Anniversaries

A new lithostratigraphic theory 250 years ago

GIOVANNI ARDUINO AND HIS *SAGGIO FISICO-MINERALOGICO* (1774)

Ezio Vaccari (ITALY)

Among the contributions made by the Italian scientific community to the origin of stratigraphy (Morello, 2003), Giovanni Arduino's system of subdividing rocks into four basic units attained a unique level of precision (Vaccari, 2006; 2024). Arduino (Fig. 1) was a leading figure in the Italian scientific community in the second half of the 18th century. He was born in 1714 at Caprino Veronese, a small village near Verona, in the Venetian Republic of northern Italy. At the age of eighteen, Arduino started his technical apprenticeship as a mining assistant in the iron mines of Klausen in the Alpine region of south Tyrol. During the 1740s, as Supervisory Assistant, he took part to the attempt to restore the lead and silver mines of Tretto near Schio in the Venetian Republic. His technical ability in mining exploitation and in the smelting processes for extracting metal from ore minerals became widely known. From 1753 to 1757 Arduino worked as Director of some copper mines in Tuscany and in the Apennines: his interest in the study of the Earth's strata and in the interpretation of different kinds of rocks grew together with his advanced experience in mining. This practical knowledge, together with his self-taught preparation in mineralogy and chemistry, would influence his geological knowledge and determined much of his lithostratigraphical theory, which was proposed between 1760 and 1775. In these years Arduino worked first as land surveyor for the municipality of Vicenza, and later, from 1770, as Superintendent of Agriculture of the Venetian Republic in Venice until his death in 1795.

Fig. 1 - Portrait of Giovanni Arduino (engraving by Benedetto Musitelli, published in Gamba, 1822).

Arduino's geological research and fieldwork, carried out during the 1750s mainly in the Venetian Prealps, produced a new lithostratigraphical theory (Arduino, 1760; Ell, 2011-2012), which included a sub-division of rocks into four units (called in Italian *ordini*). This classification was based on lithology without using paleontological indicators, although some significant references to fossils may be found. François Ellenberger (1994, p. 261) has noted that Arduino's method was mainly based on a litho-structural analysis and by consequence his system did not yet concern what is today called biostratigraphy. Arduino's sub-division included different rock types which formed three kinds of mountains: the oldest "Primary" mountains were composed of a sequence of mineral-bearing crystalline rocks, sandstones and conglomerates underlain by "primeval talc-quartzose rocks", known by the 18th century German

miners as *schieffer-stein* (slates) or *horn-stein* (horn-rock) and which in Tuscany were called *lardaro*, *lavagna* or *sasso morto* ("dead stone"). This rock was considered by Arduino to be the oldest, as it was found at the base of all the reliefs he had examined over the previous twenty years. The second unit included younger rocks which formed the "Secondary" lower mountains, composed mainly of sequences of marble and regularly stratified limestone. These were mostly lacking in mineral deposits, but contained abundant marine fossils. Other stratified rocks were also noted which were thought to be the same type of crystalline rocks as those of the first unit, but which were very different in appearance. The third unit was defined as being still younger in age and composed the "Tertiary" mountains, which were hills and lower relief mountains, formed of gravel, fossiliferous sand and clay, debris from the primary and secondary mountains, and volcanic material (the latter indicated with a certain caution). The fourth and youngest lithological unit did not include mountains or hills, but consisted of sediment, derived from the previous mountain types, and which was laid down by streams in the form of alluvium.

Arduino's classification was based on extremely accurate fieldwork and in particular on the results of a 5-day geological travel through the Agno Valley, in the Prealps northwest of Vicenza in north-eastern Italy. The data collected during this fieldtrip, from the 19th to the 23rd of October 1758, are preserved in Arduino's handwritten notes and sketches kept in the Public Library of Verona (Italy). One of these drawings (Fig. 2), representing a cross-section of the Agno Valley, clearly shows the origin of Arduino's lithostratigraphical theory.

