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MATRICES, NOT SEEDS. VALLISNERI'S RESEARCH ON MINES: BETWEEN EMPIRICISM AND PHILOSOPHY

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Abstract. Since the beginning of his scientific activity the physician and naturalist Antonio Vallisneri (1661-1730) devoted many studies to the Earth sciences. In those years his interest focused particularly on the features of mineral kingdom and its relationship with spring water. The first observations date back to the last decade of XVII century, when the author analysed the gypsum and sulphur veins on the Monte Gesso, in the Duchy of Modena and Reggio.
Some years later, during one of his journeys across the northern Apennines in search for the origin of springs, Vallisneri reached the Este domain of Garfagnana. There he explored the iron caves of Fornovolasco: this experience allowed him to support his theory with many empirical information, later exposed in the *Lezione Accademica intorno all'Origine delle Fontane* (1715).
The many data collected by Vallisneri encouraged him to outline a theoretical interpretation of mineral genesis. He supposed the mineral veins as developed by 'seeds' released in the Earth by God. The successful growth of ore veins, therefore, depended on the more or less favourable environment they would have found by accident. These 'seeds', as the author clarified, were not intended to be the very same of 'perfect germs of generation' typical of animals or plants. Rather, they were 'matrices' that had to be detected in order to exploit the wealth of mines posed, in a proper Leibnizian conception, 'by God for world's use'.

1. INTRODUCTION

In 1687, after he studied medicine at Bologna University, young Antonio Vallisneri (1661-1730) returned in his homeland, the Duchy of Modena and Reggio, where he began to serve as general practitioner in Scandiano and Luzzara. Since these early days Vallisneri devoted his pastime to various sorts of scientific subjects ('bright studies', as he called them). He accurately reported these experiences in his *Quaderni di osservazioni* (Vallisneri, 2004): naturalistic diaries in which the author proved his skill in different experimental fields like entomology, microscopy, botany and, of course, medicine.

A small, but significant part of the *Quaderni* was filled with Earth sciences related notes. The author reserved a keen interest for the gypsum and sulphur veins recently discovered on the Monte Gesso (Fig. 1): a mountain located in the gypsum-sulphur formation typical of the northern borders of the Apennines, whose thick evaporitic strata result from the Messinian salinity crisis occurred in the late Miocene epoch. In a first,

Figure 1. A gypsum outcrop on Monte Gesso (Albinea, Reggio Emilia, Italy). Picture by Stefano Meloni.

Figure 2. A detail of the gypsum outctrop on Monte Gesso (Albinea, Reggio Emilia, Italy). Picture by Stefano Meloni.

remarkable note, dated November 1691, Vallisneri reported the new finding and the prompt economic concern shown by the authorities:

«It has been discovered in our Monte Gesso a new sulphur vein, that once tested has resulted to be of a greater perfection than the commonly sold kind. The Most Serene Prince ordered to bring here a certain Mr. Raggi from Romagna, in order to work and to discover the mine, but nothing has been revealed yet» (Vallisneri, 2004, p. 35).

2. IN THE FIELD

Vallisneri carefully studied the Monte Gesso, collecting many specimens and precious information about several features of the rocks (Fig. 2). He also analysed the surrounding geological context, not even despising to explore some of the caves near to the mountain. In May 1694 he discovered in a cavern «a dark and chilly site», where he saw a spring whose «most clear and cool water» was «rejected by the beasts». He tasted it, and found it was extremely bitter. This peculiarity was to him a proof of the underground presence of gypsum:

«The origin [of the bitterness] is not a mistery, being the mountain entirely made by gypsum. The spring likely passes between chalky stones, whose bitter particles soak in the water. Perhaps the underground heat or the sulphur itself calcined them, so that they are partially dissolved, and washed away by the flow» (Vallisneri, 2004, p. 42).

