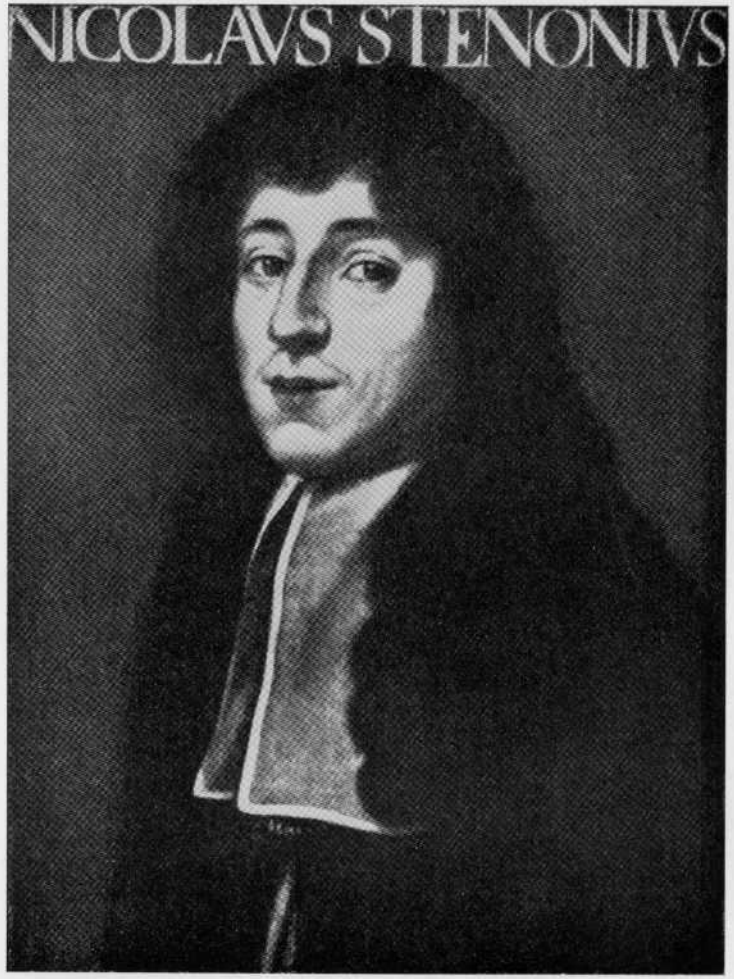


THE YOUNG NICOLAUS STENO (NIELS STENSEN) (1638–86)
From a picture in the Uffizi Gallery, Florence, by an unknown artist

THE EARLIEST GEOLOGICAL TREATISE (1667)

BY

NICOLAUS STENO
(Niels Stensen)

★

Translated from *Canis Carchariæ Dissectum Caput*
With Introduction and Notes
by
AXEL GARBOE, Ph.D.

LONDON
MACMILLAN & CO LTD
NEW YORK · ST MARTIN'S PRESS
1958

MACMILLAN AND COMPANY LIMITED
London Bombay Calcutta Madras Melbourne

THE MACMILLAN COMPANY OF CANADA LIMITED
Toronto

ST MARTIN'S PRESS INC
New York

PRINTED IN GREAT BRITAIN

CONTENTS

	PAGE
INTRODUCTION	1
LATIN TEXT AND TRANSLATION OF STENO'S EARLIEST GEOLOGICAL TREATISE (1667)	7
NOTES	46

LIST OF PLATES

	FACING PAGE
Nicolaus Steno	*Frontispiece*
Title-page of *Elementorum Myologiæ Specimen*	7
Steno's figure of a shark's head and teeth	43
Fossil shark's teeth from Malta	45

INTRODUCTION

I

WHENEVER Nicolaus Steno (Niels Stensen, 1638–1686) is mentioned [1] as the founder of Geology as an exact science, it is generally with special emphasis upon his work *De solido intra solidum naturaliter contento dissertationis prodromus* (Florence, 1669). It was, indeed, this treatise that, at the beginning of the nineteenth century,[2] turned the attention of the learned world to the great significance of the almost forgotten Danish scientist Nicolaus Steno's geological and mineralogical studies and gave him his true position in the History of Geology.

The treatise *De solido* (1669) — 'concerning a solid body enclosed by process of Nature within a solid' — is available to the English-speaking world in John Garrett Winter's translation (1916), with introduction and explanatory notes.[3]

In his brief, intensive period of work as a natural scientist (*c.* 1660–*c.* 1674)[4] Nicolaus Steno, however, published — also in Latin — another treatise, his very first geological work, which appeared in the year 1667, two years before *De solido*. It was incorporated as 'a digression' in a larger anatomical treatise on the muscles.[5] It seemed appropriate to make this most significant treatise of 1667 available to the English-speaking world in order to supplement the English translation of *De solido* (1669) and the English translation of Nicolaus Steno's letters (1671) about his investigations in some Alpine grottoes.[6]

Last but not least, attention must be directed to the *Indice di cose naturali, forse dettato da Niccolò Stenone*,[7] which gives a vivid impression of Steno's mineralogical-geological collections and his firm grasp of the problems they presented. The *Indice* permits us to catch a glimpse of that great pioneer, Nicolaus Steno, at work.

II

The life story of Nicolaus Steno is well known,[8] and will not be repeated here in detail. He was born in Copenhagen on January 1 (according to the Julian calendar, or January 11, Gregorian calendar), 1638, the son of a well-to-do goldsmith, and was taught the elements of anatomy and medical science by Professor Thomas Bartholinus (1616–80), the famous anatomist.[9] In 1660 Steno left Denmark for several years of study abroad and carried out independent research work in anatomy (on the glands and muscles) in the Netherlands. Already in 1660 he had discovered the parotid salivary duct (now known as the *ductus Stenonianus*) and stated *inter alia* that the heart is a true muscle.

No post in the University of Copenhagen could be found for Steno, either during his stay there in 1664 or later (1672–4). Italy became, so to say, his second fatherland. Generously patronized by the Grand Dukes of Tuscany, Steno found in Florence and in the Accademia del Cimento (an academy for experimental science) favourable conditions to develop his scientific, human and Christian qualities. Steno had grown up in the Lutheran Church in Denmark, but in 1667 he was converted to the

Catholic Church, took Holy Orders (1675) and gave himself more and more completely to religious work. He died (1686) in Schwerin, Germany. His tomb is in Florence, in the Basilica di San Lorenzo, the burial church of the Grand Dukes of Tuscany (the Medici family).

Steno's chief interest in natural science was anatomy, and it was anatomical investigation that led him into the sphere of geology.

In October 1666, the year of Steno's arrival for the first time in Italy, a gigantic shark was caught in the Mediterranean off Livorno (Leghorn), and the Grand Duke of Tuscany, Ferdinando II, ordered its head to be sent to Florence for Nicolaus Steno's anatomical studies. The examination of this marine animal included a study of its teeth, their structure and development, which were described in relation to the much discussed problem of the 'tongue stones' (*glossopetrae*).

In Steno's time the question was whether these tongue stones were stones produced in the rocks by a supposed 'formative power' (*vis plastica*) that was able to imitate teeth and other parts of animals, or whether they were in reality sharks' teeth from a former period which had somehow found their way into the rocks. Steno saw the striking similarity between the fossil *glossopetrae* and the recent shark's teeth and became more and more inclined to follow the opinion of those who thought that the 'tongue stones' in reality were petrified sharks' teeth.

Consequently Steno took up the problem of the origin and nature of all other 'bodies resembling parts of animals'. Step by step he came to the conviction that the fossils which resembled parts of

animals 'may be supposed in reality to be parts of animals'. Step by step an image of the evolution of the earth's crust began to take shape in his mind. He understood that the strata are sediments, deposited in water and later hardened to a greater or lesser degree. If the sediments do not always lie in their original horizontal position, a later disturbance is responsible. He studied both marine and freshwater deposits and their contents of plants and animals. He also studied the effects of 'juices' — aqueous solutions — circulating in the strata of the earth. The processes in the earth crust he compared with chemical and physical processes known in the laboratory. But so new and almost overwhelming were these thoughts that Steno only hesitatingly published them to the scientific world. 'About the greater tongue stones', he writes,[10] 'the problem is not yet settled.' But he proposed to give his own preliminary views, based upon his field observations, and then he would wait upon the final decision of 'those who know better'.[10] The geological convictions to which Steno himself had already come in the year 1667 from the facts which he had 'observed with his own eyes'[10] are clear from the brief treatise, with its logical arguments and indisputable conclusions.

Without calling it 'Geology', Steno gives in the little treatise of 1667 the first outline of a scientific history of the earth arrived at through exact studies of Nature and through inductive reasoning. Geology as a science was born.

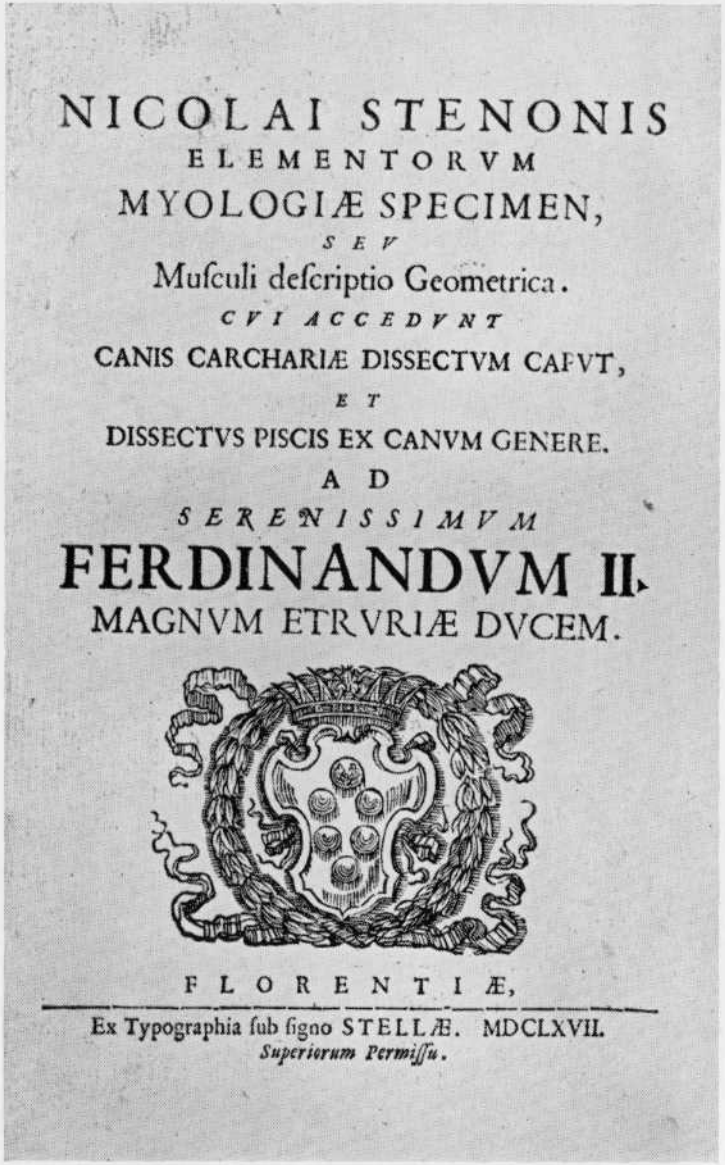
Two years later, Nicolaus Steno gave in *De solido* (1669) a more detailed 'geology', and if it had been possible for him to publish all his observations, the

history of geology and mineralogy would have taken a different course. Unfortunately, the greater part of his material, however, must be regarded as lost.[11]

In his earliest geological treatise (1667) Steno sums up the knowledge he had hitherto gained and divides it into (1) a series of *observations of facts* and (2) six *conjectures* in which he discusses the possibilities and draws his conclusions. It is very fascinating to follow his thoughts. But so concentrated is the literary form he uses that the best one can do is to let the small, but fundamental, treatise speak in its own fresh language.

