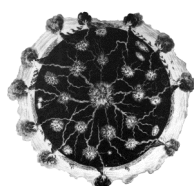


TWO LETTERS OF SIGNOR GIOVANNI ARDUINO, CONCERNING HIS NATURAL OBSERVATIONS: FIRST FULL ENGLISH TRANSLATION. PART 1

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ABSTRACT

Giovanni Arduino is renowned for his introduction of a fourfold subdivision of the Earth's strata, as described by him in two letters to his friend Luigi Vallisnieri in 1759 (published in 1760). In this, and a follow-up paper, the first full English translations of these letters are provided. Also his famous profile of strata on the sides of Valdagno is reproduced here, with a translation of its accompanying annotations. The first letter described Arduino's fieldwork in 1758 in some detail. He seems to have been concentrating on the chemical and physical characteristics of the rocks that he had examined but did not offer a lithostratigraphy for the mountains. The second letter took a different approach, providing his fourfold subdivision.

1. INTRODUCTION

The chronological division of the strata of the Earth's crust into stratigraphic units is an instrument as fundamental to geology as the principles of superposition. The first major step towards subdivision was published by the Italian mining engineer, mineralogist,¹ and surveyor, Giovanni Arduino (1714–1795) in 1760, when he proposed a fourfold subdivision for strata in northeast Italy. Yet as with so many indispensable ideas, this step is often taken for granted and its origins forgotten. This is unfortunate, as the circumstances surrounding Arduino's proposal reflect a change that was remarkable not only for its profundity but also for its apparent spontaneity, proposing a solution to a problem that had persisted for many centuries—namely how to classify and (hence) think about the Earth's rocks and strata.

For most of the time that humans sought to interpret the world around them scientifically, from Pliny the Elder to the Enlightenment, there was no general system for the chronological ordering of rocks. It was evident that many rocks existed in layers that in some manner represented the progressive development of the Earth's surface, but generalisations about the relative ages of rocks were difficult to formulate, apart from the simple notion that the younger

¹ I have designated Arduino's work as 'mineralogy' since that is the term he himself used most often (*mineralogia*), deriving from his interest in the properties and chemical interactions of distinct mineral substances. At the same time, Arduino also reflected seriously on fossils and rock types, but did not differentiate between these activities with consistent terminology: for him 'mineralogy' sufficed for the whole. Nevertheless, he did occasionally use the term 'geology', a usage which, though uncommon at the time, has a particular historical significance. While it has been argued that the term 'geology' acquired its modern application only in the late eighteenth/early nineteenth century, the fact is that it had been in use, even if only occasionally, for some two centuries before that. Its precise meaning may have varied but the word did at least exist, and was generally understood to mean 'scientific consideration of the Earth', which is certainly the sense in which Arduino used it. The earliest recorded use of the term 'geology' is claimed to have occurred in 1603, in the will of the Bolognese physician and naturalist Ulisse Aldrovandi (see Vai 2003), and it is interesting to note that the term appeared at the opening of Arduino's first letter to Vallisnieri. In Arduino's case, 'geology' appears to have been synonymous with the notion of a 'Theory of the Earth', or the formulation of a system to explain the Earth's development and present constitution by natural causes (see Vaccari 1993). 'Geological' thinking, as it related to Arduino's work, will be discussed further in the introduction to the translation of the second of Arduino's letters, in the next issue of this journal.

ones lay above the older ones. Every site examined had its own local variations and anomalies: rocks at the bottom of one set of strata could appear at the top of another set in the same region; rocks from one country seemingly differed entirely from those of another with comparable terrain; attempts at reasoning out the history of a mountain chain could fall apart when its component materials began to display completely new characteristics half-way along. In short, it did not seem possible to develop a coherent pattern that could relate the myriads of strata, or reveal some generalisation that governed the almost infinite variations visible across the surface of the Earth.

The broad subdivisions of the Earth's strata may appear fairly obvious today but they are in fact relatively recent in origin and were only enunciated in the mid-eighteenth century (and even then in a form that has not survived unscathed to the present). What is more, despite the considerable quantities of information accumulated before 1760 by scholars through painstaking chemical experimentation and analysis, the idea of classifying strata into four basic chronological units eventually came from outside the structure of a learned institution. The concept grew from one man's contemplation of how the characteristic properties of certain kinds of rock might be related to their physical situations in and on the Earth, based on personal observations in different regions of Italy and the Alps, and work conducted as much below the Earth's surface as above it. It was based on a knowledge of multiple terrains, practical experience with the properties of different materials, and an eye for the magnitude and complexity of terrestrial processes in order to perceive the basic patterns that governed the arrangement of strata and the formation of landscapes.

These were the qualities that distinguished Giovanni Arduino, whose expertise in mineralogy and metallurgy was in constant demand at foundries, quarries and mines all over northern and central Italy for much of the eighteenth century. Arduino's other notable attributes were his seemingly limitless energy in fieldwork and chemical experimentation and his enthusiasm for discussing his findings with members of learned academies—in short, engaging in mineralogical inquiry for its own sake and making known his ideas to the public. It was Arduino's reasoning in the years 1758 and 1759, after his work in parts of Tuscany and the Italian Alps, that enabled him to demonstrate that there was a pattern amongst all the seemingly jumbled features that had eluded observers before him, and led to his delineation of four distinct stratigraphic orders (which he called *ordini* from the outset), which still survive in the system in use today, albeit greatly elaborated and modified.

Following extensive fieldwork in the Italian Prealps in 1758 (and much previous work elsewhere) Arduino recounted his observations and proposed his stratigraphic system in January and March 1759, in a pair of letters to the respected professor Antonio Vallisneri (1708–1777)² of the University of Padua, who published them for Arduino in 1760 in the periodical *Nuova raccolta d'opuscoli scientifici e filologici*.³ Their significance and value were quickly recognised but the very speed of the acceptance of Arduino's proposed generalisation and the circumstances of the system's publication may perhaps explain why his contribution to geology is, even now, rather little understood outside Italy. The lack of an English translation may also be a contributing factor.

The fact that Arduino's system was published not as a treatise but in its original epistolary form, embedded in his account of how it was derived, rather than being set forth as 'pure argument', meant that scholars wishing to understand his proposed stratigraphic classification had to disentangle the principle from a large body of narrative and description. This was the case for the main agent in disseminating Arduino's ideas outside Italy, the peripatetic Swedish mineralogist Johann Jakob Ferber (1743–1790), who, rather than reproducing the 1760 text of the letters wholesale, in 1773 synthesised Arduino's proposal of the four orders in his own words, in a German-language text that was then partly translated into

² Also sometimes written as Vallisneri.

³ *New Collection of Short Scientific and Philological Works*.

French and English, and thus made accessible to the majority of European mineralogists.⁴ Ferber, of course, acknowledged Arduino as the originator of the system of four orders, but in presenting it in this ‘second-hand’ way he also unintentionally kept Arduino rather on the margins of his own work. In effect, in being synthesised into a straightforward and readily memorised scientific generalisation, the four orders left the story of their origins behind; those origins, as shall be noted, are described only in a few highly specialised settings. Indeed, the discarding of the letters themselves in favour of just one aspect of their contents was so complete that they have never been reprinted, either in Italian or any other language. In modern times, small portions were translated into English as part of an appraisal by Ezio Vaccari of Arduino’s wider contribution to geology (Vaccari 2006, pp. 162–164), but those wishing to read the letters in full still have to consult the 1760 edition.⁵

One of the most unfortunate consequences of the letters’ obscurity has been some misunderstanding of exactly what Arduino proposed, with the notions of Primary, Secondary, Tertiary and Quaternary strata sometimes all being attributed to him. In fact today’s Quaternary was not a concept of Arduino’s and indeed was not even specifically named by him. Rather, the Quaternary was first proposed by Jules Desnoyers (1801–1887) in 1829 after a survey of deposits in the Seine basin that he deemed to be younger than and distinct from the underlying Tertiary strata, and which further examination showed to be consistent with similar outcrops elsewhere in the world. Desnoyers, however, later relinquished the term ‘Quaternary’, believing that its existence as a distinct stratigraphical unit was being overstated, and it was not until 1833 that Henri Reboul (1763–1839) defined the Quaternary in the sense that has come through to modern times.⁶ It was Arduino, however, who made this distinction possible, because he had laid the conceptual foundations. The Primary, Secondary (subsequently divided into Palaeozoic and Mesozoic⁷), and Tertiary orders were initiated by him; and while his ‘fourth Order’ was only described relatively briefly the second letter of 1759 and the credit for its formal introduction (as Quaternary) should really rest with Desnoyers and Reboul. However, the fact that Arduino made provisions for a fourth order perhaps paved the way for the later men’s suggestions. That is, Arduino’s projected fourth order allowed Desnoyers’ and Reboul’s Quaternary to fit well with an already established system.

