Dansk Geologisk Forenings Årsmøde

lørdag, den 24. november

ELLA HOCH

1984 er året for uddeling af Steno-Medaljen i guld. Følgende det indarbejdede mønster er den »af Dansk Geologisk Forenings bestyrelse og de tre sidst afgåede formænd for foreningens bestyrelse« udpegede kandidat hovedtaleren ved årsmødet, som struktureres omkring vedkommendes emne.

Steno-Medaljen blev indstiftet i 1969, der var 300-året for publiceringen af *Nicolai Stenonis De solido intra solidum naturaliter contento dissertationis prodromus.* Medaljen tildeles »udlændinge, og i særlige tilfælde danske, for betydningsfulde bidrag inden for de geologiske videnskaber«. Siden indstiftelsen har Kryolitselskabet Øresund A/S ydet økonomisk baggrund for medaljeuddelingen.

Steno-Medaljen blev første gang givet til Sigurður Thorarinsson, Reykjavik. Fem år senere, i 1974, blev den modtaget af John Haller, Harvard University, og i 1979 af Stephen Moorbath, Oxford.

Ved Årsmødet den 24. november overraktes Steno-Medaljen til Jörn Thiede, professor ved Kiels universitet. Emnet for mødet var *Nordatlantens geologi og palæoceanografi.* I stedet for mange foredrag af kort varighed havde bestyrelsen ønsket at få gedigne præsentationer fra forskere, som befinder sig midt i emnets videnskabelige problematik. Det medførte, at Geologisk Forening fik fem vægtige bidrag af international standard, men desværre ingen manuskripter til trykning, idet alle foredragsholderne er så hårdt presset af arbejde, at de ikke kunne nå at forberede en publikation. Følgelig er det besluttet at afvige fra reglen om dansksprogethed i Årsskriftet og udgive resumeerne her vedføjet forfatternes adresse til brug for kolleger, som ønsker de pågældende emner yderligere belyst.

Formanden havde samlet nogle tanker om Steno til brug ved medaljeoverrækkelsen. Da flere har bedt om at se dem på tryk, vil de blive gengivet her direkte efter manuskriptet uden litterær bearbejdelse og kildeangivelser. Læseren bedes erindre, at udgangsmaterialet er særdeles omfattende, mens taletiden efter programmet var 20 minutter; derfor, og fordi indlægget ikke er ment som en videnskabelig afhandling, er uddybning og argumentation udeladt. Af de oprindelige 20 illustrationer medtages kun 3.

– on Steno

by ELLA HOCH, Geologisk Museum, København

Steno was a great man of science and, later, of the Catholic church in the 17th century. He was born in Copenhagen in 1638. Following the rule of his time, as a student he latinized his Danish name Niels Stensen into *Nicolaus Stenonis.* The short version Steno may also have been used by himself, and was in any case used by the English. The French call him Nicolas Sténon.

The English spoke and wrote about Steno in last century. So, for instance, Th. H. Huxley, the friend and protagonist of Charles Darwin, in a discourse given at the York meeting of the British Association in 1881, entitled "The Rise and Progress of Palæontology", said that "the scientific grounds of the true interpretation of fossils had been stated, in a manner that left nothing to be desired, in the latter half of the seventeenth century. The person who rendered this good service to palæontology was Nicholas Steno, ... The principles of investigation thus excellently stated and illustrated by Steno in 1669, are those which have, consciously or unconsciously, guided the researches of palæontologists ever since".

In 1669, Steno published *De solido intra solidum naturaliter contento dissertationis prodromus.* It appeared two years later in an English translation: "The Prodromus to a Dissertation Concerning Solids Naturally Contained within Solids". 300 years later, in 1969, a Steno Medal was inaugurated by the Geological Society of

