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PERSPECTIVE

Steno, Targioni and the two forerunners

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ABSTRACT - The brief and enigmatic *Forerunner* written by Nicholas Steno after a two-year residence in Tuscany (1667-1668) contains several basic intuitions of earth sciences. His work influenced contemporary natural philosophers through Europe, but was seemingly forgotten in the course of the next century. Only in Florence the naturalist and polymath Giovanni Targioni Tozzetti undertook a geological study of Tuscany and tested the validity of Steno's hypothesis on the origin of mountains and hills. In relevant passages of his Travels (1751-1754), Targioni expressed a substantial agreement with Steno's reconstruction, therefore planning a modernized version of Steno's theory of the earth, which he published in his own Forerunner (1754). In this work he sets the agenda for the new disciplines of physical chorography and topography, wishing to complete their application to Tuscany in his own lifetime, so that Tuscany could be presented as a template of the earth. His fame as author of Travels and owner of one of the best natural history museums of Europe reached many savants who visited him and learned the results of his fieldwork and his geotheory. Some of the people who met with Targioni have influenced the development of geology, and important aspects of his ideas can be found in their writings. For example, the two sets of strata of Steno's Forerunner were retained in Targioni's scheme, in their turn representing the basic distinction of Secondary and Tertiary strata first brought to international attention by Giovanni Arduino. Targioni conceived the need for a methodological change in the study of the earth and its history, praising fieldwork and mapping. He inspired Nicolas Desmarest, a pioneer of modern geology who travelled Tuscany testing Targioni's hypotheses and learned about his understanding of Steno's geology. Neither Steno nor Targioni could develop their particular vision of the history of the earth were it not for the exceptional variety of rocks of Tuscany, the abundant Tertiary fossils and the clear angular unconformity between Secondary and Tertiary strata. Giambattista Brocchi, among the most influential geologists of the early nineteenth century, travelled Tuscany on the footsteps of Targioni, validating his vision of the basic stratigraphy and bringing the concept of Tertiary fossils and strata to a wider public. Brocchi refocused attention on Tuscany, and key figures of the history of geology like Alexandre Brongniart and Charles Lyell duly came to see with their own eyes. In Brocchi's Subapennine fossil conchology the link between Steno and Targioni was lost track of, but Steno's work on the organic origin of fossils was brought to the general attention after almost one century of near oblivion. At the same time, Brocchi was unconsciously revaluating Steno's history of the earth.

KEY WORDS: history, geology, geotheory, Tuscany, Nicolas Desmarest, Horace de Saussure, Giambattista Brocchi, Charles Lyell

INTRODUCTION

"*What has long baffled historians is the absence of reference to Steno in so much of the geological literature of the eighteenth century*" (Rappaport, 1997).

Steno's role as one of the founders of modern geology is grounded on one geological setting, Tuscany, and two published works, *The head of a shark dissected* (1667) and the brief *Forerunner to a dissertation concerning a solid body enclosed by process of nature within a solid* (1669). Born in Copenhagen in 1638, where he developed a ground-breaking approach to the study of nature (Rosenberg, 2006), Steno arrived in Florence at the age of 28, already famed as the most skilled anatomist of Europe. Today he is mainly remembered for his proof of the organic origin of fossils and that they could not have grown inside sedimentary rocks, as held by both Aristotelian and Neoplatonic schools in pre-Galieian times (Rudwick, 1972; Cutler, 2003; Fisher and Garrison, 2009). In the *Forerunner* he also established several principles, such as the principle of superposition of strata ('the lowest is the oldest') and the law of constancy of angles in crystals, principles that characterize modern geological sciences. His writings reached England as early as 1667 thanks to Henry Oldenburg, foreign correspondent of the Royal Society. For Steno's contemporaries like Robert Hooke the issue of the origin of fossils became the paradigm of 'experimental method of enquiry' applied outside the realm of physics (Rudwick, 1972), spreading among members of the Royal Society to inspire some of the most influential theories of the earth produced at the end of the century. These in their turn gave rise to a long series of "systems" to explain the history of the earth. In the growing state of uncertainty as to the origin of the earth and of its productions, Steno's little book fell into near oblivion. Today historians suggest that he left no immediate following in Tuscany after his death in 1686 (Galluzzi, 1986) and that his name soon disappeared in the rest of Europe (Rappaport, 1997). If this holds true, some questions remain: to what extent was he seemingly forgotten, when was he re-discovered, and by whom?

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FLORENTINE AND BRITISH FELLOWS

Steno's arrival in Florence in the autumn of 1666 coincided with the decline and the end of the activity of the *Academy of Cimento*. Sustained by the Tuscan Grand Duke and shaped around Galileian principles, the academy is often presented as the prototype of all European societies of the scientific revolution. Here Steno established important connections with some of its most distinguished members, including Francesco Redi, Marcello Malpighi and Lorenzo Magalotti (Galluzzi, 1986; Cutler, 2003). The second important paper written during the Florentine years and so relevant for the history of geology, the *Forerunner to the Dissertation on a solid naturally included in another solid*, is a prelude to a longer writing which, if ever penned, did not reach his contemporaries nor us. It is thus in the *Forerunner*, an enigmatic little book, that are contained the several propositions basic to various fields of knowledge, ranging from crystallography, to sedimentology, stratigraphy and paleontology (Rudwick, 1972; Cutler, 2003; Fisher and Garrison, 2009). In the seventeenth century, however, these disciplines did not exist as we know them today and one could hardly find a mention of the *Forerunner* in relation to Steno's principle of superposition, or constancy of crystal angles. One striking aspect of the book, however, and one that evidently continues to inspire modern historians, is the claimed discovery of the history of the earth by the application of a few mechanic and geometric principles to the field study of Tuscany (Rudwick, 1972; Rappaport, 1997; Cutler, 2003). What was more, Steno seemed particularly proud to announce the concordance between Nature and Scripture, the two sources of knowledge for the history of the earth conceivable at that time (Rappaport, 1997). According to Steno's *Forerunner*, the history of Tuscany can be subdivided in two cycles during which sea level had increased and then dropped, the second and last time in coincidence with the Universal Deluge of the Bible (Gould 1987). The first period of high sea-level was responsible of the formation of strata by deposition of sand and clay from suspension in marine waters. According to Steno, these strata are presently devoid of organic remains because they were deposited before the creation of life and have changed their original horizontal arrangement because of the failure of subterranean cavities (Fig. 1A). After the sea receded, the earth was populated by plants and animals first, then by man. Then the sea-level was raised again (the Deluge) and submerged Tuscany (and the earth) with the deposition of new marine sedimentary strata, this time enclosing mollusc shells and all kinds of organic remains. Finally the sea receded to its present position, so that today we are left with two sets of parallel bedsets, one variously displaced from horizontality, lithified and forming the Apennine chain-mainly turbiditic sandstones and mudstones with no macrofossils (Fig. 1A) - the other made of horizontal and richly fossiliferous strata forming the Apennine foothills. On

