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Geological issues in Alberto Fortis' *Viaggio in Dalmazia* (1774)

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Abstract

The Italian abbot Alberto Fortis (1741–1803), educated in geology, petrology, mineralogy, and palaeontology by eminent 18th-century naturalists, performed several extensive explorations in Istria and Dalmatia – provinces of the former Venetian Republic, now the littoral part of Croatia. Notes from some of these journeys, collected in 1774 in the book *Viaggio in Dalmazia*, encompass observations of almost all aspects of social and physical features of Dalmatian people and land. From a geological point of view, Fortis' remarks generally correspond to recent studies, with some exceptions in palaeontological and petrological issues. His understanding of natural processes, mainly in karstology and hydrology, is mostly surprisingly good. Besides, he addressed critics to previous writers, whose theories, influenced by older authorities, had been taken for granted instead of being re-examined by field explorations. His unjustly neglected work was the first extensive and comprehensive study of this part of Europe, little known in the then scientific community. ***To cite this article: M. Surić et al., C. R. Geoscience 339 (2007).***

Résumé

Excursions géologiques extraites du *Viaggio in Dalmazia* d'Alberto Fortis. L'abbé italien Alberto Fortis (1741–1803), instruit en géologie, pétrologie, minéralogie et paléontologie par d'éminents naturalistes du XVIII[e] siècle, a mené plusieurs vastes explorations en Istrie et en Dalmatie – provinces de l'ancienne république de Venise, constituant à présent la partie littorale de la Croatie. Les notes écrites au cours de certains de ces voyages, réunies dans le livre *Viaggio in Dalmazia*, renferment des observations de presque tous les aspects des caractéristiques sociales et physiques de la population du pays. D'un point de vue géologique, les remarques de Fortis correspondent, en général, à des études récentes, avec quelques exceptions en matière de paléontologie et de pétrologie. Sa compréhension des processus naturels, particulièrement en karstologie et en hydrologie, est, la plupart du temps, étonnamment bonne. En outre, il adresse des critiques à des auteurs précurseurs, dont les théories, influencées par d'anciennes autorités, ont été considérées comme admises au lieu d'être repassées au crible de l'examen sur le terrain. Son travail, injustement négligé, a été la première vaste étude d'ensemble de cette partie de l'Europe, alors peu connue au sein de la communauté scientifique.

Keywords: Alberto Fortis; Geology; History of sciences; Dalmatia; Croatia

Mots clés : Alberto Fortis ; Géologie ; Histoire des sciences ; Dalmatie ; Croatie

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1. Introduction

This article is an overview of thorough explorations performed in the 18th century by the Italian naturalist Alberto Fortis during his several travels in littoral Croatia – Istria and Dalmatia, their coast, islands, and hinterland. Fortis' observations, mostly written in the form of letters, were compiled and published in 1774 in the book *Viaggio in Dalmazia*, subsequently translated into English, Croatian, French, German, and Swedish. Prior to Fortis, only a few authors published notes from geology, referring mostly to speleology and karstology of this region: Nikola Gučetić from Dubrovnik in 1585 [17], and the Slovenian Johann Weikhart Freiherr von Valvasor in 1689 [29], while in the 18th century, along with Fortis, this subject and region attracted Baltazar Hacquet [18] (French born, but served throughout Europe [20]) and the Croat Ivan Lovrić [23]. Based on his exploration, the latter discussed and recapitulated Fortis' achievements.

Although Fortis' work encompasses observations and discussions on a wide range of physical, social and human subjects from geology, mineralogy, petrology, geography, geomorphology, hydrology, climatology, biology, history, ethnology, and sociology, our work focuses mainly on geological issues *sensu lato*. The aim of this work was not to criticize or correct Fortis' thoughts, ideas and perceptions, but to analyse and point out some respectable remarks and conclusions, as well as to emphasise his dedication and devotion to natural science.

2. Methodology

The main source of the analysed matter is the Croatian edition of Fortis' *Viaggio in Dalmazia* (*Put po Dalmaciji*) [15]. In order to avoid possible misleading translations, the original version of *Viaggio in Dalmazia* from 1774 [11] (Fig. 1) and a reprint of the original Italian edition published in 1974 [14] have been consulted for every questionable issue. Because of exceptionally detailed Fortis' elaborations, many of the items will be discussed in general and not by every particular location he visited, except for some distinctive places, remarks, or ideas.

In order to compare Fortis' annotations on the explored area with actual geological settings, Basic Geological Maps (1:100 000) made by the National Geological Survey of ex-Yugoslavia, as well as other geological articles on the particular themes, were consulted. Ore deposits and mining resources mentioned in the *Viaggio* have been checked after Marković's monograph [24] on Croatian mineral and