The initial relegation of Arduino’s letters to incidental status and inaccessibility has also meant that they have been further hidden from geologists by language. Ferber’s summary in 1773 and Vaccari’s more recent English translation of a few passages were welcome, but the two famous letters remain unknown ‘first-hand’ to most geologists, and probably to many historians of geology also, despite their contents being generally accepted. The letters are mentioned in the well-known English-language history of the development of the geological time-scale—William B. N. Berry’s *Growth of a Prehistoric Time Scale Based on Organic Evolution*⁸—but only briefly, as Berry’s account was limited to outlining the bases of the four orders, leaving aside the nature and circumstances of their appearance in the literature. The letters are, understandably, slightly better known to geologists in Italy and the circumstances of their origins are described comprehensively in Vaccari’s important biography of Arduino.⁹ However, since this, too, is available only in Italian, it may be helpful to summarise the main points here.¹⁰

⁴ See Ferber (1773) and Vaccari (1993, pp. 232–234).

⁵ More of Arduino’s correspondence has been published recently by Vaccari, and is reviewed in the present issue of *Earth Sciences History* by Gian Battista Vai (ed.).

⁶ See Desnoyers (1829); Reboul (1833); Gibbard and Head (2010).

⁷ But see the discussion of Letter 2, forthcoming.

⁸ Berry (1968, pp. 33–34 and 64–65).

⁹ Vaccari (1993).

¹⁰ Readers with knowledge of Italian will find most of what is summarised here between pages 78 and 82 of Vaccari (1993).

Arduino and Vallisnieri probably became acquainted through having lived and worked in neighbouring districts near the city of Modena¹¹ in the 1750s, Vallisnieri at a family retreat at Scandiano¹² and Arduino at neighbouring Sassuolo,¹³ where he spent a short time carrying out metallurgical experiments. Just what brought about their first meeting is not known, but it is certain that their shared enthusiasm for mineralogy and their combined knowledge of a vast array of sites and mineral substances soon led to a strong personal friendship between the two men. Vallisnieri's father had himself been an eminent mineralogist and collector of rock specimens.¹⁴ On his father's death, the younger Vallisnieri donated the collection to the University of Padua, an act of philanthropy that earned him a personal chair and the curatorship of the collection itself, which became open for inspection both by scholars and by the public. At the time of his acquaintance with Vallisnieri, Arduino was not associated with any particular seat of learning, but was in the midst of an extremely busy engineering career that all but required him to be everywhere at once. He had spent much time in Tuscany, overseeing mineral works in all kinds of terrain, from foundries near Siena¹⁵ to marble quarries high in the Apennines above Massa and Carrara.¹⁶ Subsequent to meeting Vallisnieri, Arduino took up a civil engineering post in Vicenza,¹⁷ near his native Verona, which required him to make supervisory visits to mines and earthworks all over the Veneto,¹⁸ from its fertile river flats and foothills to the highest reaches of the Alps. Arduino was also engaged to venture further north and provide advice on certain mines in Germany. Despite the demands of his employment, Arduino never lost his curiosity for geological surveying and experimenting with mineral samples, and he kept up these pursuits in his spare moments, energetically clambering up ravines and mountain peaks and spending days on end exploring caves.

These contrasting characters—the distinguished curator tied to Padua by his analysis and cataloguing, and the engineer ranging widely through the different geological terrains of northern Italy—enjoyed a collegial relationship in which the work of each man was indispensable to the other. Vallisnieri relied on the peripatetic Arduino to describe and supply samples of the mineral substances he encountered in the field, while Arduino found a learned companion with whom he could share mineralogical discoveries and ideas that he believed could be significant, which otherwise he had little opportunity to discuss. In short, Arduino and Vallisnieri established a connection that ensured that any fortuitous discovery or realisation could be exploited; and this was precisely what happened in the case of Arduino's concept of *ordini*, the significance of which Vallisnieri apparently recognised immediately and quickly published.

It was in response to Vallisnieri's request for news of some surveys in a particular part of the Italian Alps—the district of Recoaro¹⁹ in the Veneto—that Arduino wrote the two letters that

¹¹ Modena is situated just north of the Apennines, on the southern edge of the Po plain, in the region known today as Emilia-Romagna.

¹² Scandiano is a locality some 30 km southwest of Modena, on the lower northern slopes of the Apennines.

¹³ Sassuolo is about 10 km to the east of Scandiano.

¹⁴ See Luzzini (2011, pp. 105–112). Interestingly, this exposition of some of the elder Vallisnieri's inquiries suggests that his character and interests were very similar to Arduino's, especially concerning fieldwork and exploration.

¹⁵ Siena is located in central Tuscany, in the fertile hilly region known as Chianti, some 250 km north of Rome.

¹⁶ Massa and Carrara are towns neighbouring each other in the far north-west of Tuscany, close to the western coast of Italy and the Tyrrhenian Sea. Both towns sit at the feet of a particularly high and precipitous stretch of the Apennines known as the Apuane Alps, and are renowned for the high-quality marbles that are quarried and worked there.

¹⁷ Vicenza, a small but affluent city of the Veneto, is approximately half way between Venice and Verona, about 60 km from each.

¹⁸ The Veneto lies in the far northeastern corner of Italy, forming most of the large bight at the northern end of the Adriatic Sea; it is some 500 km north of Rome. The Veneto contains some of the most fertile and varied terrain in Italy, with the flat, marshy plain of the Po Delta in its southern part, the Venice lagoon in the east and the rich foothills of the Alps in the north. The Dolomites form part of its border with the neighbouring mountainous region of Trentino–Alto Adige (of which Trent is the capital). In Arduino's time, that region was known as the Tyrol and was a possession of the Austro-Hungarian Empire.

¹⁹ Recoaro—known today as Recoaro Terme—is some 40 km north of Verona.

are of interest here in 1759. Among their most noticeable characteristics was their concision. There is little by way of ornately rhetorical flourish in Arduino's language (not even in his opening greetings to his illustrious correspondent, which are gracious but do not rely on great length to be sincere). Such stylistic restraint was unusual for an Italian scholar of the period, but it is understandable given the friendliness and relative informality of the letters, and it certainly does not reflect any kind of reserve in Arduino's character. In fact, the reverse is the case: his concision was a result of his enthusiastic wish to come to the point and describe a large body of findings as vividly as possible. His language reveals that he had an acute eye for detail and a particular flair for rendering in words the character of unusual features of the landscape.

The contents of the two letters, however, do not parallel the consistency of their vivid style. Despite sharing much subject matter, there is little methodological connection between them. The first letter is a comprehensive account of Arduino's observations, experiments, reasoning and conclusions concerning his survey of the Recoaro region, but there is little sense of how these investigations might establish any kind of systematic relationship between the minerals and strata he had encountered. Then the second letter puts forward the concept of the four orders, derived from observations similar to those described in the first letter, but governed by reasoning so elegant and lucid that even Arduino himself admitted to feeling surprised! It is as if the difference between the two letters manifests a profound change that the concept of the four orders ushered in. The first letter shows a man relying on old methods—drawing conclusions from observations of individual minerals and local strata but unable to relate one discovery to another. By contrast, the second letter reveals a fresh approach to the classification of the rocks of the Earth's surface: ordered, unified, eminently sensible, and encouraged by the potentialities that might now lie ahead.

It is essential, however, to understand that this unexpected difference does not represent some kind of epiphany. Between January and March 1759 the scales did not fall suddenly from Arduino's eyes! In reality, the idea of separate orders of strata had evidently been developing in Arduino's mind for some time. This fact is revealed by the only other known document that elaborates Arduino's system to any extent: a stratigraphic profile that he made by hand immediately after the Recoaro survey, in November 1758. A copy of this quite well-known diagram and a translation of its accompanying notes are presented in Section 2.

The diagram consists of a cross-section of the hills to the east of the Valle dell'Agno (Valdagno), the narrow river valley running southwest through the Veneto Prealps towards the Adige River (and thence the Adriatic) from Recoaro to Montecchio Maggiore. No fewer than sixteen distinct sets of strata are identified, each labelled alphabetically and described in what Arduino clearly interpreted as their chronological sequence. The Valdagno is more than twenty kilometres in length—and Arduino's subdivision of it is both detailed and confident. In itself, however, the diagram does not represent a theoretical innovation. As impressive as the diagram may be, there was nothing fundamentally different to distinguish it from other contemporary interpretations of a local collection of strata; the sequence that Arduino identified, moving upwards from oldest to youngest, was merely in keeping with Steno's principle of superposition, which had stood as received wisdom for nearly a century.²⁰

The true novelty of Arduino's diagram derives from one detail: his nomination of the oldest (visible) strata, *Schiefferstein* [schist], which he labels 'A'. His description reads thus: '*Questa è quella Pietra che, per essere sempre sotto a tutte l'altre, e²¹ la Base visibile delle montagne minerali, e per trovarsi in tante parti del mondo sempre simile di natura e d'accidenti, si può sola dire propriamente primitiva*' ('This is Rock that, always underlying all others, is the visible Base of mineral mountains [*montagne minerali*], being found in many parts of the world always having the same nature and peculiarities, can only properly be called primitive [*primitiva*]'). This statement is the first evidence that Arduino's extensive practical experience had led him to perceive unifying trends in different environments. He had found, he

²⁰ Steno (1669).