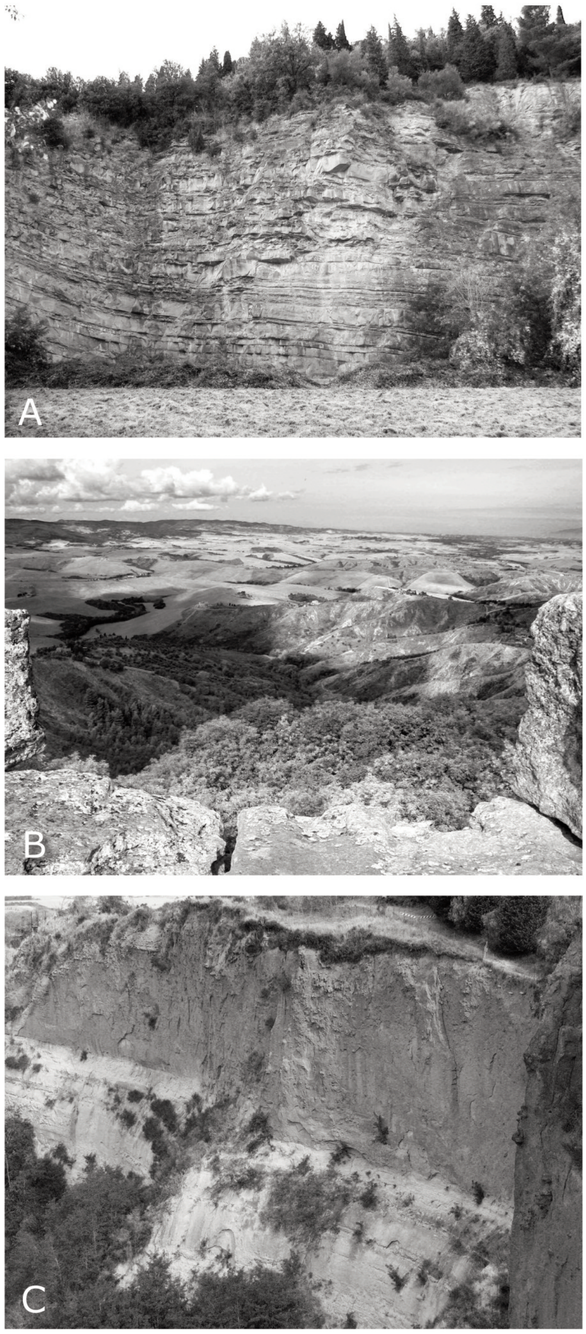

Fig. 1 - Strata of Tuscany. 1A. Turbiditic sandstones and intercalated mudstones (Oligocene Macigno Formation) at Maiano, near Florence, as an example of the prevalent category of rocks of the Tuscan Apennine. According to Steno's Forerunner: 1) direct grading within individual strata was a sign of deposition from turbid waters, 2) tabular bodies were horizontal in origin, now oblique and faulted because of the collapse of subterranean cavities, and 3) shelly fossils were absent because the strata formed before the creation of life. 1B. Panoramic view of hills from Volterra (Pisa province), a key locality for the understanding of the geological history of Tuscany, visited and mentioned by Nicholas Steno (1669), Giovanni Targioni (1753), Nicolas Desmarest (1765), Giambattista Brocchi (1814) and Alexandre Brongniart (1822). The prevalent mudstone lithology, weathered into smooth landforms, to Brocchi formed "ridges like ocean waves", consistently with the observation of Targioni that hilltops form a straight horizontal line. Strata are here roughly horizontal and wedge out over the flanks of the higher reliefs (in the background). In the foreground, the Etruscan walls of Volterra, for Steno the sign of the most ancient repopulation of the earth following the Deluge. 1C. Close up of horizontal strata forming the hill of Volterra (Pliocene). In the lower half of the succession is a coarsening-upward alternation of tabular sandstones and mudstones, similar to turbiditic sandstones of the Apennines (Fig. 1A), only still horizontal and with scattered shelly material. Massive fossiliferous sandstone, resting sharply over the alternation, form the upper part of the succession (part of it was used to build the town). All these characters were for Steno indicative of the diluvial origin of the strata forming Tuscan hills, postdating the creation of life.

top of the hills, Etruscan towns like Volterra testified to the repopulation of the earth by Noachian progenies (Rudwick, 1972; Dominici, 2009; Fig. 1B,C).

