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The scientific revolution and Nicholas Steno's twofold conversion

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ABSTRACT

Steno's life was punctuated by two conversions: (1) from anatomy and medicine to geology, and (2) from Lutheran to Roman Catholic confession. Why was Steno (1638–1686) motivated to solve geological problems soon after he entered the Tuscan region of Italy? Was there any link between his scientific conversion and the religious one, which occurred almost simultaneously and produced a revolution in his life?

The origin of marine fossils found in mountains had been debated in Italy for one and a half centuries. Leonardo da Vinci (1452–1519) had already given a modern scientific explanation for the problem. Ulisse Aldrovandi (1522–1605) later tackled the problem with an experimental-taxonomic approach (his famous museum and studio), and it was he who coined the word "geology" in 1603. Italy provided spectacular exposures of rocky outcrops that must have impressed the Danish scientist who had lived in the forested north European lowlands. Since the time of Giotto and his successors, such as Mantegna, Pollaiolo, Leonardo, and Bellini, the imposing Italian landscape had stimulated the visualization of geology. Inevitably, science and art merged perfectly in the work of painter and paleontologist Agostino Scilla (1629–1700). Steno was methodologically skilled and intellectually curious and was thus open to the stimuli that Italy had to offer in order to unwittingly rediscover, after Leonardo, the principles of geology and to solve the problem of fossils. Steno's inclination to detailed "anatomical" observation of natural objects and processes as well as his religious conversion were influenced by his acquaintance with the circle of Galilei's (1564–1647) disciples who formed the Accademia del Cimento. They were firm Roman Catholic believers. To the inductive mild rationalist and open-minded Steno, this connection could not be dismissed, and it prepared him for changing his paradigms for the sake of consistency. This occurred when a Corpus Domini procession triggered a revelation and led to his religious conversion.

Keywords: geology and painting, Leonardo, Aldrovandi, geometrical perspective, Accademia del Cimento, Leibniz.

INTRODUCTION

Steno's intellectual and routine life was punctuated by two markedly different, though related, conversions: (1) from the study of the anatomy of organic bodies to the geology of rocky strata and bodies, and (2) from the Lutheran Reformed Church to the Roman Catholic confession.

We may ask: why was Steno (1638–1686) so deeply motivated to solve basic geological problems soon after entering the Tuscan region and after having had the opportunity to know and enjoy many other regions of Italy? Additionally, it is tempting to enquire whether there was any link between his scientific

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conversion (or change of scientific target) and his religious conversion (or change of life target). The suspected link is even more striking in that both conversions occurred almost simultaneously and resulted in a literal scientific and religious revolution in his life (Naldini, 1986; Ellenberger, 1988; Angeli, 1996; Oldroyd, 1996; Ascani et al., 2002; Yamada, 2003). The aim of this paper is to investigate the reasons leading to such major changes in Steno's works and life and, especially, to look for the context and relations, or even connection between the two conversions.

FROM ORGANIC ANATOMY TO INORGANIC GEOLOGY VIA PALEONTOLOGY

The first of Steno's conversions can be explained by focusing on the following points: (1) the origin of marine fossils found in the mountains had been freely debated in Italy more than in other European countries for one and a half centuries, leading Ulisse Aldrovandi (1522–1605) to define and name the new science of geology in 1603; (2) Leonardo da Vinci (1452–1519) (Fig. 1) had already given a modern scientific solution to the fossil problem; (3) Italy provided spectacular rocky outcrops that would have impressed the Danish scientist, who had previously lived in the forested north European lowlands during the Little Ice Age; and (4) the imposing Italian geological landscape stimulated three-dimensional (3-D) visualization of the strata, so that painting and geology went hand in hand with the assistance afforded by the discovery of the principles of geometrical perspective.

When disembarking in Leghorn on 1666, the 28 yr old Steno was already well known to leading European savants as one of the most prominent anatomists (Scherz, 1958, 1971b; Kardel, 1994). He was aware that he was entering a country where medicine and anatomy had been illustrated by scientists such as Ulisse Aldrovandi (1523–1605), Girolamo Cardano (1501–1576), and Girolamo Mercuriale (1530–1606) in the late sixteenth century. The school had progressed with a degree of innovation and excellence so as to produce anatomists on the level of Marcello Malpighi (1628–1694) and Francesco Redi (1626–1697), who were renowned throughout Europe. Both were soon to become good friends of Steno. It should not be forgotten that early, mostly unofficial, dissection of human bodies had been extensively performed and illustrated by Leonardo and Michelangelo in Tuscany for scientific and artistic reasons, as well as by the Flemish anatomist Andreas Vesalius (1514–1564), who was trained at the Padua and Bologna universities.

Let me elaborate on the four points listed here.

1. Once in Italy, Steno soon became aware that the origin of marine fossils that were so commonly found in the hills and mountains and were similar to, or identical with, the shells of organisms now living in the surrounding seas had been debated in Italy for more than 150 yr, well before similar discussions in other countries. The topic had perhaps been the most deeply and widely discussed topic in scientific and cultural circles among natural philosophers, teachers, collectors, priests, abbots, chemists, herbalists, and even artists and craftsmen. It was thus a diffuse movement of cultural interest among several different groups and classes (Morello, 2003a; Vai, 2003a; Vai and Cavazza, 2006). It is evidence of pluralism, intellectual freedom, and good use of human rationality in the society of the Italian Renaissance. The debate soon spread from natural to general philosophy, and even cosmology, at a time when there was developing interest in cosmogonies and theories of Earth (Lyell, 1830, chapter 3).

The tradition of considering the fossils found in the hills as remnants of marine organisms was well established in Tuscany since the time of the writer Giovanni Boccaccio (1313–1375) (Brocchi, 1814), and more generally in Italy since Alessandro degli Alessandri (1461–1523). The view was shared and elaborated by, among others, Girolamo Fracastoro (1483–1553),

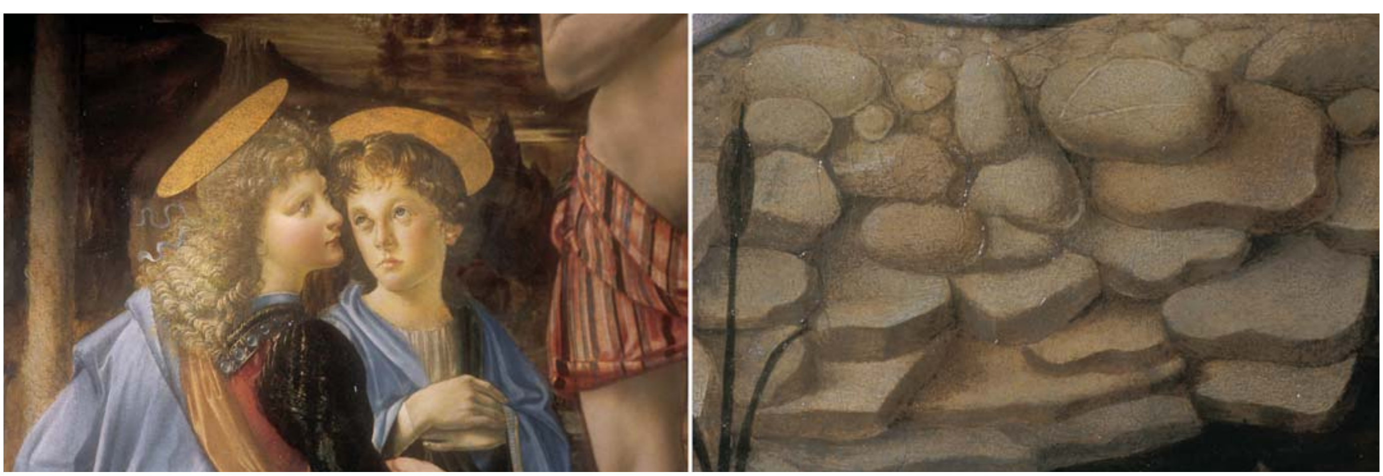

Figure 1. Details from *Battesimo di Cristo* by Verrocchio, Leonardo, and others (1470–1480) (A), showing gradual transition from in situ fractured strata below to rounded transported and cemented gravel above (B). Courtesy of Galleria degli Uffizi, Florence, Antonio Paolucci (photo by P. Ferrieri and G.B. Vai).

Girolamo Cardano (1501–1576), Andrea Cesalpino (1519–1603), Ferrante Imperato (1550–1625), and Bernard Palissy (1510–1589), the latter of which was the first person outside Italy to support this view (Morello, 1979, 1981, 2003a). All of them rejected the answer customarily given to the fossil question by the ancient Mediterranean and Near Eastern cultures, who had adopted the myth of the deluge, later reinforced in the Christian Middle Ages through the biblical tale of the Noah's Flood. Instead, they relied upon observational and experimental approaches being helped also by the resemblance between fossil shells and living beings in the Mediterranean Sea.

On the other side of the discussions, Georgius Agricola (1494–1555), Andrea Mattioli (1500–1577), Gabriele Falloppio (1523–1562), and others rejected an organic origin of fossils and spoke about fermentation of materia pinguis, or the influence of heavenly bodies (Michele Mercati, 1541–1593), or lusus naturae (Francesco Calzolari, 1522–1609), which supposedly produced a simulation of shells.

An extensive review of the different explanations provided by individual theories within the two opposing groups was given by Aldrovandi in the manuscript *Historia Fossilium* (ca. 1580) and in *Museum Metallicum* (p. 818–819), published posthumously and possibly altered by his follower Bartolomeo Ambrosini (1588–1657) in 1648. Aldrovandi also added the view of the organic origin of the fossils he shared with those believing in the role of the Noachian Deluge, as had been done by authors in Greek and Roman times.

At the end of his life and the sixteenth century, Aldrovandi (Fig. 2) was well aware of the scientific significance of the discussion and elaboration of the origin of the fossils in his large collections, observations, and experiments, such that he felt the need for a new discipline that he termed "geology" (Aldrovandi, 1603; see Dean, 1979; Vai, 2003a; Rudwick, 2005; Vai and Cavazza, 2006; Vai, 2008, with a comment on the origin of the name). This was a natural outgrowth of his lifelong taxonomic and comparative study of the largest collection of fossils

Figure 2. Aldrovandi's restored museum room. Courtesy of Museo di Palazzo Poggi, Bologna, Fulvio Simoni (photo by D. Lelli).

ever assembled before in a museum of natural history (Findlen, 1989, 1994; Vai, 2003a).

Aldrovandi defined geology as the science dealing with dug and outcropping fossils (Vai, 2003a). When Steno reviewed the still-open question about the origin of fossils (at least in Europe) in the first pages of his *De Solido* (1669, p. 7–8), he practically duplicated the list of possible hypotheses considered many decades before by Aldrovandi in his manuscript *Historia Fossilium* (ca. 1580) and published by Ambrosini in 1648 in *Museum Metallicum*.

In fact, Steno summarized the issue of marine objects abandoned in places far away from the sea, and he separated (1) bodies produced in the sea; (2) bodies produced on land based on natural forces of uncertain nature, flooding, and very lengthy periods of time; (3) bodies produced partly in the sea and partly on land; and (4) the special case of the Maltese *glossopetrae* (sharks' teeth).

When describing many fossil groups (e.g., p. 600, 606) and speaking more generally about opaque stony bodies, Aldrovandi distinguished (1) bodies of different nature, which, after the lapse of time are transformed into stone; and (2) shelly tests occurring in the mountains as stone, either generated in situ or transported from elsewhere (*Museum Metallicum*, p. 818). Aldrovandi was probably the first to compare the *glossopetrae* with sharks' teeth (Morello 2003a, p. 135). He also repeatedly stated his conviction about the organic origin of many fossils (Morello, 2003a, p. 135; Vai and Cavazza, 2006, p. 54, 55, 59). Contrary views sometimes occur in the *Museum Metallicum*, but these were probably due to amendments made by the editor Bartolomeo Ambrosini in 1648.