Steno's few introductory words to his 'Geology', part of which is quoted above, have not been included here. His observations and conclusions are given *in extenso* in this translation of the geological parts of the treatise on the dissected shark's head (1667).

Steno's Latin is often difficult to translate because it contains references to ideas (physical, chemical, etc.) that are alien to us or cannot easily be expressed in the terms of today. Accordingly I am much indebted to my friend the classical scholar A. G. Drachmann, Ph.D., of Copenhagen, who has spent much time and interest in my work and has helped me in making this new translation, for which we have found August Krogh's Danish translation of 1933[12] to be a valuable help. I wish here to express my gratitude to Dr. Drachmann for many interesting hours spent in collaboration and discussion of the problems.



NICOLAI STENONIS
ELEMENTORVM
MYOLOGIÆ SPECIMEN,
SEV
Muſculi deſcriptio Geometrica.
CVI ACCEDVNT
CANIS CARCHARIÆ DISSECTVM CAPVT,
ET
DISSECTVS PISCIS EX CANVM GENERE.
A D
SERENISSIMVM
FERDINANDVM II.
MAGNVM ETRVRIÆ DVCEM.

FLORENTIÆ,
Ex Typographia ſub ſigno STELLÆ. MDCLXVII.
Superiorum Permiſſu.

Title-page to Nicolaus Steno's (Niels Stensen's) anatomical treatise on the muscles (1667) with the description of his dissection of a shark's head and his geological investigations.

THE EARLIEST GEOLOGICAL TREATISE (1667) BY NICOLAUS STENO (NIELS STENSEN)

From CANIS CARCHARIÆ DISSECTUM CAPUT [12]

HISTORIA

Qvæ de terris iſtis & corporibus per experientiam conſtant.

1. TERRA, unde aqvatilium animantium partibus ſimilia corpora eruuntur, qvibuſdam in locis durior eſt, ut tophus, & alterius generis lapides; in aliis mollior, ut argilla, ſabulum.

2. Eadem terra & mollior, & durior, fere ubiqve compacta eſt, & preſſioni minus violentæ reſiſtens.

3. In variis locis vidi, eandem terram compoſitam eſſe ex ſtratis ſibi mutuo impoſitis, & ad horizontem obliqvis.

4. In terra argilloſa vidi eadem ſtrata colore inter ſe diſcrepantia variis in locis fiſſa eſſe, & fiſſuras omnes unius coloris materia plenas ad ipſa ſtrata qvaſi perpendiculares eſſe.

5. In illis terris, qvæ mihi videre hactenus contigit, varii generis corpora in eadem terra tum duriori, tum molliori delituere.

6. In argilla vidi, corporum illorum numerum in terræ ſuperficie admodum freqventem, intra ipſam terram ſatis rarum eſſe.

7. In eadem argilla vidi, qvo profundius in terram deſcenditur, eo magis tenera eſſe prædicta corpora, imo qvædam illorum ad leviſſimum qvemlibet contactum in pulverem delabi; qvæ in ſuper-

From DISSECTION OF A SHARK'S HEAD [12]

DESCRIPTION OF OBSERVATIONS

Observed facts about these soils and bodies.

1. THE soil from which bodies resembling parts of aquatic animals are dug is in some places rather hard, like tufa and other sorts of stones; in other places softer, like clay or sand.

2. This soil, whether softer or harder, is almost everywhere compact and resistant to a not too violent pressure.

3. In various places I have seen that this soil is composed of layers superimposed on each other and oblique in relation to the horizon.

4. In clayey soil I have seen that these layers, differing from each other in colour, in several places are split apart, and that all the fissures, which are filled with a substance of a single colour, are, so to say, at right angles to the layers themselves.

5. In those soils that I so far have been able to observe, bodies of different sorts have been hidden in the same soil, sometimes of the harder, sometimes of the softer sort.

6. In clay I have seen that the number of these bodies is rather large on the surface of the soil, but quite small in the soil itself.

7. In the same clay I have seen that the deeper one goes down into the ground, the more fragile are these bodies; indeed, some of them crumble into powder at the very lightest touch; those that were on

ficie erant, & ipſa fere omnia ſine magno negotio in albicantem pulverem redigebantur.

8. In ſaxo & freqventia magis corpora illa deprehendi, & per totum ſaxum ejuſdem eſſe conſiſtentiæ, eoqve modo ipſi ſaxo infixa, ac ſi calce vel gypſo fuiſſent conſtricta.

9. Corpora variis aqvatilium animantium partibus ſimilia, ſive duriori, ſive molliori e terra eruta, non modo ſibi invicem, ſed etiam animalium partibus, qvibus reſpondent, ſimillima ſunt; nec ulla eſt in ſtriarum ductu, in lamellarum textura, in cavitatum gyris anfractibusqve, in bivalvium commiſſuris & cardinibus differentia.

10. Eadem corpora vel ſolidiora ſunt, ſaxi inſtar, vel minus ſolida, qvæ non difficulter in pulverem reducuntur.

11. Qvibuſdam in locis oſtreorum teſtæ plurimæ difformes reperiuntur, & in unam maſſam concretæ; eruuntur interdum etiam pectines & conchæ diffractæ; viſæ itidem nonnullis gloſſopetræ plures eidem qvaſi matrici adhærentes, qvæ nec ejuſdem inter ſe magnitudinis erant, nec omnes integræ.

Ex allatis hiſtoriis veri qvandam ſpeciem ſibi pollicentur ſeqventes conjecturæ.

CONJECTURA I

An terra hodie illa corpora producat.

Terra, unde animalium partibus ſimilia corpora eruuntur, corpora illa hodie non producere videtur.

(a) *Hiſt. 1.*

Qvod terram mollem ſpectat, cum (*a*) eo molliora

the surface could also, almost all of them, be reduced to a whitish powder without any great exertion.

8. In rocky ground I found both that these bodies are much more numerous, and that they are of the same consistency all through the rock, and that they were attached to the rock as if they were imbedded in lime or gypsum.

9. The bodies resembling various parts of aquatic animals, whether they are dug out of hard or soft soil, resemble exactly not only each other, but also the parts of the animals to which they correspond; and there is no difference at all in the course of the stripes, in the structure of the lamellae, in the windings and bulges of the cavities, in the joints and hinges of the mussel shells.

10. The same bodies may be either rather hard, like stone, or less hard, so that they are reduced to powder without difficulty.

11. In some places many oyster shells are found, deformed and moulded together into a solid mass; sometimes also broken shells of scallops and snails are dug out; some people have seen in the same place many tongue stones imbedded, so to say, in the same matrix, and they were not all of the same size, nor all unbroken.

From the observations here presented the following conjectures give promise of a certain degree of truth.

CONJECTURE 1

Whether the soil today produces these bodies.

The soil from which the bodies resembling parts of animals are dug out does not seem to produce these bodies today.

(a) *Observation 1.*

As for the soft soil, since (*a*) these bodies are the

ſint corpora illa, minusqve contactum ferant, qvo profundius latent ; tantum abeſt, producat ea terra, ut potius eadem deſtruat. Nec eſt, qvod qvis credat, ideo molliora ea eſſe, qvia necdum perfecta ſunt ; qvæ enim mollia ſunt, dum generantur, qvodam qvaſi glutine unitas inter ſe partes continent (ut videre eſt in recentibus pinearum & amygdalorum corticibus), at hæc corpora omni glutine privata in pulverem dilabuntur, adeoqve mollities ea deſtructionis, non productionis argumentum
(b) *Hiſt. 1.* videtur. Nec obſtat, qvod in (*b*) ſuperficie terræ numerus eorum augeri videatur ; id enim pluviis debetur intermediam terram diluentibus : qvin ipſa
(c) *Hiſt. 7.* eorum in ſuperficie exiſtentium ſubſtantia, dum (*c*) levi negotio in pulverem teritur, demonſtrat, cœptam illorum in terra deſtructionem pluviæ interventu fuiſſe interruptam.

Qvod in terra dura hodie non producantur, inde
(d) *Hiſt. 8.* conjicitur, qvod (*d*) toto ſaxi ductu ejuſdem conſiſtentiæ omnia reperiantur, & qvod undiqve dura illa materia obſepta ſint ; qvod ſi enim hodie qvædam de novo in iſta duriori terra producerentur, deberent circumſtantia creſcentibus cedere poſſe, & ipſa corpora hodie producta haberent ſine dubio, in qvo a productis olim corporibus differrent.

Cum itaqve in duriori terra nulla de novo produci videantur corpora ; cum terra mollior eadem corpora multis in locis veroſimiliter deſtruat : non ſine ratione ſuſpicari licebit, terram, unde animalium partibus ſimilia corpora eruuntur, corpora illa hodie non producere.

softer and withstand touching less the deeper they are hidden, there is little likelihood that the soil produces them, but rather that it destroys them. Nor should anybody believe that they are softer because they are not yet full grown ; for the things that are soft while being formed keep their parts together by something glue-like (as may be seen in the soft shells of young pine seeds and almonds), but these bodies lack every sort of glue-like substance and crumble into dust, and so their softness seems to indicate decay, not growth. It cannot be argued against this that their number seems to increase in (*b*) the surface of the soil ; for this is due to the rain that washes away the soil between them. On the contrary, when the substance of those that are on the surface is (*c*) easily rubbed to a powder, this is proof that their decay, begun in the soil, has been interrupted by the intervention of the rain.