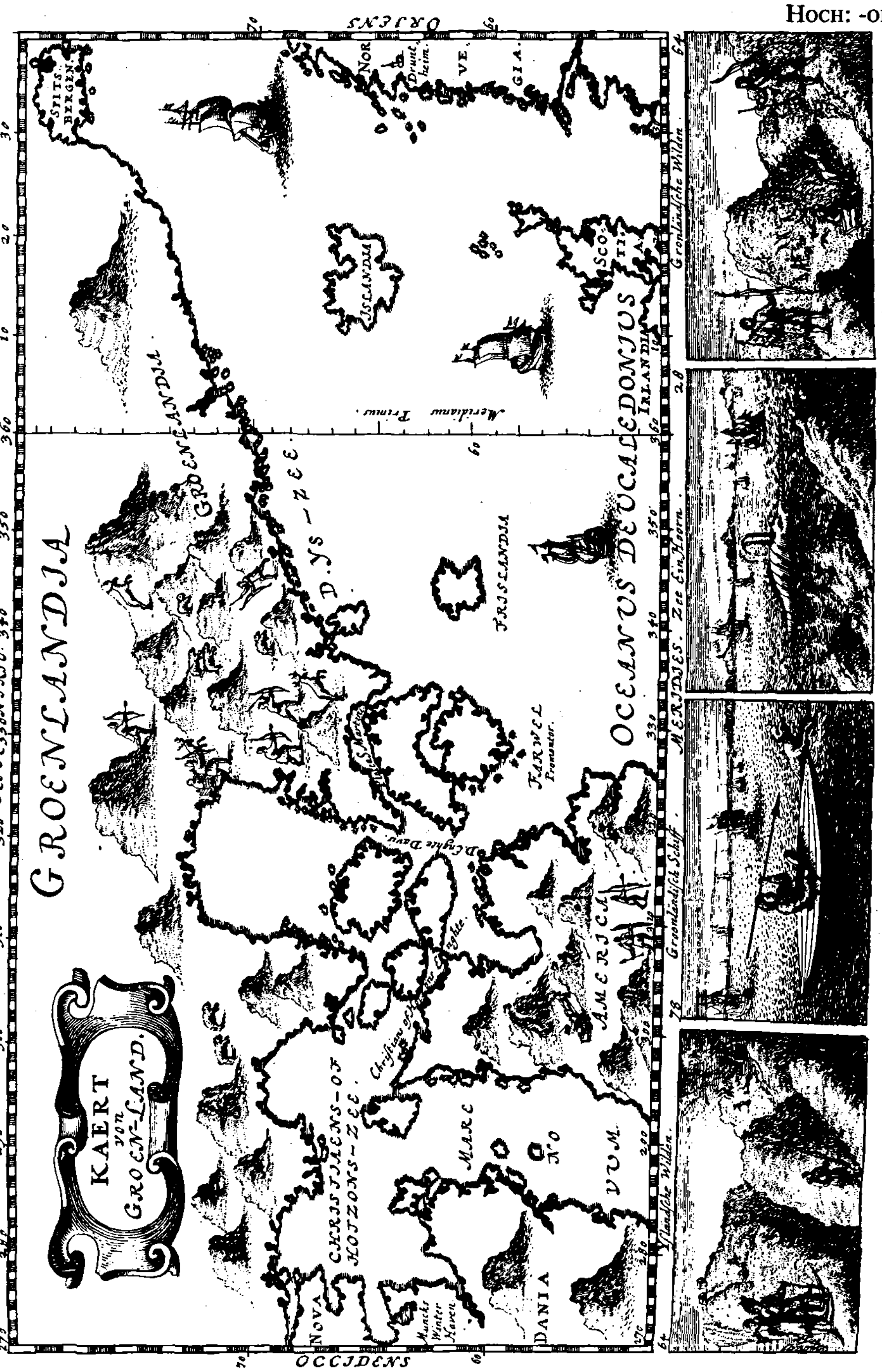

Fig. 1. Nordatlanten. Kort fra 1679 i S(imon) von V(ries): »Neueste Beschreibung von Alt und Neu Groen-Land«; Nürnberg/in Verlegung Christof Riegels (Geologisk Museums Arkiv). Den uafbrudte forbindelse mellem Østgrønland og Spitsbergen markerer formentlig, at området nordfor var lukket af af is året igennem. At skibe ikke kunne trænge frem til Grønlands nordøst-kyst i denne periode, hvor hvalfangsten i Nordatlanten var på sit højeste, støttes af manglen på beretninger om landgang (efter ferskvand og kød) på nævnte kyst. Derimod omtales rener og isbjørne fra både Sydgrønland og Spitsbergen. Forholdet harmonerer med zoologen Christian Vibes model for klimasvingninger i de arktiske og subarktiske egne. (Kortet er restaureret af Chr. K. Rasmussen, Geologisk Museum).

The North Atlantic. Map from 1679 in S(imon) von V(ries): "Neueste Beschreibung von Alt und Neu Groen-Land"; Nürnberg/in Verlegung Christof Riegels (Geology Museum of Copenhagen Archives). The uninterrupted connection between East Greenland and Spitsbergen is believed to represent the edge of northern perennial ice. Supporting this is a conspicuous lack of reports of sailors' visits on the northeast coast of Greenland during this period of intense whaling in the North Atlantic. South Greenland and Spitsbergen were at the same time well known for their reindeer and polar bears. The map thus gives a fine illustration of the climatic situation predicted by the Danish Zoologist Christian Vibe in his model of arctic and subarctic climatic oscillations. (Restauration of map by Chr. K. Rasmussen, Museum of Geology, Copenhagen).

Denmark, to be awarded to: "... foreigners, and in exceptional cases Danes, for their important contributions within Geological Sciences".

We shall do this today. However, before we get on with the presentation of the medal, we can pay a little more attention to Steno himself, although this may not be in his spirit, since he remarks in the *Prodromus* with a certain regret that "in the course of centuries one undertook to praise the deeds of illustrious men, but not the wonders of Nature". – In spite of his regrets it is appropriate at this particular occasion to focus for a short time on Steno.