²¹ This is the third-person singular conjugation of the verb 'to be' (*essere*), and should be accented thus, *è*.

believed, the rock that underlay all others, and to classify it as such, in relation to its neighbouring strata, was a bold step. Bolder still was the terminology he used to distinguish it—the word ‘primitive’. This is, of course, vague in comparison to today’s technical terminology, and in fact at the time the term was by no means free from problems. In the theories of Descartes and Leibniz, ‘primitive’ rocks were those first formed as the *primaeval* Earth cooled. Moreover, in his letters of 1759, Arduino used the term rather inconsistently, interchanging it apparently randomly with the word ‘primary’. Nevertheless, the word’s appearance here is highly significant, as it suggests that Arduino had already begun to formulate his own notion of what constituted Primary, original, old rock—which presupposed at least one further Secondary, subsequent, younger layer, from which it had to be distinguished. Arduino did not articulate his system any more explicitly in this diagram. There is no mention of what the presupposed Secondary strata might be, nor any hint of the third and fourth orders he would soon propose to Vallisnieri. It is possible that other documents exist that do reveal how Arduino drafted the rest of his system, but, to my knowledge, any such materials have not yet been discovered. Despite that uncertainty, the one ‘primitive’ denomination in the diagram of 1758 counts for a great deal, because it represents the basis from which, in accordance with the principle of superposition, the other upper or overlying orders of strata could be delineated and designated. To read Arduino’s diagram of 1758, in its confident movement upwards from layer ‘A’ to layer ‘R’, is to follow a clear interpretation of a sequence of strata grounded on an understanding of relative ages. On the other hand, as will be seen in the second of the present pair of papers, the terms ‘primary’ and ‘primitive’ were ‘slippery’ for at times Arduino also mentioned a ‘*primogenial*’/‘*primaeval*’/‘*primordial*’ rock that underlay the ‘primary’ or ‘primitive’.

Be this as it may, it appears that the length of time between the conception of a system of *ordini* and its articulation in the second letter was little more than five months. Arduino made his survey at Recoaro in October 1758, responded to Vallisnieri’s request for news of the survey with the first letter in January 1759, and concluded that news with the proposal of his system in March that same year. During that period, Arduino was as busy as ever with his official duties at Vicenza, and it appears that his correspondence with Vallisnieri was his only chance to set out his ideas in any degree of detail. The spontaneity and concision of the system’s appearance in the second letter are the results of Arduino’s eagerness to take advantage of that opportunity. And while the exact origin of the orders is a matter of some uncertainty, though it was obviously related to his fieldwork of 1758, it is certain that by March 1759 Arduino had confidence in his classification and publication followed in 1760.

The difference between the two letters is nonetheless strongly evident and this, quite apart from the question of space, warrants publishing the translations of the two letters separately. They are mutually indispensable, particularly as the second often refers back to the first, but they deserve their own individual shares of attention. In this first letter we find all the makings of Arduino’s great generalisation, both in the form of the results of his observations and the demonstration of his keen perception and reasoning, with only the barest hint—in the final paragraph—that Arduino had in mind something that could give the whole subject a new shape and meaning. This first letter also gives us a clear conception of Arduino the man—climbing mountains as high as he could go or boldly exploring caverns—and using all his senses to seek to understand mineral substances as intimately as possible (Arduino’s visual and tactile descriptions are especially vivid, but his references to smell and taste are even more surprising) and eagerly sharing the fruits of his work with his correspondent. The pleasure he gained from exploring the landscape is unmistakable.

In translating the two letters I have sought to preserve the length and structure of Arduino’s sentences as closely as possible. He was not long-winded, but sentences in Italian inherently tend to run to greater length than in English, with meanings working themselves out through the inflections and agglomerations of the language itself. I have not sought to make the translation read like a contemporary eighteenth-century English letter. To have imitated exactly a work of eighteenth-century English scientific inquiry would have been more anachronistic than helpful. Historical sensitivity is paramount, however, and whilst trying to keep my rendition as

clear as possible for today's readers, I have endeavoured to retain a tone and form of diction that are at least reminiscent of the learned discourse of the period. This decision was also required because Arduino's Italian involved some turns in grammar and style that cannot be matched by today's English. I have also followed Arduino in capitalising certain important words. It should be noted that his technical terminology was occasionally uncertain or inconsistent, particularly in the Second Letter, perhaps because he himself was treating his new ideas cautiously and was still working out a suitable terminology. Where this is the case, I have translated Arduino literally and given the original Italian term in parentheses—[]. To allow interested readers to follow Arduino's original text, I have also indicated in parentheses the page breaks of the version that appeared in the *Nuova Raccolta d'Opuscoli Scientifici e Filologici* in 1760, giving the number of each new page in lower-case Roman numerals, as were used in that journal.

Arduino's Second Letter, containing the actual postulation of the four orders, will appear in the next issue of this journal, accompanied by a more detailed assessment of how Arduino's system related to others that had been proposed before it, but which did not function as successfully. For the present, the First Letter makes an essential preliminary. Its first part describes the localities and rock types that proved so central to Arduino's stratigraphic ideas, and thus provides a necessary background to the second letter's reasoning and proposals. The second part of this first letter is less pertinent to stratigraphy, in that it is a description of experiments that Arduino carried out on the waters of a particular spring that he encountered at Recoaro; a case-study, so to speak, somewhat at a tangent from the main argument. Yet this second section should not be overlooked. It stands, as a snapshot of the world of geology just before its basic reasoning was transformed, as attempted understanding via crude chemical analysis gave way to the study of the geometrical relationships of strata, their structure, their lithological and mineral composition, and their organic contents.

2. ARDUINO'S PROFILE OF THE ROCKS ON THE EASTERN SIDE OF VALDAGNO (VALLE DELL'AGNO)

The profile for the rocks of Valdagno, referred to in Section 1, is reproduced in Figure 1. The original is held in the Verona Public Library, which has placed it in the public domain. The notes accompanying the section are translated below. They have previously been translated by Vaccari (2004) in a field-guide prepared for an excursion by the International Commission on the History of Geological Sciences, but I have sought to provide greater precision here.

A. Strata of Siefferstein [*Schiefferstein* – schist], known as *Lardaro*, Rock both foliated and talcose; fissile, shiny with the colour of metal, or like Fish scales, all interwoven with veins of quartz which form innumerable tangles [*scherzi*], disposed in strata that are wavy, irregular, and sometimes interrupted.

a.a.a. Oblique fissures containing veins of a kind of ferruginous Soil, similar to the iron mineral that was excavated between the lakes of Levico and Caldonazzo,²² by the late Giacomo Milesi.²³ This is Rock that, always underlying all others, is the visible Base of mineral mountains [*montagne minerali*], being found in many parts of the world always having the same nature and peculiarities, can only properly be called primitive [*primitiva*] —

B. Strata of quartzose micaceous Sandstones, which are seen to be composed, at least in the greater part of their substance, of sands [derived] from the aforementioned primitive Rock.

C. Strata of black, cinereous, red earths, & intermediate strata of rocks similar to *albazzano*,²⁴ beige, jaundice yellow, and other colours.

D. Strata of fissile sandstones in thin flat slabs, the colour of a red seal, of fine grain and full of minute specks of mica

²² Two lakes some 25 km east of Trent.

²³ Identity uncertain.

²⁴ Marly limestone, also called *alberese* in Tuscany.