(b) *Ob ſervation 1.*

(c) *Obſervation 7.*

That they are not produced in our time in hard ground, one may conclude from the fact that they are found (*d*) all through rock of the same consistency, and that they are surrounded on all sides by the hard material ; for if any such bodies were produced today anew in these rather hard soils, the surroundings ought to give way to them when growing, and the bodies themselves would no doubt show differences from those produced long ago.

(d) *Obſervation 8.*

Since, then, no bodies seem to be produced anew in the harder soil, and since the softer soil in many places probably destroys these bodies, we may suspect, not without reason, that the soil from which the bodies resembling parts of animals are dug does not produce these bodies today.

CONJECTURA II

An ſemper æqve compacta fuerit eadem terra.

Eadem terra non videtur fuiſſe compacta, cum prædicta corpora ibi producta ſunt.

Poſſunt qvidem, qvæ creſcendo lente ſe expandunt, impoſita dura elevare, imo ſaxorum dilatare rimas; qvod arborum radices in terra dura, in muris, in rupibus oſtendunt: nihilominus dum eadem corpora congruens ſibi ſpatium efformant, non poſſunt non a durioris obſtaculi renitentia ſæpius impediri; qvod eiſdem plantarum radicibus evenit, qvæ in terra duriori mille modis intortæ & compreſſæ a figura recedunt, qvam in terra molliori alias conſervare ſolent. At vero corpora illa, de qvibus hic agimus, (*a*) ſibi ſimilia omnia ſunt, ſive e terra molliori eruta, ſive e ſaxo exciſa, ſive ab animalibus evulſa intuemur: cum itaqve illis in locis, ubi reperiuntur corpora illa, (*b*) hodie non videantur produci; cum, qvæ in locis compactis creſcunt, mire difformia reperiantur, hæc vero corpora ubiqve ſibi ſimilia ſint: non videtur compacta fuiſſe terra, cum prædicta corpora ibi producta ſunt.

(a) *Hiſt. 9.*

(b) *Conject. 1.*

CONJECTURA III

An aqvis tecta eſſe potuerit.

Nec forte repugnat, qvo minus eandem terram aqvis olim tectam fuiſſe credamus.

Duobus modis id contigiſſe poterit, pro ut eandem terram ſtatuamus, vel eodem modo ſemper fuiſſe ſitam, vel ſitum aliqvando mutaſſe.

CONJECTURE 2

Whether the soil in question has always been of the same firmness.

This soil does not seem to have been firm when the bodies in question were produced.

Bodies that expand by slow growth can certainly raise heavy objects resting upon them and may widen fissures in rocks; which tree roots in hard ground, in walls, in rocks will prove: none the less, while these bodies obtain a space that suits them, they are inevitably hampered by the resistance of the harder obstacle; and this is just what happens to the roots of trees, which in hard ground become twisted and compressed in countless ways, so that they take on shapes different from those found in softer ground. But the bodies with which we are dealing here are always of (*a*) the same shape, whether they come to light from softer ground, or are chipped out of rocks, or taken out of animals [13]; since, then, these bodies do not seem to be produced today (*b*) in the places where they are found and since that which grows in firm soil is found to be strangely deformed, but these bodies everywhere are alike, the soil would seem not to have been compact when the bodies in question were formed there.

(a) *Observation 9.*

(b) *Conject. 1.*

CONJECTURE 3

Whether it may have been covered with waters.

Nor would there seem to be any objection to the belief that this ground was once covered with waters.

This may have occurred in two ways, according to whether we assume that this piece of ground has always had the same site, or that it has changed its site at some time.

Qvod primum ſpectat, ex ſacra pagina diſcimus, & creationis initio, & diluvii tempore aqvis omnia obſita fuiſſe ; qvod eleganter hiſce exprimit *Tertullianus : mutavit & totus orbis aliqvando aqvis omnibus obſitus : adhuc maris conchæ & buccinæ peregrinantur in montibus, cupientes* Platoni *probare, etiam ardua fluitaſſe.* Nec urgent, qvæ a contrariæ ſententiæ patronis afferuntur argumenta, dum dicunt, debuiſſe id generis corpora in omnibus locis reperiri, ſi aqvis loca omnia tegentibus ea corpora debentur ; aut ſaltem, ubi reperiuntur ea corpora, non in ſolis editis locis eſſe reperiunda. Facile enim utriqve objectioni reſpondetur : cum non omnis aqva ferat omnia ; & ſi videmus pluviarum vi abraſis qvaſi ſtrigmentis montium repleri loca plana montibus ſubjecta, qvid mirum, in editis nuda apparere illa corpora, qvæ in depreſſis latent novis terris obruta ?

De pall.

Qvod ſi qvis crediderit, in locis, unde dicta corpora eruuntur, mutaſſe aliqvando ſitum ſuum terræ partes, nec ille vel rationi, vel experientiæ contrarium qvid admittere tenetur. Sane ſi ſtratorum fiſſuras (*a*) unius coloris materia plenas intuemur illis in locis, ubi ipſa ſtrata diverſi coloris ſunt ; vero admodum ſimile videtur, ingenti motu excuſſam eandem terram, cum relaberetur, diffractam fuiſſe, adeoqve novum ſitum obtinuiſſe. Qvantas in terra mutationes terræ motus ſæpius producant,

(a) *Hiſt. 4.*

With regard to the first assumption, we learn from Holy Scripture that all things, both when Creation began and at the time of the Flood, have been covered with waters. Of this Tertullian [14] writes elegantly : *A change occurred in all the world when it was covered with all the waters ; even now mussel shells and conches range about the mountains seeking to prove to* Plato [15] *that the very peaks have been under water.* And the arguments set out by people of the opposite opinion carry no weight when they say that bodies of this sort ought to be found everywhere, if these bodies are due to the waters covering all places, or at least that these bodies, when they are found, should not be found in high places only. For it will be easy to answer either objection : since every kind of waters will not carry everything, and if we should see plains at the feet of the mountains being filled with something like the scourings scraped from the mountains by the force of the rains, what wonder that in the high places those bodies appear uncovered, which are hidden in the lowlands, covered by fresh soil ?

De pall.

But if anyone should hold that the layers of soil in the places from which the bodies in question have been dug have at some time changed position, he cannot be held to think anything in conflict with reason or experience. Indeed, when we look at the fissures in the layers filled with a substance of (*a*) one colour only, where the layers themselves are of varying colours, then it seems quite likely that this piece of ground, having been shaken by a violent movement, has been broken when it fell back, and so has reached a new position. How great changes in the ground are often caused by

(a) *Observation 4.*

variis exemplis demonſtrare facile eſſet, niſi unius *Taciti* authoritas ſufficeret. *Eodem anno duodecim celebres Aſiæ urbes collapſæ nocturno motu terræ, qvo improviſior graviorqve peſtis fuit. Neqve ſolitum in tali caſu effugium ſubveniebat, in aperta prorumpendi, qvia diductis terris hauriebantur. Sediſſe immenſos montes, viſa in arduo, qvæ plana fuerint, effulſiſſe inter ruinam ignes, memorant.* Cum itaqve & ipſius terræ facies, & aliorum locorum exempla ſvadeant, fuiſſe terram illam aliter olim ſitam ; cum (*b*) videtur eadem terra olim minus fuiſſe compacta, qvid obſtat, qvo minus mollitiem illam ab aqvis deducamus, adeoqve, anteqvam terra ſitum mutaret, aqvis illam tectam fuiſſe credamus ; ſive aqvæ illæ libero aëri expoſitæ fuerint, ſive terræ cruſta fuerint obductæ ?

Annal. lib. 2.

(b) *Conject. 2.*

CONJECTURA IV

An aqvæ immixta eſſe potuerit eadem terra.

Nihil qvoqve obſtare videtur, qvo minus credamus, eandem terram aqvæ olim fuiſſe immixtam.

Præcedenti propoſitione inſinuavimus, potuiſſe eam terram aqvis olim fuiſſe tectam, modo ulterius pergemus ad probandum, potuiſſe eandem terram aqvis fuiſſe immixtam.

Qvod argilla & ſabulum aqvæ vehementius agitatæ immiſceantur, præceps torrentium per id generis terras prolapſus, & aqvarum a ventis agitatio notius reddidere, qvam qvod pluribus exponi

earthquakes it would be easy to show by various examples, if the evidence of Tacitus [16] alone were not enough. *During the same year twelve towns in Asia Minor were laid waste by an earthquake in the night, whereby the catastrophe became even more unforeseen and calamitous. And the usual resource on such occasions — to take refuge in the open places — was of no use, since people were swallowed up in the yawning earth. Huge mountains are said to have been levelled to the ground ; the flat ground is said to have risen into steep mountains, and fire broke out among the ruins.* Since then both the face of the ground itself and the example of other places indicate that this ground once has had another position ; since (*b*) it seems that this soil was once less firm, what is to prevent us from ascribing this softness to the waters, and even to believe that this ground, before it changed its position, had been covered with waters, whether the waters were open to the free air, or they were covered by a crust of earth ?

Annal. lib. 2.

(b) *Conject. 2.*

CONJECTURE 4

Whether this soil may have been mixed up with water.

Equally, there seems to be no objection to the belief that this soil has at some time in the past been mixed up with water.

In the foregoing, I have suggested that this ground may once have been covered with waters ; now I shall go a step further to prove that this same soil may have been mixed up with waters.

That clay and sand are mixed with strongly agitated water is too well known from the headlong course of torrents through such soils, and from the agitation of water by the wind, to need to be

mereatur. Nec probatu difficile eſt, in aqvis ſtagnantibus, imo in limpidiſſimis aqvis, ſabulum, argillam, & tophus, omnisqve generis ſolida ſæpius deliteſcere.

Duobus modis in aqva deliteſcunt ſolida, dum vel pulveres eorum, vel eorum elementa ibi deliteſcunt.

