Stenonian Revolution or Leibnizian Revival?: Constructing Geo-History in the Seventeenth Century

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1. Introduction

In general narratives of the history of geology, many authors have regarded the birth of this science as occurring in the seventeenth century.[1] But it is also widely accepted that geology as a scientific discipline was established during the late eighteenth and early nineteenth centuries in Western Europe.[2] What, then, was the background or context for those like Robert Hooke (1635–1703) and Nicolaus Steno (1638–1686) who took the initiative of making 'geology' in the second half of the seventeenth century? This question is worth to reconsider today. The American historian of early modern philosophy Roger Ariew, in testing the Leibnizian theory of the Earth from the points of fossils and the flood, found out a revival of scholastic thoughts such as that of Avicenna (Ibn Sînâ) and Albertus Magnus rather than an emergence of new science 'geology'.[3] This implies a criticism of opinion such as that of Gordon Herries Davies and other writers. For, the Irish historian of geoscience Herries Davies stressed that the science had so evidently received its character in the seventeenth century that he could appropriately refer to the 'Stenonian Revolution.' [4] In this paper, I shall investigate Steno's geological work linking it to that of continental system builders such as René Descartes (1596–1650), Benedictus de Spinoza (1632–1677) and Gottfried Wilhelm Leibniz (1646–1716). I pay special attention to the historical dimension, which is recognized in the works of Spinoza, Steno and Leibniz. In doing so,

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[1] For example, Stephen Toulmin and June Goodfield, *The Discovery of Time*, Chicago and London: The University of Chicago Press, 1965, chap. 4; Martin J. S. Rudwick, *The Meaning of Fossils: Episodes in the History of Palaeontology*, Chicago and London: University of Chicago Press, Second Ed., 1976/ 1985, chap. 2; Claud C. Albritton, Jr., *The Abyss of Time: Changing Conceptions of the Earth's Antiquity after the Sixteenth Century*, San Francisco: Freeman, 1980, chaps. 3–4; Gabriel Gohau, *Histoire de géologie*, Paris: Editions La Découverte, 1987, chap. 5; David R. Oldroyd, *Thinking about the Earth: A History of Ideas in Geology*, London: Athlone, 1996, chap. 3.

[2] See: Ezio Vaccari, "Geology: Disciplinary History", in Gregory A. Good, ed., *Sciences of the Earth: An Encyclopedia of Events, People, and Phenomena*, New York and London: Garland, vol. 1, 1998, pp. 329–337.

[3] Roger Ariew, "A New Science of Geology in the Seventeenth Century?," in Peter Barker and Roger Ariew, eds., *Revolution and Continuity: Essays in the History and Philosophy of Early Modern Science*, Washington D. C.: Catholic University of America Press, 1991, pp. 81–92. Almost the same version: R. Ariew, "Fossils in Medieval and Early Modern Geology", *Knowledge and the Sciences in Medieval Philosophy*, **3**, 1990, pp. 566–574.

[4] Gordon L. Herries Davies, "A Science Received its Character", in G. L. Herries Davies and A. R. Orme, eds., *Two Centuries of Earth Science 1650–1850*, Los Angeles: University of California, 1989, pp. 1–28. See also, François Ellenberger, *Histoire de la géologie*, t.1, Paris: Lavoisier, 1988, chap. 4.

we shall be able to examine Ariew's Duhemian thesis and at the same time seek to characterize seventeenth-century 'theories of the Earth' from a viewpoint rather different from those like Herries Davies.

As to the historical dimension of knowledge and geological science, Cecil Schneer has previously discussed the rise of historical geology in seventeenth-century England.[5] Later, David Oldroyd made an important reference to the eighteenth-century German case of the relation between historicism and historical geology.[6] On the other hand, Paolo Rossi and Rhoda Rappaport have dealt with the theme from the broader sequence and scope as their book-titles show.[7] However, in spite of such scholarship, the Spinoza-Steno relationship has not been fully discussed and there is still much more to be said on the topic. In the following, I shall have a brief look at the life and works of Steno and see how and to what extent he was influenced by the Cartesian theory of the Earth. Second, the historical aspect of Spinoza's system is discussed in the context of its relation to Steno's work. Third, focusing on the fact that Steno and Leibniz were colleagues in the court of Hanover during the years 1677-1680, I shall argue that the significance of the connection between Steno and Leibniz is not overlooked in efforts to explain the emergence of geological thought and its context.

2. Steno's Career and Geological Works: Was Steno a Cartesian?

Nicolaus Steno (Niels Steensen), being in his student years of Copenhagen University 1657–1659, basically devoted to medical learning under the professorships of Thomas Bartholin (1616–1680) and Erasmus Bartholin (1625–1698).[8] Erasmus Bartholin was a Cartesian mathematician and seemed to have had a great influence upon Steno's early study. At the same time, Ole Borch (1626–1690), an iatro- chemical scholar, gave instruction on a rather wider range of topics. Steno's geological interests had already appeared in his *Chaos-manuscript* (1659).[9] We can trace his excerpts on that topic from the works of

[5] Cecil Schneer, "The Rise of Historical Geology in the Seventeenth Century," *Isis*, **45**, 1954, pp. 256–268.

[6] David Oldroyd, "Historicism and the Rise of Historical Geology," *History of Science*, **17**, 1979, pp. 191–213, 227–257.

[7] Paolo Rossi, *The Dark Abyss of Time: The History of the Earth & the History of Nations from Hooke to Vico* Lydia G. Cochrane, trans., Chicago & London: The University of Chicago Press, 1984 (original ed., 1979). Rhoda Rappaport, *When Geologists were Historians, 1665–1750*, Ithaca and London: Cornell University Press, 1997.

[8] For the description of Steno's life, see, Gustav Scherz, "Nicolaus Steno's life and work", in Scherz, ed., *Nicolaus Steno and his Indice*, Copenhagen: University Library, Scientific and Medical Department, 1958, pp. 9–86; Max Bierbaum, Adolf Faller and Josef Traeger, *Niels Stensen: Anatom, Geologe und Bischof, 1638–1686*, Münster: Aschendorff, 1989 (3.auflage); Troels Kardel, "Niels Stensen 1638–1986: Life and Science", in Kardel, *Steno, Life · Science · Philosophy*, Copenhagen: The Danish National Library of Science and Medicine, 1994, pp. 9-66. For the works of Steno, I shall refer to: Vilhelm Maar, ed., *Nicolai Stenonis Opera philosophica*, 2 vols, Copenhagen: Vilhelm Tryde, 1910, 2 vols (hereafter *OPH*); Knud Larsen and Gustav Scherz, eds., *Nicolai Stenonis Opera theological*, 2 vols, Copenhagen: Nyt Nordisk Forlag, 1941, 1947, 2 vols (*OTH*); G. Scherz, ed., *Nicolai Stenonis Epistrae et epistrae ad eum datae*, 2 vols, Copenhagen: Nyt Nordisk Forlag, 1952, 2vols (*EP*); Gustav Scherz, ed., *Steno Geological Papers*, Alex J. Pollock, trans., Odense: Odense University Press, 1969 (*GP*).

[9] August Ziggelaar, ed., *Chaos: Niels Stensen's Chaos-manuscript, Copenhagen, 1659, Complete edition*, Copenhagen: The Danish National Library of Science and Medicine, 1997.

Pierre Borel (*ca.* 1620–1689), Athanasius Kircher (1602–1680), Bernhard Varen (1622–1650), and Pierre Gassendi (1592–1655).

Steno started his foreign studies at the Athenaeum of Amsterdam and then entered Leiden University. Among his professors were there physicians Jan van Horne (1621–1670) and Franz de le Boë Sylvius (1614-1672), and a mathematician and orientalist Jacob Golius (1596–1667). As an able young anatomist, Steno investigated from glands, heart and muscles to embryology and brain research; and he developed skill in comparative anatomy during these years. We should also remember that Steno had two eminent friends - Jan Swammerdam (1637–1680) and Regnier de Graaf (1641–1673) - noted for their embryological achievements and anatomical studies. On the other hand, Steno was still attracted to mathematical study and he experienced internal crises on religious matter.

Failing to get a post in Copenhagen, Steno went to Paris and moved in the circle of Melchisédeck Thévenot (1620–1692). He met many important figures including Pierre Borel, the royal physician, and Jean Chapelain (1595–1674), one of the founders of the Academy. Steno's experiences in Paris seemed to bring him to two crucial turning points: his contact with Catholicism and recommendation by Thévenot to the Medici court in Florence. In this period, we can see that Steno publicly criticized Descartes' theory on the functioning in brain.

After a short stop at Montpellier, where he met English scholars such as the learned naturalist, John Ray (1627–1705), and the physicians, William Croone (1633–1684) and Martin Lister (1638–1712), Steno left France for Italy. In the Tuscan court of the Grand Duke Ferdinand II (1610–1670), he was warmly welcomed and stimulated by the members of the Cimento Academy, Vincenzo Viviani (1622–1703), Francesco Redi (1626–1698) and Lorenzo Magalotti (1637–1712). During this first stay in Florence, 1666–1668, Steno reached the peak of his geological research and determined to converse to Catholicism in 1667, to the satisfaction of the Grand Duke. Starting with a muscle study, Steno completed four treatises in this period, two of which were geological in character: *A Charcharodon-Head dissected*[10] and *Prodromus.*[11]

However, the summons of the Danish king, Frederik III, compelled Steno to undertake a long journey of approximately 6,400 km, during which he travelled though Italy, the Tyrol, Hungary, Bohemia, Germany and Holland, where he received news of the king's death. Meanwhile, informed of the critical condition of Ferdinand II, Steno decided to return to Florence. His second stay there 1670–1672 was the beginning of Cosimo III's (1642–1723) reign. Under the patronage of the new Grand Duke, Steno undertook further scientific studies, one of which was the investigation of grottos scattered at the foot of the Alps. In letters to Cosimo,[12] Steno reported the interior conditions of the grottos making thermometric measurement. Also, he attacked Aristotelian concept of antiperistasis. At this time Steno began to write his first theological paper, being stimulated by a debate with

[10] "Canis Carchariae dissectum caput", in *Nicolai Stenonis Elementorum myologiae specimen*, Florence, 1667, pp. 69–110 (hereafter *Canis*). *OPH* 2, pp. 113–145; *GP*, pp. 66–131.

[11] *Nicolai Stenonis De solido intra solidum naturaliter contento dissertationis prodromus*, Florence, 1669 (hereafter *Prodromus*). *OPH* 2, pp. 181–227; *GP*, pp. 134–234.

[12] *OPH* 2, pp. 239–248; *EP*, pp. 238–246; *GP*, pp. 236–248.

a Protestant minister when he was in Amsterdam.