The way Steno treated the section of shelly tests and the Maltese *glossopetrae* (p. 60–61) in 1669 strongly suggests that he had good knowledge of Aldrovandi's works. We know by exchanges of letters in late 1660 and early 1670 that Steno was a good friend of Marcello Malpighi (1628–1694) (Galluzzi, 1986), a great anatomist and a fellow of the Royal Society, who was a successor to Aldrovandi at the University of Bologna (Fig. 3). Additionally, the Grand Dukes of Tuscany Ferdinando II and Cosimo III, who had called Steno to Florence and protected him throughout his remaining life, were descendants of Francesco I and Ferdinando I, both of whom were supporters of and in contact and exchange of samples with Aldrovandi (Tosi, 1989; Vai, 2003a). Therefore, Steno would almost certainly have been well acquainted with Aldrovandi's works available in the Grand Duchy library.

In the meantime, definite experimental evidence of the organic origin of fossils had been provided in 1616 by Fabio Colonna (1567–1640) in his *De Glossopetris Dissertatio* (Morello, 1979, 1981, 2003a, 2006b). It was long before Robert Hooke (1635–1703), in his *Micrographia* (1665), also expressed the view that fossils were organic remains, as many Italian savants had already done. One can thus agree with Eyles (1958, p. 179) that even in a case where Steno had some information about Hooke's lectures and work, "one can largely discount the possibility that Hooke's ideas had any marked influence on the development of Steno's geological ideas." In fact, he had found in Florence a wealth of earlier extensive Italian sources suggesting the same ideas. Steno's original merit was to have discovered in the field a rational way to explain how organic shells and inorganic crystals can become embedded within sediments and the ensuing strata. In so doing, he rediscovered the general principles of the new science of geology already stated by Leonardo da Vinci (Vai, 1995). Colonna's experiment resulted in an increase of the number of diluvianists also in Italy (except for Tuscany), as shown by the works of Athanasius Kircher (1602–1680) (Vai, 2004), and later elsewhere in Europe.

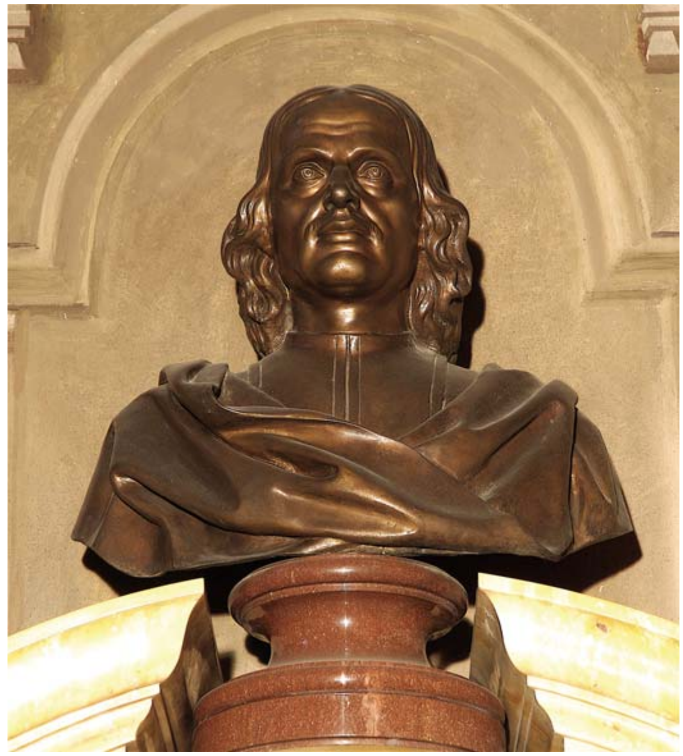

Figure 3. Malpighi's bust in his grave monument. Courtesy Chiesa dei Santi Gregorio e Siro, Bologna (photo by P. Ferrieri and G.B. Vai).

Called to Florence to supervise the collections of the Grand Dukes of Tuscany and improve scientific studies, Steno could have expanded his previous anatomical research in competitive cooperation with the already renowned Tuscan Francesco Redi (1626–1697). However, the momentum reached by the discussion on the origin of fossils in Italy and the new science of geology, as shortly before defined by Aldrovandi, convinced Steno (Fig. 4) that studying geology was more appealing to him and more interesting to some of his Italian colleagues and sponsors than simply continuing his studies on the anatomy and physiology of muscles. Steno succeeded in this challenge indeed, attaining in geology even more general and important results than in anatomy (Scherz, 1971b). The transition from anatomy to geology was easier because of Steno's skill in comparative animal anatomy, including fish, similar to Georges Cuvier in the earliest nineteenth century. Both savants contributed strongly to the improvement of geology via palaeontology.

Figure 4. Steno's bust. Courtesy of Museo Geologico Giovanni Capellini, Bologna (photo by P. Ferrieri and G.B. Vai).

2. Actually, long before Steno, Leonardo da Vinci in the early Renaissance had already obtained the same results. He had formulated the same general principles as Steno after studying almost the same Italian areas of northern Italy, and especially Tuscany. Like Steno, he wrote about strata, their original horizontality, their original continuity, their superposition, and their tilting and ensuing angular unconformity (Vai, 1986; Vai, 1995, p. 17–19). More than Steno, he illustrated their folding and faulting in remarkable geological profiles (Vai, 1995, 2003c) (Fig. 5). As an example, after frequently crossing the Romagna Apennines from Florence to Imola or Cesena, Leonardo concluded that:

> going down the Apennine valleys northwards, after having left the *true lithic beds*, dipping for a short distance at the root of the mountains, one can see *beds or soils, made of earth used for pottery*, full of shells; this last group of beds still dips for some distance at the foot of the hills, until *common earth or terrain* appears, just where the rivers, flowing down the Marche and Romagna regions, go out of the Apennines. (Vai, 1995, p. 18; my italics)

Unlike Steno, Leonardo (like Aldrovandi) rejected the role of the Universal Deluge to explain the marine fossils found in the mountain. In so stating, Leonardo anticipated the philosophical and scientific European debates on diluvianism of the next three centuries. Instead, according to Leonardo, diluvianism was to cause serious inconsistency with the observed distribution of the fossils. The major scientific weakness in Steno's otherwise admirably consistent doctrine was indeed the uncritical acceptance of diluvianism.

Leonardo's notebooks, however, remained practically secret until the beginning of the nineteenth century. This is not to say that nobody could have had direct or indirect access to his ideas. It could have happened by verbal transmission or informal circulation through restricted groups of friends, especially in Florence, Milan, and Amboise (in France, where Leonardo spent his closing years). Just to give an example, Girolamo Fracastoro (1485–1553) used arguments very close to those of Leonardo in a letter for supporting a non-diluvianistic interpretation of the marine fossils excavated in Verona in 1517. I have been tempted to suggest that Fracastoro had some access to the manuscripts of his contemporary Leonardo or that he was influenced by some verbal reports of them (Vai, 2003b, p. 234). In a similar way, some of the cultural and artistic circles of Florence and Tuscany could have preserved a verbal tradition and memory of Leonardo's geological ideas, which then became available to the very inquiring and prepared mind of Steno, once he came to look at the same landscape with strata and outcrops and began to seek information when visiting the Medici's collections and library. In this way, Steno may well have benefited from or been inspired by Leonardo's ideas about geological structures and processes.

3. Most of Italy is hilly or mountainous country, except for the Po Plain and some minor and narrow coastal plains. Beginning with the Middle Ages and progressing into the Renaissance, Italy underwent heavy deforestation related to the expansion of economic development, birth of cities, shipbuilding, and population growth (Vai, 2003b, p. 248–248). As a consequence, the backbone of the Italian peninsula—the Apennines—showed much better exposures of rocks and strata than today.

Paintings, engravings, drawings, and views of that time provide clear evidence of large underground exposures, beginning with the works of Giotto (1267–1337) (Fig. 6) and his bare and

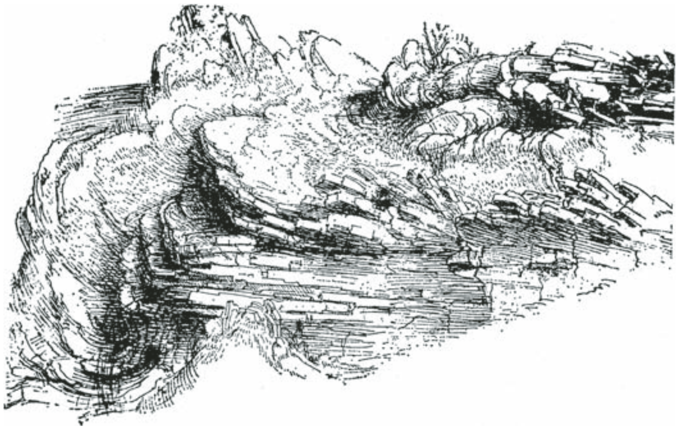

Figure 5. Geological cross section by Leonardo da Vinci. View from the southern Alps, possibly Venetian area or Lombardy, when Leonardo stayed in Milan from 1510 to 1513 (Carlo Pedretti 9 May 2007, personal commun.). Windsor Royal collection, no. 12394, reproduced by permission of H.M. the Queen Elizabeth II.

Figure 6. Giotto's *Miracolo della fonte* (1295–1300), Basilica di San Francesco, Chiesa Superiore, Assisi. St. Francis prayer on bare rock.

rocky Umbrian landscape (the present-day green land). The same evidence continues through the early and late Renaissance up to the period of naturalism and the Baroque era.

To a curious and open mind such as Steno's, keen to observe and unravel the intimate anatomical structures of the human and animal organisms with a confident use of his reason, the spectacular Italian landscape displaying the internal structure of Earth must have acted as a shocking and fascinating intellectual challenge, and it was one that he immediately accepted. Like Saint Paul on the way to Damascus, Steno was dazzled and "converted" from anatomy to geology. This was not for him an immediate and dramatic change, but rather a major shift in his basic new scientific interest without an abandonment of the former (Troels Kardel, 2007, personal commun.). Even more, Steno recognized that anatomical aspects of living organisms were intimately connected with the mineralogical and lithological ones in the transformation of sediments into rocky materials referred to as the subject-matter of the new science called "geology" by Aldrovandi in 1603. On the other hand, it should be remarked that Steno had shown some early interest in "geology," as witnessed by several remarks in his student notes, the so-called *Chaos* manuscript of 1659 (Ziggelaar, 1997; Yamada, 2003, p. 76; Vai, 2004; Yamada, 2006; Rosenberg, 2006), and by references made in 1663 to the *glossopetrae* brought back from Malta by his teacher Thomas Bartholin in 1644 (Scherz, 1969, p. 128, no. 72). Additionally, Steno knew about *glossopetrae* also from the Danish scholar Ole Worm (see *Museum Wormianum*, 1655, p. 67). Thus, the teeth of the shark at Livorno reawakened Steno's interest in geology, and his anatomical skill paved the way to his turn from anatomy to geology (August Ziggelaar, 2007, personal commun.).

4. The interplay between geology and painting, just used as evidence of the stimulus that the rocky landscape of Italy, four centuries ago, would have had on Steno, acquires even more relevance if we seek to explain his "conversion" to geology.

The new Italian—and European—painting was born with Cimabue (?1240–1302), Giotto, and Masaccio (1401–1428) a millennium after Roman paintings and mosaics had been almost completely buried or lost and as a reaction to the dominant Byzantine two-dimensional painting. Technically and philosophically, it was characterized by the aim to represent not only ideas and spiritual beings, through symbolic icons, but also bodies and material masses using shading and perspective to produce realistic 3-D effects. The revolution in art can be viewed as result of a more popular and incarnated Christian religion and a reappraisal of the value of both body and natural world as basic components of the Creation after the millennial fears. Italian and Western humanism came as a perfectly balanced vision, integrating both human and divine aspects of the world unknown to other cultures. It aimed to improve the static and purely theocentric Eastern Orthodox Byzantine and Russian iconic and spiritualistic culture. Under different conditions, this may also apply to Chinese art (Edgerton, 1975).