These were, in summary, Steno's ideas on fossils and strata that had spread throughout Europe among natural philosophers, as was then customary in what was known as the Republic of Letters, or the international community of intellectuals (Rappaport, 1997). Fellows of the Florentine academy kept active connections with members of the Royal Society in Britain, which in turn fruitfully animated with their speculations and experiences the debate on the origin of the earth, during the last decades of the 18th century. One of these connections was kept by Lorenzo Magalotti, who actively travelled to Britain, another by Marcello Malpighi, a fellow of the Royal Society since 1668 and a correspondent of Steno. At the Royal society, Martin Lister did not agree with the conclusions contained in the *Forerunner* and rejected the organic nature of fossils on the basis of his knowledge of the much more problematic British fossils, while the greatest contemporary British naturalist, John Ray, wandered what event could bring about so much water to cover the highest mountains where fossils are found today (Rudwick, 1972). In the last two decades of the century two theories of the Earth were then published, the *Sacred history of the earth* by Thomas Burnet (1680) and the *Essay towards a natural history of the earth* by John Woodward (1695). Burnet believed that the immense quantity of water necessary for the Deluge was housed within a collapsible Earth's surface (the Great Deep of Scripture), an idea originally devised by Descartes and espoused also by Steno. Woodward built a system on the power of gravity to sort solid element during the waning of the great diluvial catastrophe, sharing with Steno the organic origin of fossils and an ordered sequence of strata as a testimony to the deluge.

At his death in 1686, Steno had left his contemporaries with a methodological legacy, several arguments for the building of a theory of the earth, and a rough description of local history based on his fieldwork. Regarding method, while he accepted both natural and civil histories as sources for geotheory (Rappaport, 1997), Steno's hallmark was distinctly naturalistic, based on geometry, philosophically advanced (Rosenberg, 2006). Accordingly, in the *Forerunner* he referred to textual sources only to explain the presence of fossil elephants in the upper Arno valley, and in the few last pages devoted to concordance with Moses' tale. Finally, antiquarian data became a tool to connect pre- and post-diluvial histories by focusing on fossiliferous rocks used to build Etruscan towns. Steno's battery of arguments stemmed from his unitary vision of nature, his experiences on the precipitation of crystals, on sedimentation, animal anatomy and fossils, and an attitude to use geometric principles to unravel relationships (Rudwick, 1972; Rappaport, 1997; Cutler, 2003). Geotheorists like Burnet and Woodward were thus followers of Steno in method, albeit not explicitly and in very different ways, and often used the same arguments. In spite of this, Steno was no longer mentioned by eighteenth century geotheorists. Since his method was common practice, the organic origin of fossils no longer an issue and geometrical visions deemed unnecessary, the name of Steno simply disappeared from the Republic of Letters (Rappaport, 1997). Yet one aspect of the *Forerunner* is usually overlooked, one connected with his fieldwork in Tuscany. Available biographical data confirm that Steno actually travelled the region during and after the writing of the *Shark Dissected*, focusing on a variety of geological phenomena, and striving to understand how the earth functioned (Cutler, 2003). More than Steno's methods and arguments, the point here is if the *Forerunner* constituted any kind of agenda to those subsequently involved in the physical study of Tuscany, and if Steno's hypotheses resisted scrutiny.

TARGIONI'S FORERUNNER

Giovanni Targioni Tozzetti was born in Florence in 1712, his father being a disciple of Francesco Redi. During his adolescence Giovanni had spent summer days in Certaldo, amid the highly fossiliferous hills of Tuscany that had fascinated Boccaccio before him, not far from Leonardo's (Gould, 1997), or Steno's shelly outcrops. As he later recalls, here he learned to collect fossil shells, plants and other objects of natural history, an early interest developed under the tutorage of Pier Antonio Micheli, great botanist and naturalist, friend of his father. After the death of Micheli in 1737 he was appointed curator of the Florentine botanical garden and two years later curator of the library of Magliabechi (Arrigoni, 1987). Magliabechi was the great correspondent of seventeenth century Italian and European natural philosophers, a prince of communicators (Rappaport, 1997), and his books supplied Targioni throughout his life with material for historical studies, nourishing a vast knowledge of scientific literature from Galileo to Steno. Targioni ordered also the most important natural history collections of his time, including the minerals, fossils and dried plants that once belonged to Steno, Micheli and the Grand Duke, following the systematic arrangement he had devised for his own museum. He became best known as the author of several volumes of *Travels in several parts of Tuscany*, but he was also the physician of the Tuscan court and an advocate of land reform within the Academy of Georgophiles, which he helped founding (Arrigoni, 1987; Cipriani and Scarpellini, 2007). With so many commitments, it is no wonder that he could not accomplish his most ambitious project, the writing of a geotheory inspired by Steno, and like him outlined his project in a *Forerunner* (1754).