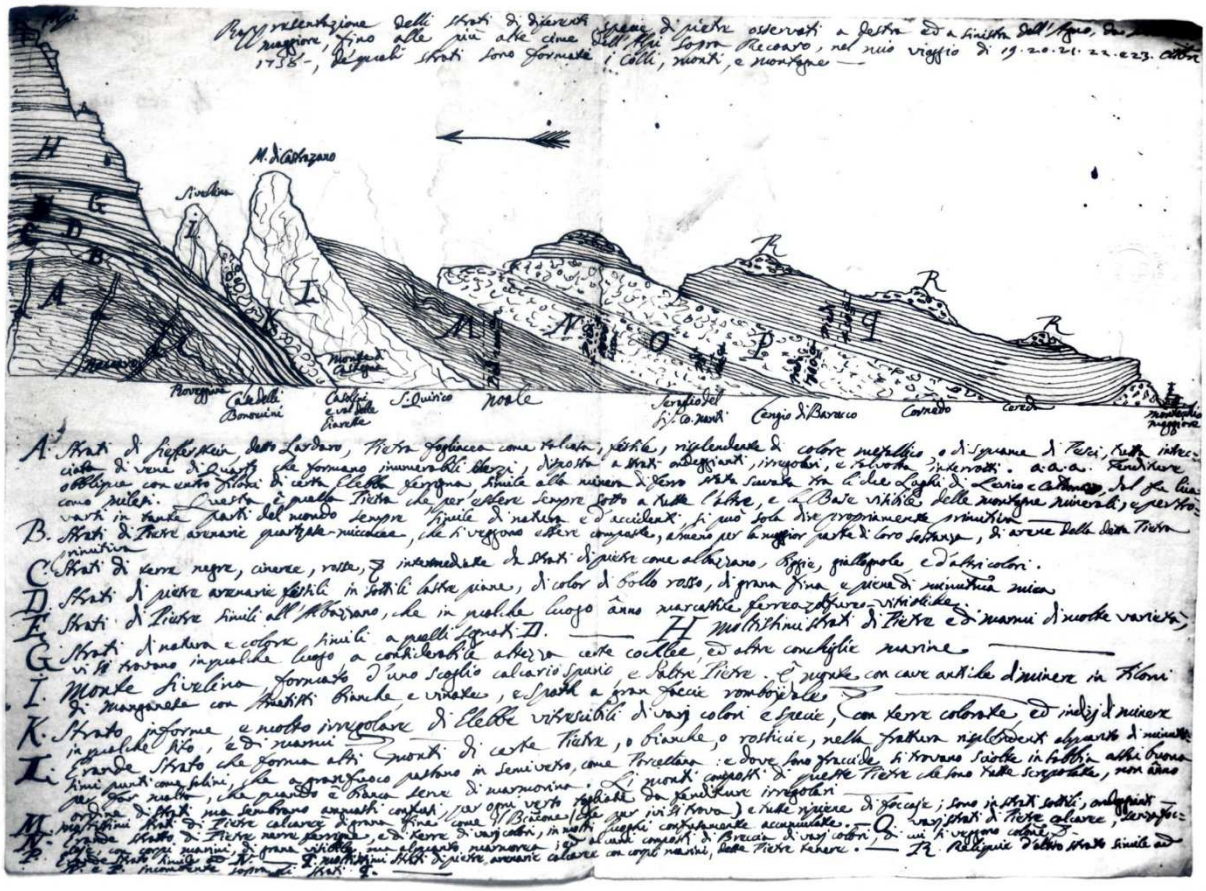

Fig. 2 - G. Arduino, "Representation of the strata of different species of rocks, observed on right and left of river Agno, from Montecchio Maggiore as far as the highest summits of the Alps above Recoaro, in my journey of 19.20.21.22 and 23. October 1758 - of which strata hills, mounts and mountains are composed". [Manuscript kept in] Biblioteca Civica Verona, *Fondo G. Arduino*, b.760, IV.c.11 (45 x 30 cm / 18 x 12 in).

This theory was later refined and enlarged in Arduino's major work, the *Saggio Fisico-Mineralogico di Lythogonia e Orognosia* (Physical-Mineralogical Essay of Lithogony and Orognosy: Arduino, 1774; Fig. 3), where he reinforced the main points of his lithostratigraphic 'classification' proposed 14 years earlier, including a new lithological sub-division within the "Primary" mountains: the *vetrescibili*, which were only formed by fire and the *calcarie*, which were formed by the interaction of fire and water. The latter were considered younger and were placed near the boundary with the rocks of the "Secondary" mountains. Arduino also assigned the name *schisto* (schist) to the "primeval" rock - now known as a metamorphic crystalline rock made essentially of quartz and mica - which he had observed several times at the base of the Alps, Venetian Prealps and Apuane Alps (crystalline schist). At the beginning of the *Saggio*, Arduino summarized the true tripartite distinction of the reliefs: "I included in the primitive order those mountains, which are formed by those underground materials, which used to be the ordinary original receptacle of the metal mines, and for this reason are called the Mineral Mountains by the practical men [miners] in order to distinguish them from those of another quality: and I have considered as secondary the mountains of marble and stratified calcareous rocks, in which those mines are extremely rare, and probably always occasional and accidental; but they are commonly full of petrified organic marine products. I refered those low mountains and hills to the third order which are seen to be composed of gravel, sandstone, muddy, clayey and marly soils etc.; material with always a large abundance of mixed marine minutia." (Arduino, 1774, first edition, p. 229: translated by E.Vaccari).