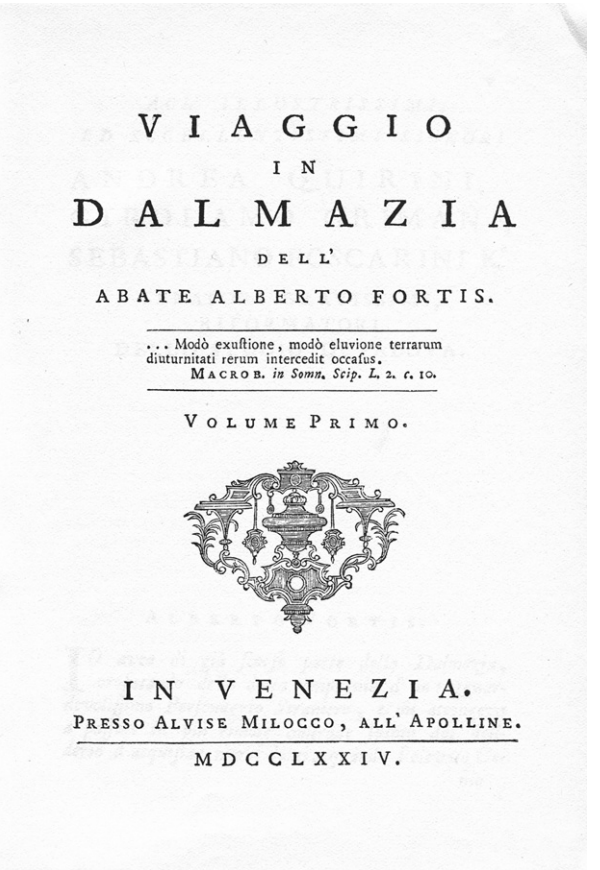
VIAGGIO
IN
DALMAZIA
DELL'
ABATE ALBERTO FORTIS.
... Modò exustione, modò eluvione terrarum diuturnitati rerum intercedit occasus.
MACROB. *in Somn. Scip. L.* 2. *c.* 10.
VOLUME PRIMO.
IN VENEZIA.
PRESSO ALVISE MILOCCO, ALL' APOLLINE.
MDCCLXXIV.

Fig. 1. Front page of the first edition of Alberto Fortis' *Viaggio in Dalmazia*, published in Venice, Italy, in 1774 (from A. Fortis, *Viaggio in Dalmazia* I &·II, 1774, J. Vuković and P. Rehder, Eds., Munich, 1974).

Fig. 1. Page de garde de la première édition du *Viaggio in Dalmazia* d'Alberto Fortis, publiée à Venise, Italie, en 1774 (d'après A. Fortis, *Viaggio in Dalmazia* I &·II, 1774, J. Vuković and P. Rehder, Éds., Munich, 1974).

mine resources. Finally, Fortis' perceptions have been compared with field observations made by authors.

While getting acquainted with Fortis' life and work in broader sense, publications of the Croat Žarko Muljačić, and the Italian Luca Ciancio, acknowledged authorities on Fortis' work, were the most helpful. Their enormous contribution to 'fortisology' consists of 1338 items (mostly documents, papers and letters written by or sent to Fortis) analysed and discussed by Muljačić, and 349 by Ciancio, until 2004 [1,5]. Muljačić synthesised all his studies about Fortis' travels in Croatia and Slovenia in a detailed monograph [25], focused on cultural, social, and linguistic aspects of Fortis' travels to this part of Europe. Ciancio published a number of scientific papers dealing with Fortis' biography [6], style and methods of scientific research [2], relationship between Fortis and other important

18th-century scientists and naturalists [4], and in 1995, he published a monograph [3] about the Enlightment and geology in Fortis' work.

3. Alberto Fortis (1741–1803)

Alberto Fortis was born on 9 or 10 November 1741 [6] in Padua, Italy, as Giovanni Battista Francesco Antonio Fortis. His father was, according to some older biographers, a barber at the church of San Francesco Grande in Padua. Further researches proved that he was, in fact, an impoverished nobleman. Fortis' mother played a vital role in his early intellectual and scientific development. She was well educated and possessed quite a large house library, a meeting point of Padua's aristocracy and educated class. Having such a background, young Fortis became interested in Earth science and began collecting rocks and fossils. The turning point in his life was at the age of 16, when he joined Padua's Roman-Catholic seminary and became a member of the Augustinian order. It is not yet clear whether he was ever actually ordained, though he changed his birth name to Alberto upon entering the order. He was expected to be the order's theologian, but, at the time, he was more occupied with the writing of the epic about Earth's cataclysms. The Augustinian order sent Fortis to Rome where he studied under the supervision of A.A. Giorgi, a member of the highly influential Vatican office *Propaganda fide*, and expert in oriental languages and scripts. In Rome, Fortis was given a unique opportunity to work in the Biblioteca Angelica, where he impressed his tutors with his immense knowledge of virtually everything but theology. In 1777, he moved from Rome to Venice because of his constant disagreements with the elders of the Augustinian order, who did not approve his liberal views and his inclination toward the ideas of the Enlightenment.

