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A Man with a Master Plan: Steno's Observations on Earth's History

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Abstract. We present specific sources, including specimens of the Medicean cabinet and geological outcrops in Tuscany, probably used by Nicolaus Steno to build a theory on the origin of organic fossils, crystals and sedimentary strata, in order to construct the history of the Earth based on universal geometric principles. Phenomena he observed in Tuscany and in preceding travels were revealing a sequence of events consistent with the biblical account. We propose that he devised his method to reconstruct a chronology of primordial events to demonstrate the historicity of the biblical creation in contrast to unorthodox thinking. This had been spreading in philosophical circles of northern Europe since the 1650s, circles frequented by Steno before his arrival in Tuscany in 1666. Steno knew in advance what places to visit to find fossils, from literature such as Michele Mercati's *Metallotheca*. This was a manuscript owned by the Florentine Carlo Dati, whom Steno probably heard about while in Paris in 1664-1665. In Tuscany he soon formed a tight interaction on matters regarding the interpretation of fossils with the local community of learned men. These included Giovanni Alfonso Borelli who was asked by Prince Leopoldo de' Medici to provide Steno with fossils from Sicily and Malta. Steno's theory and scale-independent, geometrical method of inquiry of geological objects found in Tuscany is hinted at in his *Canis Carchariae Dissectum Caput*, a geological essay completed in a few months in 1666. The theory was published in its most complete form in the so-called *Prodromus* of 1669. In both works he demonstrated that fossils in younger strata in the Tuscan hills, such as shark teeth and molluscan shells, have an origin analogous to solids which living animals form. In both essays he explicitly related the deposition of strata with marine fossils to the biblical flood, an idea foreshadowed in "Chaos," his oldest known manuscript of 1659, when he was a student in Copenhagen. He found no fossils in older sandstones of the Apennines and understood those strata to have formed before the creation of life. These discoveries and other observations he made in Tuscany were, for Steno, the final proof that natural philosophy and biblical revelation disclose in synergy the mysteries of God's creation.

Keywords: Nicolaus Steno, Meaning of Fossils, Natural Philosophy, Accademia del Cimento, Biblical Chronology, Early Modern Science.

1. INTRODUCTION

The most important and lasting contribution that Nicolaus Steno (1638-1686) left to modern science is the 78-page book titled *The Prodromus to a*

Dissertation on a Solid Naturally Contained Within a Solid (the *Prodromus* in short).¹ The dissertation that the title alluded to never followed, and the *Prodromus* was the last published scientific essay of the intense and brief career of a young researcher bound to influence his generation of natural philosophers.² Most of his precedent-setting works were centered on anatomical research and the study of the animal body, but the *Prodromus* dealt with crystals, fossils and rocks. Why turning to a different subject? And why Steno accepted the parallelism between the natural history revealed in the rock record and the biblical narrative? Since his scientific endeavour ended in coincidence with his conversion to Catholicism and the start of a vocation in theology, modern understanding has to deal with history of science and history of religion at the same time. Consequently the aim behind the *Prodromus* remains obscure unless readers are familiar with both contexts. According to biographers who emphasized Steno's role in the history of science, such as the late Gustav Scherz (1895-1971), the standard story is that Steno turned to the study of fossils in 1666 when he realized, while casually studying the anatomy of a shark's head, that fossils called *glossopetrae* (meaning "tongue stones") were actually shark's teeth and not, as generally supposed, sports of nature. A second widely-accepted narrative suggests that denying biblical chronology in the face of hard empirical evidence was "a losing game,"³ so that Steno "continued to hesitate about the implications of his finding"⁴ and in the final chapter of the *Prodromus* "took care to reassure readers that his science did not contradict the Bible."⁵ This emphasis implies that during those years some empirical evidence, or science in the modern sense, could undermine the credibility of biblical chronology. Historians of religion know very well, however, that it was not natural philosophy, but textual criticism itself, which at that time called into question Scripture. Furthermore, criticism stemmed from disputatious free-

thinkers, such as the French Isaac La Peyrère (1596-1676) and Richard Simon (1638-1712), Isaac Vossius (1616-1689) and Baruch Spinoza (1632-1677) in the Dutch Republic, and Francis Lodwick (1616-1694) in England, people who had no public followers of their caliber until the second half of the eighteenth century.⁶ Indeed, biblical chronology was understood to be a science with its worthy followers, and seventeenth-century natural philosophers did not doubt that the Book of Genesis was a reliable historical account of the distant past. This needed interpretation, the reason why a science of biblical chronology was necessary.⁷ This means that the parallelism drawn by Steno in the last chapter of the *Prodromus* between an empirical reconstruction of historical events and the biblical account, from Creation to repopulation of the Earth after the Deluge, was not motivated by fear of the authorities of the Church to which he had recently converted, as instead suggested by some.⁸ Steno, like any other natural philosopher of his time, took the Bible as "obviously and predominantly *historical*," an account to be carefully interpreted using all available translations.⁹ The evidence presented in the present paper reinforces the opinion that Steno sincerely wanted to prove that he had found a limited, but relevant and additional means to reconstruct history. Steno's latest scientific production is underlain by a search for true religion and a way to reconcile natural philosophy and biblical revelation, in years when unorthodox thinking triggered debate in northern Europe.¹⁰ It is suggested that Steno actually had planned field work before moving from Paris to Tuscany.

The standard point of view is therefore disputed and it is hypothesised that the young Dane knew that in Italy he could find evidence for a reconstruction of primordial history based on an unprecedented way to study crystals, fossils and rocks. Since his student years, Steno's multifaceted general research plan to uncover the mysteries of God's Creation included aspects of his ongoing

¹ N. Stensen, *De Solido Intra Solidum Naturaliter Contento Dissertationis Prodromus*, Florence, Stella, 1669 (*Prodromus* in following notes). English translation, pp. 621-660, in T. Kardel, P. Maquet, *Nicolaus Steno, Biography and Original Papers of a 17th Century Scientist*, 1st edition, Heidelberg, Springer, 2013 (K&M in following notes).

² A treatise on precious stones, written after the *Prodromus*, was never published, indicating that Steno left the scientific community by 1669: F. Sobiech, in *The Revolution in Geology from the Renaissance to the Enlightenment* (Ed.: G. D. Rosenberg), *Geol. Soc. Am. Mem.*, 2009, 203, 179-186.

³ A. Cutler, *The seashell on the mountaintop*. Dutton, New York, 2003, pp. 5-16, 115-122, 191-192.

⁴ P. Findlen, *Possessing Nature: museums, collecting and scientific culture in early modern Italy* University of California Press, Berkeley, 1994, p. 237.

⁵ R. Rappaport, *When geologists were historians*, Cornell University Press, Ithaca and London, 1997, p. 201.

⁶ R. Rappaport in ref. 5, p. 76. Criticism towards historicity of the biblical narrative was discussed only privately, and in small circles: see an eloquent example in W. Poole, *Scripture and Scholarship in Early Modern England* (Eds. A. Hessayon, N. Keene), Ashgate, Aldershot, Hampshire, 2006, pp. 41-56

⁷ M. J. S. Rudwick, *Earth's deep history*. Chicago University Press, Chicago, 2014, pp. 9-30.

⁸ A. Cutler in ref. 3, pp. 5-16, 192.

⁹ Quote and emphasis from R. Rappaport in ref. 5, p. 72. On the role of the different translations of the Bible see E. Jorink, "Horrible and blasphemous": Isaac La Peyrère, Isaac Vossius and the emergence of radical biblical criticism in the Dutch Republic," in *Nature and Scripture in the Abrahamic religions: up to 1700* (Eds. J. M. van der Meer, S. Mandelbrote), Brill, Leiden, 2016, pp. 429-450.

¹⁰ S. Miniati, *Nicholas Steno's challenge for truth. Reconciling science and faith*, Milan, Franco Angeli, 2009, 336 p.

studies of anatomy, and other studies aimed at proving the historicity of the biblical account by geometrical means. His contemporaries understood the *Prodromus* as such, looking forward to seeing the full dissertation published.

It is questioned whether Steno's interest in the origin of fossils stemmed from a serendipitous discovery that glossopetrae were shark's teeth (a finding already publicly demonstrated in 1616 by Fabio Colonna).¹¹ Instead of moving top-down from philosophical, metaphysical and theological questions that mattered to Steno and his peers, this study reconsiders the timing with which he collected geological data in Tuscany, what textual sources on local paleontological sites he most certainly drew from, and his relationships with a network of sources. The amount of data he swiftly collected and the conclusions he drew in the very first months after his arrival in Florence imply that he had planned to do geological research, a plan that ultimately related to chronology of biblical events and had of course something to do with debates on the interpretation of Scripture occurring in cultural circles that he had frequented before 1666. Those circles embodied the spirit of the 'new philosophy', as termed by John Donne in 1611,¹² and at least in part coincided with 'the Republic of Letters', a transnational community that cultivated science based on observation, experiments and mathematics, not on scholastic authority.

His work in Tuscany, started at the age of 28, came at the climax of a series of readings and experiences traced back to 1659, when he was 21 years-old. These had made him receptive to evidence concerning the nature of fossils and sedimentary rocks and will be reviewed as such. Learned men at the Medici court were connected with European intellectual circles and would have offered Steno plenty of knowledge on geological matters. The Italian tradition dealing with *Re Metallica*, "metallic things", or geological data in the modern sense, with studies practiced by Italian Renaissance and early modern writers, such as Andrea Cesal-

pino (1524-1603), Michele Mercati (1541-1593), Ferrante Imperato (1550-1631) and Fabio Colonna (1567-1640) was famed enough to attract Steno to visit cabinets of natural history and rock outcrops from which geological specimens came. The geological data he referred to have remained somewhat obscure, because none of the essays he published in Italy, with few exceptions, contain clear information on location and description of specific places he visited and specimens he studied. This situation has influenced the perception of the *Prodromus* as an abstract work that assembled an "odd array of material,"¹³ an opinion that the present paper will attempt to dispel.