First, one must become conscious of where human knowledge had reached at Steno's time. The map on the programme of today's meeting (fig. 1) shows an informed person's conception of geography in the North Atlantic region at the time of Steno. "Muncks Winter Haven", Munk's winter harbour, is where most of the crew, *i.e.* 61 out of 65 men, of Jens Munk's two expedition ships miserably perished with hunger and cold in the winter of 1619–20. Captain Munk had been entrusted by the Danish King Christian IV to find the Northwest Passage. But they became trapped by the Hudson Bay. As the map shows, as late as 1679 no opening was known from the North Atlantic towards the northwest. And – it should be recalled – the North Atlantic was at the epoch one of the better known parts of the World.

To take another example: Steno lived a century before Linné, and the Linnean binomial system of scientific nomenclature as well as the Linnean classificatory system had not yet come into existence at his time.

Steno studied anatomy and medicine, first at Copenhagen University, next at the universities in Rostock, Amsterdam, Leyden, Paris, Montpellier and in northern Italy, where the Grand-Duke of Tuscany, Ferdinand II, and later his son, Cosimo III, both highly cultivated men, provided him the best possible conditions for scientific research.

According to V. Meisen, a Danish Doctor in Medicine and co-editor of STENONIANA, the renaissance of anatomy began around 1543 with Vesal's great work from the chair in Padua; and by 1600 human anatomy was understood in outline. Vivisection was in fashion, anatomists thus also became physiologists. In 1652, when Steno was 14 years old, his future teacher and tutor at Copenhagen University, Thomas Bartholin, discovered the lymphatic veins.

Steno was influenced by Bartholin and continued along his line of research during his time in Holland, where he made important discoveries in the fields of glands and various bodily secretions. The *Ductus Stenonianus* from the parotid gland was one of his first discoveries. He demonstrated, among other things, that milk and tears are glandular excretions, and that tears do not originate in the brain, as suggested by the Englishman Thomas Wharton. Later Steno concentrated on muscles and nerve tissue, especially the brain. He stated that the tongue is a muscle and not a gland, as maintained by others; and that the heart is a muscle, which was a revolutionary interpretation.

Steno wrote two works during his stay in Tuscany which are of close relevance to us as geologists, mineralogists and palaeontologists, namely *Elementorvm myologiæ specimen, sev musculi descriptio geometrica. Cvi accedvnt canis carchariæ dissectvm capvt, et dissectvs piscis ex canvm genere. Ad Serenissimvm Ferdinandvm II. Magnum Etrvriæ Dvcem. Florentiæ 1667,* which exists in manuscript at the Danish Royal Library; and the already mentioned *De solido intra solidum ...,* of which the Royal Library possesses a first edition published in Florence two years later. A Danish translation by August Krogh and Vilhelm Maar was published in 1902, entitled "Foreløbig Meddelelse til en Afhandling om faste Legemer, der findes naturligt indlejrede i andre faste Legemer". When placed in the context of the 17th century these works are ever more remarkable, since they live up to modern requirements to good science: the author's statements are based on critically evaluated observations; his reasoning is sound, non-speculative and controlled by personal modesty; his thoughts are unrestricted by prejudice and dogmas. Steno was a keen observer, who mastered the art of asking himself relevant questions. As the late Danish Zoologist Ragnar Spärck remarks: "Steno had a preeminently analytical intelligence combined with a high ability to make syntheses".

Steno was totally respectful to Nature and Science.

In the first of the two mentioned works, Steno discusses the function of muscles on the basis of geometrical principles. From the manuscript it is