Responding to a second summons of Danish king in 1672, Steno was occupied in the services as Royal Anatomist in Copenhagen until 1674, when he became uncomfortable with the attacks from Lutheran theologians. On his way back to Florence, Steno stayed at Hanover and made contacts with the Duke Johann Friedrich (1625–1680), also a convert from Lutheranism to Catholicism and brother of the Danish queen, Sophie Amalie.[13] In his third stay in Florence 1674–1677, Steno became a priest, published his letter to Spinoza and was appointed Vicar Apostolic in Hanover and the titular bishop of Titiopolis. It is supposed that a sermon entitled *Ornaments*[14] containing mineralogical references was written in this period. His engagement in the religious activities continued until his death at Schwerin in 1686, having transferred from Hanover after the Duke's death of 1680 to Münster and then Hamburg.

Steno scholar Gustav Scherz has republished Steno's first dissertation *On Hot Springs* (1660) in 1960.[15] This is only a student's report, but we find the idea of the relationship between containing body and contained body was already discussed nine years before *Prodromus* in a rather scholastic Aristotelian way.[16] The second paper, *A Charcharodon-Head dissected* of 1667, reveals three aspects of the Stenonian theory of the Earth: anatomical presentation, imprint of microcosm - geocosm analogy and tradition of natural history.[17] These are expressed in the complex structure of the work, i.e. a digression in the additional article to the *Specimen of Elements of Myology*. In the digression part of this article, Steno discussed the formation of strata of sediments or deposits. As Scherz and later Hsu pointed out,[18] Steno's physiological interests seemed to play a role for the concept of sedimentation. Moreover, the drawings of the Lamia's head and teeth (Fig. 1) as well as glossopetrae, borrowed from Mercati's still unpublished *Metallotheca* with philologist Carlo Dati's help, were added. The figure was useful and persuasive for it revealed the resemblance between the shark's teeth and glossopetrae.[19]

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[13] Cf. Hans-Joachim Waschkies, "Leibniz' geologische Forschungen im Harz", *Studia Leibnitiana Sonderheft*, **28**, 1999, pp. 187–210, on p. 197. For Steno's correspondence with Johann Friedrich, see *EP*, E98, etc.

[14] *OTH* 2, pp. 342–349; *GP*, pp. 250–267, the version Steno himself corrected. See: *GP*, pp. 36–37.

[15] *Disputatio physica de thermis*. *GP*, pp. 49–63. See also: G. Scherz, "Stensen's first dissertation," *Journal of the History of Medicine and Allied Sciences*, **15**, 1960, pp. 247–269, which contains photographic reproduction of the material.

[16] Thesis X-XII. *GP*, p. 56. Cf. Aristotle's *Physics*, book 4, chaps.1–4; *Prodromus*, pp. 15–18; *GP*, pp. 150–153. The terminology seemed common in physiological textbooks. Cf. Eio Honma, "Compositions of Renaissance Physiology Textbooks and Mechanical Physiology Textbooks in the Sixteenth and Seventeenth Centuries," *Tetsugaku Kagakushi Ronso* [*Archive for Philosophy and the History of Science*], **5**, 2003, pp. 1–36 (in Japanese), esp. pp. 6–7.

[17] Detailed discussion was given in my paper: Toshihiro Yamada, "Hitokui-zame to kaseki no kigen: Suteno no 1667 nen ronbun [Man-eater shark and the origin of fossils: Steno's treatise of 1667]", *Kagaku-Igaku Shiryo Kenkyu* [*Document Research in Science and Medicine*], no. 316, 2000, pp. 1–15 (in Japanese).

[18] *GP*, p. 15. Hsu asserts medical and chemical tradition. See: Kuang-Tai Hsu, "Gabriele Fallopio's *De medicatis aquis* as a major source of Nicolaus Steno's earliest geological writing: *Dissertatio* [sic] *physica de thermis*", *Philosophy and the History of Science: A Taiwanese Journal*, **2**, 1993, pp. 77–104.

[19] The engraving was also adopted by Boccone (1674), Valentini (1704) and Leibniz (1749) [cf. Fig.2]. Professor D. Oldroyd suggested to me that the shark's head in this figure resembled that of embryo shark within uterus. According to the fossil shark expert, Dr. Teruya Uyeno of the National Science Museum, Tokyo, it was the dried head of an adult shark because of its lack of the lateral cusplets on the teeth.

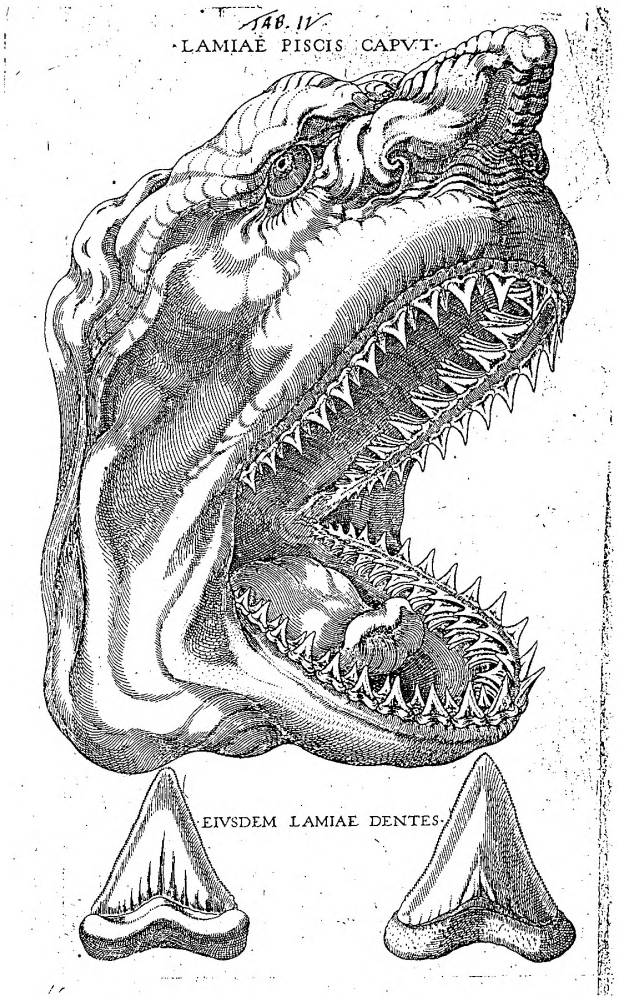

Figure 1. Shark's head and teeth from Steno's Canis (1667). Steno borrowed the figure from Mercati's unpublished *Metallotheca.* (Courtesy of Noma Research Archives for Science and Medicine.)

The third and most famous work was the *Prodromus* (1669). This opus is usually referred as an important 'geological' achievement, but it might be necessary for us to note that it was originally intended to be a general consideration about solids within solids: not only for the reinterpretation of fossil bodies within the Earth but also for the interpretation of the products within human bodies (e.g.: parasite, calculi, etc. on one hand; fat, callus, cartilaginous substances, etc. on the other).[20] The work was just a prolegomenon to a dissertation proper, which was not completed. It consists of four parts: (1) an announcement of the first question of glossopetrae; (2) a guide to the method of research represented by three propositions; (3) descriptions of fossil objects reinterpreted as 'solids within solids', that is, incrustations, strata of the earth, mountains, veins, angular bodies (mineral crys-

[20] *Prodromus*, pp. 17–18, 24; *GP*, pp. 150–153, 158–159.

tals), fossil shells, other parts of animals, plants; (4) a history of the Earth, having six stage of change of the Earth surface. The second part reveals the Steno's method for interpretation of fossil objects and his reconstruction of history of the Earth.[21] The relation between a containing and a contained body tells us the order of formation by their impressions one on another (the first proposition). The similarities of solids are interpreted actualistically (the second proposition). For example, strata are similar to the deposits of muddy water, so the manner and place of production could be also similar each other even in their internal structure. A solid body is produced from a fluid (the third proposition). The description of the work is impressive and many favourable appraisals of it have been made, such as "the developmental Earth-history",[22] "Steno's revolution in thought" for "a new system of classification",[23] "la percée décisive",[24] and ultimately the "Stenonian Revolution".[25] From the viewpoint of Steno as a founder of modern geology and mineralogy, the *Prodromus* is of course a fundamental work, but we are able to find texts on this subject from his *Chaos-manuscript*, as I have mentioned. What kind of momentum or opportunity, then, made Steno take such a breakthrough in the study of the generation of things, especially of the Earth?

Steno's geological works are usually interpreted under Cartesian influence. For example, David Oldroyd put the point in his paper of 1974, concerning the formation of the Earth and crystals.[26] Also, Norma Emerton, examining matter theory of Steno, explicitly declared that Steno was Cartesian.[27] Certainly, Steno referred to Descartes by name in his *Prodromus* and developed the formation of strata-structured Earth:

> 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.[28]

There seems to be here a succession reminiscent of Cartesian ideas. Ariew also cited this text and pointed to Cartesian influence upon Steno.[29] We can cite the other example of Cartesian 'collapse tectonics' and its depiction in the figures of the Earth's formation in the *Principia* (1644). Descartes described the stratified formation of the Earth, and that after a part of the strata is lost, then the upper layers collapse into the abyss. The unevenness of

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[21] *Prodromus*, pp. 12–24; *GP*, pp. 146–159.

[22] Rudwick, 1985 (n.1), p. 75.

[23] Stephen Jay Gould, "The Titular Bishop of Titiopolis", in *Hen's Teeth and Horse's Toes*, Harmondsworth, etc.: Penguin, 1984, pp. 69–78, on p. 73. (First appeared in *Natural History*, vol.90, no. 5, 1981, pp. 20–24.)

[24] Ellenberger, 1988 (n.4), p. 232.

[25] Herries Davies, 1989 (n.4), pp. 17–22.

[26] David R. Oldroyd, "Mechanical Mineralogy", *Ambix*, **21**, 1974, pp. 157–178, on p. 166; and for the formation of crystals, see David Oldroyd, "Some Neo-Platonic and Stoic Influences on Mineralogy in the Sixteenth and Seventeenth Centuries", *Ambix*, **21**, 1974, pp. 128–156, on p. 156.

[27] Norma E. Emerton, *The Scientific Reinterpretation of Form*, Ithaca and London: Cornell University Press, 1984, p. 35. Also see, Rachel Laudan, *From Mineralogy to Geology: The Foundations of a Science, 1650-1830*, Chicago and London: University of Chicago Press, 1987, pp. 41–43.

[28] *Prodromus*, p. 28; *GP*, pp. 162–163.