In spite of living in abbeys, he managed to spend most of his free time on various geological excursions on the Italian territory. These excursions were the basis of the formation of his future ideas and ways of scientific exploration, since he was accompanied by some of the most important Italian natural scientists of the 18th century [6]. Fortis' general geological ideas and methodology of geological field explorations were adopted mostly from Giovanni Arduino, professor of mineralogy at the University of Padua and 'father of Italian geology', who was the founder of the basis for stratigraphic chronology (he introduced three main strata of the Earth's crust: Primary [Primitive], Secondary and Tertiary). Fortis' knowledge in palaeontology was based on the researches and writings of Giovanni Bianchi and Vitaliano Donati, whose five travels to Dalmatia resulted in the publication of *Della Storia naturale marina dell'Adriatico* in 1750. Other important scientists whose ideas influenced Fortis were Antonio Vallisneri Senior, Italian physician and naturalist, one of the first refuters of the Flood Theory, Antonio Vallisneri Junior, professor of natural history at the University of Padua, and Martin Thomas Brunnich, Danish zoologist, professor of natural history at the University of Copenhagen. In order to expand their ideas about marine zoology and palaeontology, Fortis organized a number of field researches with the naturalist and abbot Guido Vio [6]. In fact, among the scientists of the 18th century, Fortis was one of the strongest promoters of field research, together with the Swiss geologist Horace-Bénédict de Saussure, the French geologist Déodat Gratet de Dolomieu, and the Scottish naturalist John Walker [8]. Fortis considered fieldwork as the most important and indispensable scientific research method, especially in natural sciences; so, the fact that all of his printed books, papers, documents and letters were the result of the researches done in the field is not surprising at all. Fortis was exceptionally accurate when performing field exploration, although his scientific equipment was rather poor and simple compared to Woodward's list (*The brief instructions for making observation in all parts of the world* published in 1696) [2]. During field trips, he always had a geological hammer, scalpel, bottles with acids, compass, barometer, thermometer, callipers for measuring layer thickness, simple microscope, telescope and metal points for testing hardness of the materials. He also used to carry arms, notebooks, drawing kit, topographic map, geographic books with detailed descriptions of the prospected area and sample containers for palaeontological, archaeological, and zoological samples, or mineral water and gas samples in volcanic areas [2].

Fortis employed all the experience and knowledge gathered from different sources in the exploration of the littoral part of Croatia, which resulted in the book *Viaggio in Dalmazia*. After the book was published, he did not get the honours he thought he deserved. For some years, he was hoping to be appointed as a professor of natural history at the University of Padua, but he never succeeded, because of his liberal views and friendship with members of the Anglican Church and, at one point of his life, he was even labelled as a heretic. Due to constant pressure and monitoring by the secret service of the Venetian Republic, Fortis moved to Naples, where he served as the court's mineralogist from 1783 to 1790, and he took another set of journeys to the eastern Adriatic coast. As a whole, Fortis

travelled to Dalmatia eleven times, the first time in 1765 and the last time in 1791. He died in Bologna on 21 October 1803, at the age of 62.

4. Book *Viaggio in Dalmazia*

Alberto Fortis is best known by his book *Viaggio in Dalmazia*, giving a comprehensive description of the land and the people of Dalmatia based on his first four (out of a total of eleven) voyages to this part of Croatia. Though neighbouring Italy, in the late 18th century Dalmatia was almost unknown to the European public. It was a province at the crossroads of the Ottoman and Austrian Empires and of the Venetian Republic, and the border zone between the Christian and the Islamic civilization, thus rarely visited by the Europeans, other than soldiers. However, the ideas of the Enlightenment and pre-romantic period brought attention to remote and somewhat forgotten parts of Europe, searching for the ideal of simple and undisturbed life.

On Easter 1765, at the age of 24, Fortis went on his first journey to the east, to Istria (Fig. 2). His second

Fig. 2. Geographical frame of Fortis' travels to the eastern Adriatic coast from 1765 to 1773.

Fig. 2. Cadre géographique des voyages de Fortis sur la côte adriatique orientale de 1765 à 1773.

journey took place in May 1770, when he visited the islands of Cres and Lošinj. This journey was sponsored by John Stuart, Earl of Bute (former Prime Minister of the United Kingdom and devotee of botany) who wanted to find out more about the plants of this area; unfortunately, illness disabled him to take part in this expedition. On that journey, Fortis was accompanied by John Symonds (British jurist, historian, and expert in agriculture) and Domenico Cirillo (Italian botanist and physician). Impressions from this part of his travels were published in 1771 in the booklet *Saggio d'Osservazioni sopra l'Isola di Cherso, ed Osero* ('Observations on the islands of Cres and Lošinj'). Fortis' cooperation with the British continued on his third trip to Dalmatia. Lord Frederick Augustus Hervey, Anglican bishop of Londonderry, and his nephew James, together with the designer Michael Shanahan, followed Fortis through a major part of the province, including the towns of Split, Zadar, and Trogir, as well as some inner parts of Dalmatia. Friendship with bishop Hervey led Fortis to constant disputes with Augustinians, forcing him to leave the order in 1772, which meant that from this point on, he had to earn his own wages by working, exploring, writing, and contributing to scientific journals. Important source of his incomes was collecting rocks, minerals, and fossils for collectors across the continent. Being free of his religious duties, Fortis was able to start sorting his notes and preparing the book. Nevertheless, before he was ready to publish the book, he went to Dalmatia two more times.

In autumn 1772, he was instructed to leave to Dalmatia in order to study the fishing methods on the Dalmatian islands and the possibility of exporting fresh fish to Venice. This time he was accompanied by Jack Hervey and the designer Angelo Donati. Since, at the time, the fishing season had just ended, Fortis took another journey in the summer of 1773. He was sponsored by the Special Committee for Manual Trade (*Deputazione straordinaria alle arti*) and, this time, he was banned from taking any money from his former private sponsors. Notes from this fifth journey were not included in the book.