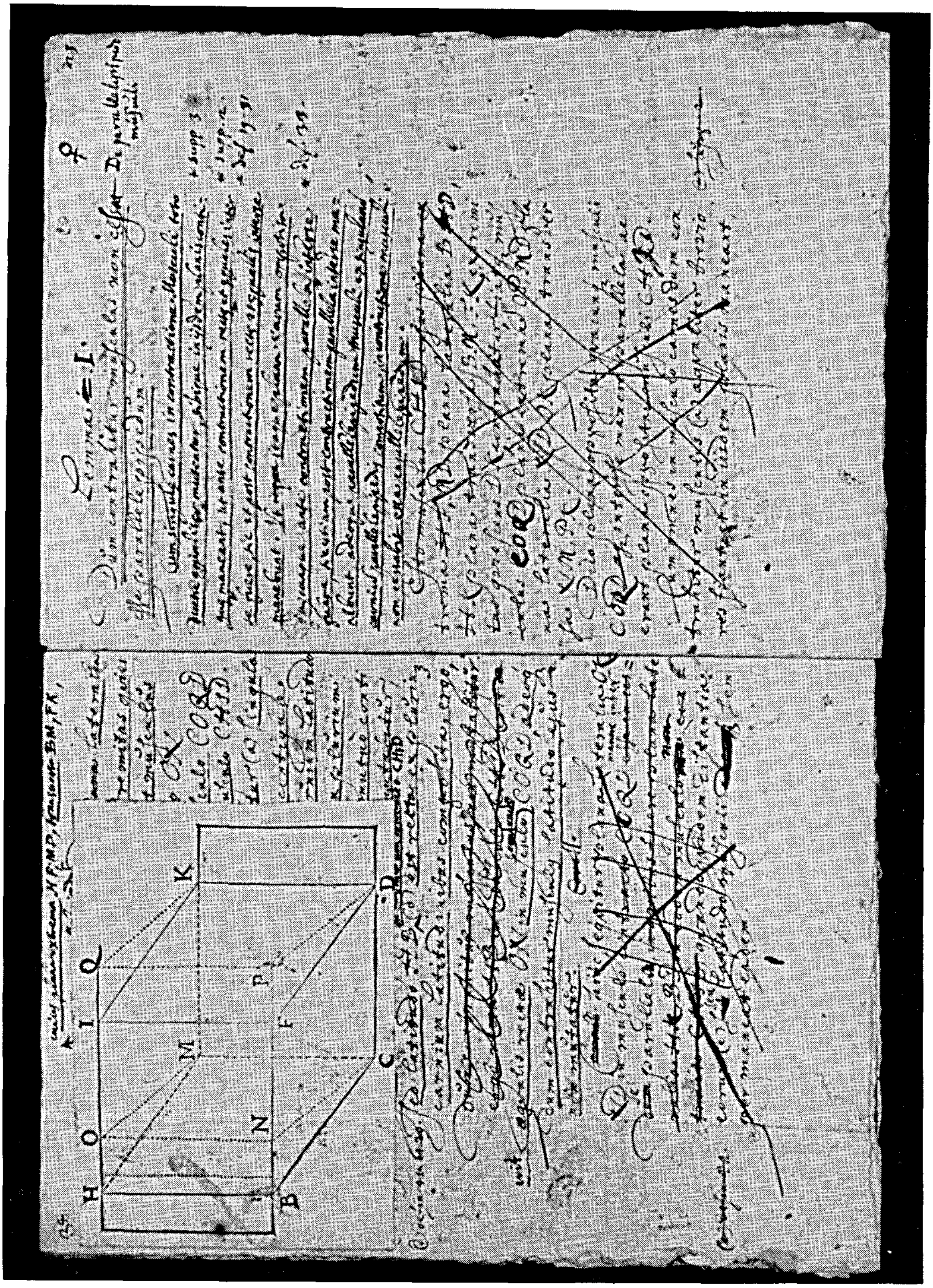

Fig. 2. Dobbeltside fra manuskriptet til *Nicolai Stenonis Elementorvm myologiæ specimen* . . . Som almindeligt dengang, foreligger teksten ved en skrivers hånd; men rettelserne er Stenos. Manuskriptet findes på Det kongelige Bibliotek, København. (Fot. Det kgl. Bibliotek).

Double manuscript page of *Nicolai Stenonis Elementorvm myologiæ specimen* . . . Text in a scribe's handwriting; corrections by Steno. The manuscript is now in the Royal Library, Copenhagen. (Phot. Royal Library).

evident that it cost him much trouble to express his ideas (fig. 2).

One should remark that Steno's works, as scientific works generally, treat problems, which other researchers of his time, and before, also tried to deal with. Their starting points were different from ours, and Steno's conclusions are not always in accordance with our conceptions. For a fair evaluation of Steno we should understand the philosophy of his contemporaries. But this is another lecture. I shall, however, quote Dr. Meisen for the following description: "It is characteristic of many authors of those days that they believed, they had adduced a proof, when they had advanced an elegant phrase or a euphonious comparison – a phenomenon, which is not totally unknown at the present time, however now mostly confined to political discussions". In this respect Steno was markedly different from many of his contemporaries.

After the muscle section of his 1667 work, Steno turns with fresh energy to the following section, where he begins "I do not doubt that the reader became tired from the long and uninterrupted presentation of the muscular matters"; and "since the mind takes pleasure in variation ..." he desides to turn to quite another subject, namely the dissection of "*Caput Canis Carchariœ*", the head of a large shark, which had been brought to him on demand of the Grand-Duke Ferdinand II. Steno discusses, among other things, the strange similarity between organic objects, such as sharks' teeth, and objects found in the ground, called *glossopetrae*. They were generally believed to have grown there by some *vis plastica*, or to have been induced by divine agency. Steno gives a description in 11 points, of objects found in the ground of the kind, which we would now call fossils, and presents an argumentation in "6 Assumptions", which leads to the following: "Since thus those from the ground excavated bodies, which look like parts of animals, may be regarded as parts of animals; since the shape of *glossopetrae* look like the shark's teeth just as one egg looks like the other; since neither their number nor the situation of the ground (in which they were found) speaks against it, (then) will those, who declare the big *glossopetrae* to be sharks' teeth not appear to me to be very far from truth".