Pulvis ſolidi vel ſolus aqvæ miſcetur, qvod omnis generis ſalia & vitriola docent, vel tertii interventu aqvæ jungitur: ſic mineralia ope acidorum, lixivioſorum ſalium beneficio oleoſa in aqvas reſolvuntur, ubi oleo ſal, acidum aqvæ gravitatem dat, qva in aqvam deprimi oleum, & minerale in eandem aqvam poſſit elevari.

Poſſunt & ſolidi elementa duobus modis in aqva latere; vel enim ipſa ſolidi elementa ſive omnia, ſive ex parte ibi reperiuntur, vel ſui generis corpora ibi ſunt, qvæ aliam inde figuram induentia in ſolidum tranſformantur. Hac ratione credunt pleriqve, minerales aqvas elementa minerarum in ſe continere, & ex hoc fundamento originem traxit radicalis illa metallorum ſolutio, qva mercurium & ſulphur ex ſingulis metallis educere anxie laborant.

Loca, unde ſolida reſoluta potuerint profluxiſſe.

Et hi qvidem modi ſunt, qvibus aqvarum ſpecie ſolida poſſunt apparere, nec ſollicito labore opus eſt ad invenienda loca, unde hæc ſolida aqvis terras noſtras occupantibus fuerint communicata.

Omnis generis & ſolida & fluida terræ gremium recondit, nec poterint per occultos terræ meatus

explained further. Nor is it difficult to prove that in stagnant water, even in the clearest water, there may often be hidden sand, clay, porous stone and all sorts of solid bodies.

In two ways solid bodies may be hidden in water: they may be hidden as a powder, or their elements may hide in it.

The powder of a solid body may be mixed into the water by itself, as we learn from all sorts of salts and vitriols, or it may be united with the water by the agency of a third substance: in this way minerals are dissolved in waters by the aid of acids, oily substances by the help of alkaline salts, where salt gives to the oil, acid to the water the weight by which the oil may be pressed down into the water, and the minerals raised up into the same water.

The elements of a solid body may also be hidden in the water in two ways: for either the elements of the solid body themselves, all or in part, are found therein, or there are particular substances in the water that assume a different form from it and become a solid body. On this account most people hold that mineral waters contain the elements of the minerals, and this principle is the origin of that radical solvent for metals, by which they work eagerly to extract mercurius [17] and sulphur [17] from the single metals.

Places from which the dissolved solids may have flowed.

These then are the ways in which solids may appear under the guise of water, and no great work is needed to find the places from which these solids have got into the waters covering our lands.

The bosom of the earth hides solid and fluid bodies of every kind, and the juices that seep through the hidden veins of the earth, or the

delabentes ſucci, vel oberrantes in iiſdem locis halitus intacta relinqvere, ſi qvæ alias ſolida offenderint, qvibus diſſolvendis a Natura deſtinati ſunt. Jam vero in aqvas & aëri expoſitas, & terræ cruſta obtectas omni momento e terræ venis illabentes ſucci intra terram diſſoluta ſolida per aqvæ ſubſtantiam diſpergunt. Sed & in aërem ab aqva, terra, plantis & animalibus expulſa omnis generis corpora, & mire ibi inter ſe combinata pluviarum ſpecie, vel alio ſenſus noſtros fugiente modo iiſdem aqvis communicari poterint. Qvid qvod varii generis animalia, aqvarum indigenæ, dum vivunt, corporis ſui effluvia ibi deponant, & a morte qvaſi tota in aqvas reſolvantur.

Cum itaqve omnis generis ſolida aqvis immiſceri poterint; cum manifeſta loca ſint, unde eadem ſolida aqvis potuerint eſſe communicata: qvid miramur, argillæ, ſabuli, tophorum aliorumqve lapidum vel pulviſculos, vel elementa aqvis iiſdem delituiſſe immixta? Nec eſt, qvod qviſqvam credat, noſtro ſenſu acidos eſſe debuiſſe ſuccos dura illa corpora diſſolventes, adeoqve animalibus nutriendis fuiſſe ineptos. Vidi amiciſſimum Præceptorem *Borrichium*, duriſſimum calculum inſipida aqva in aqvam redigentem: & qvidni id daremus Naturæ, qvod arti denegare non poſſumus?

CONJECTURA V

An pro aqvæ ſediuento haberi poterit.

Nec qvicqvam obſtare video, qvo minus eandem terram pro aqvæ ſedimento ſenſim congeſto habeamus.

exhalations that flit about in these places, cannot leave intact, if they meet them elsewhere, such solids as by Nature they are destined to dissolve. Now, the juices that all the time find their way from the veins of the earth into the waters, either those open to the air or covered by a crust of earth, spread through the substance of the water the solid bodies dissolved below ground. But also all sorts of bodies which are given out into the air from water, earth, plants and animals and here combined in a wonderful way will be able to reach the same waters either in the form of rain, or in some other way that escapes our senses. As for instance animals of various kinds, belonging to the water, during their life void the excretions of their bodies there, and when they die are, so to speak, altogether dissolved in the waters.

Since, then, solids of every kind may be mixed with the waters; and since the places whence these solids may have found their way into the waters are evident, why should we wonder if either powders or elements of clay, sand, porous stones and other stones have been mixed, unseen, into the same waters? Nor need anyone believe that the juices that dissolve those hard bodies must have been acid to our taste, and therefore unable to nurture animals. I have seen my very dear teacher Borch [18] dissolve a very hard limestone in ordinary water; why then should not we grant to Nature what we cannot refuse to art?

CONJECTURE 5

Whether it may be taken for a sediment of water.

I cannot see what should prevent us from regarding this soil as a sediment of water, gradually accumulated.

(a) *Conj. 4.*

Videmus modo (*a*), nihil obſtare, qvo minus terram illam aqvæ fuiſſe immixtam credamus; viſui autem patet, (*b*) eſſe eam variis in locis ex diverſorum colorum ſtratis ſibi mutuo incumbentibus compoſitam; imo illis in locis, ubi ejuſdem coloris tota terra eſt, ſtratorum diverſitatem nihilominus dignoſci. Ipſa itaqve ſtrata invitant nos ad credendum, eſſe eam terram aqvæ ſedimentum; ſtratorum vero diverſitas ſenſim congeſtam eandem terram ſvadent, ad minimum, ſi non in totum perſvadent.

(b) *Hiſt. 3 & 4.*

Ut vero intellectui clariora hæc evadant, oſtendam, qvibus modis idem ſedimentum potuerit eſſe congeſtum.

Modi, qvibus ſedimenta aqvarum congeruntur.

Si credimus, aqvam, de qva agimus, potuiſſe turbidas aqvas vel a mari, vel a torrentibus recipere, certum eſt, debuiſſe corpora aqvam turbidam reddentia, ceſſante violento motu, fundum petere. Nec opus eſt in eam rem exempla ſtudioſe conqvirere, cum fluminum & alvei, & oſtia ejus rei fidem certam faciant. Unicum hic notandum, corpora illa, aqvam turbidam reddentia, non eſſe omnia ejuſdem gravitatis, qvo fit, ut, ſenſim ad qvietem redeunte aqva, graviora primo, inde minus gravia ſubſidant, leviſſima autem in fundi vicinia diutius fluitent, anteqvam fundo ſe jungant. Patet inde, eodem in ſedimento ſæpius diverſa ſtrata fieri.

Modi, qvibus ex aqva ſecernuntur, qvæ ibi deliteſcunt ſolida.

Qvod ſi credimus, eandem aqvam limpidam ſolida corpora continuiſſe ab aëre, terra & animalibus ipſi communicata, nec in hoc caſu difficile eſt

(a) *Conj. 4.*

We have just seen (*a*) that there is no hindrance to the belief that this soil has been mixed up with water; but it is evident to the eye (*b*) that in various places it is composed of layers of contrasting colours, superimposed upon each other; and in places where all the soil is of uniform colour, it is even possible to distinguish a difference between layers. The layers themselves, then, lead us to believe that the soil is a sediment of water, but the difference between the layers indicates at least that this soil has been deposited little by little, if it does not prove it altogether.

(b) *Observations 3 & 4.*

To make this more easily understood, however, I shall now show in what manners sediments may have been deposited.

The way in which sediments in waters accumulate.

If we believe that the water in question may have taken up muddy water, either from the sea or from torrents, it is certain that the bodies which made the water muddy must have sunk to the bottom when the violent movement ceased. And it is not necessary to seek examples of this with care, since both the beds and the estuaries of rivers prove this. Only one thing has to be noticed here, to wit, that these bodies that make the waters muddy are not all of the same weight, by which it has come about that when the water slowly becomes quiet, first the heavier particles, then the less heavy will settle down, but the lightest will float about somewhat longer near the bottom before they will add themselves to the bottom. From this it is clear that often different layers will be found in the same sediment.

The ways in which solid bodies hidden in water may be secreted.

But if we believe that some clear water has contained solid bodies added to it from the air, the earth and animals, even in this case it will not be

modos varios invenire, qvibus ex limpidis aqvis contenta ibi ſolida potuerint eſſe ſecreta ; præcipuos eorum paucis hic exponam.

1. Si fluidi partes agitans ſubtilior materia non ſemper eodem impetu fluidum permeat, qvæ ſolida corpuſcula majori ipſius motu cum fluidi particulis æqvaliter movebantur, ceſſante eadem vi, a fluidi amplexibus excidunt. Sic ſangvis non, niſi dum calidus eſt, totus fluit, totus rubet ; ſuperveniente frigore in partes colore & conſiſtentia diverſas ſecedit. Sic urina clara ſæpius tranſparentiam cum calore amittit, reſumptura eandem, cum igni imponitur. Pari ratione poterint ex terra affluentes calidi ſucci, vel ab eadem terra ſpirantes calidi halitus aqvæ immixti adductos ſecum ſolidiores pulviſculos ceſſante calore deponere. Nec opus, ſemper magnus fuerit ille calor, & vitæ animalium in iſtis aqvis degentium adverſus : ſuffecerit, ſubtilem materiam aliunde advenientia fluida agitantem ſolito velocius fuiſſe motam.

2. Si leviores fluidi partes ſenſim exhalare poterint, mutata diſſolventis ad diſſolutum proportione, ex diſſoluto ſolido tantundem ſubſidere debet, qvantum ex diſſolvente pro rata portione evolavit. Freqventi experientia id demonſtratur tum in illis fluidis, qvæ ſolidi pulviſculum continent, tum in illis, in qvibus ſolidi elementa deliteſcunt. Primo modo ſalium cryſtalli ex aqvis ſalſis, ſecundo modo

difficult to find different ways in which the solid bodies contained in the clear waters may have been secreted ; I shall here explain shortly the more important of these.