Representation of the strata of different species of rocks observed on the right and left of the Agno, from Montecchio Maggiore, as far as the highest summits of the Alps above Recoaro, in my journey of 19.20.21.22. and 23. October 1758—, of which strata hills, mounts, and mountains are composed—

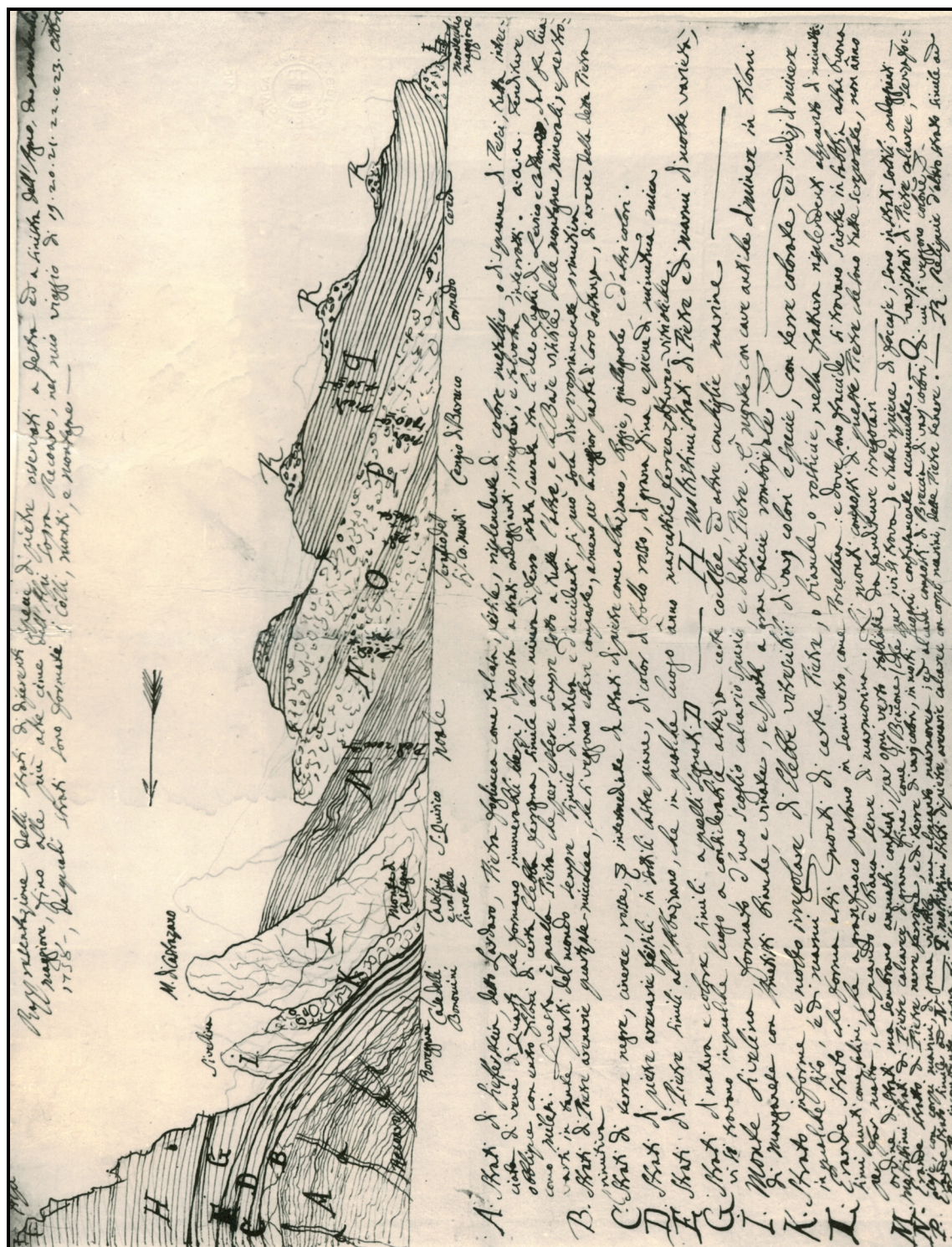


Figure 1. Arduino's profile (1758) of the strata forming the valley walls of Valdagno.

E. Strata of Rocks similar to *Albazzano*, which in some places have ferruginous–sulphureous–vitriolic marcasite[s].

G. Strata with nature and colour similar to those marked **D.** —

H. Very many strata of Rocks and marbles of many varieties, in which are found, in some places, at considerable height certain coiled snail shells [*cochleae*], and other marine shells. —

I. Monte Sivelina [now named Civillina], formed from a precipice of bastard limestone, and of other Rocks. [I]t is a mountain with ancient quarries and mines excavated into Veins of manganese with white and variegated Amethysts, and Spar with large rhomboidal faces. —

K. Amorphous and very irregular Stratum of vitrescible Earths, of various colours and kinds, with coloured earths and indications of mines at some sites, as well as marbles —

L. Large Stratum which forms high mountains of certain Rocks, either white, or reddish, with shiny surfaces in cleaving and very minute points like salt [crystals], which in strong fire become caked into a partial glass, like Porcelain: and where they are very wet they are found broken [*sciolte*] into sand very good for making mortar, which when white serves to make plaster. The mountains composed of these fractured Rocks, do not have ordered strata but seem to be in confused masses, cut in every direction by irregular fissures —

M. Very many Strata of fine-grained Limestones such as Bracone²⁵ (which is indeed found here) and all filled with *foccaje* [a kind of hornstone]; they are in thin, wavy strata —

N. Large Stratum of black ferruginous Rocks, and earths of various colours, in many places confusedly accumulated. —

O. [V]arious strata of Limestones, without *foccaje*, with marine bodies formed of visible grains, but somewhat resembling marble; and some composed of Breccias of various colours, some of which may be seen in the form of columns —

P. Large stratum similar to **N.** —

Q. Very many strata of calcareous sandstones with marine bodies, known as Softstones. —

R. Relics of another stratum similar to **N.** and **P.** lying upon strata **Q.** —

3. ARDUINO'S FIRST LETTER TO VALLISNIERI

[xcix]

To the Most Learned Signor Cavalier

ANTONIO VALLISNIERI

Professor of Natural History in the University of Padua

First Letter

of

GIOVANNI ARDUINO

VERONESE–VICENTINE

concerning his various Natural Observations

NOBLE SIR

I know you shall be displeased with my tardiness in responding to your erudite and most esteemed Letters of last December, and I am the more displeased myself at being unable to correspond more often with so learned a Person, who gives me ever greater signs of cordial friendship, and who inspire me to the furtherance of Physical observations, pertaining to Geology, and to Mineralogy; that study which has long been my dominant passion. You already know very well how assiduously I employ myself, of necessity: and how it grieves me to be kept from [*c*] freely attending to the research and contemplation of the productions of the Fossil

²⁵

Grey–white limestone of the Dolomites, known locally as *bracone* or *biancone*.

Kingdom, and to regular literary correspondence with Men of Philosophy: yet I am assured that you will not ascribe my tardiness to negligence.

In your latest communication you enumerate in chronological order many great men, who from Thales to this day have all held, as one, the same opinion on the Theory of the Earth (which has become in our own times most enlightened and regarded) such that some may think the study superfluous. Yet to my mind, it seems that this uniformity of sentiment (at least in the principal points) among such a great number of perspicacious and knowledgeable Observers, concerning the origins of the innumerable strata that form Mountains, Hills and Plains, surely should not dampen our fervour to redouble inquiries and observations on that same subject.

Certainly I myself—who have a true desire that those truths of things which Nature herself manifestly demonstrates to us, and which to the multitude appear as paradoxes, shall be rendered more commonly understood—should much prefer appraising every study in a way that purges those truths of errors and prejudices, and greatly enriches their demonstration, and renders them apparent, to racking [*ci*] the brains to fabricate new Systems.

Such is my desire to comprehend this Theory, insofar as one may, that on all the occasions which arise to journey through this Vicentine Territory, bountiful as it is in mineral productions and marine fossils, I do not omit to make all those researches and observations that my circumstances permit. It is already known to you that, beyond those we made together last Autumn among some of these nearby Hills, I also undertook a journey to the Valle del Torrento Agno, in the Recoaro Alps, with that same object.

There I not only made curious observations concerning the structure of a long series of Mountains, and of the most varied nature of the rock and earth Strata that compose them; but also many discoveries of very fine Jaspers of Marbles and gypseous alabasters, of fossil Coals, of some indications of Mines and ancient mineral quarries.

The most interesting are perhaps those of the great bands of hard rocks full of vegetable matter, reduced to the substance of fossil coal, and of Marcasite, or Pyrite, of extremely fine grain, metallic colour, dark, and not very shiny, with a prodigious quantity of small Shells, [*cii*] and fragments of true Coal; together with certain saline-vitriolic formations that discovered on the Mountain, from which can be extracted the famed medicinal acidulae [*acidule*] of Recoaro.

From the Alp, which stands opposite the Villa of Recoaro to the south, two Valleys descend (as well as many others) of the kind the Tuscans call *Botri*, or *Borri*; one is called the Righelamor, the other the Valle del Crogole. These two *Botri* converge almost at the foot of the Mountain and join to form one single Valley, which, after a short distance, releases their waters into the Torrente Agno close by the aforementioned Villa. Marking the site of the convergence of these two *Botri*, in land belonging to the Griffani Family, there is a Capital set in a wall, from which emerges a canal of the aforementioned acidic-vitriolic water: and all about there can be seen many springs and out-wellings of the same, as well as fresh water.

Wheresoever this acidulous [*acidula*] water runs and is diffused, before merging with that of the Valley which lies nearby, it deposits great quantities of martial ochre, mixed with tartarous substances, which in surrounding and enveloping the grass, the leaves and branches of the Trees—indeed all that is to be found there—and turning to stone, forms a Tuff, or aqueous Pore, [*ciii*] pallid-russet in colour, curious to behold for the patterns so vividly expressed by those materials, as well as for parts of vegetables. This deposit of Crocus of Mars, or ochre, is common (and well known) to all Acidules [*Acidule*], and to many other mineral Waters; but not likewise this tartarous substance so ready to congeal and turn to stone.