In the *Prodromus*, two years later, which Steno calls "a brief, not to say a chaotic, communication about the most important things which I had decided to present both more clearly and in a more detailed way in the treatise itself ..." – the treatise, which unfortunately never saw the light of day – in this *Prodromus* he took up again the problem of tooth-like, shell-like and other bodies of similarity with organic elements found included in rocks. Now he states that they are indeed organic remains. And he talks about petrification, dissolution, chemical replacement etc. in terms so much up to the present date that they could be used in modern teaching. – When it comes to fossil remains of elephant-like animals found in the ground of Italy he, however, is too bound by known historic events, so he interprets them as the bones of Hannibal's elephants. An excusable mistake.

He gives fine explanations of stratigraphic and tectonic conditions and phenomena, and he touches upon petrological problems. It was Steno, who in his *Prodromus* established the Law of Constancy of Angle in crystals – almost as an aside: in the explanation to the single plate of the book.

The *Prodromus* was written quickly, and was printed after Steno had left Florence. The Danish King Frederik III had called him back to his country, and Steno decided he would follow the invitation. He set out on a long journey, which took him to many fine geological sites. He did not return to Denmark this time, however. Frederik III died, and Steno received a message that Ferdinand II had fallen seriously ill, which made him hurry back to Florence.

What made Steno interested in geologic matters, such as rocks, crystals and fossils? He evidently was sensitive to the beauties of nature, and without doubt took great aesthetic pleasure in the landscapes of Tuscany, where he travelled, and which yielded the objects for his studies. Was it an innate inquisitive disposition alone, which led him into these new fields away from his dissection chambers and learned circles? – It appears that Steno had become inspired by some Englishmen.

To give the background to this, we turn back to the early 1660's. Steno was studying in Leyden, as was – among many others – the 3 years older Peder Schumacher, the later great Danish Statesman Griffenfeld. Steno's stepfather died in late

1663, then his mother was alone, and there may have been some economic troubles; Steno returned to Copenhagen. There he applied for a chair at the University for which he was utterly qualified. But it was given to a less qualified member of the dominant Bartholin family. Steno's mother died in 1664, and Steno decided to go to Paris, another of the great European intellectual centres.

He spent a prolific year in Paris, staying at the house of Thévenot, and entering into scientific society. Among other things, he gave demonstrations of anatomy by dissection before interested laymen in Paris, which aroused much admiration. In letters, the French Naturalist Graindorge repeatedly praises Steno for his skill, his patience and his kindness. Graindorge exclaims enthusiastically: "He counts all the bones of a flea, if there be any".

After Paris, Steno travelled towards the south. It is known from letters that he spent 1–2 winter months in Montpellier, supposedly at the famous

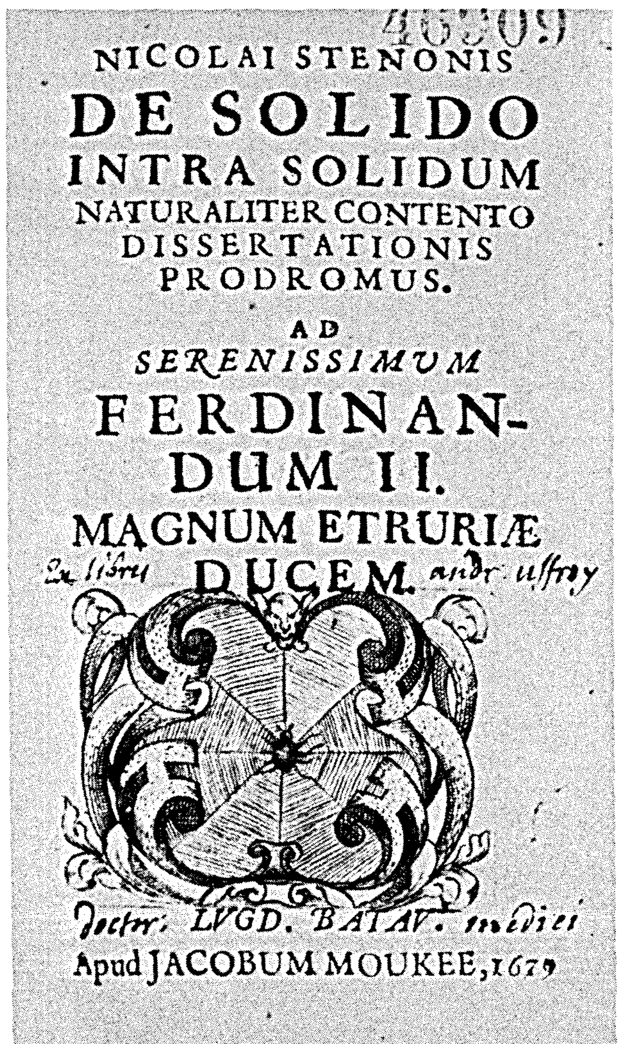
NICOLAI STENONIS
DE SOLIDO
INTRA SOLIDUM
NATURALITER CONTENTO
DISSERTATIONIS
PRODROMUS.
AD
SERENISSIMUM
FERDINANDUM II.
MAGNUM ETRURIÆ
DUCEM.
LUGD. BATAV.
Apud JACOBUM MOUKEE, 1679

Fig. 3. Titelblad af 1679-udgaven af Stenos *Prodromus,* trykt i Leyden. Bogen, som er knap 15 cm høj og indbunden i brunt skind med guldtryk, er nu i la Bibliothèque Universitaire, Montpellier. Mens 1669-udgaven har mange trykfejl, er 1679-udgaven nøje gennemrettet. (Fot. E.H.).