2. A MAN WITH A PLAN

Steno's philosophical and religious background must be recalled in order to understand the reason he searched for confirmation of Scripture in Nature. Empiricism underlay both his natural philosophy and his theology¹⁴ and transcended what is recognized today as a separation of physics from metaphysics. Within the physical world, Steno dealt jointly with 'geological', chemical and anatomical observations. This he did in the light of the Scripture since at least 1659, when he recorded in his journal, entitled "Chaos", lessons which he derived from the writing of others.¹⁵ This collection of extracts, an aid for the memory when he was a student and a sort of commonplace book,¹⁶ is Steno's oldest known manuscript. It starts with words and concepts directly referred to the Christian Faith and the writings of Moses, the purported author of the Book of Genesis:

In the name of Jesus
 CHAOS
 Not out of Aristotle's [elements]

¹¹ F. Columnus, *De Glossopetris Dissertatio*. In *Fabii Columnae Lyncei Purpura*, Rome, 1616, pp. 31-39. See M. J. S. Rudwick, *The meaning of fossils. Episodes in the history of paleontology*, Chicago, University of Chicago Press, 2nd edition, 1976 [1972], pp. 42-44; A. Ottaviani, "La natura senza inventario: aspetti della ricerca naturalistica del linceo Fabio Colonna", *Physis*, 1997, 34, pp. 31-70.

¹² "And new philosophy calls all in doubt,/The element of fire is quite put out,/The sun is lost, and th' earth, and no man's wit/Can well direct him where to look for it:" J. Donne, conclusion from *An Anatomy of the World*, cited in D. Wootton, *The invention of science: a new history of the scientific revolution*, New York, Harper Perennial, 2015. Donne writes about a 'new philosophy' a year after the publication of Galileo Galilei's *Sidereus Nuncius*, and is thus identified by Wootton as the first accountable testimony to the birth of modern science.

¹³ R. Rappaport in ref. 5, pp. 99-101; but see M. J. S. Rudwick, *The meaning of fossils. Episodes in the history of paleontology*, Chicago, University of Chicago Press, 2nd edition, 1976 [1972], pp. 58-60; D. Garber, *Steno and the Philosophers* (Eds.: R. Andrault, M. Lærke), Brill, Leiden, 2018, (A&L in following notes), pp. 201-232.

¹⁴ F. Sobiech, *Ethos, bioethics, and sexual ethics in work and reception of the anatomist Niels Stensen (1638-1686)*, Springer, 2016, pp. 30-35.

¹⁵ A. Ziggelaar in N. Stensen, *Acta Hist. Sci. Nat. Med.* (Ed.: A. Ziggelaar), 1997 [1659] (*Chaos* in following notes), 44, 453 pp.; G. D. Rosenberg, *Geol.*, 2006, 34, pp. 793-796; S. Olden-Jørgensen, in ref. 2 (Rosenberg), pp. 149-157.

¹⁶ The practice of writing commonplace books, a form of text collections, emerged particularly during the late Renaissance and remained in use among literate people during the early modern age: E. Havens, *Commonplace books: a history of manuscripts and printed books from antiquity to the twentieth century*. University Press of New England, 2002, 99 pp.

*That man is composed of the four elements is against Holy Scripture, where Moses only mentions water and earth. For Aristotle's air nowhere appears and fire is an accident. [...] bodies are only resolved into water and earth.*¹⁷

The first two lines can be regarded as a synthesis of the first part of the Creation seen from a Christian perspective: “in the beginning was the Word [...] and the Word was God” (meaning Jesus), says the Prologue according to the evangelist John. In this sense, ‘In the name of Jesus’ right before ‘CHAOS’ becomes God’s word commanding order to raise from non-order. This last concept is confirmed in a later remark in Steno’s *Elementorum Myologiae Specimen* of 1667: “in Holy Scripture it is said that the world has come forth from ‘unseen’ matter as from chaos.”¹⁸ The other part of the opening regards the third day of the biblical Creation, when God separated dry land from water. Steno quoted the passage from the surgeon Cornelius Schylander’s *Practica chirurgiae brevis et facilis* (1575),¹⁹ where the authority of Aristotle on the number of elements is submitted to the authority of the Bible: the basic elements all bodies are made of are water and earth (air and fire being secondary). Furthermore, taking the point of view of a student writing not for publication, Steno’s private collection of excerpts seems also to start with an auspice that his knowledge be ordered, from the chaotic form of the commonplace book into that of a mature anatomist.²⁰ Several times Steno, while excerpting the books he was reading, fell into despair and doubted his ability to bring order to the many subjects he approached.²¹ He subtly declared an attempt to reach a unitary comprehension of nature and in the same page he confirmed that ‘the profane is not to be excluded from the sacred’ (a quote taken from Jeremias Drexel’s *Ioseph Aegypti prorex descriptus* of 1641).²²

Most of the above, written in 1659, are about medical matters, but water, earth and Scripture are for the first time related with fossils in some revealing quotes taken from Pierre Borel’s *Historiarum et observationum*

Medico-Physicarum (1656). In a passage Steno focused on analogies between the human body and the Earth that allowed him to realize that marine fossils were evidence of an “ancient deluge”.

*Singular stones of the bladder, shells turned into stones. Therefore stones in places that lie very far from the sea, it is certain that seas change their beds. In the right kidney a grey stone was observed, in the left kidney clay. [...] Snails, shells, oysters, fish etc. found petrified on places far remote from the sea. Either they have remained there after an ancient deluge or because the bed of the seas has slowly changed. On the change of the surface of the Earth I plan a book.*²³

The last sentence, although taken from Borel, may well allude also to Steno’s program, at least denoting what he considered worthy of serious consideration when he was 21. The original Borel’s text reports that:

*Near the town of Montpellier I found large petrified oysters, mussels and even fossil fishes [...] all these things show that in ancient times the flood for long covered this place (as discovered also elsewhere, very far from the sea), that is to say that the sea has changed position, (which I will prove in my book ‘On the changed position of the globe’, and at other places I saw dragon’s teeth), so the sea receded from innumerable places.*²⁴

The importance of quotes taken from this contemporary French cartesian philosopher is underlined by side notes made by Steno in the 1659 manuscript.²⁵ The above passage also indicates the region around Montpellier as one where marine fossils occur, suggesting why Steno sojourned in that town of southern France in winter 1665-1666, before continuing his trip to Tuscany.

As a young student, Steno approved the method of inquiry laid out by René Descartes in the *Discourse de le methode* (1637) and *Les Principes de la philosophie* (1644), without sharing the cartesian preference to separate natural philosophy from theology.²⁶ In the words of historian of science Justin E.H. Smith, young Steno appears “speculative, somewhat mystically inclined,

¹⁷ N. Stensen, *Chaos*, in ref. 15, p. 21.

¹⁸ N. Stensen, *Elementorum Myologiae Specimen, seu Musculi Descriptio Geometrica*, in ref. 1 (K&M), p. 435; J. Smith, in ref. 13 (A&L), pp. 177-200.

¹⁹ A. Ziggelaar, in ref. 15, p. 103.

²⁰ Francis Bacon praised the activity of text collecting in his *The advancement of learning*: “there scarcely can be a thing more useful, even to ancient, and popular sciences, than a solid, and good aid to memory; that is, a substantial and learned digest of common places. [...] I hold that the diligence and pains in collecting commonplaces, is of great use and certainty in studying”: quoted in E. Havens, *The Yale University Library Gazette*, 76, 2002, pp. 136-153.

²¹ F. Sobiech, in ref. 14, pp. 59-61.

²² N. Stensen, *Chaos*, in ref. 15, p. 22; Smith, in ref. 2, p. 197.

²³ N. Stensen, *Chaos*, in ref. 15, pp. 46, 58-59. The original Borel’s text relates the presence of marine fossils with the biblical flood, with writing a book on the argument.

²⁴ P. Borel, *Historiarum et observationum Medico-Physicarum*, Billaine, Paris, 1656, p. 261. The italics are in the original text and refer to the title of the book that Borel had planned to write.

²⁵ A. Ziggelaar, in ref. 2 (Rosenberg), pp. 135-142. J. Bek-Thomson, ref. 2 (Rosenberg), p. 289.

²⁶ E. Jorink, *Reading the book of nature in the Dutch Golden Age, 1575-1715*, Brill, Leiden, 2010, p. 16. See also Olden-Jørgensen in ref. 2 (Rosenberg), pp. 149-157. On the role of Borch in directing Steno’s education, see A. Ziggelaar, in ref. 2 (Rosenberg), pp. 135-142.

and at the same time keen on absorbing the latest lessons from empirical natural philosophy, including those of Bacon, Descartes, and others, even when these come from thinkers who do not share the same mystical and theological concerns.²⁷ When in 1661 he went to study medicine in the Low Countries, he connected with the circle of Dutch *savants* and *curieux*, first in the hotbed of radical thinkers that was Amsterdam, then in nearby Leiden. There he had relations “far from marginal” with the unorthodox philosopher Baruch Spinoza²⁸ and the innovative physician Johannes Swammerdam.²⁹ Swammerdam and Steno were fellow students and close friends in Leiden from 1661-1663 and then in Paris in 1664, the two sharing a motivation to search for a bridge between natural philosophy and true religion. Swammerdam maintained that skilful dissections of animals, even insects, disclosed to the anatomist the immense wisdom that God had instilled in the minutest parts of creation. The two came to believe that ‘studying the intricate fabric of anatomical structures was a tribute to God, the omniscient architect’.³⁰ They lived in a critical place at the critical time for the future of religion when, following the interventions of Descartes and Spinoza, ‘the relation between belief and natural science became problematic’.³¹ The philosophy underlying Steno’s and Swammerdam’s research consciously moved away from the *Deus sive natura* principle of Spinoza, a motto that denoted the identity between the infinite substance of God and the finiteness of Nature. The two chose instead a religion grounded on ‘the argument from design’, the idea that God is not identical to nature, but is the great Architect, whose brilliance can be deduced from the ‘great fabric of the world’.³²

Historiographers still discuss if, in his early twenties, Steno was a genuine Lutheran³³ or a deist, however “*sui generis*”,³⁴ yet opinions converge in depicting those years as a period during which he gradually lost faith in cartesian dogmatism and a mechanistic perspective, instead becoming more meditative and inquisitive in religious matters. In autumn 1664 he joined Swammerdam in Paris, where, for nearly a year, both were

hosted by Melchisédec Thévenot (1620-1692). Thévenot had been a diplomat in Italy during the 1650s, and was an experimentalist in close contact with the Accademia del Cimento in Florence, himself hosting a sort of academy in his house. There Steno met with Pierre Borel and admired his skills, as he recalled two years later:

*In Paris, in the Academy at the house of my great friend Thévenot, I have seen Borel, greatly skilled in chemistry, pour together two quite clear liquids which immediately became so solid that not even a drop left the glass container when it was inverted.*³⁵

Thévenot was also a collector of travel accounts from long-distance voyagers and the owner of a cabinet of curiosities.³⁶ Among Thévenot’s other connections was Athanasius Kircher, founder in 1651 of ‘Museum Kircherianum’ in Rome. In the early 1660s Kircher’s popularity was immense, based on his encyclopaedic interests, vast experience, and even vaster imagination regarding late Renaissance visions in natural matters that often conflicted with the new philosophy. Savants throughout Europe, including Prince Leopold of Medici³⁷ in Florence, had been awaiting the publication of his *Mundus subterraneus* in 1664,³⁸ preceded in 1641 by *Magnes sive de arte magnetica*, extensively quoted in Steno’s *Chaos*.