To give you succinctly an idea of this Mountain, and of all that I discovered and observed, I should commence from its structure, and with a description of the materials which compose it. Its visible base consists of that kind of foliated, or fissile, rock, laminated as Talc, in colour and lustre seemingly metallic, or as Fish scales; all tightly compressed, laced with veins of that white flint-stone known today as Quartz, and indeed sometimes entirely impregnated and compacted with Quartz. This rock, of which one may find very many varieties, is vitrifiable in nature; it contains a slight presence of iron, and is often found tainted with its rust; and sometimes it contains, either within its substance or between its beds and cuts, Crystals, Garnets

and other similar rocks, and veins of metals, and minerals of every kind; as I myself have been able to observe in various countries. [civ] The German Mineralists call it *Schieffer-Stein*; in Agordo and Trentino it is called *Sivedr*; at Schio and in the Sanese, *Pietra lardara*: and in other places *Lavagna*, and *Sasso morto*. These last two names are used in descriptions of this rock by the Most Learned Signor Giovanni Targioni Tozzetti²⁶ in the Accounts of his travels in Tuscany, for which, as well as for his profound knowledge in natural Science &c., he merits particular esteem.

This rock however is not the visible base of this Mountain alone; but also of all the nearby surrounding mineral Mountains of Recoaro, of Roveggiana, of the de' Signori and de' Conti Valleys; of Ena, of Pieve, and of Torre; of Schio, and of Tretto; as indeed of the towering, sheer, forbidding Alps, which these Mountains enclose along the Austrian Frontier. By the term "Base" I mean to convey that this kind of rock is placed lower than all others, for beneath it—neither hereabouts, nor in any other place in Germany or Italy—I have never been able to find strata of rock of a different nature; for which reason, and for many others which I shall adduce in a second Letter on a similar subject, it seems to me that this can be called one of the truly earliest rocks, with respect to those which are visible to us.

[cv] Above this kind of rock there runs a thick, vast stratum of sandstones which they call Whetstones, for with them are made the Round Stones which are used to sharpen iron blades: and this stratum is made up of many subordinate strata, or lesser beds, which vary among themselves only in colour, in the thickness of the sand of which they are composed, and in their quantity of Mica, which is mixed in among them. An examination of these sandstones shows us clearly that they are composed of petrified sand: and this sand seems to originate in the aforementioned foliated rock and in Quartz, which is mingled with it in great quantities; indeed the constituent sand is almost entirely Quartz, in many places mixed with rounded quartzose pebbles such as those found in the sands of rivers and the sea; the Mica, which is disseminated throughout in small leaves or glistening scales, with a metallic colour, is also of the same nature as the aforementioned foliated rock.

Above these sandstones—*Saxum arenarum, sive molare Agricolaë; Cos Linnei, & Wallerii*—there lies a stratum greater in height again, composed of many minor strata of limestones, sandstones, and of earths in blackish, cinereous, yellow and other colours, which [cvi] alternately succeed one another. Where the last of these lesser strata ends (it is a vivid red), it is followed by a stratum of limestone, which spreads through those Mountains vastly with the same order and direction as the other strata; and this rock is very compact, and hard, of a soiled cinereous colour, and in some places a dull grey and rusty. Upon breaking it open, one finds it full of the irregular crusts of certain small bivalve Shells, only a very few of which still preserve the distinct figure of a Shell: and one observes distributed between them many vegetables reduced to true fossil coal, with considerable quantities of fragments of ordinary coal.

These vegetables seem at first sight to be the twigs of Trees, broken off; but when more closely examined, they can be recognised as certain long leaves of aquatic grasses, the largest of which is almost an inch wide, by our measure. The pieces of true coal are of various shapes and sizes, and similar to the charcoal consumed in a fire, which we see among the ashes in Kitchens and Furnaces. It has the same colour as charcoal and the same woody fibres; when it is broken apart there is a tinge of black, and in fire it burns readily, hardly making a flame, and consuming itself as an ash that is whitish and [cvii] caustic like calcined Spar. On the whole it does not differ from our common charcoal, save in being somewhat hard and, as just mentioned, caustic, not lixiviable but calcareous in its ash; differences dependent (as far as I know) on its having

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Giovanni Targioni Tozzetti (1712–1783), Tuscan physician, botanist, historian, geographer and traveller, acquaintance of Arduino's. Targioni Tozzetti's *Relazioni d'alcuni viaggi fatti in diverse parti della Toscana* ('Accounts of some journeys made in diverse parts of Tuscany') proposed that the Tuscan landscape could be interpreted as displaying three categories of strata, namely 'mountains', 'hills' and 'plains,' defined by progressive reductions in compactness. Arduino's indebtedness to Targioni Tozzetti will be discussed further in the next issue of this journal. See Targioni Tozzetti (1751–1754).

been penetrated by that very fine fluorspar which hardened the Mud into stone, amidst which it was found submerged and enclosed, together with the aforementioned shells and aquatic plants.

I call it true or real Coal to distinguish it clearly from materials of the vegetable kingdom, transformed into fossil coal from bitumen that has penetrated and in a sense embalmed them; I do not wish to confuse them with this, which displays all the characteristics of being wood turned to coal by fire.

The vegetables mentioned above—transformed into that substance which is bituminous, compact, black and, like Jet, lustrous when broken, and combustible, called fossil carbon—burn with a large flame in fire; at first they ‘simmer’, and inflate almost in the same manner as the hooves and other combustible parts of animals. In burning, they give off a distinctive odour, and are reduced to ash entirely similar to that of the pieces of coal described above.

[*cviii*] In burning pieces of rock from this stratum, the substance of the crusts of the shells turns to lime, and becomes very white: the substance of the stone changes its dark-cinereous or rusty-grey colour into the pale red of vitriolic *colcothar* [ironstone or rouge], the colour of the tiny ferruginous particles which have entered into its composition. As with the lime of those shell crusts, so the ash of the coal and the bituminous vegetables is so caustic that as soon as it is placed on the tongue, it burns like fire, then leaves a flavour equally bitter and urinous: when spat out, it leaves a certain particular sweetness, and a skinned tongue.

Above this stratum there is another of limestone, similar to that of Alberese in Tuscany, and upon this lies yet another of ‘semi-sandstone’ [*semiarenaria*], micaceous, ash grey in colour, which when broken open appears full (even more so than the first stratum) of pieces of true coal and vegetables made up of fossil coal, but with no sign of shells.

In both of these strata, which are marvellous and exceptional for the pieces of true coal that they contain, one may observe scattered here and there, mixed into the substance of the rock, a certain sulphureous-vitriolic marcasite of iron, of a [*cix*] dark bronze colour and lustre and a minutely fine grain; as this is gradually worn away and decomposed by the action of air and water and other natural agents, it degenerates into the aforementioned hard acidic [*acidostitici*] outgrowths, in a mix of white and rust colours.

After the strata here described, there follow others which are made up of limestones, then vitrifiable stones, fissiles, micaceous sandstones of diverse colours: and above these can be seen a great many other beds, or rock strata, or earths likewise of various colours and natures, succeeding one another in order. In moving up the Valle del Righelamor,²⁷ I discovered superimposed upon these hundreds of strata a great band of pseudo-limestone, that is, one displaying a calcareous and vitrescible nature, very hard, and cinereous, whitish and grey in colour, with little veins and crystallisations of quartz, filled with stains and splashes of a marcasite very similar to that described above. This marcasite, where it is exposed to the action of the Atmosphere, is likewise gradually decomposed and forms pseudo-vitriolic efflorescences; [and] when these are subsequently dissolved and carried away by the falling waters of the Cielo,²⁸ they sully the Matrix of the river and the [*cx*] rocks adjoining it with iron rust, which is contained therein.

The said mineral band can be seen extending itself far across this Mountain, from East to West: and it does not proceed according to the order of the other strata, but cutting across them (in a certain way) it dives downwards obliquely towards the centre of the Earth. Above it are many other strata of limestone, on which lie numerous sandstones, fissiles like *Ardesia tegularis*, red in colour and with fine grains, and the whole substance flecked with a great quantity of scales of mica, as lustrous as metal, and of the same character as the sandstones previously described.

In this way, from stratum to stratum, various kinds of rocks and other fossils succeed one another, as far as the loftiest summit of the Alp: and very high up one finds various beautiful seashells: and there are strata of brecciated marble [or marbled breccia] and other marbles of

²⁷ River valley that joins the Valdagno at Recoaro.

²⁸ Stream that flows in the Valle del Righelamor.

various colours, and extremely hard and fine jaspers, red and yellow in colour, which contain stains and veins of Chalcedony.