Front page of second, corrected edition of *Nicolai Stenonis Prodromus,* printed in Leyden 1679. The book, which is less than 15 cm high and bound in brown leather with gold-printing, is in la Bibliothèque Universitaire, Montpellier. (Phot. E.H.).

Université de médecine, at that time almost 400 years old, where he performed and demonstrated anatomical dissections.

So this year, in September, when I was in Montpellier to study fossils, I looked up the Faculté de médecine in the hope to find traces of Steno. A picture of Montpellier in early 17th century shows la Cathédrale Saint-Pierre. The monastery connected with the cathedral was taken away from the church after the revolution in 1789 and became the Faculty of Medicine. I did not know that. But believing that I stepped in the traces of my famous countryman Steno, I solemnly walked in through the door.

Among various magnificent experiences I had in that building, one is my acquaintance with Professor Dulieu, the author of a number of weighty volumes on the history of medicine in Montpellier. He was immensely kind and ready to help me, and very proud to show me that he mentions Steno in one of his books, even with a picture. – He does mention Steno, however only as an example of a student of medicine who became a priest, and a Danish Lutheran who converted to Catholicism. Monsieur Dulieu did not know of the visit and activity of Steno in Montpellier, nor did any of the authors of various French 18th and 19th century encyclopedic works he brought out for me.

Professor Dulieu showed me the location of the building of the ancient Université de médecine, which was in use from 1498 to 1792. This is the place where Steno's spirit may be roaming. I was also shown the Steno work in the possession of the Medicine Faculty, *De musculis et glandulis ...*, a nice skinbound booklet printed in Amsterdam in 1664.

Next day, at the University Library, I saw two editions of *De solido intra solidum ...* The small one (fig. 3), which is an edition from 1679, bears the ex libris of a Doctor in Medicine, Andrée Uffroy. We recognize its plate.

During his stay in Montpellier, Steno associated and worked with a number of distinguished Englishmen, among whom were John Ray and Martin Lister, later to be known as naturalists and students of fossils. Lister has recorded from Montpellier that he had "ye honour to assist att an Anatomie Lecteur on some particular dissections and demonstrations made by Mr. Steno ye Dane himself in my Lord of Ailesburys cabinet". Lister also notes that he admired "ye ingenuitie and great modestie of ye person", and that he found him "infinitely taking & agreeable in conversation". – It is in particular V. A. Eyles, who has studied the connection of Steno with the British. He states that "contemporary correspondence suggests that the arrival of a new book by Steno was something of an event in scientific circles in Britain, and that frequent enquiries were made for his works".

There seems good reason to believe that not only did Steno inspire the English, but the English with their vivid interest in natural phenomena also inspired Steno.

Already in Holland, where contrary to the strictly Lutheran Denmark religious tolerance prevailed, Steno had been stirred by religious scruples. It may seem strange to modern Danes that Niels Stensen let himself be affected by the problem of one religious faith or another. But we must keep in mind that at his time Europe, and not least France, was subject to strong tensions between Catholicism on one side, and Calvinism and Lutheranism on the other. By the Edict of Nantes, in 1598, Henri IV tried to secure religious liberty to the Protestants. The repeal of the Edict, in 1685, meant that Protestants were prohibited access to the Medicine University of Montpellier. As this, however, would have meant a serious blow to the university, the French King decided that prohibition applied to French students only, and not to foreigners.

In Italy, Steno became more and more interested in Catholicism, and in 1667 he converted. In 1675 he made his definite decision to become a priest.

Then follow years of hard work as a priest in northern Europe, where the Pope sent him. Steno later became appointed Bishop, which, however, only made him still more modest in outer personal requirements, and more conscientious, if possible, in his Christian life.

When in 1680 Steno, still a priest, was appointed to a deanery, which was regarded as a post from which he would receive the income without personally performing the actual work, he did not find it acceptable; he immediately threw himself into the practical work of a priest, caring for the flock entrusted to him, relieving their sufferings. At all times he objected against unworthy candidates and denounced abuse of clerical privileges. He never spared himself of any trouble or difficulty. He cared for teaching in schools, for wise and kind direction of converts, for training of midwives, and so on. He lived asceticly, and he always had people in his house whom he helped in one way or the other. His life was an example to others. He won many souls to the Catholic Church.

No wonder that the church needed him. And it needed him so hard that it permitted him no rest. Going through the accounts of the occupations of this, the humblest, busiest and most devoted among priests and bishops, one notices that he painfully felt a want of peace and time for thinking and writing more than reports, pamphlets and petitions to various superiors. He addresses the Pope for permission to temporarily retire from his many duties. But the permission is never granted.