[29] Roger Ariew, "Leibniz's Protogaea," in *Leibniz: Tradition und Aktualität, V. Internationaler Leibniz-Kongreß, Vorträge*, Hannover, 14.–19. November 1988, pp. 11–18, on p. 13.

the Earth's surface was produced in this way. This scheme was adopted basically by Steno. For, in the description of the Earth's history, Steno referred to the loss of subterranean strata and collapse of overlying. But with his modification, Steno 'doubled' this process. Thus Steno came to explain the formation of three stages of topography - mountains, hills and plains. On the other hand, as concerned matter theory, Steno evidently represented his adoption of corpuscular theory of matters.[30]

However, it seemed to us too hasty to say that Steno was entirely Cartesian, even if we admit the examples cited. If it is necessary to cite names, Steno also mentioned Galileo[31] and Gassendi.[32] Furthermore, Descartes made no mention of fossils and consequently did not include such problematic things in his story of the Earth (or Earth-like object) formation. It is hard to say that Descartes adopted an historical method like that of Steno. Steno deliberately avoided discussing the origin and inner structure of the Earth as other theorists of cosmogony claimed, because those were not perceptible to one's sense. He even expressed a thoroughly critical attitude to any kind of dogmatism:

> Indeed, the advocates of experiments have rarely had the restraint either to avoid rejecting entirely even the most certain principles of nature or to avoid considering their own self contrived principles as proved.[33]

Certainly, Steno shared with his Cartesian mentor Erasmus Bartholin a geometrical treatment of mineral crystals in terms of solid angles and unfolded figures of crystal models, which presumably derive from the Dürer's method in Clavius' work.[34] On the other hand, contrary to the role of E. Bartholin as a defender of Descartes' works,[35] Steno's attitude toward Cartesian thought seems to have been restrained or restricted. In fact, Steno was well aware of the efficacy of chemical method, with which Descartes had not been familiar, in his studies of mineral crystals and sedimentation.[36] According to the commentator of Steno's scientific works, Galileo's paper on things upon or in the water was a possible source for the description of marcasite formation in the *Prodromus*.[37] We may also recall the rather long extracts from Gassendi in the *Chaos-manuscript*[38] and cite other writings of Gassendi about mineral production.[39] Indeed, in the *Syntagma philosophicum* of Gassendi, we can find that the prior division of *Physics*' third section treats of the terrestrial inanimate things covering the contents of the globe, meteors, stones and metals

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[30] *Prodromus*, pp. 10–11; *GP*, p. 145.

[31] *Prodromus*, p. 50; *GP*, p. 184.

[32] *Canis*, p. 102; *GP*, pp. 106–107.

[33] *Prodromus*, p. 9; *GP*, pp. 144–145.

[34] Cecil J. Schneer, "Steno: On Crystals and the Corpuscular Hypothesis," in G. Scherz ed., *Dissertations on Steno as Geologist*, Odense, 1971, pp. 293–307, on p. 296.

[35] Erasmus Bartholin, *Experimenta crystalli Islandici disdiaclastici*, Copenhagen, 1669.

[36] Especially see Conjecture 5 of *Canis*, pp. 99–104; *GP*, pp. 104–109. In this passage Steno made references to the chemical experiments served by P. Borel at the house of Thévenot and by Borch in Copenhagen.

[37] See V. Maar's note in *OPH 2*, pp. 338–339. Cf. *Le Opere di Galileo Galilei*, Edizione Nationale, **4**, 1894, pp. 63–141.

[38] Copy of Borch's exerpts from Gassendi's *Animadversiones in decimum librum Diogenis Laertii*, ..., Lyons, 1649. See, Ziggelaar, ed, 1997 (n. 9), pp. 393–447.

[39] *Opera Omnia*, Lugduni, 1658, vol. 2, Physicae, sec. 3, membrum prius, lib. 3. See also, Ellenberger, 1988 (n. 4), p. 224.

and plants. This represents, so to speak, Gassendi's 'theory of the Earth.' Moreover, we should remember that Steno made overt criticism of Cartesianism in the field of anatomy especially animal-machine theory and brain research.[40] F. A. Meschini introduces Chaplain's letter for Pierre-Daniel Huët, an anti-Cartesian writer, dated 6 April 1665, about this situation, so that his contemporaries saw Steno as a critic of Cartesians.[41] These facts are rather more coexistent with Steno's position of "anti-Cartesian reaction", which Gohau has suggested.[42]

Was there some other possible stimulus to Steno's intellectual development? Next I shall investigate the relationship between Steno and Spinoza in the Netherlands, and its aftermath.

3. Steno and Spinoza on History

As George Sarton once remarked, in a sense, Spinoza made little contribution in the field of natural science.[43] But as a philosopher in the century of the Scientific Revolution, Spinoza could not be indifferent to trends of the new science.[44] Spinoza scholar Wim Klever has suggested that the Spinoza-Steno relationship has been seriously neglected and should be examined from the viewpoint of the acceptance of Spinozism.[45] At the same time, we should pay attention to the relationship from viewpoint of seventeenth-century cosmogonies or theories of the Earth.[46] In doing so, we can recognize an aspect of post-Cartesian presentations of the Earth's history. First, we shall review the exchanges between the both, and then, make a brief comparison of the historical attitudes manifest in their works.[47]

When Steno was a student of Leiden University, Spinoza was living in Rijnsburg near Leiden, and university students used to visit the small town to learn from the eminent expositor of the Cartesian system. It was in 1662 that Steno met Spinoza. They were on good terms at that time. Steno was familiar with many Spinozists,[48] though later, Steno

[40] Adolf Faller, "Niels Stensen und der Cartesianismus", in Scherz, ed., *Indice*, 1958 (n.8), pp. 140–166, esp. pp. 146–154.

[41] Franco Aurelio Meschini, *Neurofisiologia Cartesiana*, Firenze: Olschki, 1998, p. 9. Also see, Kardel, 1994 (n. 8), p. 37.

[42] Gabriel Gohau, *Les sciences de la Terre aux XVIIe et XVIIIe siècles: Naissance de la géologie*, Paris: Albin Michel, 1990, pp. 137–140. Gohau includes Boyle, Perrault and Malebranche in this position.

[43] George Sarton, "Spinoza 1632–1677–1927", *Isis*, **10**, 1928, pp. 11–15.

[44] In this sense, it is curious enough that the *DSB* (*Dictionary of Scientific Biography*), *C. C. Gillispie*, ed. in chief, New York, 1970–1980 has no entry of Spinoza. For Spinoza's scientific contributions, see Marjorie Grene and Debra Nails, eds., *Spinoza and the Sciences*, Dordrecht, etc.: Reidel, 1986.

[45] Wim Klever, "Steno's Statements on Spinoza and Spinozism", *Studia Spinozana*, **6**, 1990, pp. 303–313, on p. 312.

[46] The points of the following authors are different from mine. Adolf Faller, "Anatomie und Philosophie: Niels Stensen (1638–1686) und sein Jugendfreund Benedictus de Spinoza (1632–1677)", *Gesnerus*, **43**, 1986, pp. 47–60; Pina Totaro, "Ho certi amici in Ollandia": Stensen and Spinoz-science verso faith," K. Ascni, H. Kermit and G. Skytte, eds., *Niccolò Stenone (1638–1686): Anatomista, geologo, vescovo*, Rome: L'ERMA, 2002, pp. 27–38.

[47] Detailed discussions have been made in the following: Toshihiro Yamada, "Steno and Spinoza: History of Nature and History of Scripture" (in Japanese), *Spinozana*, **3**, 2002, pp. 47–68.

[48] Steven Nadler, *Spinoza: A Life*, Cambridge: Cambridge University Press, 1999, p. 195.

criticized Spinoza for the contents of the *Tractatus Theologico-Politicus* (1670, hereafter *TTP*) and they departed from one another. In the document entitled "Letter to the Reformer of the New Philosopher on True Philosophy", where he said:

> Since I see a man in this darkness who was once very friendly to me and who, I hope, is not now unfriendly (for I am persuaded that the memory of an old companionship still preserves a mutual love) ...[49]

Steno's anatomical treatise and *Prodromus* were in Spinoza's library.[50] They were apparently dedicated to the philosopher by their author. Assuming that Steno read the *Short Treatise*[51] and more probably the *Descartes' Principles of Philosophy* (1663), he must have been well aware of the uniqueness of Spinoza's thought, and that it had quite different principles from those of Descartes. Even if we could not identify the Spinoza's influence upon Steno exactly, it would be unwise to neglect the possibility of mutual interaction.

There was good reason for Steno to reconsider the Cartesian system since he had already shown the failure of Descartes' theory especially in the field of anatomy, as we have seen. On the other hand, Spinoza, probably stimulated by Hobbes, was challenged to construct a moral science applicable to a new society. In any case, both of them seemed to have been aware of the needs for revision or reformation of Cartesian thought. If this is correct, then, how and by what means did they do so?

Richard Popkin, an historian of early modern scepticism, has claimed that one of the major intellectual developments was the emergence of 'the new philosophy', which overcame scepticism and provided a basis for the new science. The other consideration was a critical and historical approach to the Bible, involving the application of Cartesian methodology or the new science more generally to the evaluation of religious knowledge.[52] Needless to say, Spinoza was one of the representative figures in this setting, in which complicated features of cosmogonies and Biblical interpretations became the 'battleground'[53] of seventeenth-century intellectuals. It was in this field that the theories of the Earth appeared and were developed. One may, therefore, understand the importance of the relationship of both the figures being engaged in the interpretation of natural history and biblical history. Steno's method in his *Prodromus* was a reinterpretation of 'fossils' as solids within solids. This revealed an order of production of natural things, and ultimately, one became able to reconstruct the Earth's history from the marks or signs read in their sequence in the rocks. Nature had a history.

In the fourth part of *Prodromus*, Steno tried to summarize his observations about

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[49] Epistola LXVII bis.; From Steno to Spinoza, written in 1671 and published in 1675. *Spinoza Opera*, hrsg. Carl Gebhardt, Heidelberg: Carl Winters,1925/1972, 4 vols, vol. 4, p. 292.(hereafter *SO* 4, p. 292). Also, *EP*, pp. 231–238, E61. English trans.: A.Wolf, *The Correspondence of Spinoza*, New York: Russell & Russell, 1966 (original ed.: 1928), p. 325.

[50] Stanislaus von Dunin-Borkowski,"Spinoza und Niels Stensen", in his *Spinoza*, vol. 3, 1935, pp. 162–182, on p. 171.

[51] Klever, 1990 (n. 45), p. 305.

[52] Richard H. Popkin, "Cartesianism and Biblical Criticism", in Thomas M.Lennon, John M.Nicholas and John W. Davis, eds, *Problems of Cartesianism*, Tronto: McGill-Queen's University Press, 1982, pp. 61–81.

[53] Cf. The title of the chapter 2 in Stephen Jay Gould, *Time's Arrow, Time's Cycle*, London, etc.: Penguin Books, 1990.

solids within solids by adopting both Cartesian 'tectonics' and biblical chronology. It was, however, an attempt with "the danger of novelty (*novitatis periculum*)". He wrote:

> But lest anyone be afraid of the danger of novelty, I set down briefly the agreement between Nature and Scripture, reviewing the main difficulties that can be raised about individual aspects of the earth.[54]

In his opinion, history is divided by the events that Nature and/ or Scripture recorded. For example, on the fourth aspect of the period of the Universal Flood, Steno claimed:

> The fourth aspect, when all was ocean, seems to cause more difficulty, though in truth it is not difficult. ... Nature does not contradict what Scripture determines about how high the sea was, ... With regard to the time of the universal deluge, sacred History, reviewing everything in detail, is not opposed by secular history.[55]

Thus, Steno stressed the correspondence between Nature and Scripture, and even profane history.

