9 missing, probably non-existing. [MBSArchive c/o T. van der Eb-Brongersma]

17. Brongersma-Sanders, M. 1962a. De Zwarte Zee [The Black Sea]. Deel 1. Shell report RWK-No. 00443 unpublished. [Requested but not seen]
18. Brongersma-Sanders, M. 1962b. De Zwarte Zee [The Black Sea]. Deel 2. Shell report RWK-No. 00444 unpublished. [Requested but not seen]

#### 4-year gap

19. Brongersma-Sanders, M. 1966a. The fertility of the Sea and its bearing on the origin of oil. *In: Advancement of Science* (London), **23**, no 107, May: 41-46. Edited version of a paper presented to the joint session of section C (Geology) and section D (Zoology) at the annual meeting of the British Association for the Advancement of Science, Cambridge, 3rd September 1965. Address: Geologisch en Mineralogisch Instituut, University of Leiden. [14]
20. Brongersma-Sanders, M. 1966b. Metals of Kupferschiefer supplied by normal seawater. *Geologische Rundschau*, **55** (2): 365-375, for 1965. A preliminary paper on this problem was presented at the Jahrestagung der Geologischen Vereinigung, Strassburg in March 1965, under the title: "Normales Meerwasser als Lieferant der Metallmengen im Kupferschiefer", modified after discussion with Prof. K.H. Wedepohl. Address: Geologisch en Mineralogisch Instituut, University of Leiden, Garenmarkt 1b. [15]
21. Brongersma-Sanders, M. 1966c. Mass mortality in the sea. *In: Fairbridge, Rhodes W. (ed.), The Encyclopedia of Oceanography*. Earth Sciences Series. 474-475. Van Nostrand Reinhold Publ. Co, New York. Address: not given, Brongersma-Sanders's name simply omitted from the list of contributors. [16]
22. Brongersma-Sanders, M. 1967. Barium in pelagic sediments and in diatoms. *Proceedings of the Koninklijke Nederlandsche Akademie van Wetenschappen*, Amsterdam, ser. B., **70**, no. 1: 93-99. Communicated by Prof. H. Boschma, Oct. 29th, 1966. Address: Geologisch en Mineralogisch Instituut, Garenmarkt 1b, Leiden. [17]
23. Brongersma-Sanders, M. 1968. On the geographical association of strata-bound ore deposits with evaporites. *Mineralogica Deposita* (Berlin), **3**: 286-291. Presented at International Association on the Genesis of Ore deposits, St Andrews, September 1967; accepted March 12, 1968. Address: Geologisch en Mineralogisch Instituut, Leiden. [18]
24. Brongersma-Sanders, M. 1969a. Mortality in the sea. *In: Firth, F. E., (ed.), The Encyclopedia of Marine Resources*. 416-421. Van Nostrand-Reinhold Bibl. Co, New York. Address: Rijksmuseum v Natuurlijke (sic) Historie, Leiden, Netherlands. [19]

25. Brongersma-Sanders, M. 1969b. Permian wind and the occurrence of fish and metals in the Kupferschiefer and Marl Slate. *In: Sedimentary Ores: Ancient and Modern* (Revised). Proceedings of the 15th Inter-University Geological Congress, Dept. Geol. University of Leicester, 61-71. Presented at the 15th Inter-University Geological Congress, Dept. Geol. University of Leicester, December 1967. Address: Geologisch en Mineralogisch Instituut Rijks Universiteit Leiden Netherlands. [20]
26. Brongersma-Sanders, M. 1969c. Origin of trace metal enrichment in bituminous shales. *In: Hobson, G.D. (ed.), Advances in Organic Geochemistry*. Proceedings of the Third International Conference on Organic Geochemistry, 231-236. Pergamon Press, London. Presented at the Third International Meeting, London, September 1966; no acknowledgements. Address: Geologisch en Mineralogisch Instituut, Leiden, Holland. [21]
27. Brongersma-Sanders, M. 1969d. Oceanografisch onderzoek bij de kust van Zuidwest Afrika, December 1968-Januari 1969. "Dagverslag" Shell report RWK-No. 03344 Rijswijk unpublished, 16 pp.
28. Brongersma-Sanders, M. & Eisma, D. 1969e. Investigations in and around the 'azoic zone' off Southwest Africa, December 1968 - January 1969. I: Scope, previous investigations, acknowledgements, sampling in bay lagoon. Shell report RWK-No. 03345 Vol. 1 Rijswijk unpublished. Typed report, bound, 11pp. English version of 27.
29. Brongersma-Sanders, M. and Groen, P. 1970. Wind and water depth and their bearing on the circulation in evaporite basins. *In: Rau, J.L. and Dellwig, L.F. (eds), 3rd Symposium on Salt*, Cleveland, Ohio, 1: 3-7; The Northern Ohio Geological Society Inc., Cleveland. MBS was the presenter in Cleveland in April 1969. Address: ? [22]