In texts on Steno we often encounter one of two statements: Nordic authors maintain that with conversion to Catholicism Steno was lost to science; authors from mid- and southern Europe proclaim, exemplified by an extreme: Eloy in 1778: "... truth clarified his spirit, took away the rest of his doubts to make room for the firm belief, took him to abjure publicly his Lutheran heresy ...".

In my opinion, neither of these sides understands Steno fully. Steno was a Protestant during most of his time as an active scientist. He could have been just as good a scientist being a Catholic. Why should membership of the Catholic community prevent him from studying the function of muscles or the growth of minerals? His famous *Prodromus* was written two years after he converted. During his interim in Denmark in 1672–74, where he had been called by King Christian V on the initiative of Griffenfeld, in his remarkable inaugural lecture on anatomy at the University of Copenhagen, he presented the beauty and complexity of bodily organs as signs of God's greatness. Such point of view might have urged him to continue his scientific researches rather than stopping him – had not conditions in Denmark been so difficult and forced him to leave.

It seems to me that what ruined Steno as a great scientist was not his religion *per se,* but smallmindedness at home, and administrative burdens put upon him, or let himself take upon him, by the Catholic church. It should be remembered that during his time as a scientist – contrary to the majority of students in medicine – he never practised as a doctor. He was a researcher *par excellence,* a true scientist.

Steno died in November 1686 in extreme, selfinduced, physical poverty, and painfully; but till the last moment respectful and humble to his God. He was then 48 years old.

All through the years Cosimo III had remained a faithful friend and support of Steno's. After Steno's death in Schwerin, northern Germany, he had his body conveyed to Florence – sent by ship secretly as a package of books – whereafter it was buried in St. Lorenzo Basilika. A marble slab was put up with an epitaph recording the events of Steno's life as a man of the church. No reference was made to his scientific achievements.

In 1881 the participants of the II. International Geological Congress held in Bologna visited Steno's grave in Florence. Thos. McKenny Hughes records in NATURE of March 23, 1882: "... it was felt that it would be a fit and pleasing thing to put another slab beside the old one, in memory of that gathering round his grave, and telling of the full appreciation of his worth as a man of science by those who came two centuries after him".

POSTSCRIPT: In Montpellier, at la Faculté de médecine, Professor Louis Dulieu procured from the archives a thick, old volume with personal data handwritten by the students who were inscribed at l'Université de médecine during the 17th century. They came from Portugal, Canary Islands, England, Switzerland and many other places, attracted by the fame of the Montpellier school. Steno's name does not occur among them. This presumably, as explained by Monsieur Dulieu, is because Steno was not registered as a student, but was a visiting researcher. It appears that no French written source mentions Steno's visit in Montpellier. I want here to express my gratitude to Professor Dulieu for the inspiring conversation we had over the old books, and to direct attention to his «La Médecine à Montpellier» (tome III, 1, 1983, Les Presses Universelles). My article, «Sténon et la Géologie», in the French *Géochronique* (in press) elaborates aspects relevant to Steno's connection with France. In Copenhagen, the staff at the Royal Library was also exceedingly helpful. Fagreferent Erik Petersen arranged and demonstrated an exhibit of Stenos texts and other literary treasures, which was much appreciated by guests at our meeting; he opened our eyes to the time-typical circumstance that Steno had a scribe write his manuscript. The Danish Natural Science Research Council supported my travel to Montpellier (j. nr. 81-4497). D. Bridgwater suggested improvements of my English language (but he must not be blamed for my linguistic ineptitudes).

Dansk Geologisk Forenings Årsmøde 1984

ABSTRACTS

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Geology of the Greenland-Scotland Ridge

The Greenland–Iceland–Faeroe–Scotland aseismic ridge shows itself as a zone of comparatively shallow water across the North Atlantic Ocean. The ridge is a considerable restriction on the exchange of water and thus heat between the Arctic and the Atlantic Ocean. Changes in this barrier cause pronounced climatic and oceanographic changes.

The ridge is a composite feature comprising the Faeroes with adjoining shelf and banks, the Faeroe–Iceland Ridge, Iceland with its insular shelf and the Iceland–Greenland Ridge. This division reflects important differences in geologic structure. It is believed that the crust of the Faeroe block is continental, while the rest of the ridge is of Tertiary oceanic origin probably formed as part of the seafloor blocks to the south. Iceland is the present active sector of the ridge and is characterized by an anomalous upper mantle and crust. This has been interpreted as an indication of mantle plume activity. The Iceland–Faeroe Ridge comprise oceanic crust, however 4 times thicker than normal. Morphologically the Iceland–Greenland ridge appears as formed by the merger of the shelves of Iceland and East Greenland, but a probably volcanic ridge has been discovered beneath a 0.5–2 km thick cover of sediments in the Denmark Strait.

Widespread Paleocene–Eocene volcanic rocks occur on the East Greenland continent along the continental margin extending 200–300 km to the northeast and to the southwest of the land end of the Iceland–Greenland Ridge. Similar to this, it has been shown that the basalt province of the Faeroes extends 300–500 km along the margin of the continental crust into the northern Rockall Trough and the Møre Basin in a 100–200 km wide band. The general structure of the ridge is thus remarkably symmetrical around the Reykjanes Ridge.