This trend was reinforced by the Neoplatonic revival of humanism and the early Renaissance rediscovery and improvement of geometrical perspective by scientists and artists such as Filippo Brunelleschi (1377–1466), who rediscovered the Greek and Roman principles of linear perspective and single vanishing point, inspired by Alberti's treatise *Della Pittura*, and who was the first to built a hemispherical vault of enormous size on top of the Florence Cathedral without the traditional timbering; Paolo Dal Pozzo Toscanelli (1397–1482), mathematician; Leon Battista Alberti (1404–1472), theorist of Renaissance art; Paolo Uccello (1397–1475), a pioneer in single-point perspective and application of scientific laws to represent objects in a 3-D space following the school of Toscanelli; Piero della Francesca (1416–1492), the humanist painter most fascinated with geometry and mathematics and theorist of *De Prospectiva Pingendi*; Marsilio Ficino (1433–1499), a philosopher who revived Platonism (and Plotinus's Neoplatonism) and integrated it into Christian theology and Renaissance culture; and Luca Pacioli (1445–1517), a mathematician known for his ideas on the "divine proportion" and the concept of "golden section" used in both ancient and modern architecture and design (Vai and Cavazza, 2006). There is an immediate and natural link relating geometrical perspective to (artificial) architecture on the one side and (natural) geology on the other. This is well understood when building elements and setting of strata and other geological bodies have to be represented on a two-dimensional drawing or painting . As examples, Brunelleschi was able to build his vault in a 3-D space after having represented and calculated its building elements on 2-D plates following the laws of perspective (Vasari, 1550, p. 137–198). Similarly, Steno and Leonardo before him, based on the same laws, were able to understand and represent the 3-D setting of strata in Tuscany and Romagna (Vai, 1986, 1988, 1995) (Fig. 7). Such a simple statement, which results from historical observations and common sense, was analytically demonstrated by Rosenberg (2001, with references, 2006) and exemplified with reference to Leonardo's and Steno's works. The demonstration is convincingly backed by a wealth of publications showing Leonardo's invaluable contribution to the foundation of geology and its principles as written in his notebooks (Venturi, 1797; Richter, 1883, 1970; Uzielli, 1890; Baratta, 1903, 1912; Cermenati, 1912; De Lorenzo, 1920; D'Arrigo, 1939–1940, 1952; Gortani, 1952; Clark, 1985; Pedretti, 1953, 1985, 2002; Pedretti and Dalli Regoli, 1985; Brown, 1998; Fara, 1999; Kemp, 2001; Natali, 2002).

Figure 7. Strata from the Romagna Apennines, middle Miocene Marnoso-Arenacea Formation, high Santerno Valley (photo by P. Fabbri). Caterpillars at the base of the central wall for scale.

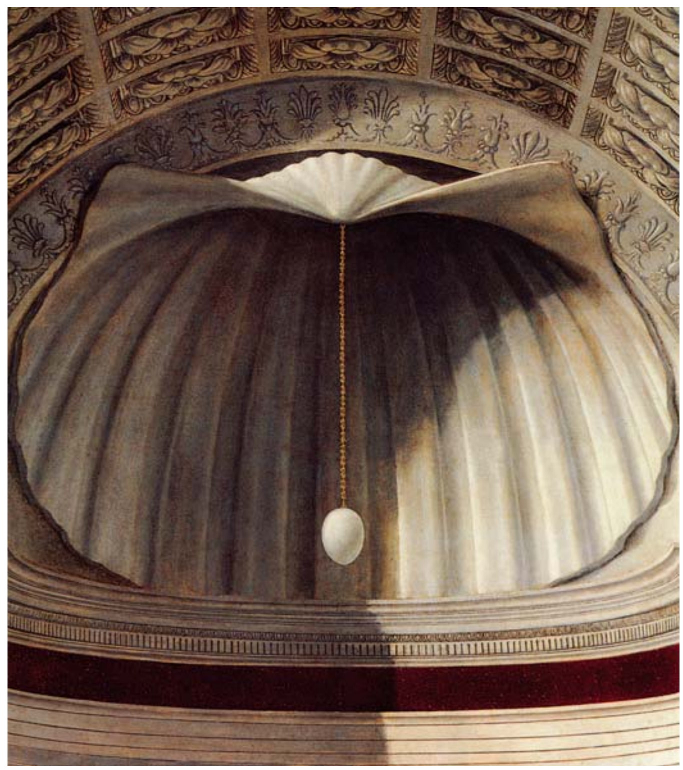

Figure 8. Detail from Piero della Francesca's *Brera Altarpiece* (around 1472). Courtesy of Pinacoteca di Brera, Milan.

Leonardo was unique in succeeding to establish an early written and illustrated treatise of what we now call geological sciences in his notebooks. However, he was not alone among artists showing in their paintings that the adoption of geometrical perspective in the Renaissance could result in the ability to unravel the setting and even the distinctive features of the geological elements of landscape. A few decades before, and after Leonardo's life, many painters, impressed by the works of Paolo Uccello and Piero della Francesca (Fig. 8), represented clear and detailed geological elements, bodies, and features in their paintings. I refer, for instance, to Andrea Mantegna (1431–1506), Antonio Pollaiolo (1432–1498), Sandro Botticelli (1445–1510), Pietro Perugino (1450–1523), Giovanni Bellini (?1430–1516), and Marco Palmezzano (?1459–1539) (Vai, 1986, 2003c). In few decades in the late fifteenth and early sixteenth centuries, geology went fruitfully hand in hand with painting, especially in Italy and also in the Netherlands (see also Rosenberg, 2001, p. 134). This occurred coeval with Leonardo setting the principles of geology around 1500 and slightly before Aldrovandi introduced the term geology in 1603. As an example, Leonardo's conclusion derived from his travels across the Romagna Apennines, quoted previously, implies that the three units recognized—"dipping true beds of hard rock," "dipping beds of earth used for pottery," "common earth or terrain"—are superposed on one another in the same order from bottom to top. Moreover, the first two crop out one after the other because of their dip toward the plain (north), whereas the third appears as "last," dipping less or even flat over the earlier dipping beds (Vai, 1995, p. 19).

Let me reiterate this correlation of geology to painting with a few, lesser known examples from Mantegna and Palmezzano, both of whom have recently been the subject of centennial celebration and important exhibitions of their works.

Andrea Mantegna's paintings often display prominent geological features, not only as distant and faint components of the landscape, but also as relevant elements of geometrical perspective and of the artist's message in the front and intermediate planes of the paintings (Vai, 1986, 2003c). It is noteworthy that this was done by Mantegna in northern Italy coeval with or even slightly earlier than Leonardo, though Mantegna, staying in Florence in 1466 and being in Rome from 1488 to 1490, could have benefited from the influence of Tuscan-Umbrian humanism. Born near Vicenza and active in Padua, Verona, and Mantua, in or close to the Venetian region, Mantegna was certainly familiar with the many quarries of Rosso Ammonitico and other limestone/marble types of rocks exploited in the Venetian region, and he became acquainted with mining exploitation techniques in relation to different types of bedding, jointing and fracturing of strata, and other geological structures, which he represented in many of his works. The Rosso Ammonitico Formation is a well-known red-to-yellow nodular marine limestone, Jurassic in age, first sketched in a stratigraphic column by Luigi Ferdinando Marsili in the earliest 1700s and later recognized in the entire Tethyan area from Caribbean through the Alpine-Mediterranean region to the Himalaya.

One of Mantegna's masterworks deserves special attention because its interest in geology is revealed even by the title, the *Madonna delle cave* (*Madonna of the Quarries*), exhibited at the Uffizi Gallery in Florence (Fig. 9). The Holy Virgin and Child are intimately related to a complex and imposing rocky outcrop that occupies most of the painting except for the far landscape in the upper left. The articulated outline of the outcrop represents a peculiar type of natural "throne," the texture of which—upper, vibrant, fractured, angular, and oblique to spiral—sharply contrasts with the peaceful, meditative, and solemn albeit natural attitude and expression of the two figures (see their two right legs). A flat-lying bedding surface, perfectly planar and covered by small scattered pebbles, supports the feet of the sitting Virgin. The related underlying stratum (bottom left) is finely laminated. The same flat-lying bedding continues and becomes fainter in the reddish, altered, and smoothed cliff in the middle-left. At the base of the cliff, the bedding, although masked by some vegetation, is still suggested by the shepherd and sheep trails. At the other side of the Virgin (center-right), the flat-lying strata and bedding are more prominent in the quarry area, where the rocks present the fresh lighter color after recent quarrying (presumably light-pink–yellowish to gray limestone). Two miners are finishing a large prismatic rectangular building or paving plate. Another group of miners is shaping cylindrical columns and drums (Fig. 10). Quite abruptly, at the level of the Virgin's breast, the rocky outcrop narrows on both sides, loses its regular flat-lying bedding, and takes an irregular pervasive texture as if the rock had been shocked by an earthquake or animated by some internal force (Fig. 11).

Figure 9. Mantegna's *Madonna of the Quarries* (1488–1490). Courtesy of Galleria degli Uffizi, Florence, Antonio Natali (photo by P. Ferrieri and G.B. Vai).

The upwardly changing texture of the outcrop can be explained in terms of the spaced jointing of a less competent marly or muddy massive layer (the upper part) following the bedded limestone beneath. This is consistent with the outcrop narrowing upward because of the lesser resistance of the mudstone to erosional and weathering processes. The selective rheologic response to regional open folding of multilayered successions of strata is quite common in the outer southern Alps (Venetian region) and the outer Northern Apennines (Marche region), for example, in the Eocene Scaglia Cinerea Formation. Man-

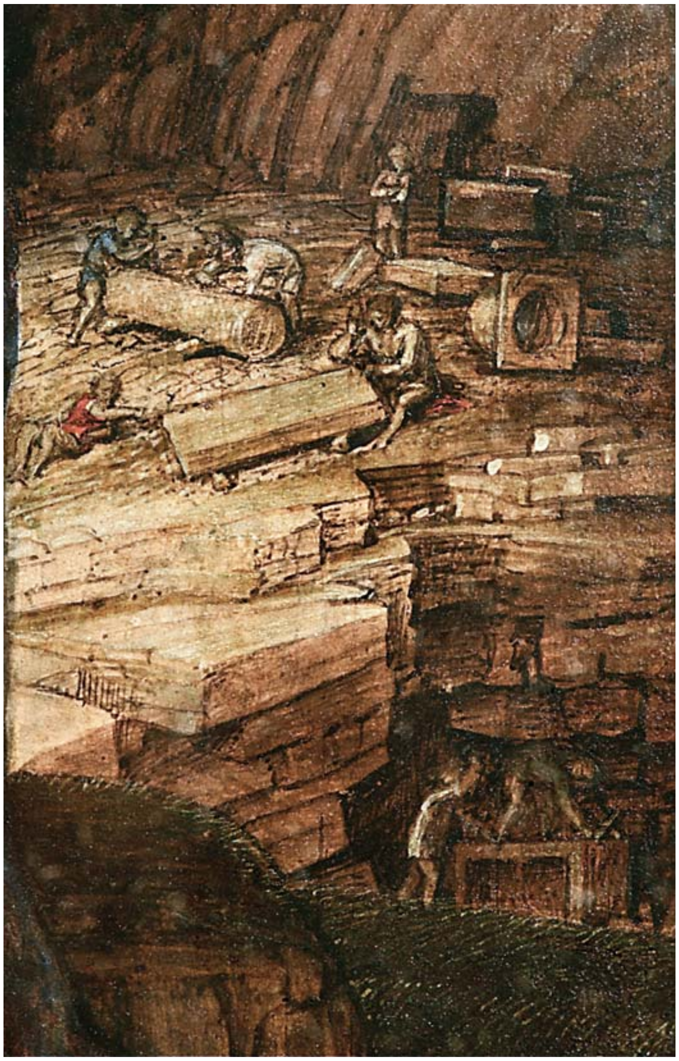

Figure 10. Detail of Figure 9. Courtesy of Galleria degli Uffizi, Florence, Antonio Natali (photo by P. Ferrieri and G.B. Vai).

tegna represented this upward transition from flatly bedded to obliquely fractured rock in other paintings too. Whether he was aware of this natural geological process or was simply surprised by the apparent evidence of "living" rocks is hard to say. Perhaps he simply recorded the basic distinction between flat-bedded and vertical-bedded rocks with no clear and conscious awareness of the differences between primary bedding, secondary jointing and fracturing of the same flat strata, and vertical displacement of previous flat-lying strata. Anyway, Mantegna might have used this graphic tool (flat to oblique and vertical transition) to converge back to the represented Divine Maternity and Christ

Figure 11. (A–B) Detail of Figure 9. Courtesy of Galleria degli Uffizi, Florence, Antonio Natali (photo by P. Ferrieri and G.B. Vai).