The history of the *Forerunner* starts from his travels in Tuscany (1742-1745) commissioned by the botanical society and for a survey of mineral resources, guided by a wide range of interests within the realms of natural, civil and literary history. The first volume of the *Travels* already contains the main elements developed in the *Forerunner* together with his acknowledgment of Steno's work as a precursor to his own. As for the reason that brought him "from some brief accounts of my travels to be read at the Botanical society", to a large project to be entitled "physical geography" and that later became "physical chorography and topography" (Targioni, 1754), this could have something to do with the wide resonance of *History and theory of the earth*, published in 1749 by George Louis Leclerc, Comte de Buffon, keeper of the French king's collections and the most authored naturalist of his time. Buffon's theory was commented on by Targioni as early as 1751 and seen as one of great importance, but he disagreed on crucial aspects such as the role of sea currents on the origin of mountains. Buffon was a critic of diluvialism and a theorist with a vast knowledge of travel accounts and natural history, but no direct experience of the field (Rappaport, 1997), in 1749 still tied to traditional chronologies (Rudwick, 1972; 2005), so different from Targioni who had grown up with a confidence on fieldwork in Tuscany (possibly more than Steno), coupled with a wide knowledge of petrifactions and other museum objects (much like Woodward), and the reading of Magliabechi's books and letters (his knowledge of the literature was comparable to Buffon's). In substantial agreement with Steno's dichotomy of history, Targioni readily moved towards geotheory with the *Forerunner to physical chorography and topography*. Physical chorography was to him "the description of a region in order to expose its natural history, or the methodological and generical explanation of its natural productions", whereas to physical topography belonged the analysis of local aspects, or "the detailed description of individual elements of the landscape [...] mainly river valleys". Chorography, occupying the first 166 pages of the *Forerunner* (physical topography only the last 30), much like modern geology, is a sum of the interaction of the physical and biological earth, disguised as history of Tuscany. This is subdivided in 10 parts, each in turn composed of up to 7 sections and a hierarchy of articles and chapters (Tab. 1). Of particular interest for the future theoretical and methodological development of geology are the parts on materials of the earth, which includes orogeny and sedimentary cycles, and those on petrifactions, the Tyrrhenian Sea, pirology and zoology (including Tuscan fossils), other parts dealing with civil history and botany (Arrigoni, 1987; Cipriani and Scarpellini, 2007). Above all stands the notion that Tuscany is a template of the world, and the basic intuition that "the uncovered face of the earth is similar to that presently covered by the sea (p. 12)". In the section on materials, Targioni introduces the two basic types of Tuscan relief, mountains and hills, as he had already written in his *Travels*. Steno's dichotomy becomes the two distinct fields of orogeny, or the origin of the mountains, and bunology, or the origin of the hills. The earth is "formed by the remains of the Primaeval, of which we know nothing", and on subsequent changes the reference is to "the immortal Steno, who after judicious fieldwork in Tuscany, came to know better than any other the structure of the earth (p. 13, already quoted in the fifth volume of *Travels*, p. 292)". The mountains, which Targioni calls "primitive for the sake of clarity", are in reality "of second, third or fourth hand, since they contain vegetal, animal and mineral bodies that were generated somewhere else" (Fig. 2). The deeper the material of the mountains, the softer, until a depth is reached where "materials have no consistency and their agitations are perceived on the surface (p. 15)". Mountains are no longer generated, but only slowly and steadily destroyed, so they will be until present causes remain. From this erosion come the materials with which the strata now forming the hills were formed, under the sea. "The sedimentary strata of this ancient sea occupy a vast portion of Tuscany and form a distinct sector of natural history, not sufficiently studied by anyone". Why the sea has receded from its former position is a matter of much speculation, which Targioni duly considers (p. 18-19). With regard to the field distribution of rocks, or materials of the mountains, he devises an "ichnographic Map" where he will show "in red the marble, in purple cherts, in cyan the sandstones, in green the gabbro, light green the carbonates andc" (p. 22; on Targioni's maps and their importance, see also Cipriani and Scarpellini, 2007). To work out systematic arrangements of petrifactions Targioni recognizes the superiority of fieldwork instead of simply analysing museum specimens (p. 34). The complexity of the rock types of Tuscany prompted him a new theoretical and methodological approach. He devised the word "lithology" for the discipline, and proposed a classification based on the way elements of the rock are bound together. In this system for instance, granite was placed with porfid and serpentine within the porfiroid genus. In treating the process of degradation of mountains and formation of horizontal sedimentary strata in marine environments, he was aware of the extension of pre-human times into unknowable time intervals: "most Tuscan rocks were much younger than the time the universe was created and original ones are almost all gone" and "rocks from many centuries have passed from the state of generation into that of degradation" (p. 31). This was even better expressed in a passage from the *Travels*, where he had well-captured deep time, actual causes, and the stability of natural laws: "what happens today in front of our eyes has happened in the past centuries and will happen again in forthcoming centuries, while the conditions of the globe remain as they are". In dealing with the Tyrrhenian Sea, he answers Buffon who thought that sea currents had carved mountain chains: "modern marine sediments are exactly like those now outcropping on the hills [...] they are structured in parallel and nearly horizontal beds; their materials are those we find today on the surface of mountains from which they are transported downward and deposited according to the order of gravity and the direction imparted from ancient rivers". Targioni suggested learning about the nature of the abyss by traveling ancient seascapes now uncovered, opening to the possibility to draw maps of actual seafloors, in a passage where he cites Ferdinando Marsili. Of particular interest in relation to Moro's hypothesis on the role of heat (Rappaport, 1997) and to Targioni's connections with the Florentine school, is the first section of his "discourse on subterranean fires" where he states that "volcanic fires have a different origin, form, activity and effects from the so-called central fires of the chemists [...] and a limited depth within mountains, as wisely stated by Borelli [of the Academy of Cimento] and contrary to the popular belief that they take their origin from great depths", and "outside a few Tuscan volcanoes there are no others and our hills have a very different origin from what supposed by Moro" (p. 59-61). This section contains interesting intuitions on the magmatic origin of granite (*lava*) and that all rocks of Tuscany were in origin magmatic. Finally, sections on Botany and particularly that of zoology, contain a link between modern and former plants and animals with interesting questions on their origins. Together with this, he often mentions the ordering of events of the Bible, more as a simple rhetorical passage, than to assert actual events, and before proposing natural explanations: "Conjectures on the origin of indigenous plants of Tuscany, if they are those that sprouted on the third day of creation of the universe under the hand of the almighty God, or if their seeds have passed to Tuscany from other regions (p. 72)". Otherwise he is liberal in arguments not strictly biblical, such as Tuscany once inhabited by elephants and hippos, or a possible future rise of sea level. So, in the section dedicated to zoology the spotlight is on the fossil megafauna of elephants, hippos, wolves, deer and bears, "animals that before any human memory were indigenous to Tuscany, but for centuries are no longer".