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SAGGIO
FISICO-MINERALOGICO
DI LYTHOGONIA, E OROGNOSIA
DEL SIGNOR
GIOVANNI ARDUINO
PROFESSORE DI MINERALOGIA, E DI CHIMICA METALLURGICA,
PUBBLICO SOPRINTENDENTE ALLE COSE AGRARIE
DELLO STATO VENETO.

FIno dall' Anno 1759. manifestai le mie congetture intorno alle differenze di origine, e di natura dei materiali del Regno Lapideo, cospicui nel Globo nostro, in due Memorie epistolari, dirette al Chiarissimo Sig. Cavalier *Antonio Vallisneri*, pubblico Professore d' Istoria Naturale nell' Università di Padova, ch' egli fece pubblicare (1).

Osservate lungo tempo le situazioni montuose, e le pianure di questi nostri, e di altri paesi, e attentamente contemplate le differenze di modi, e di tempo della loro formazione, manifestamente apparenti nelle diversità di situazione e disposizione, e di natura, e di fenomeni de' rispettivi loro materiali, parvemi di potere

(1) *Nuova raccolta di Opuscoli Filologici ec., del P. Abb. Calogerà* T. VI. *Venezia* 1760.

N.° XXII.

GIORNALE D'ITALIA
SPETTANTE ALLA SCIENZA NATURALE, E PRINCIPALMENTE ALL' AGRICOLTURA, ALLE ARTI, ED AL COMMERCIO.

3. Decembre 1774.

Saggio Fisico Mineralogico di Lythogonia e Orognosia del Signor Giovanni Arduino, *Socio della R. Accademia delle Scienze di Siena, e delle Pubbliche Georgiche di Verona, Vicenza, Padova, Udine, Belluno, e Conegliano, e delle Società, Fisica di Zurigo, e de' Curiosi della Natura di Berlino; Pubblico Soprintendente alle Cose Agrarie, ec. dello* Stato Veneto.

*Tratto dal Tom. V. degli Atti della R. Accademia delle Scienze di Siena; corretto dagli errori corsi nella detta Edizione, ed accresciuto di alcune Note; ec. ; segnate *.*

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Osservate lungo tempo le situazioni montuose, e le pianure di questi nostri, e di altri paesi, e attentamente contemplate le differenze di modi, e di tempo della loro formazione, manifestamente apparenti nelle diversità di situazione e disposizione, e di natura, e di fenomeni de' rispettivi loro materiali, parvemi di potere ragionevolmente comprendere sotto quattro generalissimi Ordini, o Divisioni la Terrestre superficie, dalla sua esterna faccia, fino almeno a quella profondità, cui giugnere possono le umane indagini.

Quindi in tre Ordini distinti tutti li monti, nominando primari, o primitivi quelli del primo Ordine, secondarj quelli del secondo, terziarj quelli del terzo, ed assegnando al quarto le pianure. Indicai pure, benchè succintamente, le ragioni di siffatta divisione, e le note caratteristiche, per le quali essi ordini fuono dall' altro si distinguono, ed i tempi vari, e successivi delle loro origini si conoscono.

Furono da me compresi nell' Ordine de' primitivi quei monti, che per essere formati di quelle fossili materie, ch' essere sogliono gli ordinarj originali ricettacoli delle Minere metallifere, vengono da' Pratici col nome di Monti Minerali distinti da quelli di altre qualità: ed ho considerate secondarie le montagne di marmi, e pietre calcarie a strati, nelle quali tali mi-

Fig. 3 - The two editions of the "Physical-Mineralogical Essay of Lithogony and Orognosy" (Arduino, 1774): on left, the first edition published in Siena; on right, the second edition published in Venice.

Arduino also recalled the importance of considering a complex chronological scale relative to the dating of the strata, mountain formations and rock types of the four lithstratigraphical units, which in turn originated from "effective causes" (*cause effettrici*) and "circumstances" (*circostanze*), which were also very varied among themselves: "As however, also the rocky and terrigenous material of each of the four said divisions are very different from each other, and considering the ways and respective places where they occur, knowing that they are not contemporaneous, but successive results, produced in different times and with the contribution

of diverse circumstances by their respective effective causes; thus speaking of primitive mountains I considered as primeval those of their material, for the position that they occupy, and for the other aspects, they seemed to me to be of an older origin: not however with respect to the constituent materials of each one; but only with regard to the modifications under which they now exist." (Arduino, 1774, first edition, p. 230: translated by E.Vaccari).