1. If a 'subtile matter' moving the particles of a fluid does not always penetrate the fluid with the same force, the solid bodies that were moved by its strong impulse, together with the particles of the fluid, will detach themselves from the grasp of the fluid when the impulse ceases. In this way blood will not be uniformly fluid and uniformly red, except when it is warm ; if it is exposed to cold, it separates into parts of different colour and consistency. In this way a clear urine loses its transparency with its heat, but recovers it when exposed to fire. In the same way the warm juices permeating through the earth, or the warm emanation issuing from it, might deposit their more solid particles when the heat ceases. Nor is it essential that this heat should always have been great and unfavourable to the life of the animals living in these waters ; it will have been enough that the 'subtile matter' that stirs the fluids coming from somewhere else should have been more vigorously moved.

2. If the more volatile parts of the fluid have been able to evaporate gradually, then, since the ratio of the dissolved matter to the solvent is changed, a quantity of the dissolved solid should settle, corresponding to the quantity of the solvent that has evaporated. This is frequently proved by experience, both in the fluids that contain particles of a solid and in those in which the elements of a solid are hidden. In the first manner crystals of salts are precipitated in salt water; in the second

tartarus ex vino ſeparatur. Pari ratione in omnibus aqvis ſedimenta congeri, freqventibus adeo exemplis indies obſervatur, ut ea hic congerere ſupervacuum judicem.

3. Si credimus, e diverſis locis, tempore vel eodem, vel diverſo diverſa fluida confluere potuiſſe; facile admittemus, potuiſſe ex uno loco allata fluidi ſpecie ſolida aliunde allatis fluidis præcipitari. Sic acidis diſſoluta ſalium adventu, ſic ſalſis diſſoluta adventu acidorum præcipitantur; cum acida & ſalſa facilius ſibi qvam aliis ſolidis uniantur. Poſſunt & aliis modis acido reſoluta ſolida præcipitari, ut in metallis videmus, ubi ſolutum acido metallum unum alterius metalli injectione præcipitatur. Ob eandem rationem ſpiritu volatili extractæ tincturæ affuſa aqva ſeparantur. Sed & duo fluida ſibi affuſa in ſolidum ſimul concreſcunt: ſic vidi Pariſiis in Academia amiciſſimi Hoſpitis *Thevenotii* Chymicis multum verſatum *Borellum* duos liqvores limpidiſſimos confundere, qvi illico concreſcebant adeo, ut everſo vitro ne gutta qvidem excideret. Qvidni liceret itaqve ſuſpicari, diverſo tempore diverſæ naturæ pluvias ab aëre, ex terra diverſæ naturæ ſuccos halitusve aqvæ immixtos modo diſſoluta in ea corpora præcipitare, modo præcipitata in ea

manner tartar in wine. We see so many examples daily that sediments accumulate in the same way in all waters, that I consider it superfluous to enumerate them here.

3. If we believe that different fluids have been able to run together from different places, either at the same time or at different times, we shall readily admit that solids may have been precipitated from the fluids coming from one spot by a sort of fluid coming from another place. Thus substances that have been dissolved by acids are precipitated when salts are added, and substances that have been dissolved by means of salts are precipitated when acids are added, because acids and salts unite more easily with each other than with solid bodies. In other ways also solids dissolved by acids may be precipitated, as we see in metals, where one metal dissolved in acid may be precipitated if another metal is added. For the same reason tinctures extracted with pure alcohol will be precipitated when water is added. But also if two clear liquids are mixed it may happen that a solid body is formed at once by the mixture. Thus, in Paris, in the house of my good friend Thévenot,[19] I have seen Borel,[20] so highly skilled in chemistry, pour together two quite clear liquids, which at once became so solid, that not a single drop came out when the glass was turned upside down.[21] Why then should we not assume that rain falling from the sky at various times and of various origin, and that juices and vapours of diverse character issuing from the earth, when mixed with waters should be able sometimes to precipitate bodies dissolved in them, and sometimes to dissolve bodies precipitated? In the urine

corpora reſolvere? In unius ejuſdemqve hominis urina diverſo tempore collecta id evidens eſt, qvandoqvidem fundo tenaciſſime adhærens ſedimentum ſolidum, qvod primis diebus deponitur, perſæpe ſeqventibus diebus a nova ejuſdem hominis urina reſolvitur, brevi inde ab alia urina de novo cumulandum. Qvod Diætæ diverſitas in microcoſmi humoribus efficit, idem Solis & Lunæ viciſſitudines variæqve mutationes aliæ in terræ humoribus poterint producere. Manifeſtiſſimo exemplo idem confirmat Galliæ lumen *Gaſſendus*, dum lapidum productionem in philoſophia ſua explicat.

4. Qvi ex qvolibet qvodlibet fieri contendunt, aut ſaltem, variis mutationibus minima naturalia obnoxia eſſe, admittunt, alio modo rem explicare poterint; ſatis enim & clare, & diſtincte imaginari nobis poſſumus, ſubtilem materiam, dum aqvam aëremqve percurrit, varias fluidorum partes nova figura ſenſim indutas in ſolida corpora tranſformare. Vidi apud *Borrichium* noſtrum ex aqva puriſſima albicantem terram, terram inſipidam ex ſale lixivioſo, ex aëre ſalem igni reſiſtentem: id qvod pro principiorum varietate varie poterit explicari.

Et hi varii modi ſunt, qvibus ex fluido ſolida, imo ex fluido fluida (ut de iis, qvæ aëri accidunt, demonſtratu facile eſt) ſeparantur: qvibus omnibus modis ſi terræ noſtræ ſtrata congeſta non ſunt, eiſdem

collected from one and the same person at different times this is clearly seen, in as much as a solid deposit clinging to the bottom of the receptacle, which is deposited during the first days, very often is dissolved during the following days, by fresh urine from the same person, only to collect again shortly from more urine. What the variety of diet brings about in the humours of the microcosm,[22] the changes of the Sun and Moon and other various changes might be able to produce in the humours of the earth. This is shown by Gassendi,[23] 'the light of France', by a clear example in the learned work in which he explains the origin of the stones.

4. Those who postulate that anything may come from anything whatsoever, or, at any rate, admit that even the smallest things in Nature are subject to various changes, will be able to explain the matter in a different way; we can, however, clearly and plainly imagine that the 'subtile matter', when it permeates the water and the air, may gradually impart to the various constituents of the liquids a new form and transform them into solid bodies. In the company of my fellow-countryman Borch I have seen an almost white sort of earth come from the purest water, a tasteless sort of earth from an alkali, and, from the air, a salt which was not affected by fire: which things may be explained in various ways according to the various fundamental principles.

These then are the various ways in which solids are precipitated from a liquid, or indeed liquids from a liquid (as is easily shown about the fluids of the air); and if the layers of the soil in question have not been formed in all these ways, it is certain

modis congeri potuiſſe, certum eſt.

Sed qvocunqve demum modo ex fluido ſecernantur ſolida, vel pulveris ſpecie apparent, ut ex acidis præcipitata metalla, vel ſubſtantiam cohærentem repræſentant, ſive molliorem, ut in ſangvine, qvod fibroſum eſt, in lacte, qvod caſeoſum eſt, in rore majali & aqva pluvia ſedimentum viſcoſum; ſive duriorem, ut in vino tartarus, in aqvis ſalſis cryſtalli, in variis fontibus lapidea cruſta. Hinc patet, ex limpidiſſimis aqvis potuiſſe concreſcere cruſtas inter ſe conſiſtentia diverſas, imo varii generis mineralibus refertas.

Qvam bene itaqve conveniunt omnia! Qvam unanimi conſenſu inter ſe conſpirant! Agnoſcimus terræ illius ſitum aqvis continendis aptum eſſe potuiſſe; ſcimus, ejuſdem terræ & pulviſculos, & elementa aqvæ potuiſſe immiſceri; non ignoramus modos, qvibus & in aqvas illas devehi, & ex iiſdem aqvis potuerint ſeparari, imo in ipſa terra ſtratorum diverſitatem intuemur: quidni poterit itaqve eadem terra pro aqvæ ſedimento haberi?

Qvibus hæc non ſufficiunt, ſubterraneas cryptas ingrediantur, unde olim educta ſaxa ſunt, & videbunt in exhauſti ſaxi locum novum ſaxum concreſcere; imo agnoſcent, ex fluido aëre ſecreta corpora ſtirias lapideas conformare a fornicibus dependentes: qvæ ſtiriæ, intus cavæ, & ex multis lamellis tanqvam cylindris compoſitæ, nec aqvam, nec ſaxum a fornicibus accipiunt, id qvod lamellarum ſtructura non ſvadet, ſed demonſtrat.

that they may have been formed in some such ways.

But in whatever way solids are precipitated from liquids, they appear either as powder, like metals precipitated from acids, or they represent coherent substances, either rather soft, as in blood, which is fibrous, in milk, which is cheesey, in May dew [24] and rain water as a viscid sediment; or more solid, as tartar in wine, crystals in salt water, stone crusts in various springs. From this it is clear that from quite transparent waters crusts of the most various consistency may have been concreted, even filled, with minerals of different kinds.

How well then everything agrees! How unanimously they all point in the same direction! We find that the position of this soil is such that it may have been able to hold waters; we know that both the powders and the elements of this soil may have been mixed up in waters; we do not ignore the ways in which they may have been able to get into these waters and to be separated from these waters again — nay, we see the variety of the layers in the soil itself: Why then could this very soil not be regarded as a sediment from water?

But let those for whom this is not enough go into the underground caves, from which stones of old have been quarried, and they will see new rock growing out where the rock has been taken away — nay, they will find that bodies excreted by the flowing air form stony icicles hanging from the vaults: and these icicles, hollow inside and composed of many lamellae like cylinders, receive neither water nor rock from the vaults, which the structure of the lamellae not only indicates, but proves.

CONJECTURA VI

An animalium partibus ſimilia corpora e terris eruta pro animalium partibus habenda.

Nihil obſtare videtur, qvo minus animalium partibus ſimilia corpora, qvæ e terris eruuntur, pro animalium partibus habeantur.