#### Retirement (fig. 10)

30. Brongersma-Sanders, M. 1970. Zuurstofloze bekkens in een extreem ariede klimaat. [Translation "Anoxic (or azoic) basins in an extremely arid climate"]. Afscheidscollege on December 18th, Leiden Universiteit, i-iii + 1-21, 1 tab. \*Retirement Colloquium, unpublished Typed; pp. i-iii lists 70 figs. [MBSArchive c/o T. van der Eb-Brongersma].
31. Brongersma-Sanders, M. 1971. Origin of major cyclicity of evaporites and bituminous rocks: an actualistic model. *Marine Geology*, 11: 123-144. Address: Geological and Mineralogical Institute, Leiden. [23]
32. Brongersma-Sanders, M. 1972a. Rood water, massale sterfte en mosselvergiftiging. [Red tide, mass mortality and mussel poisoning]. *Waddenbulletin*, jaarg. 7, nr. 1, Jan./Feb.: 2-6, + 8 figs. Address: none given. [26]
33. Brongersma-Sanders, M. 1972b. Hydrological conditions leading to the development of bituminous sediments in the pre-evaporite phase. *In: G. Richter-Bernburg (ed.) Proceedings of the Symposium on the Geology of Saline Deposits*, Hannover, 1968, 19-21, Earth Sciences, 7, UNESCO, Paris. Presented at the Symposium on the Geology of Saline Deposits, Bundesanstalt für Bodenforsch., & Natural Resources Division, Hannover, May; abstract with discussion. Address: Geologisch en Mineralogisch Instituut, University of Leiden, Garenmarkt 1b. [24]
34. Brongersma-Sanders, M. 1972c. Mass Mortality in the Sea. *In: Dietrich, G. (ed.), Geopedia, Encyclopedia of Geosciences, Oceanography*. pp? Pergamon Press, Oxford. NB.

This paper or article has not been seen and we now doubt whether this encyclopedia was actually published as no record of it occurs in international databases or Elsevier (who took over Pergamon) listings, but see Dietrich (1972). Address: unknown. [25]

### 6-year gap

35. Brongersma-Sanders, M. 1978. Sapropel. In: Fairbridge, R.W. & Bourgeois, Joanne (eds), *Encyclopedia of Earth Sciences*, vol. VI, *The Encyclopedia of Sedimentology*, 653-654. Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA. Address: Geologisch en Mineralogisch Instituut Rijks Universiteit Leiden, The Netherlands. [27]

### 2-year gap

36. Brongersma-Sanders, M., Stephan, K.M., Kwee T.G. & M. de Bruin, 1980. Distribution of minor elements in cores from the Southwest Africa shelf, with notes on plankton and fish mortality. *Marine Geology*, 37: 91-132. Address: Geological and Mineralogical Institute, Leiden (The Netherlands). [28]
37. Brongersma-Sanders, M. 1983. Unconsolidated phosphorites, high barium and diatom abundances in some Namibian Shelf sediments In: Suess, E. & Thiede, J. (eds), *Coastal Upwelling, its sediment record*. Part A: Responses of the sedimentary regime to present coastal upwelling. NATO Conference Series IV, Marine Sciences, 421-437. Plenum Press, New York/London. Address: home, Houtlaan 3, 2334 CJ, Leiden. [29]

### 5-year gap

38. Brongersma-Sanders, M. 1988. On the possible relation of cyanobacterial mats and of Rote Fäule to the metal enrichment of the Kupferschiefer. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen*, Ser. B., 91, no. 1, March 28: 15-38 + 3 figs. Communicated by Prof. H. Postma at the meeting on Sept. 28th 1987; acknowledgements to Professor Dr A. Brouwer, Professor Dr H. Postma and Dr P. Westbroek for valuable suggestions and critical reading of ms. Grateful thanks to Taco and Jeroen van der Eb for help with the figures and to J. Timmers for advice and practical suggestions. Address: Rijksmuseum van Geologie en Mineralogie, P. O. Box 9517, 2300 RA Leiden. [30]
39. Brongersma-Sanders, M. 1992. On the association of ore deposits with stromatolites. In: Schidlowski, M., Golubic, S., Kimberley, M.M., McKirdy, D.M. & Trudinger, P.A. (eds), *Early Organic Evolution: Implications for Mineral and Energy Resources*. Maria Laach-Symposium, September 19-23, 1988, 478-482. Springer-Verlag, Berlin, Heidelberg: 555 pp. No acknowledgements. Address: National Natuurhistorisch Museum, P.O. Box 9517, 2300 RA Leiden. [31]

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