One of Kircher’s disciples on sinology at the Roman College was the Jesuit missionary Martino Martini, author in 1658 of ‘History of China’,³⁹ a book that pro-

²⁷ N. Stensen, *Canis Carchariae Dissectum Caput*, Florence, Stella, 1667 (*Canis Carchariae* in following notes). English translation in ref. 1 (K&M), p. 591.

²⁸ N. Dew, in *Bringing the World to Early Modern Europe: Travel Accounts and Their Audience* (Ed.: Mancall), Brill, Leiden, 2007, p. 49. The correspondence between Thévenot and future members of the Cimento Academy dated back to 1643, continued through the years and included letters to Prince Leopold of Medici, in Florence, on experimental matters (1660-1666): ref. 38 (MG); W. E. K. Middleton, *The Experimenters: a study of the Accademia del Cimento*, John Hopkins Press, Baltimore, 1971, 415 pp.

²⁹ Prince Leopold of Medici (1617-1675) promoted the publication of Galileo Galilei works (1655-1666) and the activities of the Accademia del Cimento (1657-1667): Knowles Middleton, ref. 36; A. Mirto, *Dizionario Biografico degli Italiani*, 2009, 73, pp. 106-12. As an erudite collector of art and antiquities, in 1662-1668 he had established a productive European network: S. Dall’Aglio, *J. Hist. Collect.* 12/12/2019, pp. 1-12.

³⁰ W. C. Parcell, in ref. 2 (Rosenberg), p. 64-66; letter by A. Kircher (15 August 1965) to Prince Leopold, in digital archive, Museo Galileo (MG in following notes), Gal. 277, f. 215r: <https://www.museogalileo.it/it/biblioteca-e-istituto-di-ricerca/biblioteca-e-archivi/archivio-storico.html> (accessed on 24 May 2020).

³¹ ‘Historia’ of the title retains its traditional significance of ‘collection of facts’, not its reductive modern use as ‘chronology of events’. This is evident from Martini’s address to the reader, ‘*Extrema Asia sive Sinarum Imperii compendio & annorum ordine comprehensam Historiam*’: M. Martini, *Sinicae Historiae*, Blaeu, Amsterdam, 1659, p. 6. For the use of ‘Historia’ in Steno and his contemporaries, see J. Bek-Thomsen, in ref.

²⁷ J. E. H. Smith, in ref. 13 (A&L), pp. 177-200.

²⁸ Quote from P. Totaro, “Ho certi amici in Ollandi”, *Analecta Romana Instituti Danici*, 2002, suppl. 31, pp. 27-38. On the relation between Steno and Spinoza, see also G. Scherz, in ref. 1 (K&M), pp. 91-92, and particularly S. Miniati, *Scienza, filosofia e religione nell’opera di Niels Steensen* (Eds. M. A. Vitoria, F. J. Insa Gómez), Pagnini, Firenze, 2020, pp.

²⁹ E. Jorink, in ref. 13 (A&L), p. 16.

³⁰ E. Jorink, quoted in ref. 13 (A&L), p. 29.

³¹ E. Jorink, quoted in ref. 13 (A&L), p. 16.

³² E. Jorink, quoted in ref. 13 (A&L), p. 18.

³³ S. Miniati, ref. 10.

³⁴ S. Olden-Jørgensen, in ref. 2 (Rosenberg), pp. 149-157; F. Sobiech, ref. 14.

posed a chronology different from the biblical.⁴⁰ It is reasonable to suppose that Steno discussed Earth's history at Thévenot's circle in 1664-1665, in the wake of debates in Amsterdam circles of freethinkers, where the idea that human history is older than history told in the Old Testament had found sustainers⁴¹ and the universality of the noachian flood was questioned.⁴² A new type of anatomical observation, this time on a grand scale, so as to see the body of the Earth cut open, would have pushed him to move south where he knew he could observe fossils on the field.⁴³ Thévenot formed a bridge with the liberal court of Ferdinand II, Grand Duke of Tuscany, and his brother, Prince Leopold. At the Medici court another international circle had gathered, including the French oriental philologist Barthélemy d'Herbelot (1625-1695). By moving to Florence Steno could hope to earn a wage to pursue his research, whether on muscles or on fossils and their context.⁴⁴ The Florentine Carlo Dati (1619-1696), one of the members of the Accademia del Cimento and a correspondent with learned men from Paris,⁴⁵ was also a correspondent of Thévenot's. Steno had probably heard in advance about the paleontological heritage of Tuscany, well known to Carlo Dati as it will be shown. From Tuscany he could move further south, until eventually reaching Sicily and Malta and there collect other fossils.

First in the Dutch Republic, then in Paris, Steno was thus in the middle of a fierce polemic on which he could hardly remain neutral, judging from his inquisitiveness on religious matters.

2 (Rosenberg), pp. 296-297; N. Morello, *Niccolò Stenone e la scienza in Toscana alla fine del '600* (Eds.: L. Negri, N. Morello, P. Galluzzi), Laurenziana, Firenze, 1986, pp. 67-89.

⁴⁰ Martino Martini (1614-1661) dominated European knowledge of China in the period 1654-87: N. Dew, *Orientalism in Louis XIV's France*, Oxford University Press, Oxford, 2009, 302 p.; E. Jorink, D. Miert, *Isaac Vossius (1618-1689) between science and scholarship*, Brill, Leiden, 2012, 352 p.; see also R. Rappaport, ref. 5.

⁴¹ Martini's book influenced the reception of the preadamite theory by Isaac La Peyrère (1596-1676), particularly in the Dutch Republic starting from the late 1650s: R. H. Popkin, *Isaac La Peyrère (1596-1676): his life, work, and influence*, Brill, Leiden, 1987, pp. 85-87; J. L. Morrow, *Three skeptics and the Bible: La Peyrère, Hobbes, Spinoza, and their Reception*, Eugene, Pickwick, 2016, pp. 83-84; A. Grafton, "Isaac Vossius, Chronologer", in ref. 40 (E. Jorink, D. Miert), pp. 43-84.

⁴² A. Ottaviani, *Giorn. Crit. Filosof. It.*, 2017, 13, 272-301.

⁴³ J. Bek-Thomsen, in ref. 2 (Rosenberg).

⁴⁴ N. Dew, ref. 40, pp. 62-76. 'For many years, a prominent position inside the Medici Court meant an attractive lifestyle and high wages': L. Boschiero, *Experiment and natural philosophy in seventeenth-century Tuscany. The history of the Accademia del Cimento*, Springer, Dordrecht, 2007, p. 20.

⁴⁵ Carlo Roberto Dati, humanist, disciple of Galileo and experimentalist, in close contact with Jean-Baptiste Colbert, Minister of the Finances under Louis XIV, was consulted in 1666 for the birth of the *Académie de Sciences*. See N. Dew, ref. 40, p. 53, and W. E. K. Middleton, ref. 36.

3. THE NATURE OF TUSCANY

Steno arrived in Tuscany in April 1666. Ferdinand II and Prince Leopold recognized him as an outstanding natural philosopher, an anatomist whose public dissection of a human brain performed in Paris in October, 1665⁴⁶ proved Descartes wrong about the manner in which this organ functions.⁴⁷ By December of the same year, Steno had completed the essay *Canis Carchariae Dissectum Caput* which ended with a "digression on bodies resembling parts of animals that are dug from the earth", a writing where 'tongue stones' were interpreted as sharks' teeth.⁴⁸ This essay was subsequently published in April 1667 as an appendix to his treatise on myology.⁴⁹ The interpretation of the dissection as the starting point of a research on fossils is probably based on Steno's brief account of his scientific career, written in the opening pages of the *Prodromus* ("To take me away from a detailed account of the muscles, a shark of prodigious size was thrown up by your seas"),⁵⁰ a rhetorical artifice to emphasize that in his life he had been accustomed to submit to someone else's will. Instead, he could hardly collect all evidences contained in the 'digression' between October⁵¹ and December, so he had carried out the many observations on fossils and the sedimentary strata in which they were found before the dissection. As for the reason to carry out any field activity, *Canis Carchariae* already shows that his interest for marine fossils was related to two events narrated in the Scripture, two cornerstones of Earth's history presented in the *Prodromus*. The first event was the separation of solid matter from fluid, on the third day of Creation ("And God said, 'Let the waters under the sky be gathered together into one place, and let the dry land appear'": Gen 1, 9), an interest foreshadowed by the opening quote of the *Chaos* manuscript (see above note 17). The second event was the Universal Deluge ("The flood continued forty days on the earth; and the waters increased, [...] and it rose high above the earth": Gen 7, 17), referred to in Borel's quote transcribed in 1659 (see above notes 23-24). Both events relate to a universal fluid covering all or most of the globe.

Canis Carchariae reports that different types of fossils were contained in two types of strata, one hardened the other soft, separated by surfaces that deviated from

⁴⁶ N. Stensen, *Discours sur l'anatomie du cerveau*, Paris, Ninville, 1669. English translation in K&M, pp. 507-527; R. Andraut in ref. 13 (A&L), pp. 87-112.

⁴⁷ A. Cutler in ref. 3, p. 53.

⁴⁸ N. Stensen, *Canis Carchariae*, in ref. 1 (K&M), pp. 571-595.

⁴⁹ N. Stensen, *Myologiae Specimen*, in ref. 1 (K&M), pp. 545-570.

⁵⁰ N. Stensen, *Canis Carchariae*, in ref. 1 (K&M), pp. 623-624.