Incarnation (upper level) of the different human and natural histories carefully illustrated in the lower level. Through the body of the Virgin, the Child brings humankind, symbolized by the flat-lying “dead” strata, to eternal life, symbolized by the revitalized expanding fractured rock (as in this painting) or vertical rocks (as in the Louvre Mantegna’s *Crucifixion*).

In addition to the *Madonna of the Quarries* (ca. 1490), there is at least one other painting, *Christ on the Sarcophagus and Two Angels* (at the Statens Museum for Kunst in Copenhagen), where Mantegna provides rich and detailed representation of quarrying and mining works, also in the center-right intermediate plane of the painting. This anticipates the first drawings of mining operations published in Georgius Agricola’s *De Re Metallica* (1556) (Morello, 2006a) by six decades, and is an additional reason for Mantegna’s eulogy in Leonardi’s *Speculum lapidum* (1502) (Mottana, 2006).

Internally consistent superposition and broadly flat-lying bundles of strata varying in color and thickness are shown in many other famous paintings by Mantegna, for example, the original three basal wood plates of the San Zeno altarpiece in Verona (*Crucifixion, Agony in the Garden, Resurrection* at the Louvre in Paris and the Musée des Beaux-Arts in Tours, respectively), *St. Sebastian* at the Kunsthistorisches Museum in Vienna, *Ascension* and *Adoration of the Magi* at the Uffizi Gallery in Florence, *Agony in the Garden* at the National Gallery in London, and *Adoration of the Shepherds* at the Metropolitan Museum of Arts in New York.

A prominent, rough, and often thick-bedded rocky landscape (similar to those of Perugino, Botticelli, and Giovanni Bellini) illustrated with classic arched ancient Roman architecture (as in Mantegna) was used by Marco Palmezzano in many of his paintings to set a rigorous geometrical perspective frame. Just as in Leonardo’s works (Rosenberg, 2001), Palmezzano’s paintings show that the bedding of strata of the outcrops depicted in the front, medium, and rear planes is consistent with both a common regional dip and with the geometrical perspective of the painting, and thus that the artist had a clear perception of the 3-D setting of the strata.

The *Adoration of the Shepherds* (1526, oil on wood, 191 × 126 cm), usually kept in the archives of the Brera Gallery in Milan and temporarily available to visitors at the Palmezzano Exhibit in Forlì in 2005–2006 (Fig. 12), is of considerable geological interest. In fact, between the rocky cliffs in the far and middle distance at the left of the broken antique arch and the Christmas crib in the front, a pale, angular, and rocky ridge crosses the entire picture. The ridge is large enough to allow for a detailed fine-bedded structure to be easily observed from a short distance at both ends and less clearly midway behind the Holy Virgin (Fig. 13). The bedding of the ridge is perfectly even and partly folded and faulted similar to that which is commonly seen in what is today known as the Miocene Marnoso-Arenacea Formation, crossing the valleys in the Romagna Apennines (Fig. 7). In this case, the painter showed not only his skill in geometrical perspective and his representation of the regional setting of bedded strata, but also his interest in representing rocky features that he had evidently considered in the field and tried to understand, following Leonardo’s example.

An additional example of understanding the 3-D setting of regional geological strata and their use for providing geometrical perspective in landscape paintings is provided by Bartolomeo Montagna (1449–1523), who was not casually active in Vicenza and the Venetian region. In his *Saint Jerome* at the Brera Gallery in Milan, very gentle strata dipping to the left are consistently traced from the frontal rocky “throne” of the sitting saint to the intermediate cliffs behind him to the vertical rocky walls in the distance, and are finely underlined by the staircase that was apparently easily excavated along the bedding planes in the steep rocky walls (center-right) (Fig. 14).

Not long afterward, and still in Italy, geology and art, especially painting, again merged in the work of a paleontologist and painter—Agostino Scilla—who published a well-illustrated book on the organic origin of fossils just one year after the publication of Steno’s masterpiece: his *Prodromus*. Scilla (1629–1700) studied fossils and the sediments in which they were embedded using the same approach as Steno and made a step forward by recognizing the tectonic deformation often suffered by shells subsequent to their sedimentation.

It should be noted that Steno applied true geometrical perspective with a vanishing point in a plate of *Elementorum Myologiae Specimen* 1667 (Kardel, 2002), even if nothing similar appeared in his *Prodromus*. It is worthwhile mentioning, however, that this was only a summary of Steno’s original research, which he intended to follow with a complete work, but which never appeared. However, solid geometry is masterfully used in the part of the plate attached to the *Prodromus* where crystal morphology and growth are represented (see Ellenberger, 1988, p. 276–289). In a letter to Grand Duke Cosimo III in 1671, Steno showed the internal shape of a north Italian grotto by longitudinal and cross sections (Yamada, 2003, p. 91).

Steno’s description and interpretation of the six successive past tectono-facies of Tuscany require that he had a clear idea of the 3-D structure of subsurface strata in the region. In this sense, Steno may have influenced even the visual language of Leibniz and moreover the German mining school (Yamada, 2003, p. 90–94; Hamm, 1997).

In sum, Steno was methodologically skilled, intellectually curious, and thematically open to the stimuli of the geological landscape and geological culture of Italy in order to unwittingly rediscover, more than one and a half centuries after Leonardo, the principles of geology and to solve the problem of the origin of all kinds of *fossilia* in 1669. Winning this challenge was a worthy shift from anatomy to geology.

It should also be clear that without his Italian experiences and related researches, plus his exposure to Italian art, Steno’s conversion to geology would almost certainly not have occurred. On the other hand, Steno’s turn to geology did not require abandoning anatomy; soon after, he would become an anatomist in Copenhagen. Instead, it was an opening for other research without closing the first field.

Figure 12. Palmezzano's *Adoration of the Shepherds* (1520). Courtesy of Pinacoteca di Brera, Milan, Luisa Arrigoni (photo by P. Ferrieri and G.B. Vai).

FROM LUTHERAN REFORMED TO ROMAN CATHOLIC CONFESSION

Steno's father, the goldsmith Sten Pedersen, came from a family of Lutheran priests. Steno's upbringing was orthodox Lutheran. During his years in the Netherlands, his three best friends were Jan Swammerdam 1637–1680), Regnier de Graaf (1641–1673), and Theodor Kerchring (1640–1693). The two latter were Roman Catholics, so they may have played a role in his later conversion.

The most appropriate and essential motto to describe Steno's second conversion could well be "from science to God." In this respect, Steno was an exception to the usual "movement." Most of the physico-theologian diluvianists in fact moved in the opposite direction, deriving their science from the sacred writings. However, moving to Italy for Steno played the role of a trigger and a basic cause also for his second and major conversion. It is important to stress that it was a conversion from Lutheran orthodoxy to the Roman Catholic Church, and not from a kind of deism, as has been recently proposed. There are some early preparations to Steno's conversion. Before reaching Italy, Steno discussed Catholic faith with a lady in Paris, who for theological issues, referred him to a Jesuit in Cologne (August Ziggelaar, 2007, personal commun.).

The conversion was made possible mainly by some favorable factors, some of which were remote or operating before Steno's Italian experience, while others were closer and triggered the conversion once Steno was in Italy. Most of them were stated by Steno himself in two letters explaining his conversion to his German Lutheran friends Johannes Sylvius, Wilhelm Gottfried Leibniz, and in a theological work he wrote in reply to a dissertation by Johann Wilhelm Bayer (Scherz, 1952, 1958, 1971a, 1971b, 1987–1988; Naldini, 1986).

Among the remote factors were:

1. Steno's skill in making detailed anatomical observations down to the core of natural objects and processes to look for

Figure 13. (A–B) Details of Figure 12.

scientific truth free of ideological, philosophical, and religious prejudices and other kinds of nonscientific prejudgments. Thus, when observing, examining, and evaluating the religious beliefs and practices of his Italian colleagues, friends, and the general population, he adopted the same methodology as that manifested in his experimental dissections and stratigraphic field observations, with the same aim of reaching the truth and making new discoveries: a typically Galilean attitude.

2. This experimental, inductive, nondogmatic, scientific attitude led Steno to a critical analysis of Descartes' philosophy. The four basic rules of Descartes' *Discours de la méthode* (1637) were (1) to take nothing as true unless recognized clearly as such (methodical doubt); (2) solve problems by analyzing them part by part; (3) proceed from the simple to the more complex; and (4) review every thing to avoid omitting something. The criticism referred to inconsistencies between the method that Descartes had formulated and his actual implementation of it. This convinced the formerly enthusiastic young Steno to detach himself from the French philosopher. His sharp criticism of Cartesian philosophy was contained in his *Defensio* written in reply to Bayer's *Dissertatio* (Larsen and Scherz, 1941/1947, v. I, p. 380–437; Naldini, 1986, p. 24–82; Vai, 2003b). Steno praised the method but criticized the Cartesian presumption.

> [The method] is appreciated when it aims at discovering biases, but not when it imposes to presume everything to be false. I consider that method at the first place among the reasons why I detached from the ancient bias: it deserves from me praise instead of blame in this respect. However, I believe this same philosophy presumes as certain those things not yet established through reasoning. (Steno, Hannover, 1680; Naldini, 1986, p. 33)

In these passages, Steno demonstrated that he had reached methodological independence, essential balance, and ontological equality among experimental science, philosophy, and religion, which he considered to be perfectly integrated in an individual, thinking human being, but having autonomous and different scales of value. If his mind was open to a changing paradigm in response to outer suggestions, it must be said that the Italian cultural and religious condition he found in Tuscany was just what Steno was looking for.

Steno's *Defensio* contains a sharp detachment also from Spinoza and Spinozists. Steno had earlier been a friend of Spinoza (Naldini, 1986, p. 34; Ascani et al., 2002; Totaro, 2002; Yamada, 2003, p. 82–85; Sobiech, 2004, p. 51–68). The Spinozists are considered by Steno to have de-formed rather than reformed Cartesianism. Although in his *Prodromus* Steno had followed an historical method to understand geology, and he concluded that "Nature does not contradict what Scriptures determines," he could not accept Spinoza's statement that "the [historical] method of interpreting Scripture … entirely accords with the method of interpreting nature" (see Yamada 2003, p. 84). This would have reduced religion to the field of science, leaving no room for faith and transcendence, both of which were gaining even more importance to him.

An earlier letter by Steno to his colleague and friend Leibniz (1646–1716) (Fig. 15) written in 1677 is very useful to help understand the reasons for his conversion to Catholicism (Scherz, 1952, v. I, 143, p. 366–369; Naldini, 1986, p. 20–23). Again, Descartes' philosophy, once "held in greatest esteem" by the young Steno, was by then at the core of his refusal of the Cartesian system (Kardel, 1994; Vai, 2003b; Sobiech, 2004; Rosenberg, 2006). Steno was grateful to God "for having saved him from all the sophistry of harmful philosophers, and from all

Figure 14. Montagna's *Saint Jerome*. Courtesy of Pinacoteca di Brera, Milan, Luisa Arrigoni (photo by P. Ferrieri and G.B. Vai).

the quibbling shrewdness of certain persons who like this type of philosophy" (Naldini, 1986, p. 20). He thanked God for saving those who "inclined to the same path from the human presumption, could be dragged along the ravine of this philosophy" (Steno to Leibniz, 1677; Naldini, 1986, p. 20).