Arduino's position with regard to the different "physical causes" of the formation of his four lithostratigraphic units (and therefore of the three classes of mountains) emerged quite clearly in the *Saggio Fisico-Mineralogico*: fire alone was responsibile for the formation of the oldest "Primary" mountains of the "first subdivision", as well as for the "primeval" rocks placed at the base of all the visible rock formations, while water was the only geological agent which determined the deposition of the alluvial and coastal terrains respectively in the plains and marine coasts, composing the fourth unit (*quarto ordine*) which was of more recent formation with respect to all the others. Between these two lithogenetic stages (respectively oldest and most recent) of Arduino's 'classification' were placed the "second subdivision" of "Primary" reliefs (produced by fire and modified by wind and water), the "Secondary" mountains (produced by water and partially modified by fire) and the "Tertiary" mountains (of analagous origin to the "Secondary", but sometimes also only volcanic). Therefore, according to Arduino, water and fire had acted alternatively on all these orographic units which had formed successively within a complex chronological and orogenetic scheme (Fig. 4).

UNITS (*ORDINI*)	MOUNTAIN TYPE	ROCK TYPE	CAUSES
1	Basement / primeval rock *roccia primigenia*	Crystalline schist *schisto*	Fire cooling of the original Earth surface
	Primary or Mineral Mountains *Monti Primari o Minerali* a) first subdivision b) second subdivision	Granite, porphyry and mineral-bearing crystalline rocks (*rocce vetrescibili*); sandstone and conglomerates without fossils	Fire, Wind & Water a) volcanism b) volcanism and erosion due to wind and water
2	Secondary Mountains *Monti Secondari*	Marbles and stratified limestones with fossils; stratified rocks like *vetrescibili* but without mineral veins	Water & Fire Marine sedimentation and modifications due to the reprise of volcanism
3	Tertiary Mountains *Monti Terziari, Colline*	Gravel, clay, fossiliferous sand, volcanic material	Fire & Water Volcanism and sedimentation within sea waters
4	Plains *Pianure*	Alluvial deposits, sometimes stratified	Water Erosion caused by rain and rivers

Fig. 4 - Arduino's lithostratigraphic theory developed between 1760 and 1774.

Arduino was aware of the difficulties in order to reach a complete and detailed interpretation of the history of the Earth. He also intended to avoid the risk of a too rigid interpretation about the formation of the lithostratigraphical subdivisions outlined in his theory:

"I do not wish that it is believed that having distinguished all the mountains in only three orders that one be convinced that they were also formed in only three times. It is too easy to see that the periods had to be many, as the effects are diverse, which occur in the mountains one after the other. In our very long and very high calcareous Alps, for example, composed of strata upon strata, from their lowest visible roots, up to the highest peaks, it is inevitable to conceive of many periods successive in time due to the repetition of their formation, correspondent to how many strata there are in number, all obviously composed of

calcined marine sediments which mark the end of their formation, full of shells in immense quantities, and of many species which for the most part are diverse from one strata to another." (Arduino, 1774, first edition, p. 256: translated by E.Vaccari).

Arduino's system is presently regarded as being the starting point for the stratigraphy of northeast Italy and also the base of the modern chronological subdivisions of the Earth's geological history (Ellenberger, 1994, pp. 258-265; Vaccari, 2024, pp. 8-9). According to Ellenberger (1994, p. 259), Arduino had recognized a series of rock formations which are now assigned to the upper Palaeozoic through the lower Cenozoic or Tertiary. Moreover, geologists and historians of geology recognized the importance of Arduino's term "Tertiary", which takes its place in the modern standard stratigraphic column (e.g. Albritton, 1980, pp. 118-119; Berry, 1986, pp. 64-66), while the importance of Arduino's "Fourth Order" for the later establishment of the concept of "Quaternary" during the 19th century has been recently emphasized (Gibbard, 2019). Within the context of the history of the Earth sciences during the late 18th century, the *Saggio Fisico-Mineralogico* certainly represents the most mature expression of Giovanni Arduino's research, as well as a fundamental contribution to the development of the new science of geology.

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Publication online: Posted IUGS Website / INHIGEO Website Anniversaries
October 2024
IUGS E-Bulletin Issue 210, October 2024

Author: Ezio Vaccari
President of INHIGEO: IUGS International Commission on the History of Geological Sciences (INHIGEO)

Department of Theoretical and Applied Sciences,
University of Insubria,
Varese, Italy
Email: ezio.vaccari@uninsubria.it

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