In the end, Targioni was well aware that the *Forerunner* was already an accomplishment and that no whole dissertation would have followed in his lifetime, not based on his effort alone. Physical chorography and topography were each "the work of an academy, and not just one man", and consistently with this awareness, he set up a network of informants on the natural history of Tuscany (Fig. 2). The fame that Targioni had acquired among those closer to him is best expressed in the commemorative medal by Zanetti (Fig. 3), and in the

Part	Section	page
Periegesis or description of Tuscany	Situation, connection, size and shape of that part of the surface of the terraqueous globe called Tuscany Physical division of Tuscany Political division of Tuscany Ecclesiastical division of Tuscany into dioceses and spiritual jurisdictions	8
Tirrenoilology or discourse on the material of Tuscany	General idea of the structure of the land of Tuscany Theory of the terraqueous globe Orogeny, or speculations on the formation of mountains, which seem primitive in the earth, specially those of Tuscany Oreonemesis, or the disgregation of mountains, and bunogeny, or the formation of hills Reflections on the formation of valleys and plains Reflections on the lowering of sea level Oreology or discourse on the primitive mountains of Tuscany	11
Lithology or essay on petrification	Origin and antiquity of petrifications in Tuscany Causes and differences in the petrifications that are observed in Tuscany Methodic distribution of the petrifications in Tuscany	30
Talattology or discourse on the Tyrrhenian Sea	Nature, connection and extension of the Tyrrhenian Sea Reflections on the variations it has suffered Nature and quality of the Tyrrhenian seabottom Nature, quality and diversity of the Tyrrhenian seashores Quality of the Tyrrhenian water Movements of Tyrrhenian seawater	42
Idrology or discourse over the water of Tuscany	Origin of the waters of Tuscany, all from metheoric waters, mainly rain and snow Destiny of waters of Tuscany Potamology and idrometry, or information on the nature, course and strenght of rivers in Tuscany On the nature of most rivers and streams prior 1558 (memorial of Girolamo da Pace from Prato) Crenology or discourse over springs in Tuscany Freatology or discourse on wells in Tuscany Limnology or discourse over lakes and swamps of Tuscany	51
Pirology and Thermology or Discourse on subterranean fires and thermal or mineral waters in Tuscany	Pirology Thermology Tartar and tartaric waters	59
Meteorology or discourse on air and metheors of Tuscany	Meteorology Cronicle on meteorology and nosology of Tuscany Excerpta Tractatu de Aere, Aquis & Locis Etruriae	65
Phytology or discourse on plants of Tuscany	Terrestrial and swamp plants Reflections on agricolture in Tuscany History and progress of botany and agricolture in Tusacany Briefs on agricolture Essay on the plants of the Tyrrhenian Sea	71
Zoology	Differences and catalogues of terrestrial and acquatic animals that live in Tuscany; their division in indigenous and foreigner; quadrupeds, birds, snakes, insects, fishes, crustaceans and testaceans Terrestrial animals Ichthyology or discourse on fishes and other acquatic animals of Tuscany	142
Civil, ecclesiastic, literary and technical history of Tuscany	Ancient history of autonomous Tuscany, or the times when it was regulated by autnonomous laws, before being subjugated from the Romans	145

Tab. 1 - Subdivisions of physical chorography according to Giovanni Targioni Tozzetti (1754; sections are further subdivided into articles and chapters). Physical topography, also introduced in the Forerunner, but less relevant to geotheory, is not included here.

