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KARST HYDROLOGY OF THE CROATIAN COAST RECORDED IN THE WORKS OF ALBERTO FORTIS (1741-1803)

KRAŠKA HIDROLOGIJA HRVAŠKE OBALE V DELIH ALBERTA FORTISA (1741-1803)

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Abstract UDC 556.5:551.44:929Fortis A. (497.57+497.58)

Robert Lončarić & Maša Surić: Karst hydrology of the Croatian coast recorded in the works of Alberto Fortis (1741-1803)

Alberto Fortis (1741-1803) was an Italian naturalist who had a wide range of scientific interests, from linguistics and ethnology to geology, geography, and hydrology. This paper reviews the hydrological features Fortis recorded in two of his works, *Saggio d'Osservazzioni sopra l'Isola di Cherso ed Osero* (1771) and V*iaggio in Dalmazia* (1774). These works were the result of several of Fortis' travels in the region and were noted in the European scientific literature of the time. Fortis showed the European public the eastern Adriatic coast, a little-known part of Europe at the time, with its great variety of natural features. Despite the rare occurrence of surface water in the karst, Fortis' descriptions of the eastern Adriatic coast contain numerous interpretations of hydrological features. He often demonstrates a remarkable understanding of karst hydrology, even if some of his ideas and explanations are dubious from today's perspective. Although Fortis is not considered a karstologist in the strict sense, his works contain elements of what will later become karstology.

Key words: Alberto Fortis, karst, hydrology, Croatia.

Izvleček UDK 556.5:551.44:929Fortis A. (497.57+497.58)

Robert Lončarić & Maša Surić: Kraška hidrologija hrvaške obale v delih Alberta Fortisa (1741-1803)

Alberto Fortis (1741-1803) je bil italijanski naravoslovec s širokim razponom znanstvenih interesov od jezikoslovja in etnologije do geologije, geografije in hidrologije. V članku predstavljava pregled hidroloških pojavov, ki jih je Fortis opisal v dveh svojih delih: *Saggio d'Osservazzioni sopra l'Isola di Cherso ed Osero* (1771) in *Viaggio in Dalmazia* (1774). Deli, ki sta rezultat Fortisovih potovanj po vzhodni jadranski obali, sta bili opaženi v evropski znanstveni literaturi tistega časa. Fortis je z njima evropski javnosti predstavil naravno pestrost tega, takrat malo poznanega območja. Kljub odsotnosti površinskih voda, Fortis predstavi in razloži številne hidrološke pojave in pri tem pokaže za tisti čas izjemno razumevanja kraške hidrologije. Seveda pa so nekatere ideje in razlage z današnjega vidika naivne. Fortisa sicer ne velja za krasoslovca v ožjem pomenu besede, a njegova dela nedvomno vsebujejo gradnike bodočega krasoslovja.

Ključne besede: Alberto Fortis, kras, hidrologija, Hrvaška.

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1. INTRODUCTION

Dinaric karst is known as a *locus typicus* of classical karst due to the fact that it is an area where some of the earliest research of various karst phenomena took place (Mihevc et al., 2010). Moreover, some of the karst terminology can be traced to the names of geological, geomorphological, hydrological or hydrogeological features of Dinaric karst (e.g. doline, polje, ponor, kamenitza, uvala etc.) (Kranjc, 2008). Dinaric karst drew attention of numerous naturalists, especially during the Renaissance, when first scientific papers and books on Dinaric karst were published. Thorough and comprehensive study of foreigners who visited Slovenian part of the Dinaric karst was given by Shaw (2000), while, unfortunately, no such study exists about naturalists who ventured into Croatian karst.

Alberto Fortis was one of the few European naturalists who visited today's Croatia in late 18th and early 19th century. His work was noted across the Europe and was since subjected to numerous analyses. One of the earliest

Figure 1: Area of Fortis' journeys and geographical locations of studied karst hydrology features.

was that of Ivan Lovrić (*Osservazioni di Giovanni Lovrich sopra diversi pezzi del Viaggio in Dalmazia del signor abate Alberto Fortis coll'aggiunta della vita di Soçivicza*; *Obseravtions by Giovani Lovrich on various parts of the trip to Dalmatia of Mr. abbot Alberto Fortis, with addition of Socivizca's life, Venice* 1774) who criticized much of the Fortis' writing but was also criticized by Fortis himself. Interestingly, Fortis' books became subject of interest for ethnology, archaeology, biology and even poetry, but the geoscience aspect was mostly neglected. That part of Fortis' opus has been investigated in details only relatively recently by Shaw and Adam (2001) and by Surić et al. (2007).