On the other hand, in his famous but at first anonymously published *TTP*, Spinoza clearly explained how to interpret the texts:

> so that one and the same event is so differently related by two men of different opinions, that it seems as if two separate events; and, further, it is often not at all difficult only from descriptions to trace out the opinions of chronographer and historian. I could cite many instances in proof of this from the writings both of philosophers, who described natural history, and chronographers, ...(Chapter 6)[56]

How should one understand the text of the Bible, then? Spinoza asserted, in Chapter 7, "the method of interpreting Scripture ... entirely accords with the method of interpreting nature".[57] Specifically:

> For as the interpretation of nature consists in the examination of the history of nature, and therefrom deducing definitions of natural phenomena on certain fixed axioms, so Scriptural interpretation proceeds by the examination of Scripture, and inferring the intention of its authors as a legitimate conclusion from its fundamental principles.[58]

The certain data or sound narratives of the Scripture should, Spinoza claimed, be introduced from studies of the ancient languages in which the biblical texts had been written. And the classification and analysis of subjects in the texts enabled one to appreciate the historical construction of the Bible, it being a product of the collaboration of a number of writers and audiences. Thus, Scripture also had its history.

Although Steno, a convert to Catholicism, and Spinoza, often regarded as an atheist, had different ideas about religious matters, they seem to have shared somewhat similar atti-

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[54] *Prodromus*, p. 69; *GP*, pp. 204–205.

[55] *Prodromus*, pp. 71–72; *GP*, pp. 206–207.

[56] *SO* 3, p. 92. Cf. R. H. M. Elwes, trans., *The Chief Works of Benedict de Spinoza*, 2 vols, London: George Bell and Sons, 1883–1884, vol. 1, pp. 92–93.

[57] *SO* 3, p. 98.

[58] *Ibid.* Elwes, 1883, p. 99.

tudes and favoured a similar rationalist approach to the past, involving the application of a kind of 'actualism'. Looking into the wider general background of this situation, we might take account of the 'historical revolution' that Anthony Grafton mentioned in his studies about sixteenth- and seventeenth- century literatures especially Joseph Scaliger's.[59] Grafton's painstaking work revealed the importance of chronology as a scientific discipline among sixteenth century humanists. At the same time, we should take note of the influence of the discoveries of non-Christian civilized societies, which became mirrors of the Christian society, even though there may be sometimes kinds of misunderstandings. Spinoza made references to episodes of Chinese history and Japanese religious policy in the *TTP*.[60] In these circumstances, consideration of the functions of letters or languages in relation to religious matters in such societies might have shaken those in homeland and secularized the languages.[61] I shall refer to this theme in the next section again.

Of course, Spinoza and Steno had substantially different opinions about the biblical narrative. Spinoza severely criticized those "who attempt to show the authority of the Scripture by mathematical demonstrations".[62] Probably, this criticism would be applicable to Steno's attitude. On the contrary, Steno continued to condemn Spinoza's religious and philosophical attitudes, regarding them not as those of a reformer but a deformer, of Cartesian thought.[63] Nevertheless, it was crucial that Steno's scientific method reorganized natural histories, which guides one to the historically organized natural world. On the other hand, Spinoza's critical and historical method implied the possibility of its application to natural history as well as biblical history. Popkin has pointed out that it was "this new [naturalistic] metaphysics (or revised Greek naturalism)" that was "Spinoza's great contribution, for better or worse, to the making of the modern mind".[64]

Two years after the condemnation of the *TTP* of 1674, Spinoza received a visit from Leibniz, who had been interested in the Spinoza's thought and was to be with Steno in the Hanover court. So we are inevitably introduced to consider about the ideas on history of these three figures.[65]

4. From Steno to Leibniz

According to André Robinet, who investigated the Leibniz's long journey into Italy, to

[59] Anthony Grafton, *Defenders of the Text: The Traditions of Scholarship in an Age of Science, 1450–1800*, Cambridge Mass.: Harvard University Press, 1991, p. 5. Also see his introduction to the *Joseph Scaliger*, vol. 2, Oxford: Clarendon Press, 1993.

[60] For example, *TTP*, chaps. 3, 5, and 16; *SO* 3, pp. 57, 76 and 200.

[61] Margreta de Grazia, "The Secularization of Language in the Seventeenth Century," *Journal of the History Ideas*, **41**, 1980, pp. 319–329, esp. p. 328. For Spinoza's concept of language, see David Savan, "Spinoza and Language", *Philosophical Review*, **67**, 1958, pp. 212–225; Rossi, 1984, pp. 209–213.

[62] *SO* 3, p. 185. See also the statements in chap. 8 (*SO* 3, p. 124).

[63] *OTH* 1, pp. 371–437.

[64] R. H. Popkin, "Spinoza and Bible Scholarship," in J. E. Force and R. H. Popkin, eds., *The Books of Nature and Scripture*, Dordrecht: Kluwer, 1994, pp. 1–20, on p. 17.

[65] For the relationship between three figures including Steno in general, see Georges Friedmann, *Leibniz et Spinoza, nouvelle edition revue et augmentee*, Paris: Gallimard, 1974, pp. 124–127; Ildefons Betschart, "Stensen-Spinoza-Leibniz im fruchtbaren Gesprach", *Salzburger Jahrbuch für Philosophie und Psychologie*, **2**, 1958, pp. 135–151.

clarify the complex relations between Steno and Leibniz would need at least a book.[66] But in this chapter, focusing on the episode of the 1677–1680 Hanover court and the contents of *Protogaea*, I shall specialize the discussion about some cosmo-geological significance as well as socio-cultural one within the relationship.

4.1. The Hanover Meeting

Accepting an offer of the Duke Johann Friedrich, Leibniz left Paris on 4 October 1676 and, visiting London and the Netherlands, arrived at Hanover in December,[67] where he became Counsellor and Librarian of the Hanover court. The proposals to the Duke made by Leibniz were wide-ranging, but we can easily see the 'Harz Project' was one of his more important concerns in the early years. Leibniz planned to develop the mining of the Harz Mountains by the use of wind power and to gain funds for an academy of sciences.[68] In spite of objection of the engineers in the Mining Office, the project started in 1679. The idea of combining windmill with draining system was originated from Japanese Dutch Pieter Hartsinck (1637–1680), an engineer of the Office, who designed a system to circulate water in the mine.[69] Technological and financial difficulties, as well as meteorological conditions, shattered Leibniz's efforts. The project ended in failure in 1685.

Meanwhile, about a year after Leibniz's arrival, Steno joined the court in November 1677. He was invited as a priest, titled Apostolic Vicar from Rome. At that time Hanover was a city with a population of about ten thousand, the counsellor and the priest seemed to have had opportunities to meet each other and discuss a great range of topics, naturally including geological ones.[70] In this period and after, Leibniz was obviously interested in not only mining and chemistry but also geography and the natural history of terrestrial things. He had visited the Harz Mountains many times and because of his scientific interests continued to do so even after the end of failed mining project. He picked up a lot of specimens of fossils and investigated caverns. It is not unnatural to recognise the Steno's influence upon Leibniz in those fields, as we shall see.

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[66] André Robinet, *G. W. Leibniz iter Italicum (Mars 1689–Mars 1690): La Dynamique de la république des lettres nombreux textes inédits*, Firenze: Olschki, 1988, p. 282.

[67] For Leibniz's life in general, see E. J. Aiton, *Leibniz: A Biography*, Bristol and Boston: Adam Hilger, 1985. The abbreviation for Leibniz's bibliography is following: A: *Samtliche Schriften und Briefe*, hrsg. Deutschen Akademie der Wissenschaften zu Berlin, 1923–. Roman numerals represent Series (Reihe) and Arabic, volume (Band); GPh: *Die Philosophischen Schriften*, hrsg. C. I. Gerhardt, 7 vols, 1875–90/ Hildesheim: Olms, 1978; Grua: *G. W. Leibniz Textes inédits ... publiés et annotés par Gaston Grua*, 2 vols, Paris: Presses Universitaires de France, 1948.

[68] For the Harz Project, see Ulrich Horst und Jürgen Gottschalk,"Über die Leibniz'schen Pläne zum Einsatz seiner Horizontalwindkunst im Oberharzer Bergbau und ihre mißglückte Durchführung", *Studia Leibniziana Supplementa,* **12**, 1973, pp. 35–59; E. J. Aiton, "Leibniz's mining technology," in M. Watanabe and H. Nishimura, eds., *Five Lectures on History of Science given in Japan in May and June 1990*, Tokyo: International Christian University, 1991, pp. 51–64.

[69] Aiton, 1985, pp. 107–108. For Peter Hartzingk, see Seiichi Iwaki, "Descartes no mago-deshi Pieter Hartsinck no bohi [The Epitaph of Pieter Hartsinck, a grand-pupil of Descartes]", *Nihon Rekishi [Japanese History]*, no. 339, 1976, pp. 82–83.

[70] Gustav Scherz, "Gesprache zwischen Leibniz und Stensen", *Studia Leibnitiana Supplementa*, **5**, 1971, pp. 81–104.

During his stay in Paris 1672–1676, Leibniz had studied developed French mathematics and philosophies, including the works of Descartes and Pascal, supervised by such an prominent scholar as Christian Huygens (1629–1695). On the other hand, he was 'incubating' criticisms of the Cartesian system. In a manuscript of around 1679, while he positively evaluated Cartesian views on magnetism, tides and meteors, he stressed that Descartes' limitation in anatomy, stating "Steno has made it clear that Descartes was completely mistaken in his opinion about the movement of the heart and muscles."[71] Accordingly, Leibniz expressed his regret in a letter that "Steno was disinclined to continue the scientific studies in which he was excellently skilled".[72]

By contrast with the appreciation of Steno's achievements in anatomy and studies of the earth, Leibniz was critical of the Steno's theological or philosophical opinions. Two pieces of writing by Leibniz on the controversy in which Steno was involved have survived. One is a "Letter to a friend"[73] and relates to Steno's letter to a German theologian Johannes Sylvius in Amsterdam.[74] The other is "Another letter to the same friend"[75] in which Leibniz intended to comment on Steno's epistle to Spinoza, published in 1675. In the latter, Leibniz summarized the contents into ten points, criticizing each one with his own comment. Summing up the basic points, Leibniz doubted the generality of Steno's assertion from the position of Roman Catholicism and made objections. Having already become intimate with Spinoza and his doctrine, Leibniz was unsatisfactory with Steno's statements. Ludwig Stein called the years 1676–1679 amicable periods of Leibniz and Spinoza.[76] On the theory on the freedom of the will, Leibniz also contradicted Steno. Although Leibniz ("Théophile" in *Dialogue entre Poliandre et Théophile*) persuaded "Poliandre" (probably representing Steno) to agree with the principle of the God's best choice among the compossibles, Steno's idea on free will had certainly stimulated Leibniz and it would be necessary to consider this topic from the Steno's side. [77]

On the other hand, however, Leibniz anticipated that Steno would associate with him to promote church reunification, in which he deeply engaged. Since the Duke Johann Friedrich had himself converted to Catholicism during his stay in Assisi in 1651, Hanover was a stronghold of the reunion movement. The chief persons of the Protestant side were Gerard Molanus (1632–1722) and Leibniz. Those on the Catholic side were Cristobal de

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[71] Letter to Molanus (?), On God and the Soul (ca. 1679), in Roger Ariew and Daniel Garber, eds., *G. W. Leibniz Philosophical Essays*, Indianapolis and Cambridge: Hackett, 1989, p. 244; GPh 4, pp. 297–303, on p. 302. A similar expression is found in the article of the summer 1683- winter 1684/ 85 in A VI 4B, pp. 1474–1488, on p. 1486.