He also wrote about his disillusionment with philosophy over empirical observation

Comparing the heart with muscle structure, for which I followed the system of the infallible Mr Des Cartes, each muscle I dissected at the first cut showed me the muscle structure, what turned over Des Cartes' entire system. (Steno to Leibniz, 1677; Naldini, 1986, p. 22)

1. If these gentlemen, revered by almost all savants, have considered as infallible demonstrations what I could let be done by a ten-year-old boy in only one hour in such a way that the direct experience alone overthrows the most ingenious systems of such great minds, what reliability can the other quibbles they boast about have? I say: if they were mistaken about material things that fall under our senses, what guarantee are they providing to me not to be equally wrong when treating about God and the soul? (Steno to Leibniz, 1677; Naldini, 1986, p. 22)

2. …Although I did not abandon the entire doctrine which contains points of truth, I felt myself to be losing little by little the excessive esteem I had for them, and I began to know more and more the weakness of the human spirit and the ruins to which presumption is leading. … So sir [this is] how God, by pushing me to refrain from the philosophic presumption as an outcome of my anatomic discoveries,

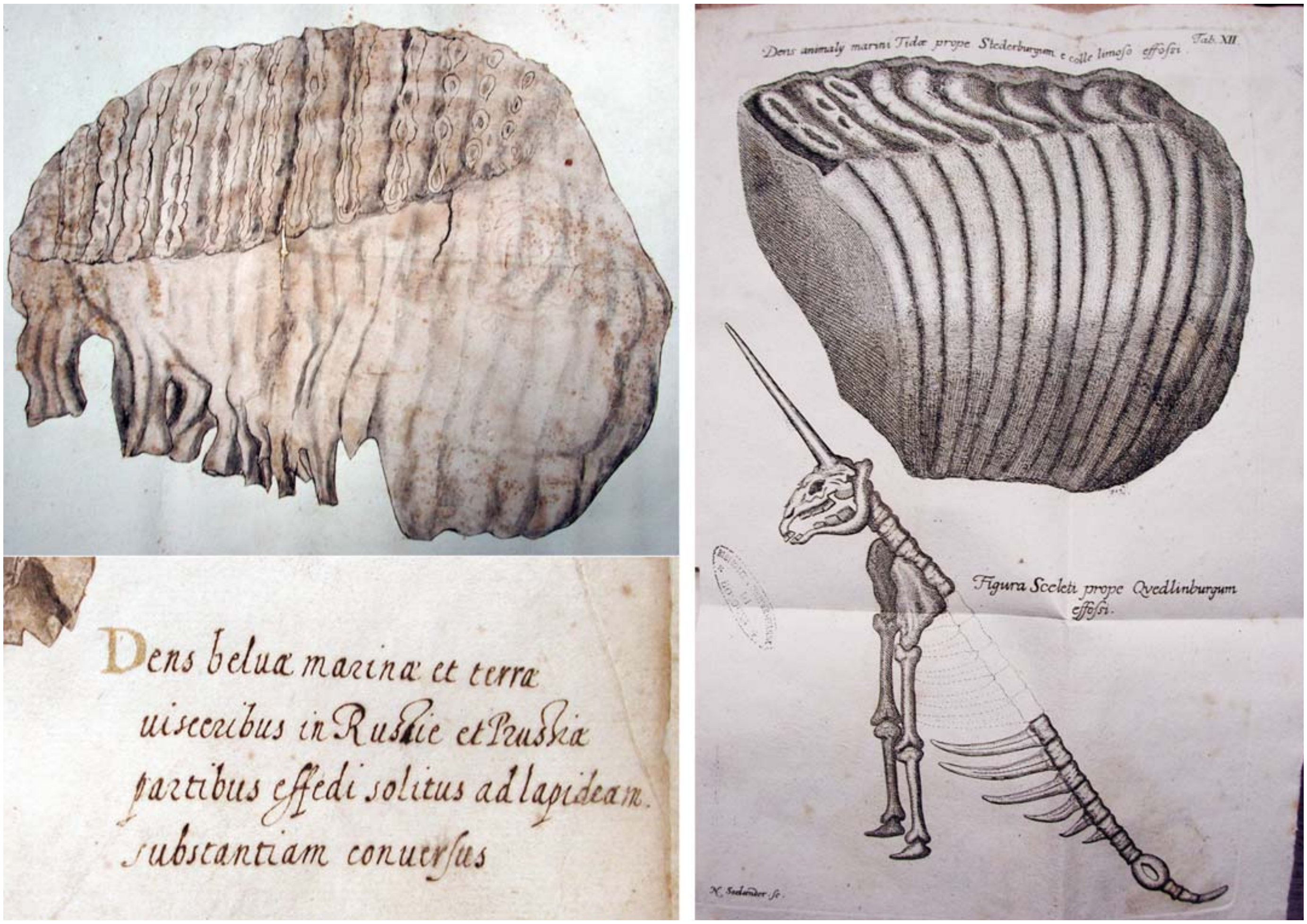

Figure 15. (A–B) Plate XII from Leibniz's *Protogaea*. Left: A mammoth tooth labeled as "Dens animaly marini Tidae prope Stederburgum e colle limoso effossi"(tooth of a marine animal excavated from a loamy hill near Stederburg). Worthy of note is the similarity with a drawing from Aldrovandi's *Tavole Acquarellate*, Volume 1 (about 1590s). Right: A mammoth tooth labeled as "Dens beluae marinae ex terra visceribus in Russiae et Prussiae partibus effodi solitus ad lapideam substantiam conversus" (tooth of a marine wild beast which is usually excavated from the interior of the Earth in Russia and Prussia after having been converted into lapideous matter) (Vai and Cavazza, 2006). Courtesy of Biblioteca Universitaria di Bologna, Biancastella Antonino (photo by G.B. Vai).

enabled me to gradually accept a love for Christian humility, which is indeed the worthiest love available to a reasoning soul. (Steno to Leibniz, 1677; Naldini, 1986, p. 22–23)

It should be noted here that Steno's scientific experiments on anatomy and geology apparently led his critical mind to abandon the Cartesian theoretical system that had fascinated him earlier, along with most of Europe's young scientists. It should also be noted that the Cartesian philosophy, through its methodical doubt and the dualism of mind and body (cogito, ergo sum), acted as a major source and streamlined much of modern thinking, denying metaphysics and God, and leading to the primacy of science over philosophy and religion. On Steno's criticism of Cartesianism, see Gohau (1990, p. 137–140), Meschini (1998, p. 9), Yamada (2003, p. 82), Morello (2003b, p. 251–253), and Rosenberg (2006, p. 795–796).

The letter to Leibniz provides information about additional reasons for Steno's conversion. Relevant questions Steno posed to himself were:

Is it by chance that God let me discover such false statements in those great philosophers just when I credited them with highest esteem, or is it due to God's goodness?

Is every religion good or the Roman Catholic one only? Is religion a human law established to witness to the Creator the duties toward Him, or is the religion a prescription by God itself so that there can be only one, necessarily uninterrupted, from the beginning of the world till its end, unique as it is that which worship Jesus Christ and represents an uninterrupted society, established since the promises of His arrival? (Steno to Leibniz, 1677; Naldini, 1986, p. 22–23)

It would seem that Steno's faith was great even before his conversion (Sobiech, 2004), which was then a natural outcome.

It is impossible that He who gave me the power to think does not see all my thoughts. … Finally, God did so much that I found myself in the Church's arms in a way that I did not understand until I came in. (Steno to Leibniz, 1677; Naldini, 1986, p. 23)

Now we may consider the factors more directly influencing Steno's conversion.

The influence exerted on Steno by his acquaintance with the circle of Galilei's disciples, the renowned Florentine Accademia del Cimento (Galluzzi, 1986, p. 114). It was the second scientific society founded in 1657, a half a century after the Accademia dei Lincei was established in Rome in 1603. It anticipated in time and inspired the aims and scope of the Royal Society in London and the Académie des Sciences in Paris. Steno was expected to interact with the scientists of the Tuscan grand duchy and therefore was immediately admitted to the circle and the Accademia.

The Accademia del Cimento was active in Florence from 1657 to 1666–1667. Prominent members were Evangelista Torricelli, Vincenzo Viviani, Carlo Dati, Orazio Rucellai, Lorenzo Magalotti (the Secretary), Francesco Redi, Giovanni Alfonso Borelli, Carlo Fracassati, Lorenzo Bellini, Claude Aubery, Carlo Rinaldini, Alessandro Marsili, Donato Rossetti, Alessandro Marchetti (Fig. 16). Most of these learned scientists were as firm Roman Catholic believers as their beloved maestro Galileo Galilei. This is why the cultural movement they represented has been called Galileian Catholicism (Raimondi, 1978).

Galileo's life itself was inspiring to Steno. In spite of the trial and retraction, Galileo did not lose his faith and did not withdraw from the Roman Catholic confession. In this, he was aided by his beloved daughter Virginia and sister Maria Celeste in a Florentine monastery.

Steno immediately felt himself well within this circle of Galilei's disciples, first from a scientific and methodologic point of view and second for its human and friendly relations (except for some disagreements notably with Antonio Magliabechi [1633–1714]). Even with the anatomist and mathematician Giovanni Alfonso Borelli (1608–1673), a potential competitor on myology (but no longer present in Florence) (Galluzzi, 1986, p. 114–116, 127, 144), agreement and integration were excellent. In fact, Borelli (1670) described the 1669 catastrophic eruption of the Etna volcano in terms of Stenonian geology, extruding basaltic lava flows down to the Catania coast of Sicily (Morello, 2003b, p. 254). The Florentine literati Carlo Roberto Dati (1619–1676) provided Steno with Mercati's manuscript *Metallotheca Vaticana* representing shark's head and teeth (Morello, 1979, p. 39).

Steno established a close friendship with the biologist Redi (1626–1697), the mathematician Viviani (1622–1703), and the humanist and scientist Magalotti (1637–1712) (Naldini, 1986). The Roman Catholic leaning of these scientists and learned savants was serious, not opportunistic, as has sometimes been suggested (Cavazza, 1990). They were really convinced of their religious confession. Their position was not instrumental toward any material benefits. They found no contradiction between the sciences under investigation and the faith they professed, nor did they feel limited in their search for truth under the aegis of the new Galileian science.

Figure 16. Session of members at the Accademia del Cimento (after *Serie di Ritratti di Uomini Illustri*, v. 4, Firenze 1773, no. 124).

Galileian Catholicism was an open-minded and balanced approach to develop the new science independently from, but not in conflict with, religion, and it had developed around Galilei's pupils beginning with the Gesuater mathematician Bonaventura Cavalieri (1598–1647), professor at the University of Bologna (Battistini, 2003, p. 35). Galileian Catholicism may be simply explained by the following statements: (1) the Bible should be followed for its moral and religious teaching, not for the astronomical implications; (2) there is compatibility of science with the Christian doctrine and religion if distinction of fields is observed. In spite of and as a redeeming reaction to regrettable events such as Giordano Bruno's burning in 1600 and Galilei's house arrest in 1635, Galileian Catholicism spread over most of Italy during the second half of the seventeenth century, and from the 1670s it evolved into the cultural movement called Aemilian Erudition (Raimondi, 1978). Basically, it was opposed to the antireligious quarrels of some cultural circles and favored the free development of science, also for educational and social purposes, supported by the Catholic Counter-Reformation.

Aemilian Erudition was propagated by savants such as Marcello Malpighi, Geminiano Montanari (1633–1687), the brothers Anton Felice Marsili (1653–1710) and Luigi Ferdinando Marsili (1658–1730)—all friends of Francesco Redi—Benedetto Bacchini (1651–1721), Jean Mabillon (1632–1707), Ludovico Antonio Muratori (1672–1750), and its influence extended up to Lazzaro Spallanzani (1729–1799), Ambrogio Soldani (1736–1808), and Luigi Galvani (1737–1798) (Figs. 17 and 18), all of whom had a common imprint: the advancement of sciences and the Roman Catholic confession (building a sort of Catholic wing of the Enlightenment). Some of them were also monks or clerics.

Malpighi, physician and anatomist, a fellow of the Royal Society since 1669, was called to Rome by Pope Innocent XII as his archiatrics (Pope's head physician) in 1691. The same year, he purchased a grave for his family in the church of Saint Gregorius in Bologna and requested to be buried there as witness to his faith (Fig. 3). Montanari, mathematician, astronomer, and expert on hydraulics, wrote in 1676:

> From a young age I had rejected Judicial Astrology, Medicine and Theology, the former two because I could not believe, the latter because I wanted to believe it. My studies for some time in Germany made me see controversies about Faith, and I learned to believe even more firmly in the Roman Catholic confession. (Montanari, 1679)

Like Montanari, Antonio Felice Marsili, the elder brother of Luigi Ferdinando and a clergyman, claimed there was a distinction between faith and science. Autonomy had to be complete in each field to avoid any risk that could arise only from mutual intrusions. Luigi Ferdinando Marsili, fellow of the Royal Society since 1691, gave to his Istituto delle Scienze e delle Arti a statute in 1711, updating the guidelines established by Aldrovandi, Galilei, Francis Bacon, and the Royal Society. The first chapter of the statute deals with the Sacred Cult to be observed in the Istituto and reads (Vai, 2003b, p. 224, 226):

> Art. 1. – Professors, and any person training in this Institute must accept as Creator God Optimus and Maximus, and have to implore from Him life existence and advancements, through the *Holy Virgin Mary's* intercession, for his major glory. To obtain effective protection for this Enterprise in all tools and writings one must number time from the Incarnation, although as for astronomic observations one follows the usage and style of the present age.
>
> Art. 2. – St Thomas Aquinas, St. Carlo Borromeo, and our St. Caterina de Vigri are to be recognized and venerated as protectors; in the home Chapel, to be erected in the Institute, professors and students must celebrate a Mass for the Holy Annunciation as thanksgiving for the goods obtained from the Institute and for her countless mercy, especially donated to General L.F. Marsili in that day … [1]

[1]Marsili was freed from the Turks on March 25, the Annunciation, after two years prison in Istanbul. See Vai (2003a, p. 103–105).