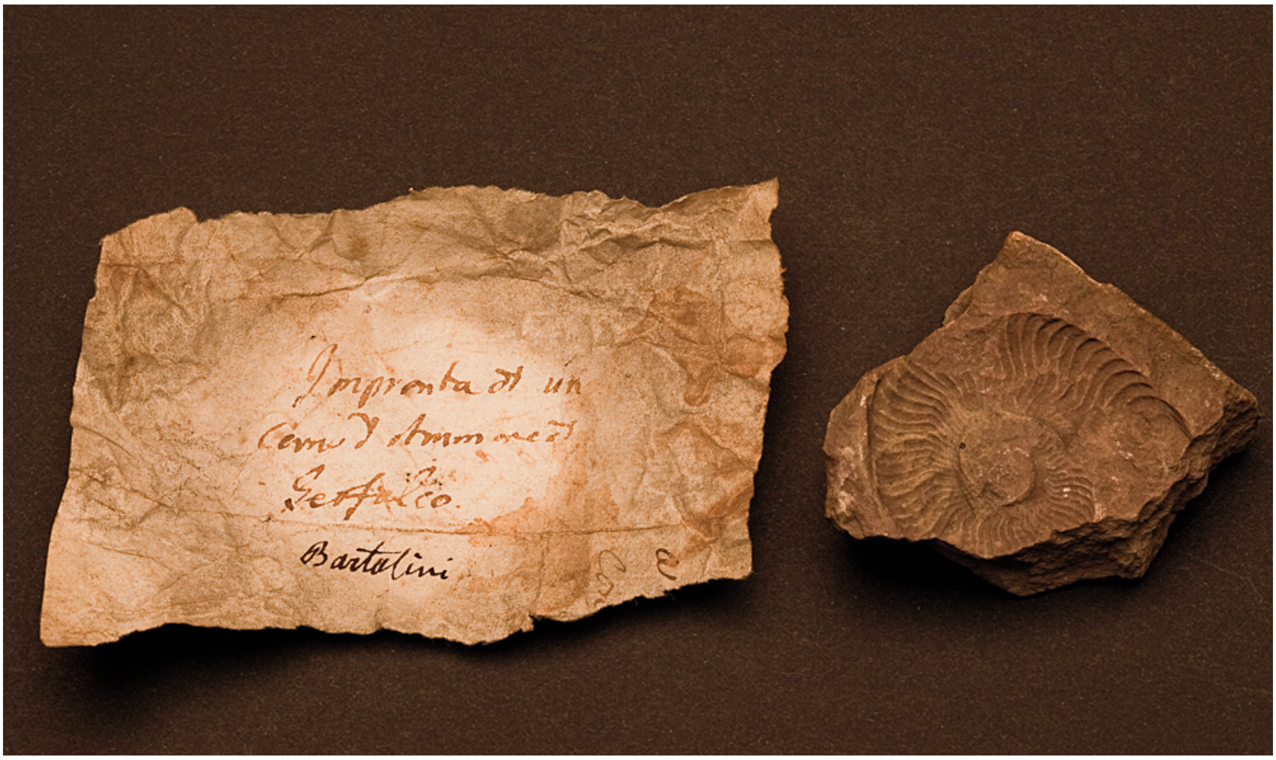

Fig. 2 - Ammonite from the collection of Giovanni Targioni Tozzetti, now at the Museo di Storia Naturale of the Florence university (IGF). The label "Corno d'Ammone da Gerfalco" (Lias, central Apennines), with the name of the collector "Bartalini" (the handwriting is not Targioni's), are written in the piece of paper wrapping the specimen possibly since the days it was collected. Biagio Bartalini, botanist in Siena, exchanged fossils with Targioni in 1776-1777 (Cipriani and Scarpellini, 2007). His letters and those of many other naturalists testify to the fame of Targioni's museum and the network of informants he had built up in Tuscany.

Fig. 3 - Commemorative death medal of Giovanni Targioni Tozzetti, from the numismatist Zanetti (1783). Targioni's portrait is on the obverse side, on the reverse the artist has depicted "allusive emblems of his erudite travels": mountains, clouds, a rushing stream, and fossil shells at his feet, represent better than words Targioni's fame as a geotheorist based on fieldwork, his other important contribution to knowledge being represented by the tree at his back. Zanetti's medal stand next to Pelli Bencivenni's words (see text) in describing what Targioni was for contemporary savants who had met him.

words of Pelli Bencivenni, fellow of the Accademia del Georgofili, director of the Uffizi, and author of Targioni's eulogy in 1783. Bencivenni remarked in 1793 that the *Forerunner* was Targioni's greatest accomplishment, and had the whole dissertation seen the light it would have stood next to the great geotheories of the end of the century, such as Delamethierie's (in Fontana and Schiavotti, 1989).

TARGIONI AS A SAVANT

Strange as it seems, Targioni never travelled outside Tuscany and all his contribution to geology came from the analysis of his homeland. His confidence that this was all he needed to set an agenda for the building of geotheory somehow repeats Steno's confidence in the same thing. Together with the knowledge of Steno's *Forerunner*, what mattered was also Targioni's vast knowledge of published and unpublished work of the Accademia del Cimento, the resonance of this and the counterarguments from fellows of the Royal Society, and the knowledge of the work of his own contemporaries, from Vallisneri to Buffon. Targioni had an updated vision of the arguments of the ongoing debate, the global fall of sea level, the role of heat, the origin of petrifactions, and everything known to him proved that Steno and his region were still of key importance. While he wrote with emphasis on Tuscany and the Tyrrhenian, he still maintained that similar experiences had to be repeated elsewhere in order to prove general hypotheses. Description of relief, or chorography, underlines his belief on the priority of fieldwork on speculation.

If not Targioni himself, his fame soon crossed the boundaries of Tuscany, and at around the time of the first edition of the *Travels,* savants started to visit from other parts of Italy and from Europe. In 1753 he was visited in Florence by Giovanni Arduino, a contemporary from Verona interested to see his museum. The collaboration between Arduino and Targioni started on the basis of mineral prospecting, both concerned to explore Tuscany's local resources, aware of the growing importance of the German and Swedish school of mining (Arrigoni, 1985; Vaccari, 2000; Cipriani and Scarpellini, 2007). Arduino worked and travelled Tuscany again in 1756-1757 and learned about Targioni's intuitions on ancient volcanoes, in their turn rooted in the observations of Pier Antonio Micheli (Rodolico, 1945; Arrigoni, 1985; Vaccari, 2006). However, more important for the development of modern geology than the practice of mining expertise or the recognition of ancient volcanoes, was to learn of Targioni's division between primary and secondary rocks, the basic ground of geohistory (Rudwick, 2005). In a letter of 1760 Arduino acknowledged Targioni's intuitions as the source of the stratigraphic subdivision he developed, today famous for the sketch he made of the Agno Valley in 1758 (Vaccari, 2000; 2006; Rudwick, 2005): "Tuscan hills, called secondary by Mr. Targioni, are of the third order [...] they are full of shells and made from clasts coming from primary and secondary mountains" (Rodolico, 1945; Vaccari, 2006). Targioni's ordering of sedimentary successions is thus renumbered, but conceptually unaltered in the stratigraphy of Arduino.

In 1765 Targioni received the visit of two French savants. The eldest of the two, and of humble origins, was the forty-year old Nicolas Desmarest who shared with Targioni a love for fieldwork, a dislike for speculations, and a penchant for mapping. Having contributed Diderot's *Encyclopedia* (1857) with an entry on *Physical geography*, Desmarest's approach to science based on observation and description was very much that of Targioni. The two had long conversations and travelled key localities of Tuscany to see the validity of "Steno's ideas, which Targioni has adopted in their entirety" (Desmarest in an unpublished letter to Pierre-Jean Grosley, dated at Rome 12 November 1765). Two years before, Desmarest had started his fieldwork in the region of Auvergne, in France, recognized by Guettard as a land of extinct volcanoes (Taylor, 1995; Rudwick, 2005). What he recognized as distinct cycles of volcanic eruptions and, more important, the implicit long phases of construction and erosion of relief, was a validation of Targioni's dismissal of the speculative approach in favor of the reconstruction of local histories, Desmarest's contribution being only more accurate and finally mapped. Both knew that careful land exploration alone could guide into the otherwise unmeasurable spans of pre-human earth's history and geotheory. With this spirit, Desmarest translated Targioni's books, visited the localities of Tuscany mentioned by him, and recognized the essential validity of Steno's intuitions (Taylor, 1995). When at the end of the century the elder Desmarest contributed a long section to the *Methodical encyclopedia*, an updated, rearranged, and extended version of the preceding, his *physical geography* was all that was left after all geotheories were proven fallacious (Rudwick, 2005). Within this scenario, Targioni remained "a mineralogist who has contributed with his intuitions and researches, and with the perfection of his method of observation, to the progress of the natural history of the earth", acknowledging that Targioni's guides were Steno and Micheli, and that Tuscany is a favorable region for various observations, since the massifs of all types are close together, situated so as to permit easy recognition of their 'limites'. As for Arduino before him, to Desmarest in Tuscany "the circumstances were essential for determining the order and the epochs in which nature had operated" (Desmarest, 1795).