Cum terra, unde animalium partibus ſimilia cor-
(a) *Conj. 1.* pora eruuntur, (*a*) hodie id generis corpora non
(b) *Conj. 2.* producat; cum eandem terram (*b*) mollem olim,
(c) *Conj. 4. De corporum eorundem in terra ſitu.* imo (*c*) aqvis immixtam fuiſſe vero ſimile ſit, qvidni liceret ſuſpicari, id generis corpora pro animalium in iſtis aqvis degentium ſpoliis eſſe habenda? Sane ſi illorum in terra ſitum examinare libet, non videntur eo modo congeri potuiſſe, niſi cum aqvæ ſedimento ſenſim dicantur congeſta. Nec adverſatur nobis, qvod tanto numero in terra duriori reperiantur. Qvi enim attente examinaverit, qvo modo in terræ cryptis, unde olim educta ſaxa fuere, novum ſaxum concreſcit, difficultatem ibi nullam inveniet. Sive enim in aqvæ ſuperficie cremoris inſtar concreſcens ſaxea cuticula, ubi gravior reddita fuerit, fundum petat, ſive ex tota aqva æqvaliter ſecreta ſaxea corpuſcula ſenſim ſubſidant, non niſi lente id ſedimentum concreſcit; unde non niſi qvæ in fundo jam tum hærent, ſive mortua animalia, mortuorum ſpolia, ſive viva, ſed motui inepta, novo ſedimento obruuntur; reliqva vero animalia viva, & ſupra

CONJECTURE 6

Whether the bodies like parts of animals dug from the ground should be held to be parts of animals.

Nothing seems to oppose the opinion that the bodies dug out of the ground and looking like parts of animals should be considered as parts of animals.

Since the ground from which the bodies re-
(a) *Conj. 1.* sembling parts of animals does not produce this sort of body in our time (*a*); since it is likely that the soil in question has been soft in former times
(b) *Conj. 2.* (*b*), indeed, presumably has been mixed up with
(c) *Conj. 4.* waters (*c*); why, then, should we not be allowed to surmise that these bodies are remains of animals that lived in these waters? Indeed, if you like to examine their position in the ground, it does not seem possible that they could have come together in this way, unless they may be said to have been deposited little by little with the sediment from water. Nor can it be objected that they are found in such numbers in the harder soil. To him who has carefully examined how new stone is formed in subterranean caves, where formerly stones were quarried, this will present no difficulty. For whether a stony crust, cream-like, is formed on the surface of the water and then, when it has become heavier sinks down to the bottom, or some stony particles are produced evenly everywhere in the water and slowly sink down, the sediment will only grow gradually; so only that which already belongs to the bottom, whether it be dead animals or their parts, or living animals unable to move, will be covered by the new sediment; but the other animals that are alive and seek their way up above

On the position of these bodies in the ground.

dictum ſedimentum enitentia, numeroſa prole aqvas replent, anteqvam novum ibi ſedimentum deponatur. Accedit: 1. Qvod ſtagnans in iſtis cryptis aqva ſemel producta animalia ſemper conſervet, ſecus ac in fluentibus contingit. 2. Qvod teſtacea & id generis animalia in propria viſcera non ſæviunt, qvam ob cauſam aqvatilia alia ſe mutuo conſumunt. 3. Qvod eorundem tegmina raro conſumantur, cum alia aqvatilia fere tota in aqvam reſolvantur. Hæc omnia argumenta ponderis non parum habere mihi videntur ad conjecturam meam ſtabiliendam, præſertim cum a corporum ipſorum figura & ſubſtantia nihil facile in contrarium poſſit afferri.

De corporum eorundem figura. (d) *Hiſt. 9.*

Qvod figuram corporum ſpectat, de qvibus agimus, cum animalium partibus (*d*) qvam exactiſſime reſpondeat, conformationis ſimilitudo originis ſimilitudinem inferre videtur; nec facile creditu eſt, a qvocunqve demum principio alio facta illa dicas, conformitatem tantam fuiſſe obſervandam. Et ecce ejus rei evidentiſſimum argumentum. Qvis non agnoſcit, hexaedram cryſtalli figuram, marcaſitarum cubos, ſalium in Chymicis operationibus cryſtallos & infinita alia in fluido concreſcentia corpora figuras habere multo magis ordinatas, qvam ſunt figuræ pectinum, bivalvium, turbinum aliorumqve? Nihilominus videmus in ſimplicibus hiſce corporibus modo anguli ſolidi apicem truncatum, modo plura ſibi ſine ordine adhærentia corpora, modo magnitudine & ſitu inter ſe differentia plana, aliosqve varios modos, qvibus a ſolita figura recedunt. Qvanto majores pluresqve notandi eſſent defectus in corporibus figuram multo magis compoſitam

the sediment in question fill the waters with a numerous progeny, before a new sediment is deposited there. To this may be added: (1) That the quiet water in these caves always preserves animals that once have been brought forth there, as flowing water does not. (2) That crustaceans and that sort of animals do not prey on their own kind, while other marine animals devour each other.[25] (3) That their shells are rarely consumed, while other marine creatures are almost entirely dissolved in the water. All this evidence appears to me to carry considerable weight in support of my conjecture, especially since the form of the bodies or their substance provides no evidence against it.

On the form of these bodies. (d) *Observation 9.*

As to the form of the bodies of which we are speaking, since it corresponds exactly to the parts of animals (*d*), the similarity of the form seems to argue a similarity of origin; nor is it easy to believe, no matter in which other way you will contend that they have been made, that so great a similarity could have been found. And here is the clearest proof of this. Who does not admit that the hexagonal shape of rock crystals, the cubes of pyrites, the crystals of salt from chemical experiments and countless other bodies precipitated from liquids have shapes far more regular than mussel shells, oyster shells, conches and others? None the less, in these simple bodies we find now the top of the crystal cut off, now several bodies clinging together without order, now planes that differ from each other in size and position, and other various ways in which they differ from the usual shape. How much larger and more frequent defects should then be seen in the bodies of a much more composite

habentibus, qvalia ſunt illa, qvæ animalium partes imitantur? Qvod ſi qvibuſdam in locis oſtreorum teſtæ plurimæ in unam maſſam concretæ (*e*) deteguntur, nihil hic diverſi eſt ab illo, qvod in mari fit, cum & inde extrahantur ingentes maſſæ oſtreorum diverſæ magnitudinis, qvæ ſibi mutuo mirum in modum hærent agglutinata. Si qvædam conchæ media ſui parte truncatæ reperiuntur, ipſe fragmenti limbus teſtatur, alteram partem illi olim adhæſiſſe, qvæ etiam interdum in prioris vicinia reperitur. Qvod ſi gloſſopetræ plures diverſæ magnitudinis, nec omnes integræ, ſimul eidem qvaſi matrici adhærere interdum videantur; in vivi animalis mandibula idem conſpicitur, ubi nec ejuſdem magnitudinis ſunt omnes dentes, nec in ordinibus interioribus conſtituti dentes omni ſui parte ſunt indurati. Cum itaqve in corporibus plurimum compoſitis illi defectus rarius occurrant, qvi in ſimpliciſſimis corporibus freqventiſſimi ſunt; cum nulli defectus obſerventur in iſtis compoſitis corporibus, qvi non eodem omnino modo in animalium partibus conſpiciuntur; cum eadem corpora, undecunqve eruta, & ſibi & animalium partibus ſimillima ſint: facile patet, figuram illorum corporum non obſtare, qvo minus pro animalium partibus habeantur.

(e) *Hiſt. 11.*

De corporum eorundem ſubſtantia.

Ut ad ſubſtantiam eorundem corporum pergam, nec illa noſtræ opinioni adverſatur. Sive enim lapidis inſtar dura ſit & gravis, ſive corporum calcinatorum more levis in pulverem facile reducatur, nihil hic effectum eſt, qvod id generis partibus animalium non potuerit contigiſſe. Videmus ſolidiora corpora, qvæ ab animantibus deſumuntur, duas diverſas materias in ſe continere: unam, qvæ,

shape, such as those that imitate the parts of animals? But even if in some places oyster shells are found grown (*e*) into a solid mass, this is in no way different from what happens in the sea, since also from the sea are taken great masses of oysters of different sizes, which in a wonderful way all hang together. If snail shells are found broken right across, the surface of the fracture itself shows that another fragment has belonged here, and this is occasionally found near the first. And if several tongue stones of different size, and not all unbroken, are found sometimes to stick together in the same matrix, so to say; why, the same thing is seen in the jaw of the living animal, where neither all the teeth are of the same size, nor all the teeth placed in the inner rows are hardened all through. Since then in the very complex bodies those defects are found rather seldom, although they are very frequent in the simplest bodies; since no defects are observed in the complex bodies except those that are found in the very same way in the parts of the animals; since the same bodies, wheresoever they are dug out, are quite like each other and the parts of the animals: it is quite evident that the shape of these bodies does not prevent us from taking them to be parts of animals.

(e) *Obſervation 11.*

On the substance of these bodies.

When it comes to the substance of these bodies, it does not tell against my opinion, either. For whether it is hard and heavy like stone, or, like calcined bodies, is light and easily reduced to a powder, nothing has occurred here that might not have happened to this sort of animal parts. We see that the more solid parts taken from animals contain two categories of substances: one which

fluidi ſubtilioris acceſſu in fluidum reſoluta, exhalationis vel liqvoris ſpecie apparet; alteram, qvæ, fluidi ſubtilioris motui reſiſtens, ad tempus ſic ſatis longum integræ partis figuram reſervat, donec tandem nimia mora in pulverem dilabatur. Sic oſſa qvæcunqve & cornua aperto igni expoſita, ſic cervi cornua aliaqve philoſophice, ut dicunt, calcinata ſubſtantiæ fluidæ plurimum deperdunt, retenta nihilominus priſtina ſua figura &, qvoad apparentiam, magnitudine. Nec enim affirmare auſim, magnitudinem non imminui. Poterunt qvidem in illis corporibus pori poſt expulſum animalem ſuccum alio fluido ejuſdem qvantitatis repleri; ſed & poterunt iidem pori imminui collabentibus in ſe ſolidioribus partibus. Sic ſolida metalla pro vario caloris frigorisqve gradu extenſionem ſuam mutare vidi, non mutata figura, id qvod mihi favore cariſſimi capitis *Laurentii Magalotti* in armilla aënea videre contigit, licebitqve propediem omnibus naturalium rerum curioſis.