Alberto Fortis was born in 1741 in Padua, Italy, as Giovanni Battista Francesco Antonio Fortis. At the age of 16, he most likely became a member of Augustinian order, although it is not clear whether he was actually ordained. Despite being a member of church order and destined to be a theologian, he was more interested in Earth sciences and began collecting rock and fossils before he joined Augustinians (Surić et al., 2007). His liberal views and inclination towards ideas of the Enlightment often brought him in conflict with other members of the order and he was more interested in travels than in spending time in abbeys and monasteries. Early on, he travelled throughout today's Italy often in company of notable naturalists of the time, which deeply influenced his scientific interest. Most prominent of these naturalists was Giovanni Arduino, mineralogy professor from Padua (*father of Italian geology*) and one of the founders of stratigraphic chronology. Arduino's influence is apparent in Fortis' work for he showed a profound knowledge and understanding of the geological, hydrological and hydrogeological processes, which resulted in particularly well described karst hydrology and hydrogeology of the Croatian coast and islands. Fortis was also a big advocate of fieldwork, which he considered a cornerstone of any natural science and he was known to carry extensive, although simple, fieldwork equipment (Surić et al., 2007). All of his written work was a result of his own field observations, which makes him an excellent and highly valuable first-hand source of natural and historical data.

Alberto Fortis is perhaps best known for his book *Voyage into Dalmatia* (*Viaggio in Dalmazia*) published in 1774 which encompasses records from Fortis' first four travels along Croatian coast (Dalmatia); by the end of his life he made total of 11 travels in Dalmatia. Prior to this book Fortis also published *Saggio d'Osservazzioni sopra l'Isola di Cherso ed Osero* in 1771 in which he noted his first journey to the eastern Adriatic coast which took him to Istria and to islands of Cres and Lošinj.

This paper discusses hydrological features of the East Adriatic coast (now part of Croatia) that were recorded in the aforementioned books[1] (Figure 1). In those books, Fortis extensively wrote about natural history as well as about social and historical issues. On numerous occasions, he discussed the hydrology of the area from various aspects, whether he was trying to solve old misconceptions of the source of river (e.g. Krka River) or he was addressing the importance of water sources and water supply systems for urban development (e.g. a case of Roman colony of Iader (today's Zadar) and so called Trajan's aqueduct). His notes on various hydrological features such as lakes, springs, rivers, etc., present an insight in the level of understanding of classical karst hydrology and hydrogeology of that time.

2. KARST RIVERS

Fortis extensively wrote about the rivers that he encountered and some of them (i.e. Cetina and Krka rivers) he followed from their spring to the river mouths (Figure 1). He was very inquisitive about the origin of water in springs as he noticed that much of the water circulation actually occurred in the underground. For example, for all rivers on Istrian peninsula Fortis believed that they start as underground flows, and then appear on the surface as fully developed rivers. He particularly studied Raša River in the eastern part of Istrian peninsula and observed that the river must have been a lot longer than today (24 km, Arbanas et al., 2004) due to the huge amount of sediments found in the river mouth. He perceived Raša River as a remnant of an earlier larger river, which flew between *Ocra* and *Albio* mountains located in today's Slovenia (Figure 2). In Croatian edition of *Saggio d' osservazioni sopra isola d'Cherso ed Osero* (2014), D. Balenović, translator of Fortis' manuscript, suggests that Albio Mt. is today's Snežnik (1797 m) in SW Slovenia and that Fortis' description of Ocra Mt. fits the

[1] For this paper authors used Croatian translations of Fortis' books:
- Fortis A., 1984. Put po Dalmaciji. Globus, Zagreb, 303 pp.
- Fortis, A., 2014. Ogled zapažanja o otocima Cresu i Lošinju. Književni krug, Split, 406 pp.

Slavnik Mt. (D. Balenović gives wrong elevation, 1622 m instead of 1028 m) some 35 km W of Snežnik Mt. On the other hand, according to Horvat & Bendek (2009) and A. Mihevc (2017, pers. comm.), Ocra Mt. is actually an old name of Nanos Mt. (1313 m) located 30 km north of Slavnik.