Figure 17. Luigi Galvani's portrait with the frog experiment. Courtesy of Archivio Storico Università di Bologna, Daniela Negrini (photo by E. Mattei and P.P. Zannoni).

Later, in 1728, Marsili himself rejected a diluvianist approach to geology and the fossil question as was usually professed by most fellows of the Istituto, including Johann Jacob Scheuchzer:

> The idea that the ordered setting of many marine bodies found in the mountains of Italy, Germany, and France are a result of the effects of the deluge is groundless, based on the many observations I have made on the living marine organisms. (Marsili Ms. 90, A, 21, c. 148v, *in* Vai, 2006)

Nevertheless, Marsili did not change his mind about his Roman Catholic confession.

Galvani and his bride are buried in the church of St. Caterina de Vigri mentioned previously as a protector of the Istituto. A single chapel is wholly dedicated to the discoverer of electricity in animal tissue and of electrophysiology (1773). Opposing the violence and religious intolerance of the French Revolution, he refused to swear allegiance to the Cisalpine Republic established by Napoleon in northern Italy in 1796. Therefore, he was dropped from rolls of the University of Bologna, and two years later he died at age 61. He was a great scientist and victim of the Jacobin abuse of power.

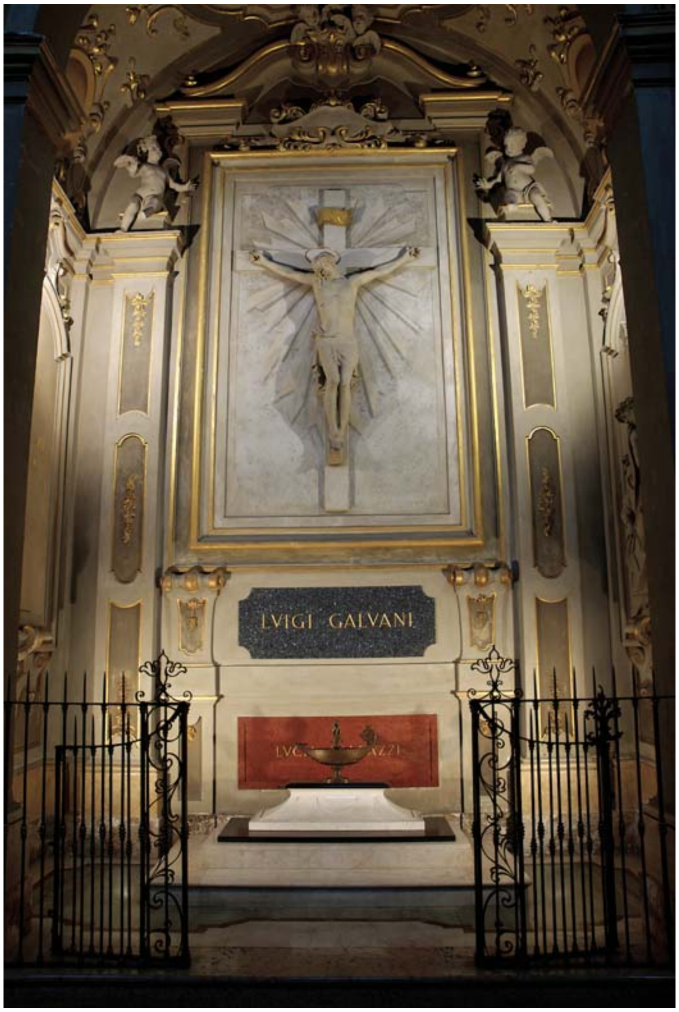

Figure 18. Galvani's grave. Courtesy of Chiesa della Santa, Bologna, Biancastella Antonino (photo by P. Ferrieri and G.B. Vai).

Are there special reasons for Galilean Catholicism and Aemilian Erudition having flourished in the two adjoining regions on both sides of the Apennines—Tuscany and Aemilia—which happened to become the birthplace of the new science of geology (Vai and Cavazza, 2003; Vai and Caldwell, 2006)? The answer is yes, mainly due to the role played by the University of Bologna on one side and the grand duchy of Tuscany on the other.

The liberal, tolerant, balanced approach followed by Galilean Catholicism and Aemilian Erudition in the advancement of sciences had in fact largely been predated by the works and actions undertaken by a brain trust strongly influenced by Aldrovandi during the late Renaissance in Bologna, when the city was the second capital and the largest city of the Church States.

Beyond Aldrovandi, the group consisted of Pope Gregory XIII (1502–1585), Christopher Clavius (1538–1612), Cardinal Gabriele Paleotti (1522–1597), artists of the Carraccis' school, and scientist members of the Jesuit schools of Collegio Romano and Collegio Santa Lucia who gathered in Rome and Bologna in the second half of the sixteenth century. All of these people strove for an integration of science, arts, philosophy, and religion (Battistini, 2000, 2003; Vai, 2003b). Some have claimed that Clavius' work and Dürer's method influenced Steno's geometrical treatment of mineral crystals in the *Prodromus* (Schneer, 1971, p. 296; Yamada, 2003, p. 81).

Aldrovandi, one of the founders of modern science and its method, which greatly influenced Galileo Galilei and Francis Bacon (Vai, 2003a, p. 87; Vai and Cavazza, 2006, p. 55–57), had been groundlessly accused of heresy. He asked for a trial and demonstrated his innocence. As an advisor for science and education of Cardinal Paleotti—one of the masterminds of the Counter-Reformation—he joined the session of the Council of Trent in 1562. Paleotti and Aldrovandi shared the same views on naturalistic and religious education and inspired the painting revolution of Carraccis and Guido Reni, which adopted a naturalistic approach along the lines of Aldrovandi's "theatre of nature" (Fig. 19) and supported the artistic goal of "joining the classical ideal to the heavenly perfection" in the late Renaissance (Emiliani, 1988, 1993) (Fig. 20). Aldrovandi's "theatre of nature" was his renowned museum. Aldrovandi had established the first natural history museum in Bologna in 1547, from the beginning having clear scientific research, taxonomic, and higher-education objectives. Unlike the courtly Wunderkammer and studiolo, and other private, collections of his time, the Aldrovandi museum was designed as a *public* institution (Vai, 2003a; Beretta, 2005; Vai and Cavazza, 2006, p. 51).

In the same year, 1562, Cardinal Legato Carlo Borromeo (1538–1584), a future saint and founder of the Roman Catholic seminaries with Pope Gregory XIII, was instructed by Aldrovandi to reform the University of Bologna by calling teachers from foreign cities and countries—such as Girolamo Cardano (1501–1576)—and providing it with a new building—the Archiginnasio Palace, which opened a year later. Pope Gregory XIII, the Bolognese Ugo Boncompagni, leader of the Roman Catholic Counter-Reformation, author of the Canonical Code, promulgator of the Gregorian calendar that reformed the Julian calendar (1582), was Aldrovandi's cousin.

Additionally and remarkably, both Aldrovandi and his older German friend Georgius Agricola (1494–1555) were impervious to the powerful Lutheran Reformation and remained faithful to the Roman Catholic Church. Aldrovandi named the pro tempore Archbishop of Bologna as his testamentary executor. He also asked for the Pope's support for his museum.

An example of firm religious belief common to many late Renaissance scientists is found in a letter that a famous botanist Luca Ghini (ca. 1490–1556), professor at the Universities of Bologna, Padua, and Pisa, sent to his pupil Aldrovandi in 1554: "because we don't know what we ask for, I have always thought God is governing me and I believe that what happens must be his will for the best" (De Toni, 1905; Vai, 2003a, p. 85).

So, as described already, Aldrovandi and his friends had created a scientific-cultural-religious network extending from Bologna to Florence (see above for his relations to the Tuscan grand

Figure 19. Detailed view from the Aldrovandi's restored museum. Courtesy of Museo di Palazzo Poggi, Bologna, Fulvio Simoni (photo by D. Lelli).

dukes) to Padua, Pisa, Milan, Rome, and southern Italy, which set the ground for the subsequent growth of Galilean Catholicism. I have called this movement Aldrovandian Catholicism (Vai, 2003b, p. 228; Vai, 2006, p. 60).

Aldrovandi's scientific and cultural approach was not driven by opportunism, having predated Bruno and Galileo by decades. It may have influenced the opportunistic metaphysical neutrality (Cavazza, 1990) later adopted by Bacon and the Royal Society in the more dogmatic Anglican realm, as shown by the long-lasting impact of the physico-theologic theories of Earth (Vai, 2003b). Conversely, Aldrovandi, questioning the effects of the Universal Deluge as to the distribution of fossils, stimulated a "soft liberal" diluvianism (visibly represented by Steno and the Bologna Istituto delle Scienze) or even an anti-diluvianism (dominating the Tuscan and Venetian geological schools) that was practiced in Roman Catholic Italy (Vai, 2003b). Also, in the Anglican "frame," there were anti-diluvianistic voices such as Robert Hooke (1635–1703), but only a few and much later than in Catholic Italy.

In a broader perspective, the central authorities of the Roman Catholic Church might perhaps have intentionally planned to support the advancement of science as a tool of both control and even education rather than to fight against it. Hard conflict and repression—up to the stage involving the loss of freedom or even life—were always deplorable and occurred only when heresy accusations were instrumental to, or in direct relation with, religious or political struggles. At least in northern and central Italy, and in the fields of natural sciences and geology, the result was to establish a pragmatic, open, and liberal approach to science. This was in contrast to the dogmatic approach of the British Anglican Church, which imposed a rigid diluvianism. The Baconian metaphysical neutrality was conceptually different from the Aldrovandian-Galilean Catholicism and represented an euphemism for many British scientists. Unlike the Italian geologists, who were earlier free to develop a school independent from prejudgments related to the Noachian Deluge, the majority of British scientists had to conform to the Holy Writ until the early nineteenth century. Instead, rather than pure defense from or compromise with religion, Italian geologists enjoyed distinction, independence, and mutual respect of the fields of science and religion.

To the rationalist and open-minded Steno, the merging of science and faith in the learned Italians both inside and outside the Accademia del Cimento was an inspiring surprise he could not

Figure 20. Guido Reni's *Arianna* (1638–1640) sitting on a vertical bedded rocky cliff. Private collection. Courtesy of Pinacoteca Nazionale di Bologna.

ignore. In a letter about his conversion to the Calvinist preacher Johannes Sylvius written on 12 January 1672 (Scherz, 1952, v. I, 73, p. 257–260; Naldini, 1986, p. 15–19), Steno said:

> I was impressed by the life-style of some Roman Catholic friends; a similar style is not assured by philosophers nor was I able to observe for friends of other religions, although I was already convinced that the truth of a doctrine does not depend on the ignorance and the badness of its believers. (Steno to Sylvius, 1676; Naldini, 1986, p. 16)

The example of a life of holiness provided to Steno by his Roman Catholic friends and by Lady Lavinia Arnolfini (Naldini, 1986) soon prepared him to change his paradigms in science and culture in the continuous pursuit of consistency that always characterized Steno. Strictly connected to this, the greater consistency of religious life of Roman Catholics compared with that of Lutherans played a decisive role in Steno's conversion.

A triggering event was the Corpus Domini procession in Leghorn in 1666, where the rationalistic Lutheran scientist was touched by the spontaneous expression of popular religiosity by the city community.