All of the innumerable and quite diverse strata which make up this Mountain, and indeed all of those vast Ranges of mountains and Alps, are in a thousand [cxi] ways curved over, as though in ways, and for this reason they are disposed at various degrees and angles of declination from the horizon. Yet their general, or rather maximum inclination is towards the sea, and in this way they correspond perfectly across all of their vast extension, from whichever angle they are observed at those heights or from the sides of the many deep valleys to be found there; they can convince any mind capable of sound reasoning that at one time they were all ongoingly continuous: and that they were broken and disconnected simply by the force of flowing waters, which through immensely lengthy work created them, and which even now is creating so many bizarre formations and deep, tortuous Valleys.

This truth, extended to the whole terrestrial surface, has long been known to many men of great merit: and the aforementioned Signor Targioni provides its most convincing demonstration, with his Observations Concerning the Mountains and Hills of Tuscany (which I have in large part seen myself), as all may read in the aforesaid Accounts of his travels, which especially concerning Mineralogy and the theory of the Earth contain things of high regard. It is concluded that we are indebted to the impetuous motion of waters, which have so deeply opened and unfolded even the [cxii] hardest rocky bowels of mountains, mountain ranges and hills, allowing us to make of them a sort of anatomy, and arrive at some knowledge of the origin, structure and nature of the modern surface of this Globe, which otherwise could never have been acquired.

To return to the observations and discoveries made on the aforementioned mountain of the acidulous [acidule] waters, I inform you that from its wildest summits there descends towards the Agno a large and precipitous Valley which they call the Reclèr, perhaps a mile from the Acidulous waters [Acidule] as one travels upstream along the right bank of the Agno itself. Amidst the enormous quantity of materials of every size which the floods in this Valley roll down from the Alps, I observed large pieces of the aforementioned jaspers, and of mixed marbles, and brecciae, tinted in green and red and other colours; as well as white marbles, much like those of Statuario,²⁹ Paros³⁰ and Carrara, of fine grain and most compact: and some pieces of white Alabaster, which makes excellent Chalk. I climbed up through this same Valley to a considerable height, and on some cliffs which form its right wall straight down to a house held in the name of the Gatra family, I found a certain white, [cxiii] crusty outcrop of bitter salt, of which they had spoken to me lower down. These cliffs are of limestone, in layers which correspond, by their direction, to those in which I found the Marcasites and the aforementioned saline vitriolic outcrops; one may also see these saline crusts in many parts covered over.

The Snow, which had fallen as far as half-way down the Alps, prevented me from going as high up as I desired: and therefore I made a long excursion around those Mountains at a medium height, making many observations concerning their structure and the progress and correspondence of their strata, which I could see very well as far as the highest summits of those high and rocky Mountains, before returning to observe again the site of the acidic springs.

These, as I said, are scattered over a small patch of ground, but the principal among them, that used in medicine, is that with the aforementioned Capital, named the *Fonte Lelio*, for it was discovered by a Veneto Nobleman of that name from the Most Excellent House of Piovene in the month of July of 1689. The water which I drank at the Spring, seemed to me to have an acid, spicy flavour; vitriolic, yes, but with a certain pleasantness I cannot describe, like the acidity of wine, which made me far less [cxiv] nauseous than did the waters from the same

²⁹ A small urban district, southeast of central Rome and close to the entry into the city of the Appian Way. Many ancient statues in finely-worked marble, probably belonging to the villas of wealthy Roman citizens which once stood nearby, have been unearthed there. In Arduino's time, the locality of Statuario would probably have been only a small hamlet.

³⁰ A Greek island, known for its Lychnites marble ('Parian marble').

source which on occasion I have tasted here in Vicenza and at Schio.³¹ I observed that these acidulous [*acidulari*] Springs pour forth partly from the rocky strata that are full of marcasites, shells, coals and the aforementioned bituminous vegetables; and partly from the ground which lies very close by and beneath which these strata pass, as their direction makes evident: wherefore I am persuaded that the waters emerge particularly from these strata, and that from them, as well as from the great seam of marcasite, which lies high and further inside the mountain, the waters draw their medicinal mineral Elements.

I am confirmed in these sentiments by analytical and synthetic examinations which I undertook concerning this mineral water and the aforementioned marcasites, and their saline vitriolic outcrops, having learned that all contain the same principles. The mineral Elements of this water are, by all the signs, a mineral Acid (named by Naturalists, indiscriminately, sulphurous or vitriolic) combined materially with true iron and a calcareous substance that is held both dissolved and suspended in the water, and forms with them two different sorts of bases and two different kinds of salts; that is, martial vitriol with an iron base, and [cxv] neutral lime salt with a calcareous base. We call it neutral lime—*neutrum calcarium acidulare*—after the Venerable Wallerius³² in his mineralogy, Volume I, Species 196, because it has the specific properties of neutral lime, which distinguish it well from the *Alkali acidulare* of Species 190 in the same Volume.

Many are the experiments to convince us of the existence of this water of mineral acid, or sulphureous or vitriolic acid, however one is pleased to call it; as much as that containing iron, and calcareous material, which perhaps is combined with a slightly bituminous substance, as I shall state below. I shall not lose time making reference to them all, for they are things excellently described by the celebrated Professor of Chemistry Signor Giacomo Bartolomeo Beccari³³ in his Pamphlet concerning these Acids, contained in the third Volume of the Proceedings of the Bologna Academy of Sciences. The same has also been achieved through many accurate experiments by Signor Doctor Antonio Mastini, a learned Physician of Valdagno and our good friend, in a small manuscript Work of his which I am pleased to report will soon be published.³⁴ These things aside, I believe no other inquiry has manifested so clearly to our eyes the presence of iron and [cxvi] calcareous substance in the said Acidula [*Acidula*] and whosoever doubts these undertakings has no right to pass judgement on the matter.

In sum, where this water runs close to its own source, it makes a deposit of ochre and of tartar, which turns to stone very easily, forming those aqueous Pores; here then is manifest, simply through visual observation, the presence within it of iron and of calcareous material; for ochre is always true iron, which Docimasy may easily reduce to a state of perfect metal: and the Tartar is, without contradiction, calcareous material, or rather calcinable material. The iron, distilled from the mineral acid and collected alone, forms Vitriol of Mars: and the calcareous substance, distilled from the same acid and collected alone, forms a calcareous salt; the one and the other exist within this acidulous [*acidula*] water, distilled from the mineral acid, and collected alone; it cannot be denied, therefore, that there is within it a true Vitriol, and calcareous salt, which experiments (as I have said) demonstrate to be neutral, or at least medium.

I would be too prolix should I wish now to reason with you, on the grounds of experiments, why this vitriol, and that of almost all vitriolic springs, cannot reduce itself [cxvii] through the evaporation of water into crystals, as does common natural or artificial vitriol. For indeed, when this water is left to stand for a time, or is put to flame, its vitriol decomposes; the elastic airy substance which is imprisoned and dispersed in all waters and which is most

³¹ Schio is a town some 25 km north of Vicenza and 10 km due east of Recoaro and the main part of the Valdagno.

³² Johan Gottschalk Wallerius (1709–1785), a distinguished Swedish professor of chemistry and mineralogy.

³³ Jacopo Bartolomeo Beccari (1682–1766), apparently mistakenly called Giacomo here by Arduino, was a Bolognese chemist who also made investigations into the nature of fossils and living plants. The ‘pamphlet’ to which Arduino refers was Beccari’s *De medicatis Recobarii aquis* of 1755. See Beccari (1755).

³⁴ Antonio Mastini (1717–1805), a physician of the Valdagno area. His “small manuscript Work” was published in an English translation in 1770. See Mastini (1770).

abundant in this example (as in most mineral waters), frees itself, rising in small bubbles, and flies away. So the iron particles, hitherto dissolved and invisible, attract one another, and gather into discernible groupings, saffron in colour, which make the water turbid and rust-toned, and, falling to the bottom, form that orange–yellow sediment called Ochre. So that finally the acid, almost entirely abandoned by the iron, and having bound itself to the tartarous calcareous substance with which it shares notable affinities or rather attractions, is in a way obscured by the said metal, and with that the acid vitriolic flavour of the water changes to being almost insipid. This disappearance of the acid flavour makes those who do not fully understand Chemical mutations and phenomena believe that the Acidula [*Acidula*] of Recoaro contains nothing but a spiritous and highly volatile vitriol, thus confusing the principle of acidity with elastic ethereal spirit; or, to put it more simply, with air, which they see [*cxviii*] so easily breaking free in such quantities from these waters.

To those who think in this way, I could show by manual experiments that whatever quantities of acid particles may emerge, blown on the air which continuously evaporates from water held in open vessels, nonetheless the greatest part of that acid remains behind, even though to the taste, and through some other tests, it may seem no longer to be there; and it is easy to demonstrate that Chemistry is rich in similar transmutations.