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The Cenozoic High Latitude Climatic Record: Stable Isotope Evidence

Emiliani proposed in 1956 that the oxygen isotope record in Cenozoic deep sea sediments could be used to infer the surface temperature record at high latitudes, because it is at high latitudes that the deep water masses form. Shackleton and Kennett proposed that account should be taken of the changing ocean isotopic composition by assuming that the Antarctic ice sheet, whose isotopic composition can be measured today, formed during the Middle Miocene. More recently Poore and Matthews have suggested that this model was incorrect and instead the ocean isotopic correction should be obtained using the low latitude planctonic oxygen isotopic record and making the assumption that low latitude temperatures have never differed significantly from today's values. Their model leads to a radically different, and in my view incorrect, record for the high latitudes.

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Palaeoceanographic and palaeoclimatic implications of the Tertiary seismic stratigraphy off East Greenland

A thick Tertiary sequence showing more than 20 regional unconformities is present off East Greenland. Seismic stratigraphic interpretation indicates strong asymmetry in the palaeoceanography of the NE-Atlantic through most of the Tertiary. An emergent to shallow water ridge existed between Greenland and Iceland until the Miocene. Eocene carbonate sedimentation probably took place south of this ridge. Glaciation of Greenland and adjacent shelf areas started about ~2.5 mill. yr.

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Some heretical views on the Norwegian Sea paleoceanography

The paleoclimatic reconstruction of the Norwegian Sea has been made difficult, because information provided by foraminifera, coccoliths and sedimentological studies is often contradictory. Whereas it is well established that hydrological conditions were similar to those of today during the last interglaciation (isotopic substage 5e), estimates of the conditions prevailing during stages 2, 3, 4 and 5a–d vary from open sea conditions to permanent ice cover.

We used the $^{13}C/^{12}C$ ratio of planktonic and benthic foraminifera from Norwegian Sea sediment cores to estimate local past surface and deep conditions because this isotopic ratio is closely related to the importance of the local CO_2 exchange between the atmosphere and the sea: The $^{13}C/^{12}C$ ratio of foraminifera reflects that of the total CO_2 dissolved in the sea water in which these animals have lived. In surface water, the $^{13}C/^{12}C$ ratio of the dissolved CO_2 is higher, the more intense are the exchanges of gas across the air-sea interface. In deep water, this isotopic ratio is high, when surface water sinks as a result of a density increase during winter conditions.

Three cores (K-11, V27–60, V27–86) from the Norwegian Sea have been studied for both $\delta^{18}O$ and $\delta^{13}C$. Using the oxygen isotope stratigraphy as a reference, the $\delta^{13}C$ record of planktonic and benthic foraminifera suggests that the Norwegian Sea was continuously open and formed deep water during isotopic stages 5a–d and the lower part of stage 4. Another short event of open sea conditions and of deep water formation has also been evidenced during a warm peak of isotope stage 3. The Norwegian Sea was then ice covered all the year long until the last glacial maximum.

The sedimentological and isotopic record of core CH77–07 collected northeast of Iceland provides detailed information on the oceanographic changes related to the last deglaciation. The analysis of clay minerals indicates that the Norwegian Sea became ice free as early as 18000 yr B.P., permitting the drift of icebergs released from the surrounding continental ice caps. However, no deep water formation is recorded in the Norwegian Sea before the second step of the deglaciation (Termination I_B).

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The Norwegian–Greenland Sea: A key area for Cenozoic paleoceanography

The Norwegian-Greenland Sea links today the polar Arctic and the temperate North Atlantic oceans, and represents the most important pathway for the warm water "import" to the Arctic and cold water "export" from the Arctic to the North Atlantic. The deep-sea basin between Norway and Greenland developed only during the past 55 my as the result of sea floor spreading, but it has probably always been separated more or less effectively by a sill in the area of the Greenland–Scotland Ridge. The early history of the paleoceanography of this ocean basin is only poorly known, but it is evident that ice-rafted material has hitherto not been found in Norwegian–Greenland Sea sediments older than middle to late Miocene in the eastern and northern part of the basin. The lack of adequate sample material from the Norwegian–Greenland Sea proper has prohibited hitherto further progress in the analysis of early northern hemisphere glacial history. Late glacial paleoceanography of the Norwegian–Greenland Sea, however, can be documented by means of numerous sediment cores which allow to describe establishment and variability of the warm water "import" from the main North Atlantic basin during Late Quaternary interglacial and subglacial times whereas cold surface waters seem to have covered the Norwegian–Greenland Sea during glacial times. The evolution of the depositional environment of the Norwegian–Greenland Sea will be investigated further by new deep-sea drill sites in the area of the Vöring Plateau and detailed investigations of the history of the Norwegian and East Greenland Currents as well as the paleoceanographic history of the Fram Strait.