⁵¹ A. Cutler in ref. 3, p. 53.

horizontality (a geometric character that implies tilting of strata after their deposition and that would become a central argument of the *Prodromus*):

*The soil from which bodies resembling parts of aquatic animals are dug is in certain places rather hard, like tufa and other kinds of stone; in other places it is rather soft like clay or sand [...]. In various places, I have seen that the said soil is composed of layers superimposed on each other at an angle to the horizon. [...] In those soils that I have been able to observe up to now, bodies of different kinds have been concealed in the same soil, sometimes in the harder, and sometimes the softer sort. I have observed that the number of these bodies in clay is quite large in the surface but quite small in the soil itself.*⁵²

*Very many oyster shells are found in some regions, deformed and hardened into one lump; sometimes also, broken scallops and mussels are dug up; some people have seen, in the same place, many tongue stones clinging as it were to the same matrix.*⁵³

Based on the comparison of 'tongue stones' with the teeth of the large shark he had dissected, he hypothesised in the essay that they did not grow in the earth, an opinion still held by many.⁵⁴ Steno had surely seen 'tongue stones' in Copenhagen in the museum of Ole Worm (1588-1654),⁵⁵ and learned about them through his teacher Thomas Bartholin (1616-1680), who had written a book on glossopetrae after travelling to Malta in 1644.⁵⁶ But he had never seen them in earlier travels:

*I do not yet have the knowledge of this matter [the tongue stones] to pass judgment on it here; and though my travels have taken me through various places of this kind, nevertheless, I do not dare to guarantee that what I shall observe in the rest of my journey will be similar to what I have observed up to now. Chiefly, since I have not yet seen what my very famous teacher Bartholin observed in his journey to Malta.*⁵⁷

'Several places of this kind' refers to localities of outcrops where assemblages of marine animal fossils are embedded in compact or hardened rock. Following Borel's indication, he had possibly seen strata with

marine shells around Montpellier, where he had met with other savants interested in the study of fossils, such as John Ray (1627-1705) and Martin Lister (1638-1717).⁵⁸ Above all, he must have been informed that Tuscany was particularly suited to carry out that type of fieldwork. Although 'tongue stones' were difficult to find, fossils they were usually associated with were a useful substitute (see comment 'some people have seen, in the same place [of oysters, scallops and mussels], many tongue stones' above).⁵⁹ The most important influence was an unpublished 'field guide' by the Tuscan Michele Mercati, a manuscript handed to him in Florence.⁶⁰ In the preceding century, Mercati had systematically arranged the Pope's collection of minerals, stones and fossils in 19 large and expensive cabinets to form the Vatican museum called *Metallotheca*. The manuscript was owned by Carlo Dati, who had lent Steno two of the engravings made for the *Metallotheca* which the Dane used to illustrate the *Canis Carchariae* essay,⁶¹ as well as the manuscript itself. This told about 'instructions' that interested Steno, as he himself revealed:

*Mercati's manuscript [contains] much that is well worth knowing and a wealth of varied instruction about soils, salts, oily fluids, stones, bodies of idiomorphic shapes, and so on; this manuscript would have remained buried in eternal darkness, had not the very learned Dati's skill brought it out of the underworld and provided an opportunity for it to be exposed to the light of day.*⁶²

Mercati revealed that at his hometown of San Miniato (locality 3 in Fig. 1), a place famous for marine shell beds as recorded also by Leonardo da Vinci (1453-1519),⁶³ large tongue stones were found with oysters (Fig. 2). Mercati had subdivided tongue stones on the basis of size and shape and pictured them in three beautiful

⁵⁸ G. Scherz, in ref. 1 (K&M), pp. 137-140.

⁵⁹ The association of fossil shark teeth with seashells was also described in Fabio Colonna's *De Glossopetris Dissertatio*: ref. 10. M. Rudwick, ref. 13, pp. 42-44; N. Morello, ref. 39, p. 71.

⁶⁰ Michele Mercati (1541-1593) and his teacher Andrea Cesalpino (1519-1603) were leading figures in late Renaissance study of *res metallica*. Cesalpino ordered the Medicean collection of natural history and completed Mercati's systematic work in *De Metallicis* (1596). See U. Viviani, *Vita ed opere di Andrea Cesalpino*, Viviani, Arezzo, 1917, pp. 186-187, 218-219; B. Accordi, *Geologica Romana*, 1980, 19, pp. 1-50; P. Findlen, in ref. 4, pp. 61, 233-235; for the Medicean gallery of natural history in Pisa, certainly visited by Steno already during the first part of his stay, see L. Tongiorgi Tomasi, *Giardino dei Semplici. L'Orto Botanico di Pisa dal XVI al XX secolo* (Eds.: F. Garbi, L. Tongiorgi Tomasi, A. Tosi), Pacini, Ospedaletto, 1986, pp. 161-170.

⁶¹ J. Bek-Thomsen, in ref. 2 (A&L), pp. 233-258.

⁶² N. Stensen, *Canis Carchariae*, in ref. 1 (K&M), p. 572

⁶³ E. Cioppi, S. Dominici, in *Water as microscope of nature. Leonardo da Vinci's Leicester Codex* (Ed.: P. Galluzzi), Firenze, Giunti, 2018, pp. 171-183.

⁵² N. Stensen, *Canis Carchariae*, in ref. 1 (K&M), p. 585.

⁵³ N. Stensen, *Canis Carchariae*, in ref. 1 (K&M), p. 586.

⁵⁴ N. Morello, ref. 39.

⁵⁵ For the *Museum Wurmianum* in Copenhagen and its role for Steno's upbringing, see Rosenberg, ref. 15 and appendix; for the significance of private museum collections for seventeenth century natural philosophers see Rappaport, ref. 5, pp. 53-55.

⁵⁶ Bartholin's essay on glossopetrae is now lost. Scherz, in ref. 1 (K&M), p. 38; A. Ziggelaar in ref. 15, pp. 466-469; I. H. Porter, *Med. hist.*, 7, 1963, pp. 99-125; A. Ottaviani, *Schede Umanistiche, Riv. sem. Arch. Um. Rin. Bol.*, 2004, 2, pp. 89-110.

⁵⁷ N. Stensen, *Canis Carchariae*, in ref. 1 (K&M), p. 585.

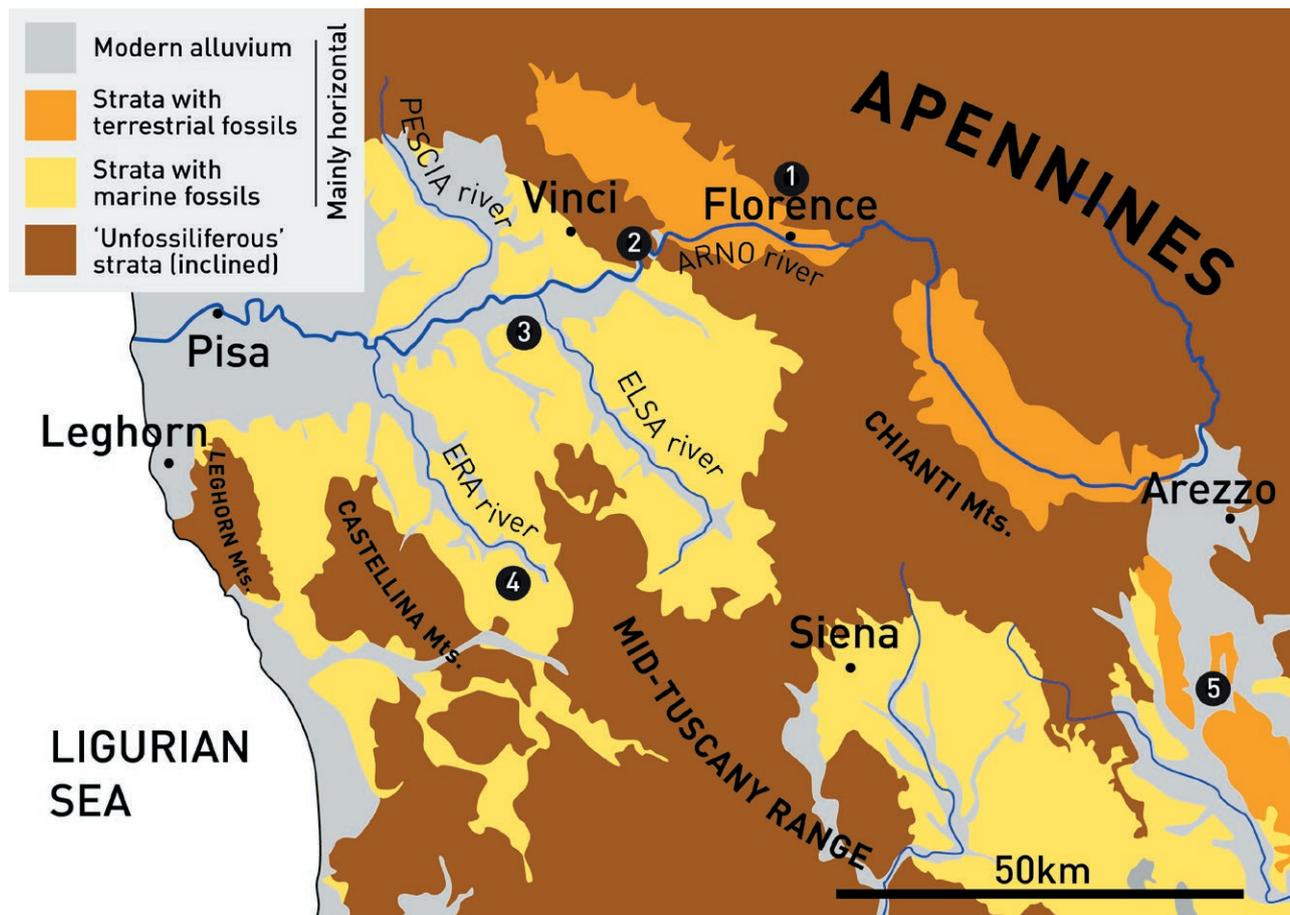


Figure 1. Schematic map of Tuscany showing localities mentioned in the present paper, in relationship with Steno's *Prodromus* description of strata on which he based his history of the Earth. These localities are: 1) Monte Ceceri, 2) Gonfolina, 3) San Miniato, 4) Volterra, 5) Chiana Valley. Original graphic by the author.

drawings that were engraved, together with all other plates, by the German artist Anton Eisenhoit (1553-1603). One type belonged to large sharks which we now know as the great white (*Carcharodon carcharias*), as the one dissected by Steno. In the words of Mercati:

*I received very beautiful [large tongue stones] from my father, fortuitously found in a field near San Miniato. [...] Ostracites [fossil oysters] are found in fields near the towns of Siena and San Miniato.*⁶⁴

Evidence is thus consistent with an hypothesis that Steno studied fossiliferous strata of Tuscany early in 1666. Consequently, when he had an opportunity to dis-

sect the head of a shark, his mind was already set. This explains the rapidity with which he published, hastening to secure a priority on the subject. At San Miniato he would also observe sandy and clayey strata, some cemented, most simply compacted, crop out in the steep flanks of the hill where the town is built. These strata are slightly inclined towards NNE (Fig. 3), so this is one of those places, in which he would have seen 'that the said soil is composed of layers superimposed on each other at an angle to the horizon' (see note 52 above), meaning they had been tilted after deposition.