Viaggio in Dalmazia was published in Venice in April 1774. The text was written in form of letters addressed to various members of the European scientific community, including Andrea Quirini, Girolamo Grimani, Sebastiano Foscarini, Jacopo Morosini, nobles of Venice, John Stuart, former British Prime Minister, Antonio Vallisneri Jr., professor of natural history at the University of Padua, Gabriel Brunelli, professor of natural history at the Institute of Bologna, Johann Jakob Ferber, member of the Swedish Mineralogical Society, John Strange, British ambassador in Venice, Giovanni Marsili, professor of botany at the University of Padua and a member of the Royal Society in London, Frederick Hervey, bishop of Londonderry and Lazzaro Spallanzani, professor of natural history at the Pavia University and also a member of the Royal Society in London. The book consists of two volumes; the first one describes Fortis' journeys from Zadar to Šibenik and the second one from Šibenik to Makarska. It was illustrated with two maps of Dalmatia and 12 copper plates carved by Jacopo Leonardi. They present archaeological remnants, some landscapes, limpets from Čiovo Island, three of them showing folk costumes of Morlachs (Venetian name for the inhabitants of northern and central Dalmatia), one is dedicated to fossil findings and as much as five present geological outcrops (Fig. 3).

Soon after its release, the book became popular throughout Europe, but, amazingly, not so much in Italy. After the Italian edition, the book was translated into German (*Reise in Dalmatien*, Bern, 1776), French (*Voyage en Dalmatie*, Berne, 1778 [12]) and English (*Travels into Dalmatia*, London, 1778). Interestingly, only the English edition [13] contains *Saggio d'Osservazioni sopra l'Isola di Cherso, ed Osero* (written three years prior to *Viaggio*) and the *Appendix* in which Fortis describes the island of Pag and Littoral Croatia, i.e. the northern part of the Croatian coast, which was under Austrian rule at the time. The best known and the most popular part of the book was the chapter about Morlachs, which somewhat overshadowed the rest of the book. It introduces an almost unknown nation to the European literature, its way of life, its customs, and raw, but highly valuable poetry.

5. Terminology problems

As aforementioned, our intention is not to criticize Fortis' work, although we must start with a serious remark about the terminology used in descriptions of rock types. Namely, the entire littoral part of Croatia, as well as most of the islands, consists almost exclusively of karstified Mesozoic and Palaeogene carbonate rocks, with some Palaeogene clastic sediments. Generally, the major part of the region that Fortis describes belongs to certain part of the following simplified sedimentary sequence: the oldest are Jurassic limestones followed by Lower Cretaceous dolomite and limestone, then Upper Cretaceous rudist limestone, which is transgressively overlaid with Palaeogene foraminiferal limestones. The latter differ by the content of forams (miliolidae, alveolinidae, and nummulites, by order of appearance). The last member of this sequence is flysch, which Fortis

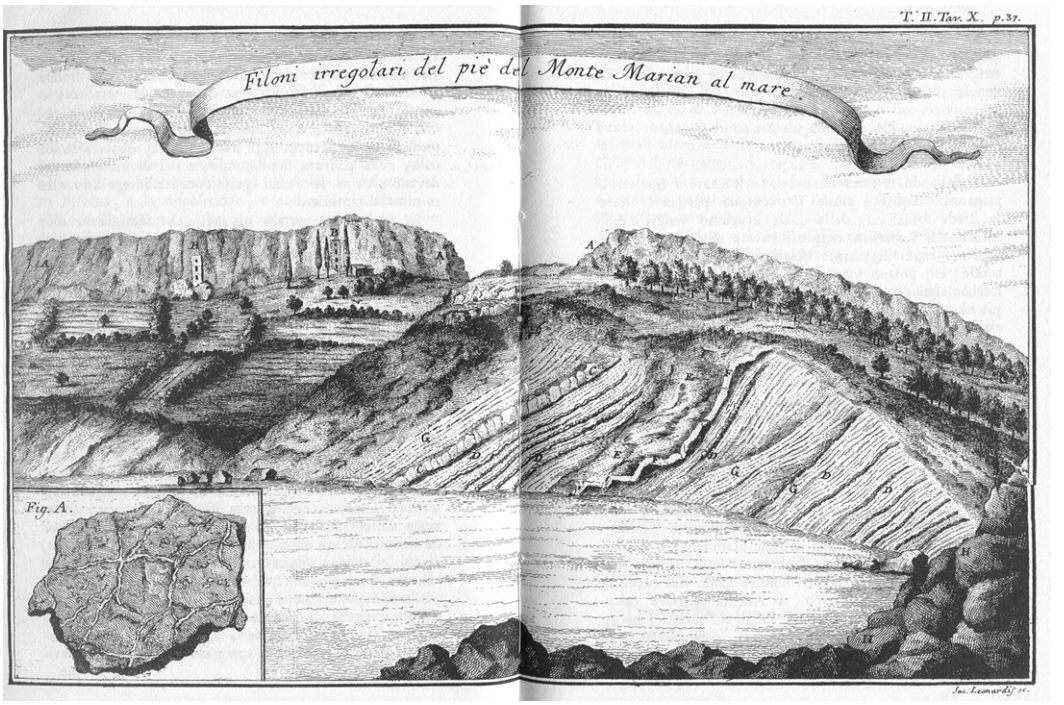

Fig. 3. Cross-section of Mt. Marjan, near Split, carved in a copper plate by Jacopo Leonardi, showing characteristic stratified marl and sandstone deposits affected by differential erosion (from A. Fortis, *Viaggio in Dalmazia* I &·II, 1774, J. Vuković and P. Rehder, Eds., Munich, Germany, 1974).