[72] Aiton, 1985 (n. 66), p. 75. A II 1, 385–389, Leibniz an Hermann Conring [3/13. januar 1678.], p. 385.

[73] "Lettre a un amy [Marz 1677 (?)" in A VI 4C, pp. 2188–2196.

[74] *OTH* 1, pp. 49–70. For Leibniz's commentation: "Annotationes in Nicolai Stenonis Epistolam Secundam ad Johannem Sylvium, Januar bis Marz 1677 (?)" in A VI 4C, pp. 2179–2188.

[75] "Autre Lettre au mesme [Marz 1677 (?)" in A VI 4C, pp. 2197–2202; Grua, pp. 158–163. Leibnz also referred to the Steno's letter to Spinoza in his letter to Jean Gallois. (A III 2, p. 227, September 1677.)

[76] Ludwig Stein , *Leibniz und Spinoza*, Berlin, 1890, p. VIII, after Scherz, 1971 (n. 70), p. 84.

[77] Aiton, 1985, p. 75. Cf. Nicholas Rescher, "Leibniz Finds a Niche (Settling in at the Court of Hannover: 1676–77)", *Studia Leibnitiana*, **24**, 1992, pp. 25–48, on p. 46. For Leibniz's essay about this topic, see "Conversatio cum Domino Episcopo Stenonio de Libertate," 27. November (7. Dezember) 1677, A VI 4B, pp. 1375–1383; Grua, pp. 268–273.

Rojas y Spinola (*ca.* 1626–1695) and Jacques-Bénigne Bossuet (1627–1704).[78] In the letter to Tschirnhaus of the early 1678, Leibniz referred to Steno and Molanus as "deux premiers Theologiens",[79] and said in a letter to Bossuet of 1679, "Nous avons icy M. Stenonis Evesqve de Titiopolis fort connu déja du temps passe pour les decouuertes qu'il a faites dans l'Anatomie: maintenant il s'applique à la controverse, ou il fait paroistre beaucoup de jugement et de moderation".[80] 1679 was the year when Leibniz made contact with Bishop Spinola through Johann Daniel Craft.[81] Leibniz intended to revive the plan of writing a theological work (*Demonstrationes Catholicae*) for reunion, but the sudden death of the Duke interrupted the project.[82]

According to Scherz, Steno may have influenced Leibniz's private religious views.[83] In fact, Leibniz evaluated the system of Catholic churches, later publishing ideas in *Systema theologicum* (1686), and people considered him having the intention of converting.[84] But Leibniz did not think that converting himself would forward reunification, and after the death of Johann Friedrich on January 1680, they departed from one another. Leibniz's effort ended in failure again.

On the other hand, Leibniz made various proposals to the new Duke Ernst August, a Lutheran brother of Johann. The proposal of compiling the history of the House of Brunswick-Lüneburg was adopted and Leibniz decided to work at this new enterprise in 1685, just after the termination of the Harz Project. From his youth, he had been interested in historical matters and realized their significance for practical issues, for example, making an assertion about political legitimacy or some kinds of rights.[85] He was ordered to devote himself to the writing the history of the House as having the status of Privy Counsellor and supported with funds.[86] He was to engage in collecting of documents, travelling and surveying as widely as possible. It would be Leibniz's most important and longest journey, undertaken in his early forties, travelling through southern Germany and Italy during 1687–1690.[87]

The fruits of the journey were not restricted to historical works. Leibniz discovered many materials concerning the House history but publication was delayed until the eighteenth and even the nineteenth centuries. At the same time, he visited mines and geological sites such as the Vesuvius, Volterra, grottos, etc., some of which evidently Steno had mentioned. He made many observations of natural phenomena as can be seen from the

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[78] Cf. Hermann Tüchle, *Geschichte der Kirche*, Bd. 3, Zürich, 1965, chap. 6; Paul Hazard, *La Crise de la conscience européenne (1680–1715)*, Paris: 1935, part 2, chap. 5; A. D. Wright, *The Counter-Reformation: Catholic Europe and the Non-Christian World*, London: Weidenfeld and Nicolson, 1982, chaps. 3–5.

[79] AIII2, 339–341, Januar/ Februar 1678, p. 341.

[80] AI2, 482–483, 1. Juni (?) 1679, p. 482.

[81] Aiton, 1985, p. 74. Cf. A letter of 3. (13.) Januar 1679 in AI2, pp. 408–409.

[82] Aiton, 1985, pp. 99–100.

[83] Scherz, 1971 (n. 70), p. 99.

[84] Hazard, 1935 (n. 78), pp. 228–230.

[85] Rüdiger Otto, "Leibniz als Historiker: Beobachtingen anhand der Materialien zum Sachsen-Lauenburgischen Erbfolgestreit", *Studia Leibnitiana Sonderheft*, **29**, 1999, pp. 197–221, esp. pp. 198–204. For the first historical work of Leibniz, see A I 2, pp. 335–337, April (?) 1678 (Aiton, 1985, p. 75).

[86] Aiton, 1985, pp. 137–138.

[87] On detailed references about this journey especially in Italy, see, Robinet, 1988 (n. 66).

descriptions in *Protogaea*. However, he never surrendered his studies of mathematics and physics. Although eschewing conversion to Catholicism, he became involved in attempts at Church reunion.

Thus, given ample materials and specimens, Leibniz drafted his *Protogaea* around 1691. A brief abstract was published in 1693, but the book itself did not appear until 1749.

4.2. *Prodromus* and *Protogaea* Reconsidered

As we have seen, Leibniz's interest in mining and natural history of terrestrial things preceded his interest in political history. But to make the history of the state of his monarch complete, he intended to natural history before the state history. What, then, was the relationship between different histories—natural, national and biblical—for Leibniz? First of all, we shall look into the structure of his 'theory of the Earth' including the history of nature.

Concerning Leibnizian theory of the Earth, besides the *Protogaea* published in 1749, we have some fragmentary texts: a brief summary of *Protogaea* of 1693,[88] the *Théodicée* of 1710,[89] and so forth.[90] But we have to consider the *Protogaea* as the main source.[91] Traditionally, the *Protogaea* has been seen as a successor to Cartesian cosmogony.[92] But I am not convinced that this interpretation is satisfactory. There is a rather more complex story.

Protogaea consists of four parts: introduction, the Creation and global 'tectonic' formation (Chapters 1–7); the origin of minerals (Chapters 8–17); fossils and related subjects (Chapters 18–38); and vestiges of natural changes (Chapters 39–48). Although it seems "much more hazy"[93] in comparison with Descartes, we can trace such Cartesian ideas as a subterranean fire derived from the inner part of a sun-like star, covered with sunspot material (Chapter 3); the formation of huge caverns underneath the Earth's surface and the production of mountains and depressions by collapsing the mass over the caverns (Chapter 4).

On the other hand, Kurt von Bülow once characterized Leibniz's *Protogaea* as a *Pro-*

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[88] "Protogaea autore GGL", *Acta Eruditorum*, 1693, pp. 40–42. For English trans. with comments, see, D. Oldroyd and J. B. Howes, "The First Published Version of Leibniz's Protogaea", *Journal of the Society for the Bibliography of Natural History*, **9**, 1978, pp. 56–60. Japanese: H. Hirai, trans., *JAHIGEO Kaiho*, no. 14, 2000, p. 23.

[89] Part 3, sections 244–245. GPh 6, pp. 262–263.

[90] See, François Ellenberger, *Histoire de la géologie*, t. 2, Paris: Lavoisier, 1994, pp. 137–148. Rhoda Rappaport, ed. and introduction, "Leibniz on geology: A newly discovered text", *Studia Leibnitiana*, **29**, 1997, pp. 6–11.

[91] G. W. Leibniz, *Protogaea, sive de prima facie telluris et antiquissimae historiae vestigiis in ipsis naturae monumentis dissertatio*, Göttingen, 1749 (hereafter *Protpgaea*). French: Jean-Marie Barrande, ed. and notes, *G. W. Leibniz Protogaea*, Bertrand de Saint-Germain, trans., Toulouse, 1993. German : W.von Engelhardt, trans., *Protogaea*, Stuttgart, 1949. Japanese: T. Tanimoto, trans., *Leibniz Chosakushu* [*Leibniz Works*], vol. 10, Tokyo: Kosaku-sha, 1991.

[92] Archibald Geikie, *The Founders of Geology*, London: MacMillan, 1897, pp. 7–8; Karl Alfred von Zittel, *History of Geology and Palaeontology to the End of the Nineteenth Century*, Maria M. Ogilvie-Gordon, trans., London: Walter Scott, 1901/ Weinheim: J. Cramer, 1962, pp. 27–28. Rather new tradition: Laudan, 1987 (n. 27), p. 68.

[93] Katharine Brownell Collier, *Cosmogonies of Our Fathers: Some Theories of the Seventeenth and the Eighteenth Centuries*, New York: Columbia University, 1934, p. 100.

dromus applied to Niedersaksen.[94] Certainly, one can point out many features that Leibniz introduced from Steno. We have, first of all, to note Leibniz's references to the well-known proposition of 'a solid within a solid ' in *Prodromus*. When a body hardened from liquid, its process accords with the general law of bodies. In Chapter 2, Leibniz puts it thus:

> Wherein solids contained within solids are demonstrated, deposited into proper angles and borders with frequency in certain strata and kernels, such as veins in cliffs and gems in rocks. But also here and there exist vestiges of old things, of plants, of animals and of artificial products under the new covering of stone. Accordingly, it is necessary that this covering we see to be hard at present, was in fact fluid at that time and subsequently hardened.[95]

In this way Leibniz clearly adopted Stenonian ideas about the formation of crystals and fossils. Similar bodies have the similar origin, so we may assume mineral crystals were produced from dissolved materials, as we see crystallization of salt proceeding in the laboratory. Evidently, Leibniz preferred Steno's diligent observations rather than the authority of Plinius (Chapter 9). He convinced that dissolved substance received "figures and angles" (Chapter 11), which alludes Steno's term and explanation of 'angular bodies'.[96] And petrified fishes found in black slates were once fishes in a sea, being buried in the earth by an earthquake, aqueous agency, or another powerful cause and sometimes replaced by metallic material (Chapter 18). Steno also stated that many and various changes have occurred by earthquakes, eruptions of fires or floodings[97] and he referred to mineral replacement of fossils in his third classification of fossil shells.[98] Like Steno and Hooke, Leibniz was obviously negative to the idea of sports of nature or the agent of formative power taken by Kircher or Becher (Chapters 18 and 29), though he had a great concern for the works of these two authors.[99] We can find more possible evidences from Steno, such as mineral deposits of mines (Chapter 9, also criticism of the divining rod is mentioned here), fossil shells in Volterra (Chapter 25), allochthonous origin of glossopetra (Chapter 26) and illustration of a Shark's head (Chapter 31) (see Figs. 1 and 2).