In the same letter to Sylvius, Steno listed three basic theological reasons for his conversion: (1) the apostolic origin of the Roman Catholic Church; (2) its previous long-standing existence, and its teaching and sacramental authority rooted in the apostles, fathers, and martyrs; and (3) the demonstration of its holiness. These reasons, however, are not discussed in terms of a scholastic approach but following the same historical and experimental-inductive method that Steno had used in his previous anatomical and recent geological works.

Additionally, the open-minded liberal or less dogmatic approach to natural sciences and the question on the origin of fossils by the learned Catholic Italians compared to the Lutheran or other Reformed Europeans was fundamental to Steno's critical evaluation and decision to change his confession (see previous discussion).

One sometimes comes across statements in the historical literature saying that, while the Renaissance was a Catholic achievement, the Scientific Revolution was a Protestant one. Such a statement is badly simplistic or even ideological. Surely, humanism and the Renaissance originated in Catholic Italy, but Reformed savants did emerge. Similarly, although the Enlightenment was strongly supported by the Protestants' more individualistic approach, Catholic savants contributed very significantly to the origin and development of the Scientific Revolution, and even the Roman Catholic Church supported this evolution as a consequence of the Counter-Reformation and the establishment of Jesuit schools and their research laboratories (e.g., Battistini, 2000). Furthermore, the evidence related to geology and the earth sciences contained in this paper and other works (Vai and Cavazza, 2003; Vai and Caldwell, 2006) supports and favors a more nuanced view. The only safe generalization one can make, based on factual evidence, is that humanism, the Renaissance, and the Scientific Revolution were all connected intimately and developed within European or Western Christian culture.

CONCLUSION

Steno's two conversions appear to have been not only contemporaneous but also intimately connected. The major scientific shift from anatomy to geology occurred as a reaction to a new, intellectually stimulating, naturally exposed, and artistically represented geological environment. Thus, new truths and a "new world" became available to Steno.

Steno's religious conversion was based on a rational and experiential process starting from scientific discoveries shedding doubts on apparently reasonable philosophical statements elaborated in a mind largely free from external constraints and

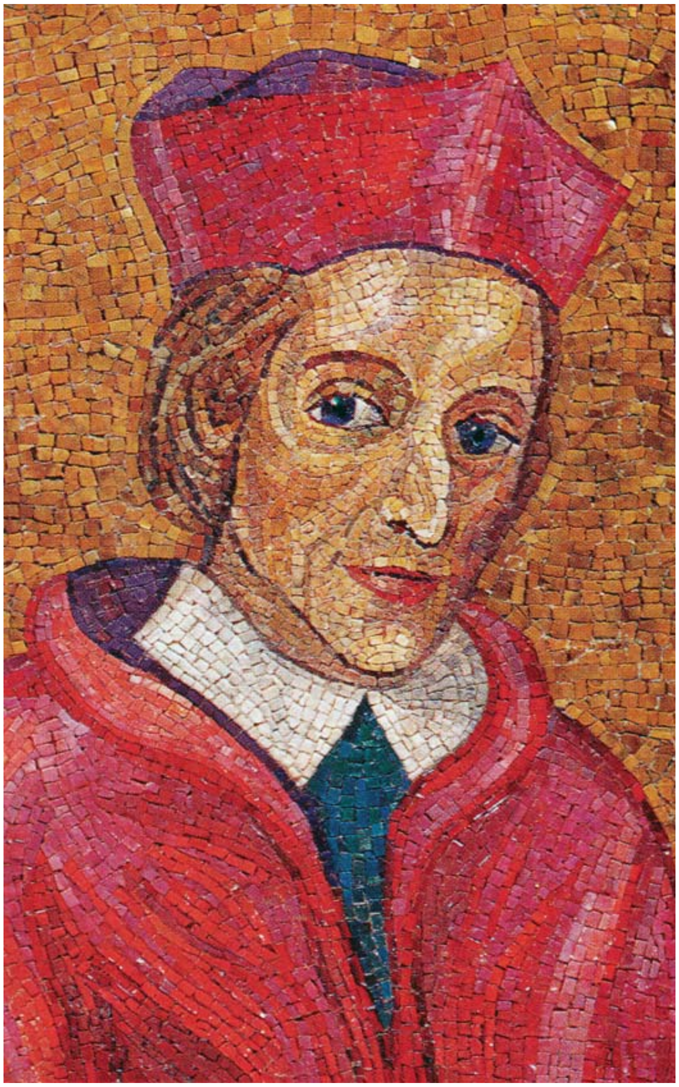

Figure 21. Steno's portrait as a bishop. Private collection. Courtesy of Basilica di San Lorenzo, Florence, Father Angelo Livi.

Figure 22. Marble inscription placed in the Basilica di San Lorenzo as a tribute to Steno by the 32nd International Geological Congress Florence 2004 (photo by E. Abbate).

inclined to a religious sensibility. The initial conditions were those of a perfect balance and autonomy among science, philosophy, and religion representing different approaches to knowledge and life. After his conversion, however, Steno decided spontaneously to devote his remaining time life to religion, after having spent a large part of it devoted to science and philosophy.

The "paradox" of this is deceptive. He did not mean to impair the balance nor to depreciate either science or philosophy. Otherwise, he would not have stressed the basic role of his scientific discoveries in rejecting Descartes' statements and in hearing and responding to the voice of God. He simply claimed the priority of what he saw as *total* religious Truth over the *partial* truths of science and philosophy. He only claimed his right to follow God's Love once his science and research method had allowed him to comprehend God's voice (Fig. 21).

On the other hand, his confidence in his research method was increased by his geological discoveries. So, the two conversions cross-fertilized each other.

Thus, Steno remained a champion of the free rational advancement of science ending with finding God. He was ready for, and reacted rapidly to, the influence of the natural, geological, cultural, and religious environment found in Italy.

In this sense, Steno's life was an anticipated claim and a warning for a sustainable Enlightenment, which was heralded by minority circles such as the Aemilian Erudition in Italy, and it also anticipated opposition to the feared decay of the Enlightenment from the darkness of rationalism, nihilism, and relativism.

Steno's two conversions provide additional evidence of an open and liberal attitude toward science that was at the time more lively in the Catholic domains than in the Reformed confession.

We called for a tribute to the Blessed Nicholas Steno—one of the founders of modern geology—celebrated in the San Lorenzo Basilica in Florence, where his body lies buried, during the 32nd International Geological Congress in Florence 2004, with the aim of emphasizing a remarkable case of harmony between science and religion, made possible by mutual respect of their autonomy and freedom (Capellini, 1870; Angeli, 1996; Anonymous, 2005) (Fig. 22).

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REFERENCES CITED

Angeli, R., 1996, Niels Stensen: Il beato Niccolò Stenone, uno scienziato innamorato del Vangelo e dell'Italia (Negri, L. ed., second edition): Milano, San Paolo, Cinisello Balsamo, 366 p.

Anonymous, 2005, A tribute to Steno: General Proceedings, 32nd International Geological Congress, Florence, Italy, 20–28 August 2004: Florence, Newtours, p. 20–22.

Ascani, K., Kermit, H., and Skytte, G., eds., 2002, Niccolò Stenone (1638–1686): Anatomista, Geologo, Vescovo: Atti del Seminario Organizzato da Universitetsbiblioteket i Tromsø e l'Accademia di Danimarca, Lunedì 23 Ottobre 2000: Analecta Romana Instituti Danici, supplementum 31, 83 p.

Baratta, M., 1903, Leonardo da Vinci e i Problemi della Terra: Torino, Fratelli Bocca, 318 p.

Baratta, M., 1912, Importanza per la geologia e la geografia fisica della pubblicazione dei manoscritti di Leonardo da Vinci: Bollettino Società Geologica Italiana, v. 30, p. 1007–1014.

Battistini, A., 2000, Galileo e i gesuiti. Miti letterari e retorica della scienza: Milano, Vita e Pensiero, 419 p.

Battistini, A., 2003, Bologna's four centuries of culture from Aldrovandi to Capellini, *in* Vai, G.B., and Cavazza, W., eds., Four Centuries of the Word Geology: Ulisse Aldrovandi 1603 in Bologna: Bologna, Minerva Edizioni, p. 13–63.

Beretta, M., ed., 2005, From Private to Public: Cambridge, UK, Natural Collections and Museums: Science History Publications, 272 p.

Borelli, G.A., 1670, Historia et Meteorologia incendi Aetnaei anni 1669 ac responsio ad censuras Honoratii Fabri contra librum de vi percussionis: Regio Julio, in Officina Dominici Ferri, 162 p.

Brocchi, G., 1814, Conchiologia fossile subapennina, con osservazioni geologiche sugli Apennini e sul suolo adiacente: Milano, dalla Stamperia Reale, v. 1, p. 1–56, i–lxxx, 1–240; v. 2, p. 241–712.

Brown, D.A., 1998, Leonardo da Vinci: Origins of a Genius: New Haven, Connecticut, Yale University Press, 240 p.

Capellini, G., 1870, Di Nicola Stenone e dei suoi studi geologici in Italia: Bologna, Gallet & Cocci, 35 p. (new edition 1881, Firenze, Gallet & Cocci, 16 p.).

Cavazza, M., 1990, Settecento inquieto. Alle origini dell'Istituto delle Scienze di Bologna: Bologna, Il Mulino, 281 p.

Cermenati, M., 1912, Da Plinio a Leonardo, dallo Stenone allo Spallanzani: Bollettino Società Geologica Italiana, v. 30, p. cdli–div.

Clark K., 1985, La Sant'Anna, *in* Leonardo, La Pittura (P.C. Marani, cur.): Firenze, Giunti Martello Editore, p. 106–112.

D'Arrigo, A., 1939–1940, Leonardo da Vinci e il regime della spiaggia di Cesenatico: Annali Lavori Pubblici, v. 77–1939, p. 1103–1135; v. 78–1940, p. 293–325.

D'Arrigo, A., 1952, Leonardo e la scienza dei litorali: Rivista di Ingegneria, v. 6, p. 1–8.

Dean, D.R., 1979, The word geology: Annals of Science, v. 36, p. 35–43, doi: 10.1080/00033797900200111.

De Lorenzo, G., 1920, Leonardo da Vinci e la geologia: Bologna, Zanichelli, Pubblicazioni Istituto Studi Vinciani, Volume 3, 195 p.

De Toni, G.B., 1905, Cinque lettere di Luca Ghini ad Ulisse Aldrovandi: Per il Terzo Centenario della morte di Ulisse Aldrovandi: Padova, Tipografia del Seminario, 18 p.

Edgerton, S.Y., 1975, The Renaissance Rediscovery of Linear Perspective: New York, Basic Books, xvii + 206 p.

Ellenberger, F., 1988, Histoire de la Géologie: Paris, Lavoisier Tec Doc, v. 1, viii + 352 p.

Emiliani, A., 1988, La vita, i simboli e la fortuna di Guido Reni, *in* Guido Reni 1575–1642: Bologna, Nuova Alfa Editoriale, p. XVII–CIV.

Emiliani, A., 1993, Ludovico Carracci. Bologna nella seconda metà del Cinquecento, *in* Emiliani, A., cur., Ludovico Carracci: Bologna, Nuova Alfa Editoriale, p. XVII–LXX.

Eyles, V.A., 1958, The influence of Nicolaus Steno on the Development of Geological Science in Britain: Acta Historica Scientiarum Naturalium et Medicinialium, v. 15, p. 167–188.

Fara, A., 1999, Leonardo a Piombino: Firenze, Leo S. Olschki Editore, 178 p.

Findlen, P., 1989, The museum: Its classical etymology and Renaissance genealogy: Journal of the History of Collections, v. 1, p. 59–78.

Findlen, P., 1994, Possessing nature: Museums, collecting, and scientific culture in early modern Italy: Berkeley, University of California Press, 449 p.

Galluzzi, P., 1986, Il dibattito scientifico in Toscana, *in* Negri, L., Morello, N., and Galluzzi, P., eds., Niccolò Stenone e la Scienza in Toscana alla Fine del '600: Firenze, Biblioteca Medicea Laurenziana, p. 113–166.

Gohau, G., 1990, Les Sciences de la Terre aux XVIIe et XVIIIe Siècles: Naissance de la Géologie: Paris, Albin Michel, 420 p.