From the ochrous and tartarous sediment that these waters leave behind in distillation or evaporation, may be extracted a bitter salt, which I myself have extracted many times, not only from this sediment, but from the very waters themselves, first chemically purified of non-saline heterogeneities. The most learned Signor Beccari calls it Selenitic Salt, and demonstrates through all possible evidence that it is composed of vitriolic acid and calcareous material; I myself made sure of this truth by experiment, and furthermore I found that a considerable quantity of this acid remains within the insoluble ferruginous-calcareous materials, which remain after the said Salt has been extracted. From this, then, it appears clearly that the Acid of these waters does not volatilise [*cxix*] so easily as is commonly believed; and as I proceed I shall adduce further proofs of this.

My further persuasion that these Acidules [*Acidule*] draw their principal medicinal minerals from the aforementioned strata and seams—those which are full of marcasite, and materials of the animal and vegetable Kingdoms—arises from the perfect analogy I recognise between the mineral substances they contain and those extant in the said marcasite and its outcrops. This marcasite, or pyrite, being exposed for long periods to the air, gradually wears away (as I have had occasion to say) and decomposes, as happens to the majority of pyrites. In this process of decomposition, the Phlogiston, which when bound to the mineral Acid forms the Sulphur of this marcasite, is given off; and the Acid, which was bound to the Phlogiston, develops; it attracts the humidity of the air, and attached as it is within the marcasite to very fine particles of iron and of its matrix the limestone, little by little it seems to sublime, forming certain saline fibrous vegetations, similar to those of saltpetre. These are the saline vitriolic outcrops which I have named at various times; and I call them saline vitriolic because they are a mix of true vitriol and of neutral-calcareous salt, with all the characteristics of [*cxx*] perfect analogy with the aforementioned mineral principles of these Acidules [*Acidule*].

I have made many experiments and many observations concerning these mineral substances, which were I to communicate them to you might be of some worth to Natural History and to Medicine; but to do so conveniently would require much greater exposition than a letter can carry. I will therefore restrict myself for now to relating to you the most important of these, which will make plainly known the analogy indicated above between the mineral principles of these Acidules [*Acidule*] and those of the aforementioned materials.

To proceed with some order, however, I shall commence with the experiments on this water, contenting myself with referring only to those carried out in recent days. Through the efforts of Noble Signor Count Giovanni Battista Piovene,³⁵ who also favoured me with his

³⁵ Possibly a member of the same noble Venetian family that commissioned the Villa Piovene, one of the many Palladian villas in the Vicenza area.

assistance and came with me on the journey in the Alps, I received from Messrs Bertoldi-Giara³⁶ of Recoaro two flasks of fine Acidule [*Acidula*] from the early days of that month. Because of my being otherwise engaged, I left this water standing for around fifteen days in closed glass vessels, before distilling it. After that time it still had its acid-vitriolic flavour, though this was weaker, and different from that which it had when I drank it at its Source: and [cxxi] some of its martial ochre had precipitated to the bottom of the vessels.

I distilled twenty-four medical pounds of it in a glass alembic over a normal fire, and having observed attentively every phenomenon from the beginning to the end of this distillation, I saw how exactly they corresponded to what was observed by the Illustrious Bolognese Physician Signor Doctor Antonio Gallo, and by Signor Lorenzo Pedoni Speziale of Valdagno,³⁷ as can be seen in the said third Volume of the Commentaries &c., which I consider superfluous to describe. When the said water had been reduced by distillation in the alembic to little more than a pound, I removed it from the fire, allowed it to deposit its sediment, and by filtration made it limpid and pure. After this I placed it in the fire once again, in a smaller vessel, to evaporate, until it was reduced to about three ounces: and having been left for two days, it deposited a sediment that was very light, intensely white, extremely soft, in little threads or fine scintillating prisms, extremely similar to true flexible amianthus [asbestos] which has been reduced to powder. This material, which in its saline appearance has misled many into believing it indeed to be the salt of this water, is not in fact a crystallisation which can occur in the cold, but forms while the water is still boiling; [cxxii] for this reason, the more the water boils, the more this material contracts in on itself and what is more loses its limpid character, instead becoming milky, and precipitating to the bottom as the water becomes cold and still.

This extremely white and micaceous sediment is certainly not salt, because it does not have the specific properties of salt, if we elect not to include stony crystallisations in the saline order, according to the Linnean system. It is insoluble in water, in which, due to its considerable softness, the weak coherence of its molecules and its notable lightness, it is somewhat dispersed while boiling, though once boiling has ceased it is quick to reunite itself once more, and precipitate to the bottom. It has no kind of flavour, and when placed in fire it neither turns to liquid nor inflates, crackles, sparks, or smokes; and it does not undergo any change, save for losing its lustre, and only after having been burned intensely by fire does it acquire a flavour, as well as a caustic quality from the calcining of the spar.

It is a curious thing, worthy of some reflection, that this asbestiform concretion, which to me appears analogous to spar, forms along with ochre in the boiling of any water that is naturally vitriolic, or that is made so with the infusion of the constituent minerals of the vitriols of Mars or Venus, [cxxiii] be they earths, rocks, marcasites, earth metals or fossil coals. I have experimented with many of these materials, in various varieties and in diverse Countries: I have seen the vitriol factories of Agordo³⁸ and Pergine,³⁹ and I have myself worked in the Montieri foundry⁴⁰ of the Mineral Society of Livorno, in the State of Siena; and I have always observed that in boiling there forms this white, fine asbestos-like crystallisation, alongside martial ochre, which manifests itself as soon as the water boils and turns an orange colour.

I have devoted some fair attention to this second sediment, because to me it does not yet seem to have been recognised and described with precision, but has been confused together with the salt of these Acidules [*Acidule*]. Their first sediment then, which was tenaciously adhering to the bottom of the alembic and in a certain way petrified, is a mixture of tartarous material and Iron ochre, with some portion of the aforementioned second sediment. Once this is well

³⁶ Presumably prominent citizens of the Recoaro area. There is a street bearing the name Giara in the present town of Recoaro, and a road named Bertoldi in the hills to the south.

³⁷ The identity of these men is uncertain.

³⁸ Agordo is a town in the far north of the Veneto, some 200 km north of Verona, in the southern part of the Alps.

³⁹ Pergine—known today as Pergine Valsugana—is a town located 20 km east of Trent. In Arduino's time it was a possession of the Austro-Hungarian Empire.

⁴⁰ Montieri is a small village in the southwestern Tuscan province of Grosseto, some 50 km west of Siena. The foundry referred to by Arduino was concerned primarily with coinage. Molten silver was combined with copper and shaped into bars, which were then cut and refined into coins of varying size and weight.

separated from the saline part and, as they say, dulcified by ordinary boiling water and then dried, it appears in a form very similar to that very soft and light sort of clay that they call mineral Agaric [rock-milk⁴¹] [cxxiv] orange in colour, very dull, and pale. It is totally insipid, and yet abounds in mineral acid, which is so imprisoned and obscured within it that to force it out takes long and violent calcinations in a powerful coal fire, after which it is found to have acquired all the properties of calcareous spar, as happens to the aforementioned second sediment. In this way the said acid manifests itself, for volatilised by the fire it is gradually exhaled, sharply hurting the nostrils and causing the same sensation that one experiences when spirits of vitriol and sulphur give off heat.

The learned Signor Beccari in his aforementioned Pamphlet refers to some experiments which led him to suspect that in the ochre deposited by these Acidules [*Acidule*] around their sources, there is a bituminous substance. This is rendered yet more credible after my own discovery that the strata from which the springs flow are full of plants transformed into bituminous fossil coals: and regarding this, there is a most curious phenomenon that I have observed. When spirit of vitriol is poured over the aforementioned sediments once these have calcinated, they instantly turn a very dark colour and there separates out from them a true bitumen, black, foetid and [cxxv] combustible, without there being any perceptible effervescence and with little dissolution of matter; but this point cannot be reached unless calcination has taken place first. At present I shall not endeavour to express an opinion as to whence this bitumen might have come in this chemical operation, and following Signor Beccari, I shall leave it to others to decide.

I shall turn therefore to the water left behind after the separation of the second sediment described above, which contracts to a still lesser volume with evaporation, and which when exposed to cold air is crystallised into salt similar to the genuine Epson variety of England, bitter, transparent, and of an aqueous colour tending to rust, which reveal that it still contains some residual iron. Its crystallisation is octagonal, in prisms of various sizes, in length from one to as many as four feet *Regio Parisiense*, with four approximately parallel sides, around half a line broad, with cuneiform apexes, which correspond contrariwise, similar to Natrum Linnæi, Syst[ema]. nat[uræ]., represented by Figure I, Table VIII. These prisms are so disposed and connected together across the concave surface of the glass vessel in which they are crystallised, that they seem [cxxvi] a forest of plants, with branches and almost innumerable leaves, to which the learned Signor Beccari gives the name *Arbore Selenitico*.