Hæc experimenta Chymiæ debemus, nec dubito, qvin ſimili modo in terræ gremio Natura operetur. Dum longa annorum ſerie ſenſim indureſcit una cum dictis corporibus congeſtum ſedimentum, non poterit ſubtilius fluidum intacta relinqvere eadem corpora, ſed oportet, pro ambientis terræ natura, vel animalem ſuccum inde extrahat, vel mineralem ſuccum illis ſuperaddat, vel exhauſto animali ſucco ſuccum mineralem introducat, vel, ſi mutationis expertia nolumus minima naturalia, in mineralem

is dissolved into a liquid by the agency of the 'subtile matter' and comes to light as an exhalation or a fluid; another, which resisting the action of the 'subtile matter' for quite a long time keeps its shape as if it were intact, till at long last it very suddenly is reduced to a powder. In this way all sorts of bones and horns exposed to open fire, in this way stags' antlers and other such things calcined philosophically, as they say, in the chemist's retort, lose most of their liquid substance, but none the less retain their original shape and, apparently, their size. Yet I dare not say for certain that their size is not reduced. To be sure, the pores of these bodies may be filled with another liquid of the same volume, after the animal juices have been forced out; but on the other hand these pores may decrease in size when the more solid parts contract. Thus I have seen solid metals change their dimensions when exposed to heat and to cold, without any change in their original shape, which my friend Lorenzo Magalotti [26] has been kind enough to show me by means of a copper arm-ring; [27] and anyone interested in natural science can see this any day.

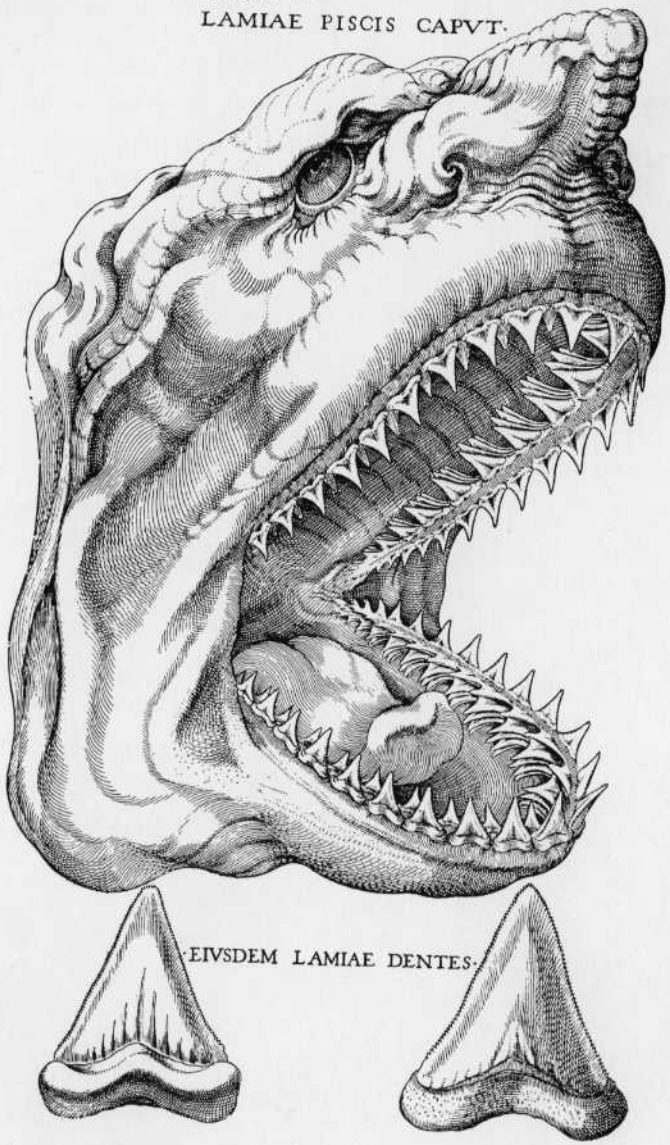
For these experiments we are beholden to Chemistry, and I do not doubt that it takes place in a similar way in the bosom of Nature. While during a great number of years the collected sediment hardens slowly together with the bodies in question, the 'subtile liquid' cannot have left these bodies intact, but it must, according to the nature of the surrounding soil, either extract the animal juice from it, or introduce a mineral juice into them, or fill them with a mineral juice after the animal juice is gone, or, unless we hold that the smallest

ſuccum ſuccum animalem tranſformet. Atqve ita qvidem ſatis luculenter me oſtendiſſe puto, nec in terra, unde animalium partibus ſimilia corpora eruuntur, nec in ipſis illis corporibus qvicqvam facile reperiri, qvod obſtet, qvo minus eadem corpora pro animalium partibus habeantur.

Dum meam opinionem vero ſimilem oſtendo, contrariæ ſententiæ Patronos falſi non arguo. Pluribus modis idem phænomenon explicari poterit; imo eundem finem diverſis mediis in ſuis operationibus aſſeqvitur Natura. Imprudentis itaqve eſſet unum ex omnibus modum ſolum pro vero agnoſcere, reliqvos omnes ut erroneos damnare. Multi & magni Viri ſunt, qvi eadem corpora ſine animalium concurſu producta credunt. Namqve, ut publico notos taceam, *Mercatus Miniatenſis*, cujus mentionem ſupra feci, eandem ſententiam tuetur, qvod etiam agit in ſuis Scenis Etruſcis *Antonius Nardi*, qvem librum manuſcriptum, problemata plurima phyſica & mathemathica continentem, poſſidet Amicus Clariſſimus *Franciſcus Redi*, Sereniſſimi Magni Etruriæ Ducis Archiater. Habent & hi ſuas rationes, qvæ tanto minus rejiciendæ ſunt, qvanto major numerus eſt admirandarum Naturæ operationum, qvæ in ſingulos dies novum nobis incutiunt ſtuporem.

De gloſſopetris majoribus.

Ut finita digreſſione ad propoſitum redeam, gloſſopetris majoribus ex dictis nonnulla accommodabo. Eſſe eas Canis Carchariæ dentes, figura illarum ſvadet, cum plana planis, latera lateribus, baſis baſi qvam ſimillima ſint. Si credimus hiſtoriis,



Steno's figure (1667) of a shark's head and teeth (from Mercati: *Metallotheca*), showing the resemblance of recent shark's teeth and fossil *glossopetrae*.

particles of Nature are unable to change, transform the animal juice into a mineral. Thus I think that I have demonstrated clearly enough that neither in the soil from which the bodies resembling parts of animals have been dug out, nor in these bodies themselves, will it be easy to find anything to oppose the view that these bodies are taken to be parts of animals.

While I show my opinion to be probable, I do not accuse the supporters of the opposite view of falsehood. The same phenomenon may be interpreted in various ways; indeed, Nature in her processes gains the same end by various means. Hence it would be unwise to regard just one method of them all as true, and condemn all others as false. Many and great are the men who believe that these bodies have been produced without the intervention of animals. For, to leave out those who are well known, Mercati [28] of San Miniato, whom I have mentioned above,[29] holds this opinion, as does also Antonio Nardi [30] in his *Scenes of Tuscany*, a handwritten book containing many physical and mathematical problems, now in the possession of my most renowned friend Francesco Redi,[31] Physician-in-ordinary to His Grace the Grand Duke of Tuscany. These also have their reasons, which are so much the less to be rejected, the greater the number of astonishing works of Nature we find, which every day causes us fresh surprise.

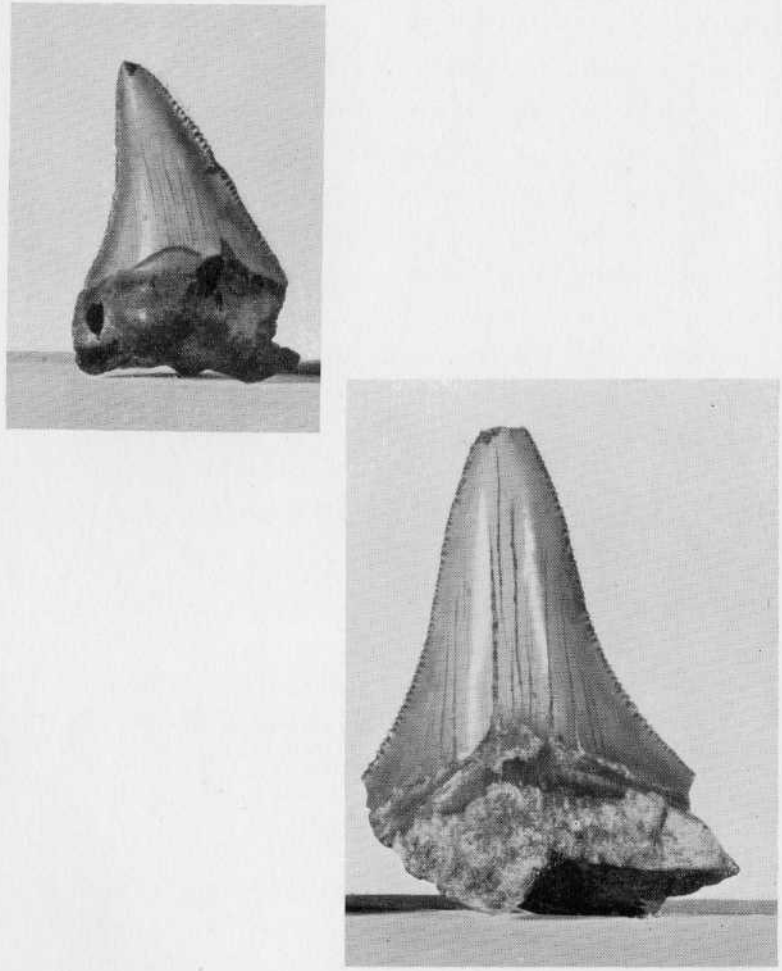
About the greater tongue stones.

To get back to the matter in hand, I shall apply a few points of what I have said to the tongue stones. That they are sharks' teeth is proved by their shape, since they are quite alike, planes to planes, sides to sides, base to base. If we believe

e medio mari novæ ſubſiluere inſulæ; & qvis Melitæ prima incunabula novit? Forſitan mari olim ſuppoſita ea terra canum marinorum latibulum fuit, qvorum dentes cœnoſo fundo olim inſepulti, mutato fundi ſitu per ſubterraneorum halituum præceps incendium, modo in media inſula reperiuntur. Nec freqvens gloſſopetrarum numerus, qvæ ex illa inſula afferuntur, difficultatem parit. In eodem piſce ducenti dentes & amplius numerantur, qvibus indies novi alii ſuccreſcunt.