The study of sedimentary strata allowed Steno to prove that water twice covered the Tuscan relief, acknowledging that observation of nature and words in Scripture work in pair:

Nor can there be strong opposition to the belief that the said soil was once covered with water. [...] [If] we assume that this piece of ground always had the same situation,

⁶⁴ M. Mercati, *Michaelis Mercati Samminiatis Metalloteca: opus posthumum, auctoritate & munificentia Clementis undecimi pontificis maximi e tenebris in lucem eductum: opera autem & studio Joannis Mariae Lancisii archiatri pontificii illustratum*, Roma, Salvioni, 1717 [1593], p. 48.

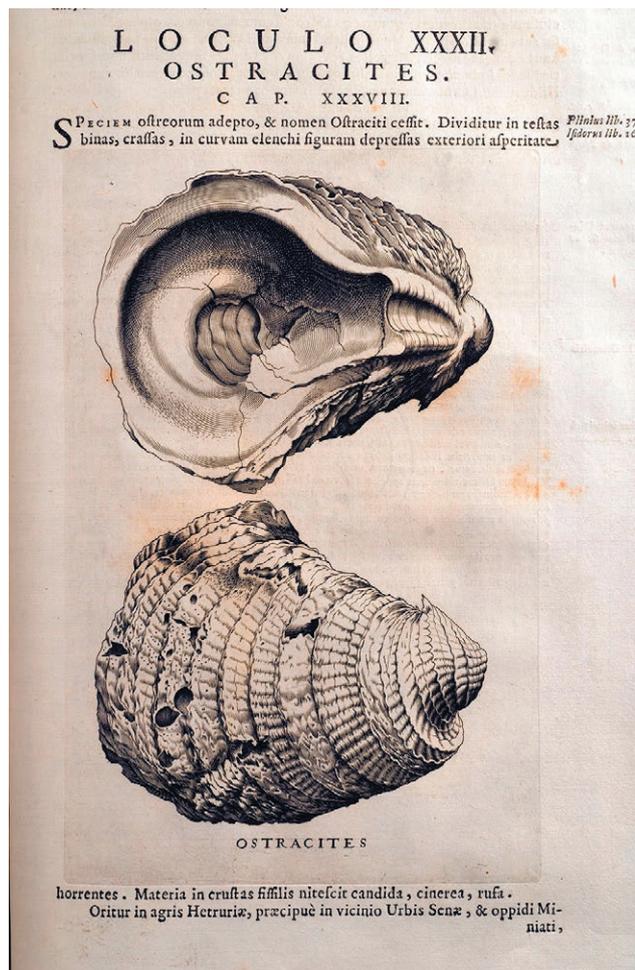


Figure 2. Copper engraving by Eisenhoit of a large oyster shell ('Ostracites') dug up from the earth at San Miniato ('oppidi Miniati'; locality 3 in Fig. 1) and drawn by Mercati, published posthumously in 1717, but available to Steno in 1666. Photograph by Saulo Bambi, reproduced with permission, courtesy of the Botanical Library of the Florence University.

[...] we learn from Holy Scripture that all things, both at the beginning of creation, and at the time of the Flood, were covered with water.⁶⁵ Tertullian writes elegantly about this: "A change occurred in the whole world when it was covered with all the waters; even now, sea shells of mussel and whelk range over the mountains seeking to prove to Plato that the very peaks have been under water."⁶⁶

Steno's digression in *Canis Carchariae* revolves around the demonstration of the marine origin of fossils (he explains this through "conjectures" numbered 1-4, 6)

⁶⁵ N. Stensen, *Canis Carchariae*, in ref. 1 (K&M), p. 587. Morello, ref. 39, p. 77.

⁶⁶ N. Stensen, *Canis Carchariae*, in ref. 1 (K&M), p. 587.



Figure 3. Slightly inclined fossiliferous strata at San Miniato (locality 3 in Fig. 1; outcrop about 50 m-thick). Rich shell beds associated with large shark teeth have been studied here since the time of Leonardo da Vinci (1453-1519) to the present day. Photograph by the author.

and the precipitation of solids from liquids (conjectures 4-5, indicating 'the ways in which solid bodies hidden in water may be secreted'). Judging from the subsequent development of these two topics in the *Prodromus*, this means that in 1666 not only had Steno already studied fossiliferous mudstones and sandstones at the top of the Tuscan sedimentary succession (his evidence of 'the Flood'), but also older unfossiliferous strata which he thought formed at 'the beginning of creation' (see above, and note 65), when God separated earth from a primordial fluid.

4. THE ITALIAN NETWORK

In 1667 Steno shared his thoughts on fossils with other learned men around him, not just on marine fossils, but also terrestrial ones. The latter were related to a 'time of giants' referable to Scripture, a third biblical event with which to compare the fossil record, as it will be shown. The Book of Genesis in fact revealed that:

The giants were in the earth in those days, and also after that, when God's sons were being entered toward the daughters of humans and they were begetting to themselves; those were the giants from the eons [greek αἰών] the humans of renown.⁶⁷

⁶⁷ Genesis 6, 4, from the Greek Septuagint Bible. See R. S. Hendel, "Of demigods and the Deluge: toward an interpretation of Genesis 6:1-4", *J. Bibl. Lit.* 106, 1987, pp. 13-26. For an exploration of Protestant and Catholic attitudes towards the interpretation of this passage, see A. Hessayon, ref. 6, pp. 5-40.

In Florence Steno was sustained by the esteem of newly-acquired learned friends, including renowned disciples of Galileo such as Vincenzo Viviani (1622-1703) and Francesco Redi (1626-1697).⁶⁸ The sea of Tuscan coast offered plenty of living shelled marine animals to compare with fossils that were dug up in nearby hills. Bruno della Molarra, a member of the court, testified that in the summer of 1667 Steno was studying living mussels and discussing his view with others:

*I am delighted by your progresses in the investigations of interesting matters, particularly of the mussels and I am even more pleased that you have made satisfactory observations which confirm your view.*⁶⁹

Among the Florentine academicians was Giovanni Alfonso Borelli (1608-1679), one of the most gifted disciples of Galileo Galilei.⁷⁰ The least friendly among the Medici courtiers, he helped Steno, providing knowledge and fossils from Sicily. Steno had contacted him soon after his arrival in Tuscany, as a suspicious Borelli revealed in July 1667 in a letter to Marcello Malpighi (of the same Galilean circle):

*I'm giving you the news that Steno is here, and that he shall remain the whole summer, and that he told me he wants to come to visit me, and that he wants me to teach him something about geometry etc. I won't refrain from offering him all the courtesy possible, but I'm not so gullible as to believe in the idea of modesty and good manners in which he is proclaimed, because those little epistles he has printed clearly hint at his avidity to absorb all the things, and put others in distress, and I know these foreigners come here to us well prepared, and willing to remain cautious, so that their cunning by far surpasses ours, with the result that in the end it will be us who will be submitted for long.*⁷¹

The Italian network of learned men interested in Steno's *Canis Carchariae* included Agostino Scilla in Sicily,⁷² collaborating with Borelli, Malpighi and John

Ray,⁷³ and the physician Giovanni Battista Capucci from Crotona, in Calabria.⁷⁴ The authority of Prince Leopold, accompanied by the general enthusiastic acceptance of Steno by the Medici Court, forced Borelli to submit and provide specimens from Sicily. In August he answered the Prince:

*I send you two chunks of stone of the type produced by date shells [rock-boring mussels; ...] I've commanded to bring you some piece of good stone, which no doubt will give the opportunity to philosophise.*⁷⁵

In two letters of October-December 1667, Borelli communicated with Prince Leopold about the interpretation of marine and terrestrial fossils. These manuscripts not only testified to the whole court being involved in Steno's research, but particularly revealed that larger fossil bones were interpreted as evidence of 'a time of giants', as mentioned in the Book of Genesis:

*I also thought that those shells could have originated from the sea, but then I changed opinion. I will await for the fine discourses of these Gentlemen to ascertain for me the truth. In the meanwhile, I have written to friends in Palermo, Siracusa and other places to get me the so called Giants' teeth, and those large petrified shells that are found at many places in Sicily [...]. If Your Highness could send me the drawing of the skull of that African ox found in the Chiane [referring to the Chiana valley, locality 5 in Fig. 1] to know how big it is, I would be grateful. [...] I will send to Livorno those teeth and shells that I am collecting.*⁷⁶

I have received the drawing of the buffalo skull, or ox found in the Chiane, and it is indeed much larger than those that we see nowadays in Italy [see Fig. 4 for a similar fossil coming from the same context]. If it came from Africa I couldn't say, since I'm told that in that savage place you don't find oxen of such an enormous size. Maybe in that time in Italy lived that race of a size larger than our [cattle] given that as among both dogs and horses we find some that by large exceed others, and I can assure Your Highness that here we find certain limestones and human teeth the size of which must relate to a man at least 2.3 m tall. For you to get the exact proportion, I send with this letter a drawing of one of those teeth. The man who owns them is too jealous of these curiosities and I didn't dare ask, even if he is a friend. I have moreover collected a large quantity of petrified shells, some of very large size, that I will send, as you commanded me to do, with the first vessel that sails

⁶⁸ P. Galluzzi, in ref. 39 (Negri, Morello, Galluzzi), pp. 113-129.

⁶⁹ For Bruno della Molarra (1639-1685) see A. Cont, *Dimensioni e problemi della ricerca storica*, 2011, 2, pp. 231-259. Letter (14 July 1667) quoted in ref. 1 (K&M), p. 187. Another learned informant was Francesco Maria Florentini (1603-1673): G. Scherz, in ref. 1 (K&M), p. 182.

⁷⁰ L. Boschiero, in *Borelli's On the movement of animals - On the force of percussion* (Tr.: P. Maquet), Brill, Leiden, 1989, p. i-xxi. P. Galluzzi, ref. 68.

⁷¹ G. A. Borelli, 17 July 1666, in M. Malpighi, *The correspondance of Marcello Malpighi* (Ed.: H. B. Adelman), Cornell University Press, Ithaca-London, 1975, 1, pp. 318-319. Borelli was studying animal movement, a subject dealt with by Steno at exactly the same time.

⁷² F. Giallombardo, *Agostino Scilla (1629-1700) e la cultura visuale della historia, fra antiquaria e storia naturale*, unpublished PhD thesis, Università di Palermo, Palermo, 2016, pp. 71-72.

⁷³ P. Findlen, *Science in the age of baroque* (Eds. G. Gal, R. Chen-Morris), Springer, Dordrecht, 2013, p. 135.

⁷⁴ G. B. Capucci, 25 July 1667, in ref. 40, pp. 352-352.