Although Fortis was wrong about the source of Raša River his idea about longer larger river in the past is actually correct. Namely, during the Last Glacial Maximum sea level was around 135 m lower (Peltier & Fairbanks, 2006) and Raša River was flowing towards palaeo-Po River in the middle of the north Adriatic basin. Moreover, Fortis stated that the river sediments of Raša could be seen on small islands in North Adriatic, such as Susak Island, so he understands that in the past this part of the Adriatic Sea was dry land. Actually, Fortis was wrong about the origin of the deposits on Susak Island which are mostly loess of aeolian and not of alluvial origin (Durn et al., 2018).

Fortis extensively described Krka River located in the central part of the Croatian coast (Figure 1). Krka River is 73 km long and has a catchment area of about 2600 km^2 (Perica et al., 2005). One of Krka's main and most researched features are tufa deposits, which also caught Fortis' attention. He claimed that tufa deposits are found in *limestone rivers,* but only in shallow and fast flowing water. He described tufa as a form of *fitoliti* (phytolith). Furthermore, he claimed that tufa could be formed in slow moving water only if the water is *thermal*, and that the size of tufa deposits in slow-moving waters is greater than those in fast-moving waters, but the density and the mass of tufa is fast-moving waters is greater. He compared these processes to those he observed in caves. For example, stalagmites, which are made of more pure and compact material than the stalactites due to the height from which water is dripping on the cave floor because the water is full of *salty atoms and particles which can crystalize* whereas the flow of water which forms crust on stalactites contains more *poorly coloured clayish particles.* When describing Skardinski buk waterfalls, most prominent example of tufa barriers on Krka River, Fortis mentioned *wavy tufa made of grainy salt*, which people often collect erroneously believing that it is petrified wood. Fortis stated that the *tree rings* in this kind of tufa are actually layers of tufa deposited in various periods of the past and that the differences in their colour

Figure 2: Spatial relations between Raša River and Slavnik, Snežnik and Nanos mountains (source: Google Earth).

reflect the difference in substances which saturated the water. From such conclusion, it is evident that Fortis understood that the environment had been changing during the past and that those changes left trace in form of different types of deposited tufa.

Cetina River located in the central part of Dalmatian coast presented a challenge to Fortis in terms of the origins of its waters. At that time, Fortis was accompanied by Frederic Augustus Hervey (1730-1803), a protestant bishop of Londonderry who financed the journey but also contributed to Fortis' scientific efforts particularly in the matters of river genesis. They travelled to the springs of Cetina River which – by their opinion – was far too rich in water when compared to the size and structure of the surrounding mountains for which they state that are too small to host such an abundant water source. Fortis argued that the springs, which he visited, are not the true source of the Cetina River and that they are remains of a much larger underground river, which flew from the neighbouring high plateaus. He further believed that the flow of this river was interrupted by the tectonics, which transformed the plateau into mountain peaks. To find the evidence of this underground flow Fortis and Hervey visited caves near the springs of the Cetina River, and in the deep part of one of the caves, they discovered pools of water for which they believed are the remains of larger underground flow. Fortis' was convinced that sometime during the past Cetina River was flowing over what he calls *Illyric Mountains* (present-day Dinara Mt.) situated NE of the Cetina River along the present border between Croatia and Bosnia and Herzegovina. He found a proof for his theory in the accounts of the people living on the banks of Cetina River who told Fortis that the rise of the water in Cetina River is connected with the outflow from the Buško blato Lake located on the opposite side of the Dinara Mt. (today's Bosnia and Herzegovina) and that the river and the lake must be connected by the underground flow. Cetina River has been intensively used in hydropower production since 1910's, so fundamental hydrological and hydrogeological researches conducted throughout the 20th century corroborated some of the Fortis' theories as well as the believes of the local population about underground connection between Cetina River and Buško blato Lake. Indeed, Cetina River is a typical karst river with estimated catchment area of about 4000 km^2, of which 2300 km^2 is topographic or "direct" catchment and 2700 km^2 is hydrological or "indirect" catchment which is comprised of complex groundwater circulation systems so the exact size of the Cetina River basin in not known (Bonacci & Roje-Bonacci, 2003).