The illustrations borrowed from natural histories well known in his time reveal Leibniz's respect for the tradition of natural history on the one hand and his commitment to the reorganization of natural history on the other along Steno's lines. But unlike Aldrovandi's natural history, Leibniz was skeptical about the medical use of glossopetrae, suggesting that they are no more effective than tooth powder (Chapter 32). We would have to pay at-

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[94] Kurd von Bülow, "Protogaea und Prodromus", *Studia Leibnitiana Supplementa*, **2**, 1969, pp. 197–208, on p. 204.

[95] *Protogaea*, p. 2.

[96] 'figurae angulique' in Leibniz's text (*Protogaea*, p. 22) and 'angulata corpora' in Steno's (*Prodromus*, p. 19).

[97] *Prodromus*, p. 75; *GP*, p. 211.

[98] *Prodromus*, pp. 58–59; *GP*, p. 195.

[99] A manuscript of Leibniz, which Claudine Cohen cites, reveals that he once evaluated the opinion of Kircher in the *Subterranean World* (1665). See C. Cohen, "Un manuscrt inédit de Leibniz (1646–1716) sur la nature des "objets fossils"," *Bulletin de la Société géologique de France*, **169**, 1998, pp.137-142. Ariew claims that Leibniz's revision of fossil objects is not so total as Steno's criticism to the petrifying virtue of the place (Ariew, 1991 (n. 3), pp. 85–86).

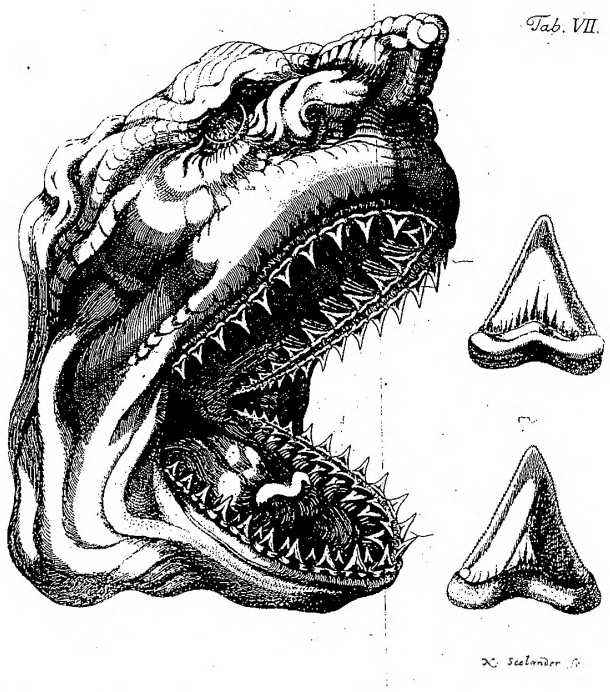

Figure 2. Shark's head and teeth from Leibniz's *Protogaea* (1749).

tention to the other illustrations presenting the Baumann Cavern and its method of presentation, namely the representation of a longitudinal section. This figure was accompanied by several figures of specimens that Leibniz picked up in the cavern, which are described in Chapters 36 and 37. This setting reminds us that Steno, also, investigated grottos in the northern Italy and intended to depict their interiors by drawings. In his letter to Cosimo III of 1671, Steno gave drawings, one of which of the Moncodeno Grotto was survived.[100] That tells us about the internal shape of the grotto with longitudinal and cross sections. He also gave a description of columnar bodies in the cave. (His purpose of this investigation was to criticize the Aristotelian concept of antiperisitasis with the aid of a thermometer. Steno demonstrated that it was not antiperistatis but the air from cold part of mountain that made grottos cool during summer.[101] Leibniz likewise mentioned antiperistasis and its testing by thermometer (Chapter 42).)

For other illustrations in which Leibniz aimed to represent underground condition, I may mention certain drawings in *Protogaeae* manuscripts, which are hitherto unpublished, so far as I am aware.[102] Two of these apparently correspond to the contents of *Protogaea*, Chapter 8, referring to the underground distribution of mineral deposits. First, he wrote:

A vein is like a leaf or a layer of indifferent thickness, long and extending widely

[100] *GP*, pp. 236–248, on p. 246.

[101] *OPH*, 2, pp. 241–242, 246–248, 343–344; *GP*, pp. 236–237, 240–243.

[102] For my first article: Toshihiro Yamada, "Leibniz's Unpublished Drawings in a *Protogaea* Manuscript", *JAHIGEO (Japanese Association for the History of Geology) Newsletter*, no. 3, 2000, pp. 4–6.

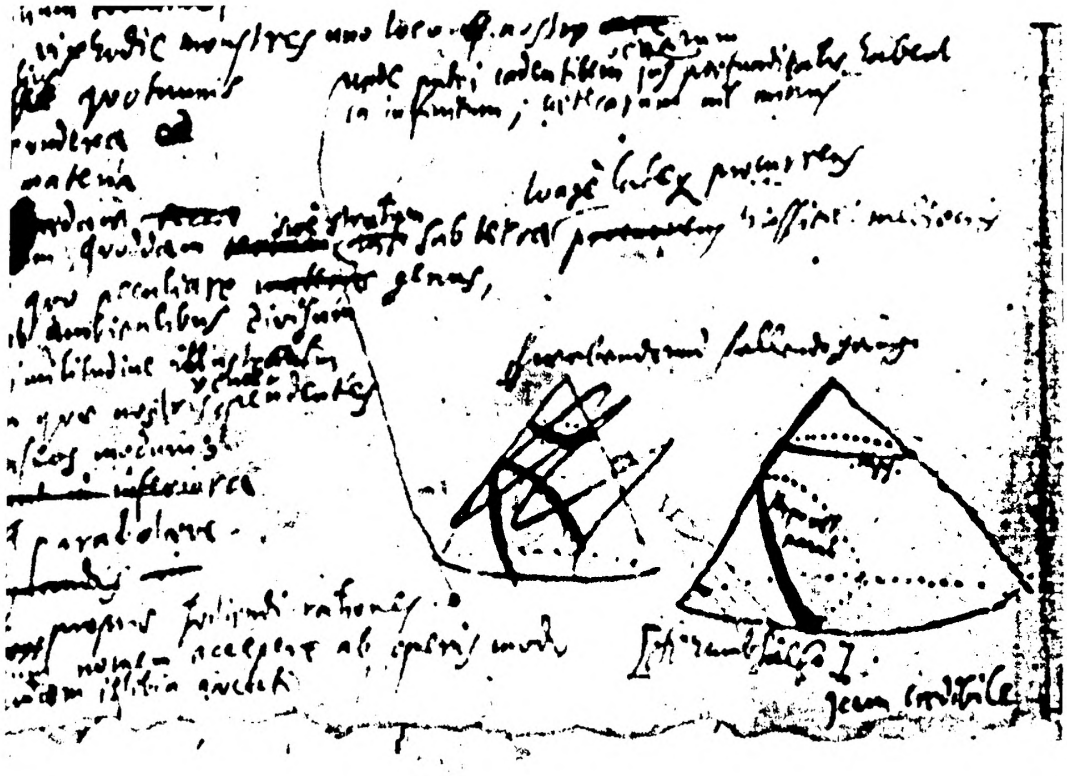

Figure 3. Suspended and falling veins in the *Protogaea* Manuscript. (Courtesy of Kousaku-sha Publishing Co.)

> under the Earth, containing a peculiar kind of earth, rock or metal, distinct from the surroundings. A vein is best illustrated by using the analogy of conic sections.[103]

In this way, Leibniz wrote about 'suspended veins' (*venae pendentes* or *schwebende Gänge*) in the shape of an ellipse, and 'falling veins' (*venae cadentes* or *fallende Gänge*), in the shape of a hyperbola or parabola, on his 'conical mound' (see Fig. 3).[104] 'Suspended veins' were also spoken of as a bedded stratum that contained fossil fishes (Chapter 18). Moreover, he gave a description of a sectional plan of strata:

> Valleys are also seen everywhere, that are broken open or hollowed out by the power of water or by some other agency and show variegated sorts of layers at each opposite side of walls of mountains. I remember that a suspended vein of copper-slate called ardosia was uncovered with iron (tools) in Osterode in the Harz Mountains not so long ago and its continuation was seen on the opposite side of the valley.[105]

This scene or situation is represented in Leibniz's hand in the marginal space of the *Protogaea* manuscript (see Fig.4). The two drawings present both an idea and an example of

[103] *Protogaea*, p. 14.

[104] The first-drawn 'conical mound' is crossed out and a larger cone is drawn, on which the two veins are depicted, as in Fig. 3.

[105] *Protogaea*, pp. 15–16.

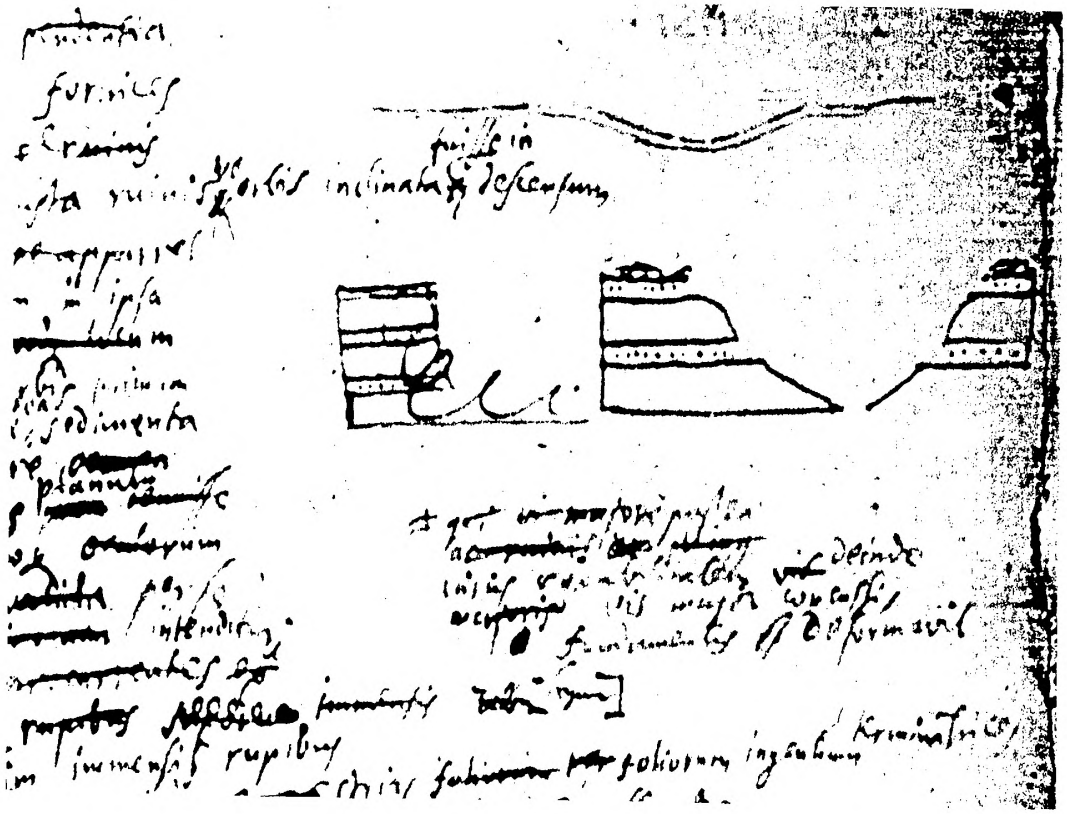

Figure 4. Sectional plan of strata in the *Protogaea* Manuscript. (Courtesy of Kousaku-sha Publishing Co.)