The person who Desmarest was accompanying was the duke Louis Alexandre De La Rochefoucauld, younger than him, but crediting him among local savants (Taylor, 2009; personal communication). Rochefocauld in 1772 wrote a letter of introduction for the savant Horace-Bénédict de Saussure, from Geneva, visiting Targioni in Florence during his geological trip to Italy (Cipriani and Scarpellini, 2007). Saussure was an emerging figure among savants working at geotheory, dedicating his life to the knowledge of the physical properties of mountains, and leaving to posterity, before his premature death, an agenda that has remained famous and a further step towards modern geology (Rudwick, 2005). Thanks to these and other savants (Annigoni, 1987; Cipriani and Scarpellini, 2007), Targioni's fame was well present in the last quarter of his century. Only Desmarest, however, cited him for the geotheory of the *Travels* and the *Forerunner*. Buffon's main mention of Targioni in the *Epochs* (1778) is in relation to the fossil megafauna of the upper Valdarno, espousing the idea that extinct animals were indigenous to Europe ("M. Tozzetti, wise naturalist from Italy, [...] said we can hypothesize that elephants were in ancient times animals indigenous of Europe, and mainly of Tuscany"), whereas Saussure in *Travels inside the Alps* (1779), mentioned the Tuscan savant on the meaning of the word "gabbro".

TUSCANY AS A TEMPLATE

The sparse reference to Targioni's *Travels,* the absence of comments on the *Forerunner* in European literature of the early nineteenth century was counterbalanced in Italy, again thanks to the revealing geometries of Tuscan strata. Giambattista Brocchi, born in 1772 in Bassano del Grappa, belonged to a generation that had not personally met Giovanni Targioni, but was still aware of his fame. Brocchi was eclectic in an eighteenth-century fashion, with qualifications similar to Targioni's, only more systematic: deep knowledge of civil and art history, a career first in mineral prospecting, then on the ordering of paleontological collections, familiarity with zoology and an updated awareness of the cultural importance of geology as the tool to discover the history of the earth. To these many interests he added a methodical approach to the history of science. An example of this is when, during a visit to Ottaviano Targioni in 1818, while the son of Giovanni was ordering his father's natural history collection, Brocchi discovered the herbaria of Andrea Cisalpino, the oldest systematic collection of dried plants known, of which Ottaviano Targioni had heard about in his youth, but could not locate (Moggi, 2008). Brocchi's legacy to the history of science is all contained in the two volumes of the *Subapennine Fossil conchology* (1814), but it is larger than usually thought, judging from the influence this work had on several fields of knowledge (MacCartney, 1976; Pancaldi, 1991; Rudwick, 2005; Eldredge, 2009; Vai, 2009). This is the first large, systematic study of fossil shells in Italy, the same shells celebrated by Boccaccio, Leonardo (to be discovered later in that century: Gould, 1997), Steno and Targioni, and their comparison with fossil shells from other Tertiary strata, mainly those of the Paris basin. The *Conchology* contained the first full and modern account of the geology of Italy, something that deserved him in 1816 a through review by an anonymous generally identified with Leonard Horner, one of the leading Edinburgh geologists, and future father-in-law of Charles Lyell (Rudwick, 2005). Brocchi's focus from the title was on Tertiary deposits, which he did clearly distinguish from the oldest strata that form the backbone of the Apennines. Deposits and fossils overlying the chalk in the Paris basin, studied by Jean-Baptiste Lamarck, Alexandre Brongniart and George Cuvier, could not be separated geometrically from underlying strata since they had conformable relationships. It was thus Brocchi and the circulation of the *Subapennine fossil conchiology* that made known to contemporaries the clear-cut division division of Arduino scheme, at that moment particularly enriched by the recent discovery of the deep change between Secondary and Tertiary faunas made by George Cuvier in Paris, also fully acknowledged by Brocchi (Rudwick, 2005), an under-standing of the history of life that was not available to Steno, Woodward or Targioni. Brocchi had learned much from his own fieldwork in Tuscany through which he could confirm Targioni's (and indirectly Steno's) scheme. On the geological landscape observable from the highest campanile of Volterra he writes in his notebook (13 September, 1811): "A vast open space of ridges like ocean waves, composed of sterile and bare bluish earth (Fig. 1B). The open space includes the hills of San Miniato and all the other hills of the lower Arno valley, which are of the same kind. I previously established the boundaries of this ancient sea bed on the northern side by observing the region from a hill in San Miniato [...] Not all the heights included in the area of this basin are composed of sand or shelly silt. Some are of stratified limestone, and of earlier origin; these were once islands [...] In the Leghorn and Pisan littoral there was an opening through which the Mediterranean Sea invaded and flooded this land" (Pancaldi, 1991). His debt to Targioni and to his work on "the physical constitution of Tuscany" is evident in several pages published in 1814. On Targioni's conceptual framework: "The different position of strata of hills with respect to those of mountains, a condition that Targioni had the merit to stress, proves that they have been uplifted at different times: the calcareous strata of mountains much more inclined, or overturned, whereas those of hills are always horizontal" (p. 66). At another passage he presents Targioni as relying on actual causes more than himself: "Targioni has warned that the top of the hills is at the same level. This does not happen north of the Apennines, and although I agree with him that these strata formed once a continuous and uniform plain, I can't believe that they acquired their present state from the action of rainfall alone, the cause is not proportionate to the effect [...] Much more natural would be to believe that the Ocean has cut his course into this area through the mountains" (p. 80). The *Discourse on the progress of Italian fossil conchology*, the famous historical essay embedded in the *Subapennine fossil conchology* (MacCartney, 1976), contains Brocchi's overall opinion of Targioni's *Travels*: "Among the books on the natural history of one region few match this one for accuracy in observation, multiplicity of scientific arguments, quantity and originality of the views, values much more important since expressed at a time when no other similar model was available" (p. LXI). In the end Brocchi gave full credit to the work and intuitions of Targioni, and missed the chance to make connections with the work of Steno, who Brocchi evaluated only in relation to the organic origin of fossils. Geology or history of conchology, however, were not the main reason of the two volumes, which were principally meant to show the coincidence of 55% of the Tertiary molluscan species of Italy with those now extant in the Mediterranean, against the almost complete extinction of the species described by Lamarck in the Paris basin.