⁷⁵ G. A. Borelli to Prince Leopold, 3 August 1667, in ref. 38 (MG), Gal. 278, f. 42v.

⁷⁶ G. A. Borelli to Prince Leopold, 4 October 1667, in ref. 38 (MG), Gal. 278, f. 73r-73v.



Figure 4. Skull of a large ox dug up in Val di Chiana (width of horns about 105 cm); a similar specimen is mentioned by Borelli in letters to Prince Leopold. Photograph by Saulo Bambi, specimen reproduced courtesy of the Museum of Natural History, University of Florence.

*to Livorno. When Mr. Steno will pass from here, I will see him and gladly serve him.*⁷⁷

The finding of fossils of 'a man at least 2.3 m tall' and the bones of animals larger than the modern certainly solicited Steno's philosophical interest for links between observation of nature and Scripture. In July 1668, Borelli informed the Prince that the vessel with its naturalistic cargo had shipwrecked and that he provided a new collection of fossils. Similarly to the first shipment, it included 'stones taken from mountains twenty miles far from the sea'⁷⁸ and other geological specimens. Clearly, there was a keen interest for fossils at the Medici court in connection with Steno's activities of 1667.

*Specimens from Malta are not all wrapped in their stoney casing, but imagine them to be [originally] contained in the same soft stone in which you see the tongue stones, or teeth; these teeth, vertebrae and eyes are dispersed in black stone, some small some large [see Fig. 5] Such observations, and better ones, will be made over there by those illustrious philosophers, being myself humbly busy with laying down this book of mine on paper, in the hope to complete it in short time.*⁷⁹

We thus know that, at least since summer 1667 and while working at a larger dissertation on solids naturally enclosed in other solids, Steno involved a group of



Figure 5. Malta 'large tongue stones' (in the terminology used in 1667) from unspecified 'Old Museum collection' (= 'Antica Collez. del Museo', written in the 19th century); similar specimens were sent by Borelli in 1667. Photograph by Saulo Bambi, specimen reproduced courtesy of the Museum of Natural History, University of Florence.

informed people in a fervent activity directed towards definitely proving that fossil shells and 'tongue stones' did not form inside the rocks, and thus verified their utility as a means to 'philosophise' on historical events. We can also reasonably speculate that 'philosophising' included a discussion of matters distinctly related with biblical events: remains of large terrestrial animals of African affinity provided information on a 'time of giants', while marine fossils, whether from Malta, Sicily or Tuscany, would mark the time when waters covered the land, ending the existence of 'those races of a size larger than ours' – in Borelli's words.

5. EARTH'S HISTORY UNROLLED IN TUSCANY

In May 1668 Steno had informed Magalotti about his intention to complete a 'treatise on the earth and the bodies found in it', described as 'a succinct, not to say disordered, account of the chief things that I have resolved to set down in the Dissertation itself, not only more distinctly, but also at greater length, with in addition, a description of the places where I have observed each item'. The final text was completed in August 1668⁸⁰ after months of additional fieldwork traveling 'from the Arno to the Tiber' (that is, from Florence to Rome: he apparently never succeeded in moving farther south).

The *Prodromus* addressed some of the basic questions of natural philosophy: what is the nature of matter, what is movement, and what is the method to answer

⁷⁷ G. A. Borelli to Prince Leopold, 1 December 1667, in ref. 38 (MG), Gal. 278, f. 95r-95v.

⁷⁸ G. A. Borelli in ref. 38 (MG), Gal. 278, f. 95r-95v.

⁷⁹ G. A. Borelli to Prince Leopold, 8 July 1668, in ref. 38 (MG), Gal. 278, 195r-195v.

⁸⁰ G. Scherz, in ref. 1 (K&M), p. 209.

these questions? More importantly, Steno took a clear position regarding Earth's history, choosing the universal flood as the fulcrum of the discourse, the occurrence of which he could now clearly demonstrate. As far as the nature of Tuscany allowed, Steno's method presented evidence of the other biblical events mentioned above, one concerning the third day of creation, when the Aristotelian element earth started to exist separated from water, another concerning the time when giants populated the Earth. To these he added in the *Prodromus* a further biblical event, the repopulation of the planet, occurring after the deluge had swept away "all things which have the breath of life, and whatever was on the dry land" (Gen 7, 22). This repopulation, starting from a handful of noachian survivors, soon spread all over the world following God's command ("increase and multiply, and fill the earth and have dominion over it": Gen 9, 1). Evidences of this were represented by the ruins of ancient civilizations, from the Etruscan in Tuscany, studied by Steno's contemporary antiquarians and briefly presented in the *Prodromus*, to the Chinese in the Far East, then made popular by Martini's chronicles (see above notes 40-41).

The first part of the book is methodological, abstract and complex, but worth the effort of reading – implies its author – because it promises to solve a problem of natural philosophy that troubled contemporary authors: 'namely the way in which marine objects had been left in places far from the sea', a problem concerning 'a kind of universal deluge' (p. 6).⁸¹ In the first part of the book (pp. 6-23), Steno presented a new category of phenomena, 'solids naturally contained in other solids',⁸² bringing order to observations of different kinds:

If one wishes to reduce solids enclosed naturally within solids to definite classes, by the above method, some of them will be found to have been produced by apposition from an external fluid, this refers either to sediments such as the strata of the earth [...] or angular bodies [...]. Other solids are produced through apposition from an internal fluid. [...] it will be easy, given the solid and its location, to make a definite statement about the place of its production. (p. 23)⁸³

The *Prodromus* then considered specific classes of solids, including 'strata of the earth' (pp. 26-28), explaining the historical meaning of the regularly-stacked bodies of turbidite sandstones that form large part of the Apennines. These are sedimentary strata characterised



Figure 6. Inclined, unfossiliferous strata of 'Macigno' sandstone at the historical Monte Ceceri quarries (outcrop about 20 m-thick, locality 1 in Fig. 1; similar strata occurred at the Gonfolina quarries, locality 2 in Fig. 1). Strata are bounded by surfaces that once were 'parallel to the horizon', to use Steno's words (*Canis carchariae dissectum caput*, written in 1666). Photograph by the author.

by sharp or erosive bases, tabular geometry (Fig. 6), good-sorting of the clastic component and sedimentary structures that indicate settling of particles while the water mass was still moving (Fig. 7). To Steno they were documents of the third day of creation, immediately before the separation of dry land from sea and when a 'universal fluid' was all that there was.

Differences in layers at the same place can be produced either by the diversity of particles leaving the fluid in succession, as this fluid is gradually dissipated more and more, or by different fluids being conveyed there at different times: so it happens that sometimes the same arrangement of layers is repeated in the same place, and often evident signs exist showing the ingress of new material. (p. 26)

If all particles in a stony stratum are observed to be of the same nature and of fine size, it cannot reasonably be denied that this stratum was produced at the time of Creation from a fluid that then covered all things; Descartes, too, accounts for the origin of the earth's strata in this way. (p. 28)⁸⁴

The significance of these primordial strata is enriched by their association with widely-separated 'high mountains' (the Apennines). This fact proved that on the dawn of the third day of creation a fluid covered all things, as explained at the end of the book:

That there was aqueous fluid, however, at a time when animals and plants had not yet appeared, and that the fluid

⁸¹ Numbers in brackets refer to pages in the original 1669 publication, translated in ref. 1 (K&M), pp. 621-660.

⁸² N. Morello, ref. 39, p. 79-80.

⁸³ N. Stensen, *Prodromus*, in ref. 1 (K&M), pp. 632-633.

⁸⁴ N. Stensen, *Prodromus*, in ref. 1 (K&M), pp. 635. Steno refers to René Descartes' *Principia Philosophiae* (1644), containing rather a model of the Earth, than an account of its history: see M. J. S. Rudwick, ref. 7, pp. 55-59.

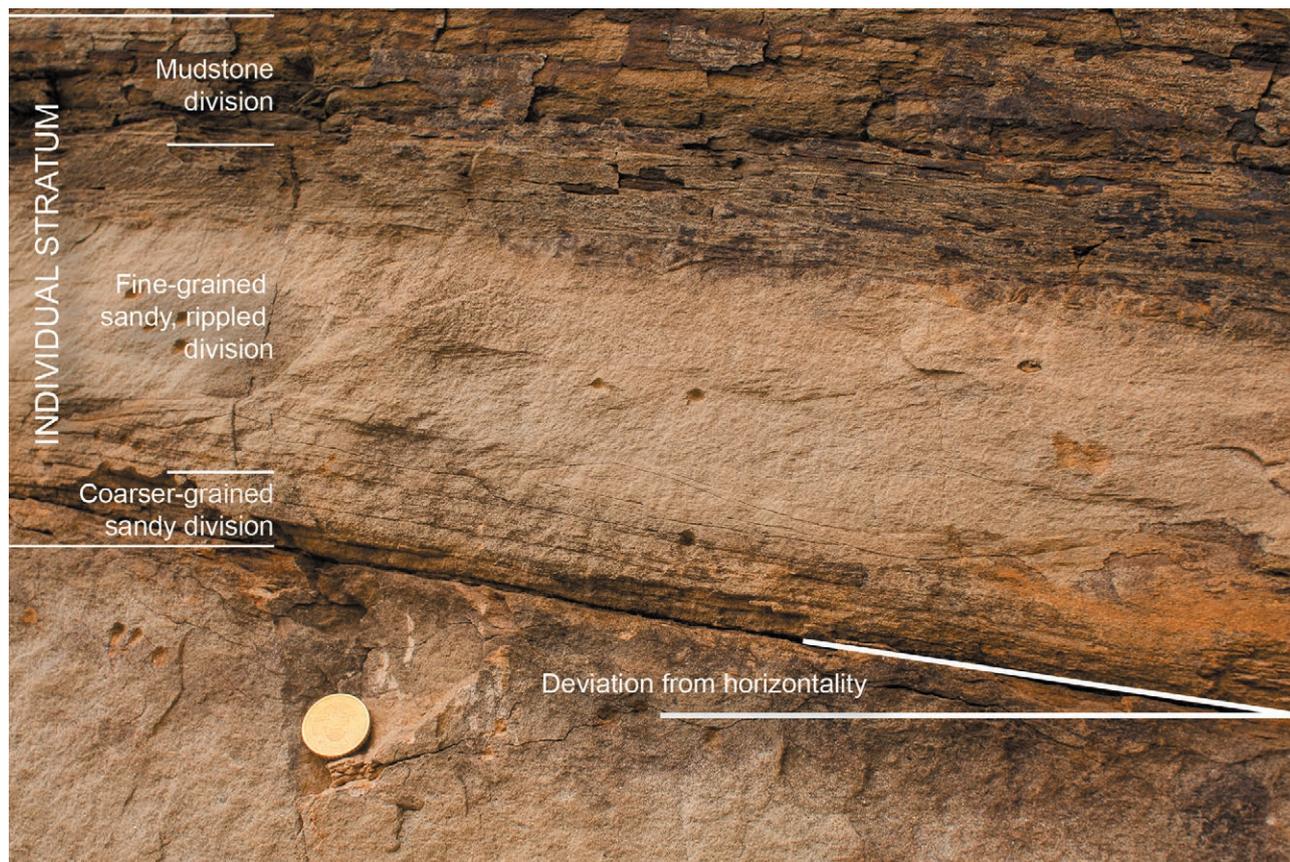


Figure 7. Turbidite sandstone of the Macigno Fm (detail of one of the strata in Fig. 6), showing sedimentary structures (Monte Ceceri quarries, near Fiesole; locality 1 in Fig. 1; coin for scale: 22 mm). Finer-grained particles have settled above coarse-grained ones as a fluid transports them in ripples, in light colour, finally giving way to mud deposition, in dark colour. Stratal surfaces are parallel one to another (Fig. 6), but all are inclined with respect to the horizontal, meaning they have been tilted after their deposition. Photograph by the author.