This is the true salt of our Acidules [*Acidule*], and it has all the known characteristics of its type: it readily dissolves in water, and also on the tongue, causing there a salty-bitter sensation, and placed in fire it readily liquefies and boils, inflating like alum, and drying into a bright white mass, quite rarefied, and hollow within. If this mass is allowed to calcinate moderately, it acquires a flavour and becomes caustic like calcareous spar: and when calcified at length among burning coals, it conserves its form without alteration, but loses all flavour and will no longer dissolve in water, even if it is boiling. If, then, while it sits among these lit coals, one blows upon it strongly, it melts, boiling like borax; but like that substance it does not vitrify, becoming instead soluble in vigorously boiling water, which in that case gives off a somewhat bitter flavour.

This salt, which could be denominated *neutrum-calcareum, seu spathosum, ferro mixtum, acidulare, Recobariense*, is perfectly analogous to that which I extracted from the saline vitriolic outcrops, found in the great marcasitic vein [cxxvii] in the Valley of Righelamor, were it not for the fact that it adds to the salty-bitter flavour a quite detectable vitriolic acidity. And those outcrops themselves—which in collecting above the strata filled with marcasite, pieces of coal, small shells and plants transformed into bituminous fossil coals, from which issue the said Acidules [*Acidule*]⁴¹—are a mixture of a little calcareous salt, and of much martial vitriol, to which I suspect is intimately bound a bituminous substance, which impedes crystallisation. These outcrops, when chemically purified, give out a calcareous salt which is not crystallised but

⁴¹ A white, powdery surface crust of calcite, formed by efflorescence in limestone caves and fissures.

coagulated, and rusty white in colour, in which the said vitriol is so predominant that it makes the flavour especially acid and astringent. Above this saline coagulate there remains a vitriolic liquor, the colour of the most acid of Vitriolic spirits, which they call black oil, and with a very strongly acidic taste; a drop of this added to twenty or more of ordinary water renders it similar in taste to the Acidule [*Acidula*] of the Fonte Lelio. This liquor cannot be crystallised in any way, but when its humidity is forced to evaporate, the substance reduces like honey, or like cooked linseed oil, and finally dries out in a form of varnish; but when left long in the cool, it attracts aerial moisture and reacquires a dense liquidity. It therefore seems to me that it may be [cxxviii] denominated *Vitriolum martiale, post purificationem semper liquidum, obscure-croceum, acidissimum, prope acidularum Recobarensium scaturigines e Marcassitis simul cum Natro calcario efflorescens*.

The saline crusts, which I gathered above the cliffs beside the home of the Gatra family,⁴² in the aforementioned Vallone del Reclèr, are a pure neutral calcareous salt, with no presence of iron when taken from the water, which exudes from between strata all over those slopes, above which, dried by the air, it hardens almost into Stalactites. When chemically purified, it crystallises into small, very thin and whitish-semidiaphanous prisms, similar in figure to those of the said Acidules [*Acidule*], even in their salty-bitter flavour and other essential properties.

Considering together the saline substances extracted from the aforementioned outcrops and crusts, they contain the very same mineral principles of the Lelio waters; that is, a martial vitriol and a neutral calcareous salt: and in purifying these two, there precipitate other materials entirely similar to the aforementioned two acidular [*acidulari*] sediments. This reciprocal analogy, indeed this identity of principles, demonstrates I believe most clearly that the minerals which contain the said marcasites and bituminous materials, in calcareous matrices or ones that are at least partly calcareous [cxxix] in nature, are the great magazine from which these waters draw their medicinal properties: and I venture to state that all that I have so far discovered proves this assertion amply. I refrain therefore from reporting many other observations and experiments, which—as though it were not superfluous to repeat what has been so soundly demonstrated by illustrious Chemists—were of use to me in proving those things which I have here taken as verified, and in establishing further those things which I have tested in lesser ways.

Neither shall I dwell much longer on this subject, since it is not my intention to write you a complete history and analysis of these waters, of their minerals, and of their mountain; something which by the way, were it carried out with exactitude and in all its fullness by someone with a profound knowledge of fossil substances and mineral Chemistry, would certainly not be without its uses in Natural History. However much has been written concerning this matter, you must believe, Most Learned Noble Sir, that there remains much to observe, much with which to experiment, and not a little to write, without superfluity. But to do this would take considerable time, and would make it necessary to stay in Recoaro and visit those mountains not for two rushed days, but for months; only in this way might it be possible to compile the Natural History of those mountains which, to my [cxxx] mind, would be most curious and interesting. Indeed this was done, to great credit, by the celebrated Naturalist Signor Doctor Giuseppe Baldassari,⁴³ a physician from greater Monte Olivetto and a particular friend of mine, in his most learned Account of the mineral waters of Chianciano in the State of Siena.

Recoaro is entirely surrounded by mineral mountains, which extend towards Schio and Sant'Orso as far as Mount Summano, and towards Posena,⁴⁴ embracing many Villas and Villages which it would be superfluous to name: and it is commonly known that in ancient times quarries were dug here for silver and other metals. As well as what has been written about these

⁴² Presumably a family of the Valdarno district.

⁴³ Giuseppe Baldassari (1705–1785). Physician from Grosseto, in southwestern Tuscany, whose investigations into clay and the chemistry of spring waters provided strong evidence that much of Tuscany had once been covered by the sea. See Baldassari (1750) and Baldassari (1756).

⁴⁴ Schio, Sant'Orso, Monte Summano and Posena are localities spread along the mountain range that extends eastwards from Recoaro.

by Vannoccio Biringucci⁴⁵ in his *Pyrotechnia*; Giacomo del Ferro⁴⁶ our Jurist, in his Treatise *de Attractu, & de Servitutibus prædialibus &c.*; Giorgio Trissino⁴⁷ in his Letter to F. Leandro Alberti;⁴⁸ and in one of his Orations to the Lord Doge of Venice, Cardinal Bembo at the commencement of his *Storia Veneta*; as well as other Authors—many other authentic monuments, as well as the very deep and almost innumerable quarries, have been explored in their entirety.

From this brief survey you shall well understand how wide a field remains open to a Chemical–Mineral Philosopher in which to form a treatise that is interesting and advantageous to the public: and what honour might be acquired in, at least, initiating the natural history of the Fossils of this Most Serene [cxxxv] State, which still lies pitifully buried in the darkness, while that of many other nations, which only a few Centuries ago were spoken of as barbarous, now shines forth in honour. Yet to bring these thoughts into effect demands circumstances which come about with such great difficulty that even to hope for it is pure vanity: hence, leaving more to talk about, I shall end this by now overlong Letter, in telling you something of the proportion which stands between the weight of the aforementioned Acidules [*Acidule*], and that of their sediments and of their salt.

This proportion is so inconstant and variable, according to the seasons in which the experiments are carried out, according to the ways of executing them, and according to the weather, all of which affect the replenishment of the water, its distillation, or evaporation, in ways which cannot precisely be determined. According to the latest aforementioned distillation, every medical pound has yielded fourteen and a quarter grains of the first sediment, into which was also mixed (as I said) some portion of the second: and one grain of this second extremely pure sediment, with five grains of the aforementioned salt. Yet sometimes one obtains seven or eight grains of this salt, and more, from every pound of water, and almost double the amount of first and second sediments, taken together.

I shall refrain from reporting to you at present the many other observations that I made [cxxxvii] on this journey, regarding the theory of the Earth and mineralogy, some of which shall be described in a second Letter, in which I shall even give you news of various other observations done in the mountains of this District of Vicenza, on the same subject. You shall then receive from my brother, who has the honour of the Superintendency of the Public Botanic Garden, the exhibits of these aforementioned materials found by me near the Fonte Lelio, but especially of those rocks full of charcoal, of bituminous vegetables, and of shells and marcasites, together with other products of the fossil Kingdom, which I shall send you so that you may examine them and combine them with the other minerals I brought you last year from the mines of Tuscany and from the Modena district, for this public Museum. I am assured of your kind thankfulness, if nothing else, for at least, in writing thus, I have abided by your repeated pressing appeals: and because I know how much You love and appreciate all that leads towards the furtherance of Natural History, which you profess with that singular genius inherited from that Celebrated Noble Gentleman your Father, of immortal remembrance, one of the brightest lights of this Science: and with most devoted respect I have the honour to be

In Your Illustrious Service

Vicenza, this 30th of January 1759

Your Most Devoted and Obligated Servant
Giovanni Arduino

⁴⁵ Vannoccio Biringucci, also known as Biringuccio (1480–ca 1539): a Siense metallurgist, whose *De la pirotechnia* is regarded as the first true manual of foundry techniques.

⁴⁶ Identity uncertain.

⁴⁷ Gian Giorgio Trissino (1478–1550), writer and humanist. Born in Vicenza but exiled for political reasons, he travelled to many of the greatest Italian courts and earned esteem for his learning and literary compositions.

⁴⁸ F. Leandro Alberti (1479–c.1552), Bolognese historian, renowned for his *Descrittione di tutta Italia* [*Description of all Italy*] of 1550, a significant archaeological, historical and topographical survey.

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