Leibniz's way of describing underground laminar or planar entities by geometrical means.

According to Ernst Hamm, Leibniz aimed to represent underground topography or to make a 'scenography' of the subterranean world[106] . Hamm was presumably unaware of the above-mentioned drawings in the manuscript, but they show remarkable evidence of Leibniz's thinking. And, it is important to think about the possible influence of Steno upon Leibniz, which Hamm does not discuss. For, in the same chapter, Leibniz clearly adopted the Stenonian scheme of strata formation.

Why is the exact description of mineral deposits or strata necessary? Because it is useful and indispensable not only to develop mines but also to reconstruct the history of nature. In fact, in Chapter 44, Leibniz suggested environmental changes of a region, pointing to the evidences of fossil plants in strata:

> Just under the spot where the clayish and slippery bottom begins, we come across an almost rotten birch and a dense fir tree, which is still fresh, lying crosswise with its roots and near by several cones being found. There is no doubt that the valley was full of trees, since multitudes of people had never been cut off in the place for their habitation, and overflowings of water turning back intermittently, filled up with

[106] E. P. Hamm, "Knowledge from Underground: Leibniz Mines the Enlightenment", *Earth Sciences History*, v. 16, no. 2, 1997, pp. 77–99, esp. pp. 77–82.

> diverse kinds of strata; ... It is not unworthy to remark that there is no fir in that region at present and so the nature of the place has changed.[107]

In these chapters Leibniz searched the data of sinking wells, such as those in Modena (*ca.* 24 metres, Chapter 42), Rosdorf (more than 7 m., Chapter 44, cited above) and Amsterdam (*ca.* 70 m., Chapter 48).[108] We may think of them as description of 'geological columns', for Leibniz discussed the changes of the environments by interpreting the constituents.

Meanwhile, in Chapter 21, Leibniz evidently accepted the theory of forming a three-stage physiognomy by double collapse, which Steno presented with six figures, i.e. doubled three-stage-sequence. Remembering the way in which Steno reconstructed the history of Tuscany in the fourth part of *Prodromus*, "different changes that have occurred in Tuscany"[109] , we can easily admit that Leibniz followed the method of Steno. Although some scholars have characterized Leibniz in the *Protogaea* as a deductivist,[110] or a theoretician[111] in a Cartesian manner, it should be pointed out that Leibniz treated terrestrial bodies, as did an historian of nature.[112] Descartes had neglected or evaded this attitude, whereas Steno had adopted.

However, admitting that Leibniz employed the Stenonian manner of geological reconstruction of natural things, his statements on Earth history was not so clear as Steno's *Prodromus*, which had expressed the Tuscan history of nature, in which he utilized profane histories, but also claimed his description accorded with the sacred history. This was a problem of biblical interpretation. So, we should pay attention again the on-going problem at that time, as was seen in the section on relation between Spinoza and Steno.

4.3. Leibniz's effort to synthesize 'histories'

It is commonly said that Leibniz draughted *Protogaea* as a preface to the history of the dukedom.[113] But Jacques Roger claimed that the problem of Earth history was unrelated to Leibniz's activities as an historian.[114] In fact, considering the tradition from Agricola,[115] his geological concerns related to mining, and seem to have preceded the historical concerns. At any rate, one can say that Leibniz had a concept of pre-human past[116]

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[107] *Protogaea*, pp. 79–80.

[108] The sample of Amsterdam is the quotation from Varen's *Geographia Generalis*, Amsterdam, 1650, Chapter 7, Proposition 7, p. 69.

[109] *Prodromus*, p. 67; *GP.*, p. 202.

[110] von Bülow, 1969 (n. 94), p. 205.

[111] Otfried Wagenbreth, *Geschichte der Geologie in Deutschland*, Stuttgart: Enke im Thieme Verl., 1999, p. 17.

[112] Ellenberger properly pointed to the historical character of *Protogaea* (Ellenberger, 1994 (n. 90), p. 138), but the influence of Steno was not sufficiently explained.

[113] For example, Yvon Belaval, *Leibniz critique de Descartes*, Paris: Gallimard, 1960, p. 111; Rhoda Rappaport, 1997 (n. 7), pp. 89, 211. These statements are probably stemmed from the descriptions of Chapters 1 and 39 of *Protogaea*. See, also, Barrande, 1993 (n. 91), pp. II–VI.

[114] J. Roger, "Leibniz et la théorie de la terre", in *Leibniz, aspects de l'homme et de l'oeuvre*, Paris: Aubier-Montaigne, 1968, pp. 137–144, on p. 137.

[115] References to Agricola in *Protogaea* are exceedingly many in comparing other authors.

[116] Cf. Rappaport, 1997, p. 209.

and endeavoured to correlate history of natural things with human arts.[117] Ultimately, Leibniz's encyclopedic system necessarily included the history of nature, and human or civil, and sacred histories. What kind of relation, then, was there between those histories?

In the *New Essays on Human Understanding,* Leibniz gives five points for usefulness of history that include the establishment of historical scholarship and the establishment of scholarship in sacred history which contains the foundation of revelation[118] . On the other hand, *Protogaea* ended with the following words, in which we see things regarded as complementary to our history as well as both supplementary to one another:

> Thus the nature of things serves us a substitute of history. In turn, our history rewards to the grace of nature, in order that the magnificent works of nature that have hitherto revealed to us are not ignored by posterity.[119]

In another article on the method of certitude, Leibniz, mentioning the relationship of mathematics to literature, observed the state and significance of historical studies, both sacred and profane:

> Pour ce qui est des belles lettres, l'histoire sacrée et profane est si éclaircie, que nous sommes souvent capables de decouvrir les fautes des auteurs, qui écrivoient des choses de leur temps. On ne sçauroit considerer sans admiration est amas prodigieux des restes de l'antiquité, ces suites des Medailles, cette quantité des Inscritions, ce grand nombre de Manuscrits, tant Européens qu'Orientaux, outre les lumieres qu'on a pû avoir des vieux papiers, chroniques, fondations et titres, qu'on a tirées de la poussiere, qui nous font connoistre mille particularités importantes sur les origines et changemens des familles illustres, peuples, estats, loix, langues et coustumes; ...[120]

We are able to see the attitude of Leibniz as a practitioner in this text, probably written in the 1680s. Thus he continued to say that these materials particularly served to establish the important critical means for distinguishing forgery from the veritable and fable from history, which also contributes to give proofs of the religion. Besides Spinoza's treatment of the Bible and attitude to Christianity, Leibniz was well aware of the validity of the 'critical method' in *TTP* for biblical interpretation.[121] However, this is less clear, or indeed vague, in the *Protogaea.*[122] At the end of the article, Leibniz suggested his enterprise for general science originally contained "observations et verités historiques ou faits del'histoire

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[117] Knobloch states that there is no barrier between nature and art in the *Protogaea.* See Eberhard Knobloch, "Theoria cum praxi: Leibniz und die Folgen für Wissenschaft und Technik", *Studia Leibniziana,* **19**, 1987, pp. 129–147, on p. 146.

[118] G. W. Leibniz, *New Essays on Human Understanding*, ed. and trans. by Peter Remnant and Jonathan Bennett, Cambridge: Cambridge University Press, 1996, Bk 4, chap. 16. AVI 6, p. 470.

[119] *Protogaea*, p. 86.

[120] GPh 7, pp. 174–183, on p. 175.

[121] Ursula Goldenbaum,"Die Commentatiumcula de judice als Leibnizens erste philosophische Auseinandersetzung mit Spinoza nebst der Mitteilung über ein neuaufgefundenes Leibnizstuck", *Studia Leibnitiana Sonderheft*, **29**,1999, pp. 61–107, esp. pp. 81–85.

[122] See, for example, Chapters 2, 3, 5 and 6.

sacrée, civile ou naturelle".[123]

Of course, from a Baconian perspective, Leibniz classified 'history' as descriptions of natural or natural corporeal things and of civil or humane matters, the latter being separated into many subdivisions including history of religion.[124] In this traditional scheme, history of time was chronology, especially universal history; history of place was geography; and the history of land and people was chorography or *Landschreibung*; and so forth. But, at the same time, Leibniz's effort to synthesize these 'histories' required some metaphysical principle or principles as represented, for example, in his *Monadology*.[125] Although this theme is beyond our present concern, it may not be inappropriate to point out here that one of the important themes that Leibniz was concerned with was the generation or formation of things. For, in *Protogaea*, he referred to cases of the generation of terrestrial things (Chapter 8), while being opposed to spontaneous generation (Chapter 28). We should remember that Leibniz was a preformationist in a biological sense.[126] And this is an important point, because Steno's interest in his *Prodromus* was in this very point of formation or generation of terrestrial and organic bodies.

On the other hand, there was a practical requirement. As remarked by Rappaport and others, one of the important threats against Christian chronology at that time was information from China.[127] An important example was Martini's. Jesuit Martino Martini (1614–1661), when he stayed in Europe 1653–1656, wrote a book on Chinese history, which was published in 1658,[128] three years after LaPeyrère's work *Prae-Adamitae* had appeared. The 'chronological controversy' had been continued since the sixteenth century.[129] Now the marvellous duration of Chinese chronology revealed by Martini made new difficulties for Christian chronology. Leibniz basically accepted Martini's report as a reliable document[130] and employed Greek version of the Bible to save the validity

[123] GPh 7, p. 182. Cf. Louis Couturat, *La Logique de Leibniz*, Paris, 1901, pp. 157–162. For a close relationship between biblical interpretation and problems of history and geology, see Daniel J. Cook, "Leibniz: Biblical Historian and Exegete", *Studia Leibnitiana Supplementa*, **27**, 1990, pp. 267–276; Edwin Curley, "Homo Audax: Leibniz, Oldenburg and the *TTP*", *ibid.*, pp. 277–312.