covered everything, is proved conclusively by the strata of the higher mountains which are free from all heterogeneous material; the outline of these strata testifies to the presence of a fluid; their material bears witness to the absence of heterogeneous bodies; the similarity in materials and outlines of strata from different mountains that are widely separated proves indeed that the fluid was universal. (p. 73)⁸⁵

By 'heterogeneous material' he meant the petrified remains of ancient living beings (see below). All three passages stress sorting of the particles that form the sedimentary bed and their origin by settling from a fluid (Fig. 7). An explanation of their actual position on 'higher mountains' as the key to infer the universality of the primordial fluid, had been anticipated in *Canis Carchariae* (without specifying if in relation to the first flood, when solid matter separated from the universal fluid, or the second universal flood, when all breathing

creatures living on land were wiped out) where earthquakes had been called into action:

No weight should be attached to the arguments set out by people when they say that bodies of this kind ought to be found everywhere if they owe their existence to the waters covering all places, or at least, that such bodies when found, should not be found only in high places. [...] It would be easy, to show how great are the changes in soil caused frequently by earth movement.⁸⁶

Other classes of solids included 'mountains' (pp. 32-34) and 'angular bodies', or crystals in modern terms. Here he informs us that 'the majority of the minerals with which human effort is engaged did not exist from the beginning of things' (p. 44). By exclusion, the third day of creation, when solid earth first formed, is still documented in the natural world by some surviv-

⁸⁵ N. Stensen, *Prodromus*, in ref. 1 (K&M), p. 654.

⁸⁶ N. Stensen, *Canis Carchariae*, in ref. 1 (K&M), p. 587-588.

ing mineral. He was possibly thinking of the minutest clasts that make up turbidite sandstones of the Appennines – although no evidence of this thought exists, but of course not including the largest and youngest crystals quarried at that time in Tuscany. For their size, these formed the object of Steno's long discussion of geometric properties of regular solids, in pages that have attracted the attention of historians of mineralogy and which formed a long digression in the central part of the book (pp. 37-53).

Also at the core of the book (pp. 53-61) is the discourse on organic fossils. Evidence of their marine origin included a comparison between modern animals and fossils he had seen in Tuscany, including Borelli's specimens, with fossils embedded in their matrix. Steno's 1666 interest in demonstrating that glossopetrae were shark teeth is not repeated in the *Prodromus*. Their heuristic role as proof of the marine origin of the sediments in which they were found, hence proof of the biblical flood, is completely substituted in the *Prodromus* by the much more ubiquitous shelled molluscs. Examples abound, while he recalls shark's teeth only in passing:

There are shells of oysters, of remarkable size, in which are found several oblong, worm-eaten cavities [Fig. 2] in all respects similar to those that are inhabited by a certain type of shellfish in the rocks of Ancona, Naples and Sicily. [...] In lumps of earth brought here from Malta, besides various teeth from various sharks, are found also various shellfish, so that if the number of teeth persuades us to ascribe their production to the earth, the construction of the teeth and their abundance in each animal, the similarity of the earth to the sea bed, and the other marine bodies found in the same place favour the opposite opinion.⁸⁷

Then he turns to remains of terrestrial animals and affirms his trust on the biblical account of the same evidence:

For others, difficulty arises from the size of the femurs, crania, teeth, and other bones that are dug from the earth; but there is not much either in this objection that unusual size should suggest a method beyond the powers of nature, since:

1. In our age, men of very large stature have been observed.
2. It is certain that there existed at one time men of gigantic size.
3. Often the bones of other animals are mistaken for the bones of human beings.
4. To attribute to nature the production of truly fibrous bones is on a par with saying that nature can produce the hand of a man without the remainder of the man. (p. 62)

The statement 'It is certain that there existed at one time men of gigantic size' is a reference to Borelli's gigantic 'human teeth' and to the 'time of giants' narrated in Genesis 6, 1-4 – again, Steno obviously had the Bible in mind – while his familiarity with fossil bones and teeth of terrestrial animals echoes Borelli's inputs on the lack of modern analogues of the bones of the 'Chiana' gigantic ox (Fig. 4) and other large animals. In analogy with marine remains, terrestrial ones (including plants, pp. 65-67) were associated with fluvial conglomerates. These abound in the upper Arno valley and other places between Florence and Arezzo (for example locality 5 in Fig. 1) and prompted yet another vision of solid particles moved by a liquid.

The place from which the said bones are dug was built up from various strata that are filled with stones rolled down from the surrounding mountains by the force of torrents. (p. 65)⁸⁸

The series of proofs of the unrolling of events that match the biblical narrative is completed by the geological description of the hill upon which the town of Volterra is built (locality 4 in Fig. 1). In this section Steno merges observation of nature with antiquarianism and historical accounts, trusting the authority of classic authors, as he had done two years before in *Canis carchariae*. Most important, this is also the point he introduces absolute time in the narrative, adopting the language of the chronologists that measure the number of years that have elapsed between some key events, albeit in Steno this takes the form of rough estimates. It is worth recalling here the obvious, that the science of chronology was essentially biblical, although not only biblical, as exemplified by the *Prodromus* itself. Earth's history was only a few days longer than human history, but a sufficiently long stretch of time to fit all the events that mattered, according to an average 17th century thinker.⁸⁹

There are those to whom the length of time seems to destroy the force of the remaining arguments, since there are no recollections in any age to confirm that floods have risen to the places where many marine bodies are found today, if the universal deluge is excepted, from which time it is estimated that 4000 years have elapsed up to the present.⁹⁰ It is certain that before the foundations of the city of Rome were laid, the city of Volterra was already powerful; but shellfish of every kind are found in the huge stones that are found in certain places there. [...] The whole hill on which the oldest of the Etruscan cities is built rises from marine

⁸⁸ N. Stensen, *Prodromus*, in ref. 1 (K&M), p. 652.

⁸⁹ M. Rudwick, ref. 7, pp. 9-23; A. Grafton, ref. 41.

⁹⁰ N. Stensen, *Prodromus*, in ref. 1 (K&M), pp. 651-652.

⁸⁷ N. Stensen, *Prodromus*, in ref. 1 (K&M), pp. 650-651.

sediments, laid on top of other, parallel to the horizon, in which there are many non-stony strata which abound in true molluscs that have suffered no change in any way, and so it is possible to say with certainty that the unchanged molluscs that are extracted from them today were produced more than 3000 years ago. From the founding of the city to the present day we reckon more than 2420 years have elapsed; and who will not grant that many centuries have elapsed since the first men transferred their homes there until it grew to the size that flourished at the time of the founding of the city? If we add to these centuries the time which elapsed between the laying down of the first sediment of the hill of Volterra and the withdrawal of the sea from the same hill, when strangers flocked to it, we shall easily go back to the time of the universal deluge. (p. 63-64)⁹¹

The final section of the *Prodromus* (pp. 67-76) strictly concerns the fit between events inductively demonstrated for Tuscany and those narrated in the Bible. They are preceded by a sentence that perhaps justified the opinion that Steno was aware of consequences from the Church: 'But lest anyone be afraid of the danger of novelty etc.' On the other hand, judging from the fact that for Steno biblical history was history *tout court*, these closing passages appear a summary of what he had finally proved, proud to announce the coherency of the marvellous plan of God. Their content had been forewarned in the introductory chapter:

The fourth part describes various conditions of Tuscany not dealt with by historians and writers on things of nature, and proposes a kind of universal deluge that is not rejected by the laws of natural movements. (p. 6)⁹²

Accompanied by the now-famous schematic drawing of the six periods during which the present Tuscan relief took shape,⁹³ the final part of the *Prodromus* is a counterpoint between the voices of the scripture and nature, the former proposing, the latter answering (whenever possible), sometimes both remaining silent. Steno's discussion of his six periods revealed the final purpose of the dissertation and of all his commitment to the study of fossils, crystals and rocks, and retrospectively the climax of a lifetime search for truth: not to found a new science ('geology'), but to reconcile philosophy and theology, physics and metaphysics:

How the present state of anything discloses the past state of the same thing is made abundantly clear by the exam-

ple of Tuscany, above all others. [...] With regard to the first aspect of the earth, scripture and nature agree in this respect, that everything was covered with water; but of how and when it began, and how long it lasted as such, nature says nothing, while scripture speaks. [...] at the time when the strata of unmixed material, obvious in all mountains, were being formed, the rest of the strata did not yet exist, but everything was covered with a fluid devoid of plants, animals, and other solids. Since no one can deny that the strata are of the kind that could have been produced immediately by the First Mover, we recognize from this the obvious agreement between scripture and nature. (p. 70)

About when and how the second aspect of the earth, which was flat and dry, began, nature is likewise silent, while scripture speaks [...]

When the third aspect of the earth, which is believed to have been uneven, began, neither scripture nor nature determines; nature shows that the unevenness was of some magnitude; scripture, moreover, mentions mountains at the time of the deluge; as to the rest, neither scripture nor nature determine when those mountains, of which scripture makes mention, were produced [...] reason persuades us that, in the first centuries of the world's existence, cavities were gnawn out by water and by fire, so that slighter collapses of strata followed from this. [...]