In this brief account it is already possible to detect a tendency, characteristic of Vallisneri's experimental practice, to take into great consideration the existing relationship between two or more analysed phenomena in the same environment. As a matter of fact, the connection between the research on springs and the study of minerals was not a case apart in Vallisneri's scientific activity. In 1700, after the author had obtained the chair of practical medicine in the University of Padua, he came to be deeply interested in the polemic on the origin of freshwater. The dominant theory in those years, which derived from the Cartesian assumption of *alembics,* considered the springs as originated from seawater after a process of filtration through rock strata. The data previously collected on the field and the correspondence with Diacinto Cestoni (1637-1718), a skilled apothecary from Leghorn (Cestoni, 1940, pp. 83, 84-85, 95-96, 344; 1941, pp. 462, 463, 467-468, 469, 577, 704,

707, 710, 711, 783), persuaded Vallisneri that all the freshwater came from rain or from the melting of glaciers on the mountains. Consequently, he firmly opposed the *alembics* belief (Generali, 2007, pp. 326-331). To prove his theory by experimental means, he devoted himself to perform various journeys in the Apennines, collecting many useful pieces of information. The most important of these field trips was the one he made in the summer of 1704, when he leaved the first hills south to Reggio Emilia and reached the Tuscan region of Garfagnana. The report of this adventure (Vallisneri, 1705), a key experience for Vallisneri's research in the field of Earth Sciences, was written in Latin. A copy of the manuscript was sent to the Royal Society, although remaining unpublished. Two decades later a synthesis in Italian was published in two tranches – *Estratto d'alcune Notizie intorno alla Provincia della Garfagnana* and *Continuazione dell'Estratto d'alcune Notizie intorno alla Garfagnana,* in 1722 and in 1726 – on the «Supplementi al Giornale de' letterati d'Italia». Though from the writing style it appears that these published texts were composed by Vallisneri himself (Generali, 2004, pp. 155-156, 176-177; Vallisneri, 2006, pp. 872, 895), the authorship was officially attributed to Giambattista Perrucchini, one of his pupils. Vallisneri often adopted this strategy, in order to better defend himself against potential criticisms (Generali, 2007, pp. 383-412).

In the account it can be noticed a constant attention both to the hydrological and mineralogical features of the mountains. A clear example of this tendency is the first reported observation, concerning, once more, the Monte Gesso and the sulphur mine (now exploited) that had been finally discovered «west of it, about one mile [from the city of] Scandiano» (Vallisneri, 1722, p. 279). The mine itself had been revealed by means of water, passing the little river Tresinaro so close to the mountain that «by eroding from side to side, it dragged along with stones, clays and gravels also pieces of pure sulphur, that once observed […] gave opportunity to search for the place from where they arose» (Vallisneri, 1705). According to a marginal note written in Italian and contained in the original —and ferociously reworked— Latin manuscript, the wealth of the mine was far from negligible. The single river carried enough sulphur to be used «by poor people» for the production of matches to be sold. Once discovered, then, the ore vein was so abundant to satisfy all the near cities. Neither the quarries were small in size, being wide enough to let the work of two standing men «with their tools to carry out the extracted mineral». Two were the pits «made by art» (Vallisneri, 1705); they were interconnecting, in order to enable the required air passage.

It is worth of notice an observation made [by the author] on the alignment of pure sulphur layers, being them wedged in the mine's clay beyond the clods [with the mineral] that are found hither and yon in various sizes. The first [layers] are like trees with the tops and the branches tending down, and the more water seeps and drips from above, the more they flourish; which [data] more and more confirm that all the water in the mines, and in the springs comes from rain and from melt snow (Vallisneri, 1722, pp. 279-280).

Once reported the exploration of the sulphur pit, the account goes on describing the rest of Vallisneri's voyage. The author moved south and crossed the valleys of river Dolo and Dragone, where he noticed many specimens of marcasite and other «apparent clues of hidden mines». Having at last passed the «hard yoke of Apennines» (Vallisneri, 1722, pp. 286-293), he came in the valley of Garfagnana: an Este enclave in Tuscan territory. There he met Domenico de' Corradi D'Austria (1677-1756), chief superintendent of artillery on behalf of the Duke. As an expert miner, he led Vallisneri in the iron caves of Fornovolasco (Fig. 3, 4), allowing him to support his theory with conclusive empirical information:

«Entering into the mines, or into the caves in the mountains, for those who examine properly it is always possible to see water falling from above, or following on a slope the path of the *cinghioni,* or layers. I have made repeatedly this observation in various pits, […] and especially in the sulphur ones in Scandiano, and in the iron and vitriol ones, […] in the land called *Forno Volastro.*

[…] I have always observed that, even if sometimes water seems to stream from the bottom of the mines,

Figure 3. Entrance of an iron mine in Fornovolasco, Garfagnana (Lucca, Italy).