Cum itaqve animalium partibus ſimilia corpora, qvæ e terris eruuntur, pro animalium partibus haberi poſſint; cum gloſſopetrarum figura Canis Carchariæ dentibus ut ovum ovo ſimilis ſit; cum nec earum numerus, nec terræ ſitus contrarium ſvadeant: a vero non multum recedere mihi videntur, qvi gloſſopetras majores Canis Carchariæ dentes pronuntiant.

Stabat hæc digreſſio jam jam prælo ſubmittenda, cum ob ſingularem rerum naturalium notitiam & indefatigatum in Muſeo ſuo locupletando ſtudium nulli non cognitus *Manfredus Settala*, Canonicus Mediolanenſis, haſce oras tranſiens mihi dixit, multa ſe aſſervare inter rariora ſua, qvæ meis conjecturis haud obſcure favent, id qvod mihi intellectu gratum fuit, utpote non ignaro, qvantum ponderis iis accedat ab illius Viri aſſenſu.



Fossil shark's teeth (or *glossopetrae*) from Malta (Mineralogical-Geological Museum of the University of Copenhagen). *Photo. Chr. Halkier.*

the accounts, new islands have emerged from the sea; and who knows where Malta's cradle was situated? Perhaps formerly when this place was submerged in the sea it was the haunt of sharks, whose teeth in times past were buried in the muddy sea-bed; then, afterwards, when it had changed its level by a sudden ignition of subterranean emanations, these sharks' teeth are found in the middle of the island. Nor does the great number of tongue stones procured from this island present any difficulty. In a single fish we may count more than two hundred teeth, and day by day more are added.

Since then the bodies resembling parts of animals that are dug out of the ground may be assumed to be parts of animals; since the shape of the tongue stones is like the shark's teeth as one egg to another; since neither their number nor their position in the ground speaks against it: it appears to me that they cannot be far from the truth who assert that the tongue stones are sharks' teeth.

This digression was quite ready to go to press, when Manfredo Settala,[32] Canon of Milan, who is known to everybody for his singular knowledge of natural history and his indefatigable zeal for enriching his museum, on a short visit to this place told me that he possessed among his rarer objects many things that favour my conjectures rather clearly, which I was very glad to hear, since I know quite well how much they gain in weight by this man's concurrence.

NOTES

INTRODUCTION

1. For example, in English, Frank Dawson Adams: *The Birth and Development of the Geological Sciences* (Baltimore, 1938), 357 f.

2. L. Élie de Beaumont: *Fragmens géologiques, tirés de Stenon . . .*, in *Annales des sciences naturelles*, vol. 25 (1832), 337 f., may be quoted.

3. The Prodromus of Nicolaus Steno's Dissertation concerning a solid body enclosed by process of Nature within a solid. An English version with an introduction and explanatory notes by John Garrett Winter, University of Michigan. With a foreword by William H. Hobbs, University of Michigan (New York, 1916) (University of Michigan Studies. Humanistic Series, volume XI. Contributions to the History of Science, Part II).

4. Gustav Scherz: *Vom Wege Niels Stensens. Beiträge zu seiner naturwissenschaftlichen Entwicklung* (København, 1956) (*Acta historica scientiarum naturalium et medicinalium*. Edidit Bibliotheca Universitatis Hauniensis, vol. 14), *Nicolaus Steno and his Indice*. Edited by Gustav Scherz (1958) (*Acta historica scientiarum natural. et medicinal.*, vol. 15).

5. Nicolaus Steno: *Elementorum Myologiæ Specimen, seu Musculi descriptio Geometrica. Cui accedunt Canis Carchariæ dissectum Caput, et Dissectus piscis ex Canum genere* (Florence, 1667). Since November

1957, the Royal Library, Copenhagen, has had the printer's manuscript of this book (Gustav Scherz in the journal *Stenoniana Catholica* (1958), 23 f.).

6. Axel Garboe: Niels Stensen's Grotto Letters (1671). An episode in the life of the young Niels Stensen (Steno) in *Hilsen til J. Christian Bay paa Firsaarsdagen* (1951), 15 f.

7. The *Indice* is published in German with notes in Gustav Scherz: *Vom Wege Niels Stensens* (1956), 141 f., cf. 128 f., and in English in *Nicolaus Steno and his Indice*. Edited by Gustav Scherz (1958), 201 f.

8. In English a short biography of Nicolaus Steno is given in *Nicolaus Steno: Opera philosophica*, edited by Vilhelm Maar, vol. i (1910), pp. i-xxviii. See also (cf. Note 3): John Garrett Winter's translation of *De solido*, and Axel Garboe: *Nicolaus Steno (Niels Stensen) and Erasmus Bartholinus: Two 17th-Century Danish Scientists and the Foundation of Exact Geology and Crystallography* (1954) (Danmarks Geologiske Undersøgelse (Geological Survey of Denmark). Series 4, vol. 3, no. 9). In Gustav Scherz: *Nicolaus Steno and his Indice* (1958) a detailed life-history is given of Niels Stensen as scientist and a cleric.

9. Axel Garboe: *Thomas Bartholin. Et Bidrag til Dansk Natur og Lægevidenskabs Historie i det 17. Aarhundrede*, vols. i-ii (1949–50) (English summary).

10. Nicolaus Steno: *Canis Carchariæ dissectum Caput* in: *Elementorum Myologiæ Specimen* (1667), 115.

11. Axel Garboe: *Niels Stensens (Stenos) geologiske Arbejdes Skæbne. Et Fragment af Dansk Geologis Historie* (1948) (English summary) (Danmarks Geologiske Undersøgelse (Geological Survey of Denmark). Series 4, vol. 3, no. 4).

LATIN TEXT AND TRANSLATION

12. The Latin text reprinted here is from Nicolaus Steno: *Elementorum Myologiæ Specimen. . . .* (1667), reproduced with some typographical corrections in *Nicolaus Steno: Opera philosophica*, edited by Vilhelm Maar, vol. ii (1910), 128–139. A Danish translation of *Canis Carchariæ dissectum Caput* (1667) is given by August Krogh in: *Stenoniana*. Edited by Vald. Meisen and Knud Larsen, I (1933), 55 f.

13. Professor Oluf Borch (1626–90), the teacher of Nicolaus Steno in Copenhagen, published a treatise on stone-building in cavities in the rocks as well as in cavities in living organisms (*De generatione lapidum in macro- & microcosmo*, in *Acta medica et philosophica Hafniensia*, vol. v (1680), 184 f.).

Oluf Borch died after an operation for stone in the bladder.

14. Tertullian, the learned theologian, born in Carthage A.D. 160, in his treatise *De pallio* mentions various processes in the earth's crust.

15. Plato: *Critias* 111 B (text and translation in The Loeb Classical Library, vol. 168 (1929), 272 f.).

16. Tacitus: *Annales*, lib. 2, cap. xlvii (text and translation in The Loeb Classical Library, vol. 350 (1931), 459).

17. *Mercurius* and *sulphur* are ancient chemical terms used also by the alchemists in their search for the transmutation of metals to gold.

18. Nicolaus Steno's relations with Oluf Borch are mentioned by Gustav Scherz: *Vom Wege Niels Stensens* (1956), 31 f., and Axel Garboe in: G. Scherz: *Nicolaus Steno and his Indice* (1958), 105.

19. Melchisedech Thévenot (1620–92) gathered a circle of scientists in his home. In the meetings of this 'Académie' Nicolaus Steno took part during his stay in Paris, 1664–5 (Gustav Scherz: *Vom Wege Niels Stensens* (1956), 59 f.).

20. Pierre Borel (1620–89), physician and chemist, attached to the Court in Paris. His work *Historiarum et observationum medico-physicarum centuriæ IV* (Paris, 1656) was eagerly studied by the young Nicolaus Steno as a student in Copenhagen (Gustav Scherz: *Vom Wege Niels Stensens* (1956), 47).

21. Borel's experiments are mentioned in the travel diary of Oluf Borch (manuscript in the Royal Library, Copenhagen, Ny kgl. Samling 373 a-c, 4°) cited by Johan Nordström: *Swammerdamiana*, in *Lychnos* (1954–5), 34 f. It is difficult to say what Borel used as ingredients in his experiments and to reconstruct them (Axel Garboe in: Gustav Scherz: *Nicolaus Steno and his Indice* (1957), 105 f.).

22. *Microcosmos* (the small world) is man.

23. Pierre Gassendi (1592–1655), naturalist and philosopher. Steno here refers to Gassendi's opinions set forth in his *Opera omnia* (Leiden, 1658), vol. ii, section iii, chapter i, p. 112, as cited by

Vilhelm Maar in *Nic. Stenonis Opera philosophica*, vol. ii (1910), 327.

24. The dew that falls in the month of May was regarded as particularly rich in substances of powerful effect for use in the chemical and pharmaceutical laboratories (Axel Garboe: *Kulturhistoriske Studier over Ædelstene* (1915), 124).

25. The Latin text here seems mutilated.

26. Lorenzo Magalotti (1637–1712), a Tuscan nobleman, was a zealous investigator of scientific problems and met Steno in the Accademia del Cimento in Florence (Gustav Scherz: *Vom Wege Niels Stensens* (1956), 68).

27. The expansion of heated metals was studied in the Accademia del Cimento in Florence (*Saggi di naturali esperienze fatti nell' Accademia del Cimento*, 3 ed. (1841), 120, pl. xvi). During his stay in Copenhagen, 1672–4, Steno demonstrated the expansion of heated metals (Axel Garboe: *Niels Stensen som Fysiker* in: *Fysisk Tidsskrift* (1947), 113 f.).

28. Michele Mercati (1541–93). From his manuscript *Metallotheca* Nicolaus Steno borrowed a few illustrations (a shark's head, *glossopetrae*) for his treatise: *Canis Carchariæ dissectum Caput*. Cf. plate facing p. 43 of this book.

29. Nicolaus Steno: *Canis Carchariæ dissectum Caput* (1667) in the part of the treatise here omitted.

30. Antonio Nardi was a pupil of Galileo Galilei. His manuscript *Scene Toscane* is available in Biblioteca Nazionale Centrale, Florence (MS. *Galilei*, vol. 130),

and deserves further study as a contribution to the background for Steno's geological studies. In Scene 26 Nardi speaks about *Imitazioni e scherzi della Natura*.

31. Francesco Redi (1626–94), physician, natural scientist, poet (Gustav Scherz: *Vom Wege Niels Stensens* (1956), 64).

32. Manfredo Settala (1600–80) had brought together a famous 'Museum'; a description was published in 1664.

PRINTED BY R. & R. CLARK, LTD., EDINBURGH