Fig. 3. Coupe transversale du mont Marjan, près de Split, gravée sur une plaque de cuivre par Jacopo Leonardi, montrant les dépôts caractéristiques stratifiés de marnes et de grès affectés par l'érosion différentielle (d'après A. Fortis, *Viaggio in Dalmazia* I &·II, 1774, J. Vuković et P. Rehder, Éds., Munich, 1974).

avoids to name, but which he describes quite well as clayish earth, marly earth, soft rock etc. However, the problem appears when writing of prevailing limestone features. Limestone is a sedimentary rock, usually biogenic or chemical in origin, which forms in shallow seas, but throughout the whole work, Fortis refers to it as sandstone (clastic sedimentary rock with grain size between 0.02 and 2 mm) or marble (metamorphic rock originated from sedimentary limestone or dolomite). Nevertheless, the fact is, there is no marble in this area at all. Even if he had found marble, due to recrystallization, it would not have had so many fossils, which he continuously quotes. Yet, other scientists of that time also used these terms improperly.

Even more confusing and contradictory are the combinations of the abovementioned terms in most of his description, such as in depiction of the Olib and Silba Islands' bedrock. In that part, he deals with, e.g., ''marble'' that corresponds to ''Wallerius' hard limestone with impalpable and indistinct particles. The appearance of this marble is quartzous.'' He continues with another description: ''. . .soft, stalactitic, coloured marble with curved veins, known among stone-masons as alabaster from Corfu.'' In this case, he mixes sedimentary forms (speleothems), which absolutely cannot be metamorphic in origin, with (metamorphic) marble, and compares them with alabaster, which is not even a carbonate, but a variety of gypsum (hydrated calcium sulphate). Again, in his description of the village of Pirovac, he writes about ''stalactitic marble''; on Čiovo Island, he mentions ''stalagmitic foliated rock called flowery alabaster'', ''striped red stalactite or alabaster'' in the village of Rogoznica, and so on. But, on the other hand, in the description of Molat Island, he mentions ''whitemost limestone, almost as hard as a marble''. Apparently, he knew the difference between these two types of rock, which makes his misinterpretations even more curious.

But not all the blame goes to Fortis. Throughout his *Viaggio*, he uses two different expressions in Italian: *calcare* meaning limestone and *calcareo* meaning calcareous (of, containing, or like calcite). In the Croatian translation [14,15], many times *calcareo* was translated to *of the limestone*, instead to *of the calcite*, causing misunderstanding in the parts that were originally correct. It is possible that other translations have the same problem. Fortis himself complained about the English [13] and French translations [12], so

the declaration from the English edition, ''translated from the Italian under the author's inspection'', seems to be false. Fortis was much more satisfied with the German translation.

6. Palaeontological issues

Consequences of the lack of formal education are probably most pronounced in petrographical topics, and partially in palaeontological ones. Namely, quite often, while describing fossil assemblage, Fortis recognizes ''orthoceras'' as dominant fossil. But, the genus Orthoceras became extinct in the Upper Triassic and the fossiliferous limestone in which Fortis finds ''orthoceras'' is, actually, Upper Cretaceous rudist limestone – one of the most widespread lithological formations in littoral Croatia. Hence, he mixes up orthoceras (cephalopod) with rudists (bivalve) that appeared in Jurassic times and were most abundant in the Upper Cretaceous, before their extinction at the Cretaceous/Tertiary boundary. The reason for this misinterpretation is in their morphological resemblance (both looking like a horn; Fig. 4) and the fact that much older orthoceras were better known at that time due to their abundance in western Europe. Another evidence of misinterpreted ''orthoceras'' fossils is their occurrence together with nummulites (Eocene index fossils) in 'normal' succession, e.g. on the Vis and Rab Islands. Nevertheless, with his level of education, Fortis was expected to recognize the familiar species, which he did relatively correctly, and not to discover and introduce new ones. Besides, other eminent geologists of that time also used the term ''orthoceras'' for similar forms. For other fossils, he usually uses names that are not common in modern palaeontology, like *Numismali*, *Nummali*, *Nummularie*, and *Lenticolari* for nummulites, *Echiniti* for Echinoidea, *Ostraciti* for ostracods, *Elmintoliti* for Helminthoida trace fossils, and Frumentaria (''tiny marine corpuses'') probably for foraminifers.

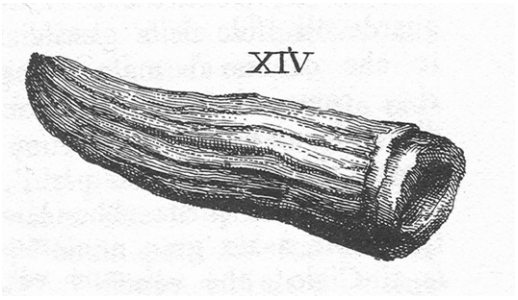

Fig. 4. Illustration of the dextral valve of Hippurites that Fortis referred to as Orthoceras, carved in copper plate by Jacopo Leonardi (from A. Fortis, *Viaggio in Dalmazia* I &·II, 1774, J. Vuković and P. Rehder, Eds., Munich, Germany, 1974).

Fig. 4. Illustration d'une valve dextre d'Hippurites que Fortis rapporte à un Orthoceras, gravée sur une plaque de cuivre par Jacopo Leonardi (d'après A. Fortis, *Viaggio in Dalmazia* I &·II, 1774, J. Vuković and P. Rehder, Éds., Munich, 1974).