Figure 4. Waste matter in the iron mines. Fornovolasco, Garfagnana (Lucca, Italy).

nonetheless those who will look very well will see under it [the bottom] a bed of stone, or *marga*, that prevents [the water] from falling further, and the other upper layers will be otherwise placed, or splitted, or fractured» (Vallisneri, 1715, p. 46).

Corradi's practical experience was regarded with great esteem by Vallisneri, being the Paduan professor a proud advocate of the «philosophical candour» of empiricism against the speculative assumptions of those labelled by him as «long bearded, and not short gowned men» (Vallisneri, 1706). This polemical approach was preserved by the author when, after having arranged the many collected data in a consistent theory, he published the *Lezione Accademica intorno all'Origine delle Fontane* (Vallisneri, 1715). In this treatise he proved the origin of springs to result from rain and melting glaciers; at the same time, he confuted the existence of filtering devices to convert salt water into freshwater. The centerpiece of the thesis, of course, was the vast mass of experimental information collected by the author (and by some reliable observers, as in this case, Corradi).

The *Lezione Accademica* was dedicated to the great mining expert Luigi Ferdinando Marsili (1658-1730). Ironically, this nobleman, who had an experience in mineral research and in cave exploration far greater than the one possessed by Vallisneri, was in part a supporter of the Cartesian theory of *alembics.* Nevertheless, the author was a sincere admirer of Marsili's knowledge and of his renowned mineral collection, as shown by the correspondence (Vaccari, 2003; 2008). In a letter dated 10 January 1705 Vallisneri informed Marsili of his interest in mineral kingdom, and prayed him to send some specimen from his rich museum. He also asked Marsili for some information on the water in mines, showing to count on him as an authority in Earth Sciences:

«[…] in this [subject] I know there is no man who can enlighten me more than Your Lordship, […] in fact you had the opportunity to satisfy your hunger for sure information in the wealthy mines of Hungary […] I therefore beg you for the time being to give me two data: if you have observed in all the mines some streams or springs, and the second, if you believe that all the springs come from rain, or snow, or both from these and from the sea» (Vallisneri, 1991, p. 282).

Marsili's judgment, with regard to the second question, leaned toward the thesis of compound origin of freshwater. This disagreement with Vallisneri, anyway, did not prevent the two naturalists from being on good terms.

Vallisneri's interest in minerals did not fade in the following years. He made other observations in the Emilian mines, also paying special attention to the techniques employed by workers to extract gypsum and sulphur.

These studies were later published in 1728 in the *Raccolta di varie Osservazioni, Spettanti all'Istoria Medica, e Naturale.* From these detailed accounts it appears that the mine industry was well tested and properly organised. The miners at first made holes in the mountain by means of drills, then filled up the cavities with explosive («rifle powder»). Once this operation was complete, the holes were sealed with «diluted gypsum» and a little fissure was left to put the fuse in; after the explosion they broke the biggest pieces with iron mallets, «in order to carry them easily to the kilns». There the gypsum was calcined and prepared «in just 24 hours of fire» (Vallisneri, 1728, pp. 138-139).

3. ON THE GROWTH OF MINERALS

Through the works of Dario Generali (1987; 2002, pp. 70-72), modern historiography has shown that Vallisneri, despite his claim for the preeminence of experimentalism over speculation, made empiricism coexist with philosophy. From a substantial adherence to the Cartesian principles during his early years of activity, and being later attracted by Nicolas Malebranche's thought, the author came at last to be deeply influenced by Leibniz's philosophy, whose theories he learned from his correspondence with Louis Bourguet (1678-1742). He also read himself some of the most important books of the German author, as, for instance, the *Théodicée* (Leibniz, 1710). The doctrines of *scala naturae* and of the recognition of divine providence in the creation significantly affected his research; the studies on Earth sciences were not an exception, as it is to be presumed. The many data collected in more than two decades of activity encouraged him to outline a theoretical interpretation of mineral genesis that he disclosed in a letter to his friend Louis Bourguet in the summer of 1721. The naturalist had observed in some mines near to Bern many stones mixed with «grains of salt», and «crystallized salt» (halite, probably) between stone layers. To Vallisneri, these findings were 'seeds' of minerals evenly released in the Earth by the Creator. The successful growth of ore veins, therefore, depended on the more or less favourable environment they would have found by accident:

«[…] where [the seeds] have found the proper conditions, they have multiplied, and on the contrary, where they have not found [the conditions], they have remained as simple traces […] *Omnia in omnibus,* said a great philosopher. In the mountains we can find every kind of mine, but a rich one here, a poor one there, elsewhere one so narrow that the traces are barely visible. Consider the example of gold, silver and other metals mines. In Italy we have them all, but due to the lack of a proper nourishment, they neither multiply, nor bear fruit, and we barely get a glimpse of their first seeds, or vestiges. The same we see to happen to plants or animals, that in a place reproduce, in another become infertile, because of the climate, or of the nutrition, etc.» (Vallisneri, 2006, p. 668).

This theory did not arouse enthusiasm in Bourguet, who firmly refused the supposition that minerals would need a sort of nourishment. He clearly expressed his opinion in October of the same year:

«I can't recognize the great genius of my beloved Mr Vallisneri, in your discourse on the minerals dropped like seeds of the mines in the mountains; […] a superstition of chemists, who want to turn the mineral kingdom into plants! And this [belief] is so bogged down in their brains, that it is almost impossible to uproot it even from the minds of the wisest among them. Minerals that need nourishment to feed and grow. For God's sake! It is a great paradox to those who understand the natural science!» (Bourguet, 1721).

Bourguet insisted on one point in particular: if not supported by «physical, and mechanical experiences», these hypotheses were nothing more than «vain suppositions» (Bourguet, 1721). Vallisneri was not indifferent to these words. Replying to his friend, he tried to refine his theory, justifying it on the basis of its adherence to the Leibnizian principle of harmony. The 'seeds', he clarified, were not intended to be the very same of «perfect

germs of generation» typical of animals or plants. Rather, they were 'matrices' («having no more expressive definitions», as he wrote). Boyle and Agricola stated that an exploited mine, exposed to air for many years, would fill again with minerals. This phenomenon, anyway, happened only in those lands provided with 'matrices' that, once nourished, would bear new fruit.

«You know that nature procreates and produces in a consistent order, gradually improving [the creation] up to man. We see that all the reproducing and growing beings have their own seed, or matrix; therefore, we see that it remains valid also for minerals, that grow and multiply inside and outside of the mines. The result is the same, thus the cause must be the same, or at least analogous, unless the greater or less perfection» (Vallisneri, 2006, p. 738).

This clarification by the author, probably, answered to the need to make a clear distinction between his thought and the 'theories of seeds' supported by many Neoplatonic scholars in the sixteenth and seventeenth centuries (Norris, 2009; Oldroyd, 1996, pp. 7-41; Rudwick, 1972, pp. 1-45). Whatever was Vallisneri's purpose, Bourguet's answer, one more time, was sharp and far from ambiguous: the belief that a mine deprived of its ore veins would refill after some time was «absolutely false». What Boyle and Agricola observed were nothing else but residual «metallic particles» that had remained in the quarries. Neither the chemists, nor the philosophers of good sense had to use terms like 'seeds' and 'generation' to explain the growth of minerals. They were equivocal words, that had «nothing in common with the real meaning» (Bourguet, 1722).

4. CONCLUSIONS

The opinion expressed by his friend Bourguet most likely had a deep influence on Vallisneri. Still remaining a faithful advocate of the Leibnizian principle of scala naturae, the Paduan professor concisely exposed his thought on 'matrices' in the *Continuazione dell'Estratto* (Vallisneri, 1726, pp. 395-396). Nevertheless, except for this paper – that, perhaps not by chance, he ascribed to Perrucchini – after 1722 he did not seem to persist in supporting his theory on mineral genesis and growth. A major role in his choice was probably played by the lack of empirical verification of this hypothesis: being him an earnest experimentalist, Vallisneri could not honestly defend arguments with no objective proof. As in other circumstances involving the study of natural phenomena, he seemed to be more at ease with experimental activity than with philosophical elaboration (Monti, 2008; 2009). Anyway, these two facets constantly influenced the evolution of Vallisneri's thought. Far from being mutually exclusive, solid science and philosophy interacted in this author, and in many cases allowed him to work on theories strong enough to prevail on rival theoretical systems. Despite its result and its marginal importance in the vast mass of the works devoted by Vallisneri to the Earth sciences, the study on the origin and growth of minerals is emblematic of this attitude.

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