Gortani, M., 1952, La geologia di Leonardo da Vinci: Scientia, v. 87, p. 7–8, 197–208 (version 1953 in Giornale di Geologia, v. 23, p. 1–18).

Hamm, E.P., 1997, 1997, Knowledge from underground: Leibniz mines the Enlightenment: Earth Sciences History, v. 16, no. 2, p. 77–99.

Kardel, T., 1994, Steno: Life, Science, Philosophy: Acta Historica Scientiarum Naturalium et Medicinalium, v. 42, 155 p.

Kardel, T., 2002, On "perhaps the weakest" of Stensen's works: What causes muscular movement, inflation or contraction?, *in* Ascani, K., Kermit, H., and Skytte G., eds., Niccolò Stenone (1638–1686): Anatomista, Geologo, Vescovo: Atti del Seminario Organizzato da Universitetsbiblioteket i Tromsø e l'Accademia di Danimarca, Lunedì 23 Ottobre 2000: Analecta Romana Instituti Danici, supplementum 31, p. 59–63.

Kemp, M., 2001, Leonardo on Painting: New Haven, Connecticut, Yale University Press, 320 p.

Larsen, K., and Scherz, G., eds., 1941/1947, Nicolai Stenonis Opera Theologica: Copenhagen, Nyt Nordisk Forlag, 2 vols., v. 1 (1944) 508 p., v. 2 (1947) 574 p.

Lyell, C., 1830, Principles of Geology: London, John Murray, v. 1, p. i–xv, 1–330.

Meschini, F.A., 1998, Neurofisiologia Cartesiana: Biblioteca di "Nuncius," Volume 29: Firenze, Olschki, 160 p.

Montanari, G., 1676, Lettera a Magliabechi, 22 Settembre 1676 (ms.): Firenze, Biblioteca Nazionale, Magliabechi (Magl.) VIII, v. 736, p. 2.

Morello, N., 1979, La nascita della paleontologia nel Seicento: Colonna, Stenone, Scilla: Milano, Franco Angeli, 265 p.

Morello, N., 1981, De Glossopetris Dissertatio: The Demonstration by Fabio Colonna of the True Nature of Fossils: Archives Internationales d'Histoire des Sciences, v. 31, p. 63–71.

Morello, N., 2003a, The question on the nature of fossils in the 16th and 17th centuries, *in* Vai, G.B., and Cavazza, W., eds., Four Centuries of the Word Geology: Ulisse Aldrovandi 1603 in Bologna: Bologna, Minerva Edizioni, p. 127–151.

Morello, N., 2003b, The birth of stratigraphy in Italy and Europe, *in* Vai, G.B., and Cavazza, W., eds., Four Centuries of the Word Geology: Ulisse Aldrovandi 1603 in Bologna: Bologna, Minerva Edizioni, p. 251–263.

Morello, N., 2006a, Agricola and the birth of the mineralogical sciences in Italy in the sixteenth century, *in* Vai, G.B., and Caldwell, W.G.E., eds., The Origin of Geology in Italy: Geological Society of America Special Paper 411, p. 23–30.

Morello, N., 2006b, Steno, the fossils, the rocks, and the calendar of the Earth, *in* Vai, G.B., and Caldwell, W.G.E., eds., The Origin of Geology in Italy: Geological Society of America Special Paper 411, p. 81–93.

Mottana, A., 2006, Italian gemology during the renaissance: A step toward modern mineralogy, *in* Vai, G.B., and Caldwell, W.G.E., eds., The Origins of Geology in Italy: Geological Society of America Special Paper 411, p. 1–21, doi: 10.1130/2006.2411(01).

Naldini, M., cur., 1986, Niccolò Stenone. Conversione e attività pastorale: Firenze, Nardini Editore, 149 p.

Natali, A., 2002, Leonardo, il Giardino di Delizie: Milano, Silvana Editoriale, 133 p.

Oldroyd, D.R., 1996, Thinking about the Earth: A History of Ideas in Geology: London, Athlone, and Cambridge, Massachusetts, Harvard University Press, 410 p.

Pedretti, C., 1953, Documenti e memorie riguardanti Leonardo da Vinci a Bologna e in Emilia: Bologna, Fiammenghi, xix + 332 p.

Pedretti, C., cur., 1985, Il Codice Hammer e la Mappa di Imola. Catalogo mostra Arte e Scienza a Bologna e in Emilia e Romagna nel primo Cinquecento, Bologna, 1985: Firenze, Giunti Barbera Edizioni, 205 p.

Pedretti, C., 2002, Presentazione, *in* Montalti, P., cur., Leonardo da Vinci a Cesena: Firenze, Giunti, 215 p.

Pedretti, C., and Dalli Regoli, G., 1985, I disegni di Leonardo da Vinci e della sua cerchia nel Gabinetto Disegni e Stampe della Galleria degli Uffizi a Firenze: Firenze, Giunti Barbera, 317 p.

Raimondi, E., 1978, Il barometro dell'erudito, *in* Scienza e Letteratura: Torino, Einaudi, p. 57–84.

Richter, J.P., 1883, The Literary Works of Leonardo da Vinci: London, Samson, 2 vols.

Richter, J.P., 1970, The Notebooks of Leonardo da Vinci: New York, Dover Publications, 2 vols.
Rosenberg, G.D., 2001, An artistic perspective of the continuity of space and the origin of modern geologic thought: Earth Sciences History, v. 20, no. 2, p. 127–155.
Rosenberg, G.D., 2006, Nicholas Steno's *Chaos* and the shaping of evolutionary thought in the Scientific Revolution: Geology, v. 34, p. 793–796, doi: 10.1130/G22655.1.
Rudwick, M.J.S., 2005, Bursting the Limits of Time: Chicago, University of Chicago Press, 708 p.
Scherz, G., ed., 1952, Nicolai Stenonis epistolae et epistolae ad eum datae: Copenhagen, Nyt Nordisk Forlag, 2 v., 1027 p.
Scherz, G., ed., 1958, Nicolaus Steno and his *Indice*: Copenhagen, Acta Historica Scientiarum Naturalium and Medicinalium, v. 15, 314 p.
Scherz, G., ed., 1969, Steno—Geological Papers (trans. Alex J. Pollock): Copenhagen, Acta Historica Scientiarum Naturalium et Medicinalium, v. 20, 370 p.
Scherz, G., 1971a, Gespräche zwischen Leibniz und Stensen: Studia Leibnitiana Supplementa, v. 5, p. 81–104.
Scherz, G., ed., 1971b, Dissertations on Steno as Geologist: Copenhagen, Acta Historica Scientiarum Naturalium et Medicinalium, v. 23, 319 p.
Scherz, G., 1987–1988, Niels Stensen: Eine Biographie: Leipzig, St. Benno Verlag, v. 1 (1987), 376 p., v. 2 (1988), 318 p.
Schneer, C.J., 1971, Steno: On crystals and the corpuscular hypothesis, *in* Scherz, G., ed., Dissertations on Steno as Geologist: Copenhagen, Acta Historica Scientiarum Naturalium et Medicinalium, v. 23, p. 293–307.
Sobiech, F., 2004, Herz, Gott, Kreuz: Die Spiritualität des Anatomen, Geologen und Bischofs Dr. Med. Niels Stensen (1638–86): Münster, Aschendorf Verlag, 381 p.
Tosi, A., 1989, Ulisse Aldrovandi e la Toscana: Carteggio e testimonianze documentarie: Firenze, Leo Olschki Editore, 472 p.
Totaro, P., 2002, "Ho certi amici in Ollandia": Stensen and Spinoza—science versus faith, *in* Ascani, K., Kermit, H., and Skytte G., eds., Niccolò Stenone (1638–1686): Anatomista, Geologo, Vescovo: Atti del Seminario Organizzato da Universitetsbiblioteket i Tromsø e l'Accademia di Danimarca, Lunedì 23 Ottobre 2000: Analecta Romana Instituti Danici, supplementum 31, p. 27–38.
Uzielli, G., 1890, Leonardo da Vinci e le Alpi: Bollettino CAI, v. 23, p. 81–156.
Vai, G.B., 1986, Leonardo, la Romagna e la geologia, *in* Marabini, C., and Della Monica, W., eds., Romagna. Vicende e Protagonisti: Bologna, Edison Edizioni, v. 1, p. 30–52.
Vai, G.B., 1988, A field trip guide to the Romagna Apennine geology. The Lamone valley, *in* De Giuli, C., and Vai, G.B., eds., Fossil Vertebrates in the Lamone Valley, Romagna Apennines: Field Trip Guidebook, International Workshop: Faenza, Litografica Faenza, p. 7–37.
Vai, G.B., 1995, Geological priorities in Leonardo da Vinci's notebooks and paintings, *in* Giglia, G., Maccagni, C., and Morello, N., eds., Rocks, Fossils and History, Proceedings of the 13th INHIGEO (International Commission on the History of Geological Sciences) Symposium, Pisa–Padova, 1987: Firenze, Festina Lente Edizioni, p. 13–26.
Vai, G.B., 2003a, Aldrovandi's will: Introducing the term "geology" in 1603, *in* Vai, G.B., and Cavazza, W., eds., Four Centuries of the Word Geology: Ulisse Aldrovandi 1603 in Bologna: Bologna, Minerva Edizioni, p. 64–111.
Vai, G.B., 2003b, A liberal diluvianism, *in* Vai, G.B., and Cavazza, W., eds., Four Centuries of the Word Geology: Ulisse Aldrovandi 1603 in Bologna: Bologna, Minerva Edizioni, p. 220–249.
Vai, G.B., 2003c, I viaggi di Leonardo lungo le valli romagnole: Riflessi di geologia nei quadri, disegni e codici, *in* Leonardo, Machiavelli, Cesare Borgia: Arte, Storia e Scienza in Romagna (1500–1503): Roma, De Luca Editori d'Arte, p. 37–47.
Vai, G.B., ed., 2004, Athanasii Kircheri Mundus Subterraneus in XII Libros Digestus, Editio Tertia, 1678: Bologna, Arnaldo Forni Editore, 22 + xxiv + 366 + vi + x + 507 + xi p. (Photostatic edition with foreword by the editor, and presentations by Nicoletta Morello and Umberto Eco.)
Vai, G.B., 2006, Isostasy in Luigi Ferdinando Marsili manuscripts, *in* Vai, G.B., and Caldwell, W.G.E., eds., The Origins of Geology in Italy: Geological Society of America Special Paper 411, p. 95–127, doi: 10.1130/2006.2411(07).
Vai, G.B., 2008, The status of geology in Italy around 1807: Light and shadow: Geological Society [London] Special Publication (in press).
Vai, G.B., and Caldwell, W.G.E., eds., 2006, The Origins of Geology in Italy: Geological Society of America Special Paper 411, 223 p.
Vai, G.B., and Cavazza, W., eds., 2003, Four Centuries of the Word Geology: Ulisse Aldrovandi 1603 in Bologna: Bologna, Minerva Edizioni, 327 p.
Vai, G.B., and Cavazza, W., 2006, Ulisse Aldrovandi and the origin of geology and science, *in* Vai, G.B., and Caldwell, W.G.E., eds., The Origins of Geology in Italy: Geological Society of America Special Paper 411, p. 43–63, doi: 10.1130/2006.2411(04).
Vasari, G., 1550, Le vite de' più eccellenti architetti, scultori et pittori italiani, da Cimabue insino a' tempi nostri: Firenze, Per i tipi di Lorenzo Torrentino, 6 vol., 994 p.
Venturi, G.B., 1797, Essai sur les ouvrages physico-mathématiques de Léonard de Vinci: Paris, Duprat, 56 p.
Yamada, T., 2003, Stenonian revolution or Leibnizian revival? Constructing geo-history in the seventeenth century: Tokyo, Historia Scientiarum, v. 13, p. 75–100.
Yamada, T., 2006, Kircher and Steno on the "geocosm," with a reassessment of the role of Gassendi's work, *in* Vai, G.B., and Caldwell, W.G.E., eds., The Origins of Geology in Italy: Geological Society of America Special Paper 411, p. 65–80, doi: 10.1130/2006.2411(05).
Ziggelaar, A., ed., 1997, *Chaos*: Niels Stensen's *Chaos*-manuscript Copenhagen, 1659: Copenhagen, Acta Historica Scientiarum Naturalium et Medicinalium, v. 44, 520 p.

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