[124] Louis Davillé *Leibniz historien: Essai sur l'activite et la methode historiques de Leibniz*, Paris: Felix Alcan, 1909/1986, pp. 341ff. See also, Werner Conze, *Leibniz als Historiker*, Berlin: Walter de Gruyter, 1951, pp. 37–39.

[125] For Leibniz's originality in concept of history and its philosophical implication for human co-existence and solution of the conflict between free will and the lawfulness of historical process, see W. Voisé, "On Historical Time in the Works of Leibniz", in J. T. Fraser and N. Lawrence, eds., *The Study of Time II: Proceedings of the Second Conference of the Internatinal Society for the Study of Time, Lake Yamanaka, Japan*, Berlin etc.: Springer, 1975, pp. 114–121, esp. p. 119.

[126] Giovanni Solinas, *La* Protogaea *di Leibniz ai margini della rivoluzione scientifica*, Cagliari: Publicazioni dell'Istituto di Filosofia, 1973, p. 62.

[127] Rappaport, 1997, p. 70.

[128] *Sinicae Historiae decas prima*, Munich, 1658. I consulted the 1659 version of J. Blaeu in Amsterdam.

[129] For the 'chronological controversy' from wider perspective, see Katsuyo Okazaki, *Kirisuto-kyo teki sekai-shi kara kagaku teki sekai-shi e: Doitsu keimou-shugi rekishigaku kenkyu* [*Von der Universalhistorie zur Weltgeschichte: Studien über die Aufklarungshistorie*], Tokyo: Keiso-shobo, 2000 (in Japanese), especially concerning the Martini's Chinese history: pp. 39–41.

[130] For reliability on ancient Chinese bibliography, see Dutens, *Leibniz Opera omnia*, 4, 1, 1768/ Hildesheim: Olms, 1989, pp. 169–210, on p. 170.

of the chronology.[131] When he visited Claudio-Filippo Grimaldi (1639–1712), a Jesuit in Rome, in 1689, Leibniz questioned him about Chinese issues including, interestingly enough, mining resourses in China and the geographical relation between northern Japan and North America as well as ancient Chinese chronology.[132] Here we can also recognize Leibniz's geographical interests, related to practical or commercial matters.

Undoubtedly Leibniz estimated various kinds of remains or monuments from another civilizations, in which languages were included. He intended to not only establish the genealogy of languages but also complete the 'history of humankind' by these historical studies. In an article entitled "New Overtures", he wrote:

> Dans peu il faudra aller fouiller chez les Chinois et Arabes, pour achever l'Histoire du genre humain, autant qu'on la peut tirer des monumens qui nous restent, soit par écrit, soit sur des pierres ou metaux, soit même dans la memoire des hommes, ... et je tiens que de tout ce qui est non-écrit les langues memes sont les meilleurs et les plus grands restes significatifs de l'ancien monde, dont on pourroi tirer des lumieres pour les origines des peuples et souvent pour celles des choses.[133]

Thus, it seems evident that Leibniz, in his troubled age, endeavoured to synthesize or harmonize 'histories' to establish not only the history of his dukedom, the history of Scripture and the regional history of nature but the history of world as a whole, though the relationship of each element was not so simple as Steno had presented it.

5. Conclusions

I have studied post-Cartesian presentations of historical perception of the world and their relation to the emergence of seventeenth-century geoscientific thoughts, especially Steno and Leibniz's. Steno's *Chaos-manuscript* reveals that his interest in this field went well back into his student years and Gassendi's work on this subject might have some role on his ideas as well as Descartes'. In fact, considering the passage in the *Canis*, we may point out that the Physics of "Physics and Geography" in the *Prodromus* might have meant the Physics of Gassendi, the Geography being probably the Geography of Varen. If so, we have to be cautious about calling Steno as a Cartesian, at least after his French stay, and revise the interpretation of Stenonian geological works to being under just only Cartesian influence.

When we think about the relationship between Steno and Leibniz, therefore, it appears to be more intricate than has previously been thought by historians of geology. As an instance, I picked up the case of Spinoza. When we compare the idea on 'history' of Steno with that of Leibniz, taking account of Spinoza's thought is indispensable. This is not only because the three were acquaintanced to one another, but also because geological thought

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[131] Hans Poser, "Leibnizens *Novissima Sinica* und das europäische Interesse an China," in Wenchao Li and Hans Poser, eds., *Das Neueste uber China: G. W. Leibnizens* Novissima Sinica *von 1697* (*Studia Leibnitiana Supplementa*, **33**), Stuttgart: Franz Steiner, 2000, pp. 11–28, on p. 17.

[132] André Robinet, "La Recontre Leibniz- Grimaldi à Rome et l'Avenir des Académies," in *ibid.*, pp. 79–88, esp. pp. 81–83.

[133] AVI 4A, 1999, pp. 686–691, N. 160, Nouvelles Ouvertures [April bis Oktober 1686?], p. 687.

at that time could not make any description without involving scriptural interpretation, in which field Spinoza's critical and historical method was significant. Although there has been little reference to the Spinoza-Steno relation from the perspective of the history of geoscience, we may notice that they had some common attitudes toward contemporary natural histories or historical descriptions in general, though there were crucial differences of critical attitude towards biblical history.

It is certain that Steno and Leibniz had different standpoints on some matters of theology and philosophy. But it is also certain that they shared the socio-cultural setting of the Hanover court in the reign of Johann Friedrich, in which they both sought church reunification and probably the development of mines. Stenonian influence on Leibniz in thinking about the earth seems evident. They had many common opinions about geological matters. We can point to Leibniz's effort at geological mapping for the subterranean world and the broader perspective to geo-history from its beginning, including 'the cradle of our globe'.[134] In this sense, including also biological ideas or the generation of things, general consideration about solids within solids in Steno's language, was a Leibnizian concern. Naturally, Steno himself also intended to synthesize his understanding of natural things. Leibniz adopted Steno's method of reorganizing natural things and reconstructing the history of nature, while being well aware of the Spinoza's critical attitude to biblical interpretation.

I accept Roger Ariew's assertion that the opinions of Kircher and Becher were "attempts to improve upon the standard scholastic doctrines",[135] which were also shared by some medieval scholars such as Avicenna and Albertus Magnus. For they all thought that the 'petrifying force' of the places where fossils were found generated the fossils. It seems likely that Leibniz revived the scholastic idea that fossils are the remains of organic bodies and emplaced by some flood, because of his sympathy to medieval thoughts. But, there seems to be some contradiction here. Ariew's discussion of the 'micro-theory' for fossils and floods is problematic.

If one admits that fossils are the remains of marine organisms such as shellfish one must explain why they are dug from the land. In most cases, people invoked some cataclysm such as flood or earthquake to illustrate.[136] So one needs a 'story', no matter how simple. This would be a 'micro-theory' of fossils in Ariew's sense. Greek geographer Strabon once gave such example.[137] Steno said in his *Prodromus* that the ancients had a correct opinion about the marine objects found far from the sea but it had subsequently become uncertain or confused.[138] The passage shows Steno's debt to the ancient writers, not medieval ones (of course although there still remains possibility). At least, we can say that his 'micro-theory' is not restricted within medieval writers.

We may cite another example in the Chinese history where we find a legend of alter-

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[134] "incunabula nostri orbis" (*Protogaea*, p. 7).

[135] Ariew, 1991, p. 87.

[136] At least, in cases of 'easy' fossils in Rudwick's term. See: Rudwick, 1985 (n. 1), chap. 2.

[137] H. L.Jones, trans., *The Geography of Strabo*, Loeb Classical Library, Cambridge, Mass.: Harvard University Press, 1917/1989, vol. 1, pp. 181–187. Also see P. Duhem, *Le système du monde*, vol. 9, Paris: Hermann, 1958, chap. 18, sec. 3.

[138] *Prodromus*, p. 5; *GP*, p. 141.

nation of sea and land.[139] Shen Kua (Shin Katsu, in Japanese), an eleventh-century polyhistor, observed fossil shells when he was travelling as an officer in the Taihang Mountain Range (Hebei), and recorded in his *Meng ch'i pi t'an* (1086):

> Among cliffs in the mountain there were often found bivalve shells and stones like birds' eggs, the stony bed wall running through the cliffs like a belt. This means that there was once seashore here, though the sea is now remote nearly one thousand *li* eastward. What we call a 'continent' is no other than the place filled out with inundation of muddy sediment.[140]

I think this can also be called a 'micro-theory' of fossils. Shen also referred to petrified bamboo-like plant fossils (probably Triassic *Calamites*) at Yanan (Shaanxi) and suggested environmental change.[141]

Certainly, we can recognize "some continuity [or discontinuity] of theories at the micro-theory level"[142] but that does not explain why so many Western thinkers suddenly adopted the theory of the organic origin of fossils in the latter half of the seventeenth century. When Steno presented his observations in the form of the changes that have taken place in Tuscany, he was obviously aware of the "novelty" of his own attempt,[143] in which he was to open up a new field of science related to physics and geography. When Leibniz wrote of "a new science that you may call natural geography,"[144] he was consciously trying to create a new science. In fact, we are able to find much geographical information in the *Protogaea* here and there. For instance, Leibniz utilized information about natural history from the New World in Chapter 26, discussing fossils that have no similar counterparts among present creatures.[145] You can easily find that he also made references to the geographical works of Ortelius, Chifletius, Varen and Thévenot. In those informations was included news from travellers or missionaries in other civilized societies such as China previously mentioned. We cannot ignore the novelty of this kind of geographical aspect. On the other side of the globe, non-Westerners also felt novelty, though naturally in different contexts.[146] East Asian scholars received the two gifts from Jesuit mission Matteo Ricci: One was Euclid's *Elements*; the other was the World Map. This was a great event for the history of science in East Asia, but it also is another story.

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[139] Tang Xiren and Yang Wenheng, eds., *Zhongguo Kexue Jishushi: Dixue juan* [*A History of Science and Technology in China: Gelogy*], Beijing: Science Press, 2000 (in Chinese), on pp. 261–263 (written by Yi Suzhen).

[140] Shin Katsu, *Mukei-hitsudan*, Japanese trans. by K. Umehara, Tokyo: Heibon-sha, vol. 3, 1981, p. 12 (t. 24, sec. 430).

[141] *Ibid.*, vol. 2, 1979, p. 16 (t. 21, sec. 373). Cf. Nathan Sivin, "Shen Kua," in *DSB*, **12**, 1975, pp. 369–393, on p. 380.

[142] Ariew, 1991, p. 92.

[143] See note 54.

[144] *Protogaea*, p. 7. Chapter 5.

[145] *Protogaea*, p. 41.

[146] A seminal reference to the meaning of the Scientific Revolution for non-Westerners was made in Chikara Sasaki, "17 seiki no kiki to kagaku kakumei [Seventeenth- Century Crisis and the Scientific Revolution]", in Sasaki, *Kagaku kakumei no rekishi kouzou* [*The Historical Structure of Scientific Revolutions*], 2 vols, Tokyo: Iwanami, 1985, vol. 1, pp. 57–143 (in Japanese).

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