Brocchi was visited at the end of 1816 by William Buckland, one of the founders of British geology and first teacher of Charles Lyell in Oxford, in 1818-1821. Buckland's travels in Italy and other parts of Europe were particularly aimed at understanding the geological evidences of the last revolution in the history of the earth, the universal deluge advocated by George Cuvier as the cause of the most recent large animal extinction. Cuvier himself had complimented Brocchi, whereas in Vienna Constant Prévost and in Paris Alexandre Brongniart were to become even more profoundly influenced by the *Subapennine fossil conchology* (Rudwick, 2005). All eighteenth century visitors of Tuscany belonged to a new generation of geologists. The growing number of fossil findings and the improved practice of comparative anatomy were suggesting to them that Secondary and Tertiary faunas were deeply different (fossils from Primary rocks were soon to show yet another set of former worlds). To Prévost and Brongniart the differences in composition between the fossil shells form the Paris basin and those of central Italy meant that there was an older and a younger Tertiary. The work of Brocchi enriched of a new and profound meaning geological travels to Tuscany, with a shift in focus from stratigraphic geometries to the systematics of fossil shells. Visitors of Tuscany were no longer aware of Brocchi's predecessors, but Volterra was still a must-see, like for Alexandre Brongniart who came here in 1822. When Charles Lyell travelled Tuscany in 1828-1829, thanks to Brocchi's notoriety among savants Tertiary had become the general name used for the interval and its rocks. Lyell's *Principles of geology* (1830-1833), in many points based on the work of Brocchi's, popularized geological historiography and kept the memory of Steno and Targioni alive, albeit in a much reduced form. In the end, the words devised by Arduino to describe strata became enriched of a meaning concerning the history of life. The word Tertiary was definitely used to describe the last long span of geological history only starting with Brocchi, possibly enforced by the clear physical difference of strata visible in Tuscany and other Italian subapennine regions.

CONCLUSIONS

Giovanni Arduino's quadripartition of earth's history has a long connection with Steno's *Forerunner*, published in Florence in 1669. This connection is mediated by another *Forerunner*, written by Giovanni Targioni in the same town, in 1754. Both *Forerunners* were based on field observations of strata and their relationships, together with their fossils, carried out in mountains and hills of Tuscany. Targioni was explicitely inspired by Steno, while both focused on the angular unconformity separating sedimentary strata of the Apennine chain, older and displaced from horizontality, and the younger rocks of the Tuscan hills, rich with shelly remains, usually poorly lithified and horizontal. For both authors the younger strata had formed by the degradation of the older rocks of the Apennines and by the deposition of sediments in a shallow marine environment. Targioni, however, judged that the time necessary for the dismantling of ancient relief by the slow action of actual processes, such as erosion by meteoric waters, was necessarily longer than that accorded by Bible-based chronologies, typically used in Steno's days. Moreover, he recognized that fossils, for example ammonites, were present in older strata too, and that their sedimentary nature pointed to the existence of older relief that were once dismantled, judging from a belief in the constancy of natural laws. Targioni's scheme is therefore richer than Steno's, including at least three sets of rocks, corresponding to epochs. By the addiction of modern sediments forming in modern fluvial plains, this subdivision is conceptually the same devised by Arduino into Primary, Secondary, Tertiary and modern sediments, as acknowledged by its author. Famed among contemporary savants for his *Travels* and his natural history collection, Targioni was visited also by the French savants Nicolas Desmarest and Horace de Saussure, who shared with him an opposition for speculative geotheories and a favour for field observation and mapping of physical properties of the earth. In the ensuing century, Brocchi was aware of the geological importance of Targioni's work in Tuscany, and had a particular interest in the systematic of Tertiary fossils. His *Subapennine fossil conchology* published in 1814 indirectly brought once again Tuscan stratal relationships to the attention of European geologists. The word Tertiary by that time was enriched of a profound and new historical meaning that was not available to Steno and Targioni. Anatomical comparisons of fossils had revealed to geologists and philosophers that a different fauna had inhabited the world before the Tertiary, one dominated by reptiles. For eighteenth century geologists, pre-human time had rapidly expanded under the growing number of sound empirical investigation, in the fashion pioneered by Targioni and Desmarest, and as described in Saussure's agenda. A subdivision of pre-human history based on stratal geometric relationships at one particular sector of the earth, Tuscany, roughly coincided with a change in the history of life that struck early eighteenth century geologists. Brocchi's work on fossils spread the use of the word Tertiary to define the last long stretch of pre-human history, indirectly trading Steno's and Targioni's geotheories.

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