7. Karst in *Viaggio*

The major part of Fortis' observations was performed on karst – environment that he understood quite well, equally in physical and social ways. After the pioneering ideas of Greek and Roman scholars (Thales, Aristotle, Lucretius), 17th century was the period of renaissance of the interest in karst phenomena (Perrault, Mariotte, Halley, Valvasor) [10], but the foundation of modern ideas in karstology were laid by Cvijić [7], Grund [16], and Katzer [19]. In the meantime, by the end of the 18th century, Fortis' exceptional remarks on karst passed imperceptibly, probably because he was not an official member of any academic community and his approach was not scientific enough, despite the fact that in his *Viaggio* he deals with some karstological issues surprisingly good.

It is still not clear whether the term karst (*carso* in Italian) was in use at that time or not, but Fortis did not use it at all. In the Croatian editions [14,15], several regions, mountains and islands were described as 'karstic', although Fortis originally used Italian terms *aspro* and *asprezza*, meaning *sharp* and *sharpness*, respectively. Namely, Croatian translators immediately used terms *karstified* and *karstic*, since these terms are used in Croatian everyday speech for *stony*, *broken*, *barren*, etc.

During the visit to a cave near Cetina River (Gospodska Cave, after Lovrić [23]), Fortis contemplated his ''misfortune'' that all the caves he had visited in ''calcareous mountains'' had similar and monotonous interior (although he admires them, after all), and hoped that he would find something different in the ''intestines of mineral mountains''. Obviously, he was not aware that caves are typical karstic features made mostly by dissolution processes in carbonate rocks (''calcareous mountains'', as he says), and not in igneous rocks (''mineral mountains''). Fortis' distinction and descriptions of ''mineral'' and ''calcareous'' mountains correspond with ''primitive'' and ''secondary'' strata, respectively, used by John Walker and many 18th-century natural philosophers [8].

It is strange that in chapters about the caves, while speaking of speleothems, Fortis properly uses the term stalactite, but he usually names stalagmites as columns

or torsi (*colonne* and *torsi* in Italian), while he occasionally attributes the adjective stalagmit(ic) to foliated limestone and ''marble''. Nevertheless, it does not depreciate his knowledge and understanding of many karstic features and processes. Continuing discussion on speleothems, Fortis overthrows Tournefort's theory that originates from Pliny, which gives speleothems the ''ability of vegetation''. He explains speleothem precipitation from dripping water very explicitly: ''...from drops full of salty atoms and particles that can crystallize''. At the moment, we cannot define what he meant by ''salty atoms'' (maybe he determined every precipitate from the solution as a salt), but, eventually, his guess was right; calcium carbonate that forms speleothems is really salt – carbonic acid calcium salt. From a morphological point of view, he makes a mistake by ascribing initial straw (feed-water canal), which is typical for stalactites, to stalagmites, as well. It is the most obvious difference between these two features, noticeable practically in every perpendicular section, but he, apparently, could not pay attention to every single detail during cave exploration with the poor equipment of that time.

About the ''marble'' (in fact, altered Cretaceous limestone and dolomite) on Olib Island, Fortis notes that it ''weakly yields to the artificial acids; yet, due to air, which often carries them, during the years, its surface becomes rough.'' Apparently, he describes surface corrosion, one of the main karstification processes. According to this remark, we can presume that he tested in situ the solubility with HCl or some other acid he calls ''artificial'', although he does not mention any experimental work on this particular issue. However, as previously mentioned, he consistently applied field methods in accordance with the achievements of that time [2]. Furthermore, it seems that he knew that the atmospheric water is slightly acid (due to the dissolved CO_2). Surprisingly, the role of carbonic acid in the dissolution of limestone was understood several years after Fortis' travels, in 1795, by J. Hutton [10].

Fortis uses the term 'corrosion' in another context. Namely, in the intertidal zone of the karstic coast in the Rogoznica village, he attributes the forming of tidal notches to ''corrosion because of the sea salt''. However, it has been proven that seawater is supersaturated with $CaCO_3$ in surface layer [21], so the corrosion of limestone is not possible by that process. The cause of intertidal destruction is bioerosion induced by biological activity of eplithic and endolithic marine organisms [28], but even nowadays, common opinion among non-scientists is that seawater corrodes carbonate coasts, just like Fortis assumed.

Tufa, as a secondary carbonate deposit, is also one of the karst landscape characteristics. Apart from being familiar with tufa's biogenic origin, Fortis also connects tufa formation to ''lime scale (or tartar) rivers'' (*fiume tartaroso*, in Italian), referring to the rivers flowing through karstic regions that are characterized by the prevalence of dissolved matter over the suspended one. Fortis describes them (particularly Krka River) as those that ''carry calcareous earth which forms precipitates and crusts''.

Karst hydrology was also a regular subject of Fortis' observations. He points out underground connection and simultaneous fluctuations of water level of Cetina River and Buško Blato Lake (Fig. 2), in spite of the twenty-mile distance and Mt. Dinara spreading between them. Fortis takes the region Rastočko Polje near Vrgorac and the area of Trebižat River as examples of karst poljes – large flat-floored basins with interior drainage, characterized by periodic inundation caused by insufficient capacity of ponors (stream-sinks) which canalize the flood water back to the underground [10]. The description of the similar karst polje Ličko Polje, Fortis ends with a notice of subterranean flow of Lika River (Fig. 2) and its emergence on the other side of Mt. Velebit in a form of submarine springs – vruljas. Also, he claims that three vruljas in the Makarska region (near Tučepi) are ''undoubtedly supplied by the water from the tanks from the other side of the mountain (Mt. Biokovo) or by the rivers that sink into the ponors before they reach the sea.'' In hinterland of Mt. Biokovo, Fortis also describes a valley with several ponors that intermittently function as springs during autumn and spring, when they eject enormous amounts of water (together with fish from adjacent lake) and cause the flooding of the valley. Subsequently, they discharge the water back to the underground during the period of lower piezometric levels. In karstology, these features are known as estavelles.