The fourth aspect, when all was ocean, seems to cause more difficulty, although in truth it is not difficult. The production of hills from marine deposits testifies that the sea was higher than it is now, and this not only in Tuscany but also in very many places far enough from the sea [...] If the activity of a living creature can bring it about that sometimes places flooded with waters are made dry by its decision, and sometimes are flooded with new waters, why should we not willingly concede to the First Mover of all things the same freedom and the same powers? With regard to the time of the universal deluge, sacred History, reviewing everything in detail, is not opposed by secular history. The ancient cities of Tuscany, some of which are built on hills produced by the sea, were founded more than 3000 years ago; in Lydia, however, we come nearer to 4000, so that it is possible to reckon from this fact that the time at which the earth was abandoned by the sea is in accordance with the time of which scripture makes mention. [...] nature does not contradict what scripture determines about how high the sea was. (p. 72)⁹⁴

Steno was finally asserting in the Latin language directed not just to his Italian readers, but to the whole European community of learned men, that a universal principle of geometry, perfectly entrenched in the new philosophy, confirmed biblical facts. This would have helped to silence unorthodox thinkers and re-assert the supremacy of a literal reading of the biblical text. If Steno's sensibility had been shaken by criticism towards standard chronology, alive in certain cultural circles,

⁹¹ N. Stensen, *Prodromus*, in ref. 1 (K&M), pp. 651-652.

⁹² N. Stensen, *Prodromus*, in ref. 1 (K&M), p. 625.

⁹³ S. J. Gould, *Hen's Teeth and Horse's Toes: Further Reflections in Natural History*. New York, Norton 1983, 413 pp.

⁹⁴ N. Stensen, *Prodromus*, in ref. 1 (K&M), pp. 653-655.

biblical references in the *Prodromus* were more than a tribute to religion by a Catholic convert. They formed instead the conclusion of a philosophical and theological journey in the search for ‘true religion’ that had commenced before travelling to Tuscany. His reasoning gave a final sense to a long study to find the meaning of fossils shells and ‘tongue stones’.

6. AFTER THE PRODRAMUS

In the same year of the publication of the *Prodromus*, Steno continued to carry out geological fieldwork in the light of his theory, as testified by a letter written in October 1669 after visiting quarries in Hungary (present day Slovakia), a new occasion to study the rocks produced during the time of the first ‘universal fluid’.

*My journey to visit the quarries caused me great happiness not just for the novelty of the observations, which were very few, but for the autopsy of those things, that upon reading metallic authors are understood with much difficulty. I have seen nonetheless something consistent with my opinions on the transformations that the earth underwent, inasmuch that in the same places soils of Macigno are inclined with respect to the horizon, so that in that place cannot have been materially made.*⁹⁵

The letter proves that the method exposed in the *Prodromus*, nicely expressed with borrowed words from the anatomist (‘the autopsy of those things’), was once again applied with success, this time to strata observed outside of Italy.

The science inaugurated by Steno relied on the observation of nature and on concordance with Scripture. The attempt at reconciling inconsistencies occupied learned men⁹⁶ and missionaries, particularly among the Jesuits including in 1667 Athanasius Kircher.⁹⁷ Debates such as this continued into the eighteenth century, while a steadily increasing number of *savants* across Europe presented new theories of the Earth, and skepticism towards biblical chronology reached further.⁹⁸ Earth as sketched in the *Prodromus* looked much

like the model introduced by Descartes in his *Principiae Philosophiae* of 1644, with its inner cavities justifying the collapse of originally-concentric sedimentary strata at its surface.⁹⁹ But Descartes despised history,¹⁰⁰ while Steno searched different sources, both textual and natural, the latter based on geometry. Few contemporary natural philosophers were equipped with Steno’s experience of the natural world, many distinctly favouring the study of annals and biblical scholarship, with a penchant for establishing systems often disconnected from empirical evidence. Despite not having Steno’s experience in the natural world, most still accepted Scripture and classic authors as trustworthy sources.

Among contemporary authors, the Sicilian painter Agostino Scilla (1639-1700; see above note 72) had studied a very large variety of marine fossils and their sedimentary context, as he demonstrated in his *La Vana Speculazione Disingannata dal Senso* of 1670. Himself creator of the wonderful engravings that illustrated his book, rivalling those of Eisenhoit used by Steno, Scilla did not cite the Dane. However, he surely knew *Canis Carchariae* through Borelli and Malpighi, academicians with whom he was connected in Sicily. Similarly to Steno, Scilla interpreted marine fossils as evidence of the biblical deluge, seeking further evidence for his interpretations in the work of classical authors and antiquarians.¹⁰¹

Robert Hooke (1735-1703)¹⁰² authored a rudimentary theory of the Earth in 1668 based on Steno’s hypothesis of 1667 that most fossils originated in the sea, but dismissing the Flood as the cause, invoking in its place the action of earthquakes. The latter he called into action, together with other natural causes, to also explain other biblical episodes, such as the time of giants, while paying close attention to contemporary biblical scholarship.¹⁰³ In his 1715 theory of the Earth, the astronomer Edmond Halley (1656-1742), of the same Baconian circle as Hooke, still relied on chronology in Genesis, however more critically interpreted.¹⁰⁴

Steno’s lesson certainly informed the other great contemporary philosopher and pioneer in the study of the Earth, the German polymath Gottfried Wilhelm

⁹⁵ N. Stensen to M. Malpighi, 27 October 1669, in ref. 40 (Adelman), p. 429-430. ‘Metallic authors’ referred to the work of late Renaissance learned men like Michele Mercati. ‘Macigno’ refers to a particular type of sandstone quarried near Florence. This is devoid of fossils and thence to Steno it is the material evidence of the third day of Creation.

⁹⁶ Debates among Protestants in the Dutch Republic were fierce, while chronologists contemporary to Steno investigated “the nature of ancient and modern, eastern and western calendars and established the dates of great events”: A. Grafton, ref. 41, p. 45.

⁹⁷ R. Rappaport, ref. 5, pp. 77-79. A. Ziggelaar in ref. 2 (Rosenberg), p. 140.

⁹⁸ R. H. Popkin, A. J. Vanderjagt, *Scepticism and irreligion in the seventeenth and eighteenth centuries*, Brill, Leiden, 1993, 373 p.

⁹⁹ M. J. S. Rudwick, ref. 7, pp. 55-56.

¹⁰⁰ R. Rappaport, ref. 5, pp. 64-65; M. J. S. Rudwick, ref. 7, p. 55.

¹⁰¹ P. Findlen, ref. 73, pp. 119-159.

¹⁰² British natural philosopher, active in Montpellier at the time of Steno’s residence there, and one of the founding members of the Royal Society in London, Hooke deciphered the organic origin of fossils as early as 1663, publishing the idea in his *Micrographia* (1665): T. Yamada, in ref. 2 (Rosenberg), pp. 107-126.

¹⁰³ W. Poole, ref. 4, pp. 43-49; K. Birkett, D. Oldroyd, *The Uses of Antiquity* (Ed. S. Gaukroger), Springer, Dordrecht, 1991, pp. 145 - 170.

¹⁰⁴ W. Poole, ref. 4, pp. 45-46.

Leibniz (1646-1716). Leibniz had met Steno more than once between 1677-1680 and the history of the world, the main theme of the *Protogaea* that the German would complete in 1693, formed the object of their discussion. Leibniz, deeply influenced by the Dane,¹⁰⁵ left the clearest testimony of the primary significance that the full *Dissertation on solids* was meant to have for contemporary philosophers:

*I have often incited him [Steno] further to carry them out [geological studies] and to draw from them conclusions to find out the origin of the human kind, the general water flood and some other nice truths which would confirm what the Holy Scripture tells of that.*¹⁰⁶

All of the above authors, and others, were evidently influenced by Steno. With them, evidence that biblical scholarship genuinely informed the work of early modern men of science is therefore ample. They were still natural philosophers, not geologists, but their science was for the first time driven by the observation of nature, to which they adapted the authority of preceding authors. In this important phase of the history that eventually led to modern geology during the last quarter of the eighteenth century,¹⁰⁷ Steno was the first to publish a history of the Earth based on the study of fossils and sedimentary strata, albeit in the summary form to which he felt pressed by a variety of factors. We can still comment on today the fact that Steno accepted an age of the Earth inconceivable by modern standards, but this should in no way influence our understanding of his role in the history of science.

7. CONCLUSIONS

Nicolaus Steno's contribution on the study of the Earth, passed on to us through two published essays of 1667 and 1669, looks to the relationship with contemporary culture and with the transnational society of learned men to which he belonged. Steno and his contemporaries shared the belief that the Bible was an historical book, and that the Book of Genesis constituted a means to learn about the early part of Earth's history. Steno thought that his work as a natural philosopher could find in nature evidence for the mysteries of creation. It is evident that Steno took Scripture as a guide to comprehend the structure and composition of the

earth beginning with his student years in Copenhagen, Amsterdam, and Leiden, in his subsequent explorations of the Tuscan region, and in his readings of and interactions with fellow natural philosophers at the Medici Court. In Tuscany he perfected a method that allowed him to reconstruct historical events independently, but consistently with Scripture. This method was based on the application of simple geometric principles to the study of different types of geological objects, from crystals and fossils, to rocks and strata, and on to mountains and the whole Earth. Evidence in his writings from 1659-1669 is consistent with an interest to carry out an anatomy of the Earth nurtured through the years, partly hidden by the primary interest in the anatomy of animal and human bodies.¹⁰⁸ It is also hypothesised that this was one of the reasons for travelling to Tuscany where he could carry out the necessary field work within the right cultural milieu. Steno was a meditative man whose anatomical studies had significance inasmuch they disclosed the immense wisdom displayed by God in creating the world. The consistency of his study of the Earth with the narrative of Scripture would have blunted criticism of the skeptics, reinforcing the authority of the Bible.

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¹⁰⁵ C. Cohen, A. Wakefield, *Protogaea*, by W.G. Leibniz, University of Chicago Press, Chicago & London, 2008, pp. xiii-xlii.

¹⁰⁶ G. W. Leibniz, quoted in ref. 1 (K&M), p. 226; see also F. Sobiech, in ref. 2, p. 181; D. Garber, in ref. 13 (A&L).

¹⁰⁷ M. J. S. Rudwick, ref. 7, pp. 79-127.

¹⁰⁸ The connection between anatomy and the idea of landscape is explored by Rosenberg, G.D., "An artistic perspective on the continuity of space and the origin of modern geologic thought", *Earth Sciences History*, 2001, 20, 127-155; G. D. Rosenberg, "The measure of man and landscape in the Renaissance and Scientific Revolution", in *The Revolution in Geology from the Renaissance to the Enlightenment* (Ed.: G. D. Rosenberg), *Geol. Soc. Am. Mem.*, 2009, 203, 13-40.