Due to these numerous outstanding explanations of karstic features and processes, we cannot blame Fortis for not recognizing karst as an entity with distinctive hydrology and landforms so typical of this part of Croatia, which is known worldwide as a *locus typicus* of classical karst [10].

8. Understanding processes

Among other well-understood processes, we shall review Fortis' outlook on sea-level changes that he mentions on several occasions. At the very beginning of the first volume of his *Viaggio*, he takes a stand that the global sea level rises, supporting it with numerous

evidences: presently submerged remnants of antique buildings all along the Adriatic coasts, old pavements discovered in the city of Zadar under the sea level, submerged spring and manor of emperor Licinius in Živogošće and walls in Makarska, retreat of the Krka and Neretva Rivers (i.e. landward progression of the sea), frequent floods in Venice, etc. He also points to the tufa deposits on some islands (e.g., Šćedro and Hvar) that can originate ''only from some lime scale river'' that existed prior to the sea-level rise. With these evidences, he opposes to those who follow the idea of apparent sea-level rise due to land subsidence caused by compaction of the sediments. In general, Fortis was right, since the land subsidence generated by the compaction is a local event than can result in relative sea-level rise, in spite of global sea-level fall. But, his opponents were right in the case of Venice, which is really more affected by intense relative sea-level rise, not only because of natural sinking of the Po River Delta and compaction of river sediments on which Venice is built, but also by subsequent overloading with buildings and groundwater removal [27].

Furthermore, Fortis argues the delusion established by V. Donati, according to whom the sea level rises because of the sea-bottom rise due to formation of a ''crust'' on the sea bottom, together with the input of riverborne material and sediments from adjacent land (Donati mentions ''destruction of the islands''). Fortis warns that such a scenario is possible in lakes, but not in the case of sea bays that communicate with open sea according to the principle of hydrostatic paradox. In addition, Fortis, respecting the extended Donati's submarine explorations, argues that ''crust'' (marine overgrowth that consists of incrusted organisms like algae, molluscs, serpulids, etc.) grows only sporadically and not everywhere as intensively as Donati claimed. Fortis supports that with the findings of urns, which spent at least fourteen centuries on the sea bottom and are still visible, covered with only a half-inch-thick ''crust''. Besides, the lack of ''crust'' in other parts of the submarine allows Fortis to reject Donati's theory and accept the thesis of global causes of sea-level changes.

Due to practical use of bitumen (or ''pitchy asphalt'') for the impregnation of Venetian boats [24], Fortis was interested in each bitumen occurrence that he had seen or heard of: in Vinišća (near Trogir), in Kokorić (near Vrgorac), on the islands of Brač and Čiovo, etc. He describes the latter in details and adds an illustration of the outcrop with the most distinctive parts marked. In his efforts to explain the origin of that bitumen, Fortis compares Čiovo Island outcrop with other known bitumen occurrences (in France, Italy, Sweden, Greece) and criticizes previous researchers for not describing the deposits which bitumen was impregnated in. According to the isolated ''spots'' of mineral pitch, which he found in fresh broken samples (along with infillings in the joints and cracks), Fortis doubts that ''the pitch existed prior to the hardening of the calcareous earth into the rock on the then ancient sea bottom'', i.e. he regards this bitumen as syngenetic. Despite recent studies declaring it epigenetic by origin [24], we must admit that Fortis' conclusion that isolated forms could not have been impregnated subsequently was quite logical.

Another process suggested by Fortis is again related to karstification. In contrast to the ideas that vertical fractures in calcareous deposits originate exclusively from earthquakes and volcanic activity, Fortis describes a series of tiny cracks uniformly distributed in all directions within the bedrock, and ascribes them to ''misbalance'' and collapsing caused by enduring activity of the groundwater. He noticed them so often in Dalmatia that he ''does not dare to give advantage to much farther (volcanoes) and seldom (earthquakes) causes.'' Although the major fractures originate from orogeny processes and tectonics, many features actually derive from corrosional and erosional activity of the groundwater.

For the end of the review of Fortis' ideas, we have chosen a part where he flirts with well-known facts. Namely, near the village of Ostrovica, in the Zadar hinterland, a lightning set a fire to a peat bog, and the underground fire, visible only during the night, lasted for days. Inspired by that event, Fortis wonders (in fact asks Jacopo Morisoni) if the lightening could be considered as one of the causes of ''volcanic mountains''. He asks: ''If the lightning had struck a sulphur mountain, wouldn't it have had more serious consequences than those from Ostrovica peat bog?'' He also recalls a case from Japan, where a volcano appeared because of unintentional combustion of a coalmine, and alum deposits on Øland Island, which had been burning for two years. Undoubtedly, after numerous visits to Vesuvius and Etna, Fortis was absolutely aware of the real causes of volcanic activities. It seems that this was homage to Nature and its exceptional variability and diversity.

9. Fortis' criticism

Aware of the importance of fieldwork and *in situ* explorations, Fortis does not hesitate to address direct bitter critics to those who ''invent and utter (laws of stratification) without leaving their writing-desks'' and to those who, ''while standing in the comfort and shelter of their rooms, scholarly claim that the Earth is in the same

state as it was 60 centuries ago''. Here we must remind that, in Fortis' time (moreover, until early 20th century [26]), the age of the Earth was absolutely unknown. At the time, the prevailing opinion [22] was that of biblical scholars, especially Archbishop James Ussher, who crammed whole Earth history into less than 6000 years, so those who suggested that this interpretation was scientifically unreliable were branded as heretics. Only in 1785, in his essay *Theory of the Earth*, Hutton emphasised the immensity of geological time, based on his comprehensive fieldwork and understanding of natural processes [22], although there were some earlier ideas on this issue introduced by many scientists (e.g., Marana, de Patit, de Maillet, Halley, Gautier, etc.) [9].

Fortis also dares to oppose, of course, with all due respect, to the then eminent scientists. Probably the most comprehensive discussion is addressed to J.G. Wallerius, a Swedish mineralogist and chemist, and his theories on the origin of the mountains, sand and sandstone. Fortis compares Wallerius' theory that mountains form from sand, instead of sand forming from mountains, with the statement that ''flour existed prior to wheat.'' Furthermore, according to Fortis, Wallerius says that ''aggregate deposits'' were formed by ''rock and stone sticking when they were softer, because sticky matter could not penetrate into perfectly hard rocks.'' Fortis refutes that with the argument that sand particles in the sandstone do not penetrate each other as they would if they were soft. Besides, Wallerius' suggestion that the gathering of fragments takes place in the underground since ''it is impossible for any rock product or glue to form in the open air'', Fortis disproves by pointing at speleothems and thermal spring deposits (it probably refers to travertine) that form in subaerial conditions. Additionally, Fortis rejects Wallerius' theory that sandstones were ejected to the surface after the underground formation in deep interior of the Earth, and supports it by the fact that sandstones are generally well bedded and not crushed and disturbed. It is interesting that, in this part, Fortis describes the formation of sandstone quite correctly, and yet, throughout the whole work, he uses the term 'sandstone' incorrectly while describing limestone.

In one footnote, not related to geology of Dalmatia, after explaining some Wallerius' petrographic misconceptions, Fortis weeps: ''Oh, how many corrections in their systems the most famous writers would make, if only they travelled a little bit more!''

10. Conclusions

Alberto Fortis' book *Viaggio in Dalmazia* is a comprehensive guide covering almost every natural and social aspect, from hydrology and geology to ethnology and sociology, on the islands, the coast, and the hinterland of Dalmatia (Croatia). Since Fortis' main preoccupation was geology, much of the text deals with these issues. Knowledge in some fields of Earth science was still rather poor at that time, at least from today's point of view, so it is not surprising that Fortis made quite a few mistakes in describing geological features and processes. Nevertheless, his ideas should not be dismissed easily, because he did show a high level of understanding of geological processes, sometimes thinking ahead of his time, but sometimes drawing wrong conclusions based on the right premises.

Some of the most apparent misinterpretations were made in the terminology of rock types. For some of these mistakes Fortis is not to be blamed entirely, for it is proven that, in some cases, the translation of the original text was rather inadequate. Since he had not received any formal education in petrology and palaeontology, it is no wonder that there were many errors in these topics, too. In his defence, one must admit that his confusion, for instance, of orthoceras and rudist fossils is the result of their morphological resemblance, since both are hornlike, and thus hard to distinguish by non-experts.

Perhaps Fortis' best efforts were made in describing and understanding karst phenomena, forming a sort of bridge in knowledge between 17th-century scientists who showed interest in karst (Perrault, Mariotte, Halley, Valvasor) and modern ideas in karstology that appeared in the works of Cvijić, Grund and Katzer in the late 19th and early 20th centuries. Still, it is doubtful whether Fortis influenced the aforementioned scientist, because of his wide range of interests and the fact that he was not a member of an academic community, which often did not acknowledge his works. In addition, studying Fortis' book, it is not clear whether the term karst itself was in use in scientific literature of the late 18th century. When describing karst features, he often deals with caves and speleothems and, once again, shows a surprisingly high level of understanding of these processes, such as speleothem precipitation from dripping water or the process of corrosion. Furthermore, Fortis presents issues in karst hydrology, mentioning karst poljes, ponors (stream-sinks), estavelles, and vruljas (submarine springs), and explaining adequately complex karst hydrological systems.

On several occasions, Fortis mentioned the problem of the sea-level changes, stating that the sea level rises and supporting it by both archaeological and hydrological evidences. He successfully opposes the ideas of sea-level rise due to land subsiding caused by

compaction of the sediments or due to the formation of the ''crust'' on the sea bottom, combined with the input of riverborne material and sediments from adjacent land.

After a thorough examination of geological postulates in Fortis' *Viaggio in Dalmazia*, in spite of a number of delusions and misleading conclusions, Fortis apparently still deserves a great deal of credit for his work. Without any formal education in natural sciences, but with great natural ability for field exploration, he provided some excellent explanations of various geological features and processes. Unfortunately, his observations on these subjects passed unnoticed in the academic milieu of that time, and were reinvented by the scientists over a century later.

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