3. LAKES

Vransko jezero Lake near Zadar is the largest lake in Croatia (ca. 30 km^2) and it captured attention of Fortis because of the drainage canal that was built in 1770, some years prior Fortis' visit, through narrow isthmus which separates lake form the Adriatic Sea (Šuljić & Rubinić, 2010) (Figure 3). The purpose of this canal was to lower the water level and drain some 14,000 acers of the arable land (according to Fortis). He expressed his disappointment by the state of the canal, which had been poorly maintained, and out of function. Furthermore, Fortis noticed that the construction of the canal was unnecessary since lake drains into the sea during the low tide, and that the canal would only allow more sea water into the lake during the high tide. Fortis was convinced that the sea level is rising, that due this rise the water flow from the lake to the sea will cease in time, and that the surface of the lake will increase. Fortis also discusses earlier notes about the lake made by Šime Ljubavac in which he states that until 1630 the lake water was "very" fresh and that there must have been an earthquake that opened underground fissures and allowed the seawater inflow into the lake elevating its salinity. He dismisses Ljubavac's hypothesis for which he found no material evidence, and insists that the sea-level rise is responsible for the deteriorating quality of the lake water. His suggestion for reclaiming the arable land from the lake is to divert the streams that were feeding the lake either directly into the sea or into the *dry fields,* which would decrease the inflow of the water in the lake and reduce the lake's surface. One might argue that Fortis was somewhat ahead of its time with the explanation of the seawater intrusion into the lake. Namely, the sea-level rise, together with prolonged droughts, both caused by climate changes, is considered to be one of the main threats for the lake ecosystem in the future (Šuljić & Rubinić, 2010).

Vransko jezero Lake on Cres Island is the largest body of water on Croatian islands. It covers the area of 5 km^2 and is 74.5 m deep (Biondić et al., 1992). It is considered as a karst phenomenon since it is located on relatively small (405 km^2) karstic island, which like all Croatian islands, is characterized by almost complete absence of surface water due to the karstic terrain. The lake is cryptodepression with the bottom of the lake 61.3 m below the sea level (Schmidt et al., 2000). Fortis visited the lake

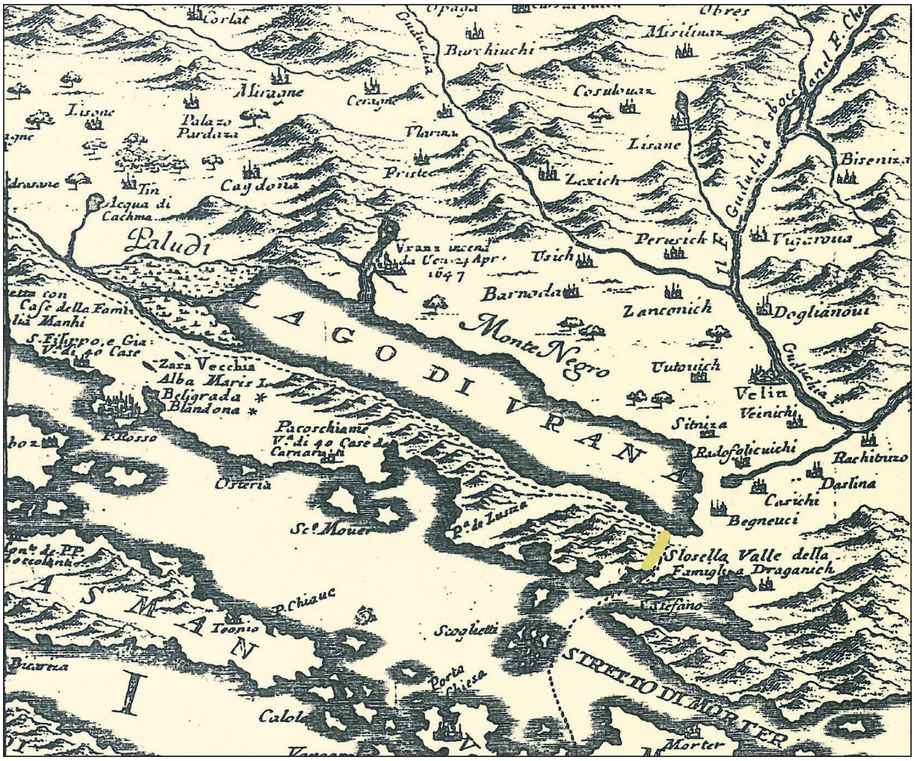

Figure 3: Vransko jezero Lake shown on the segment of map by V. M. Coronelli from 1688 without artificial canal built in 1770 (marked in yellow; source: Kozličić, 1995).

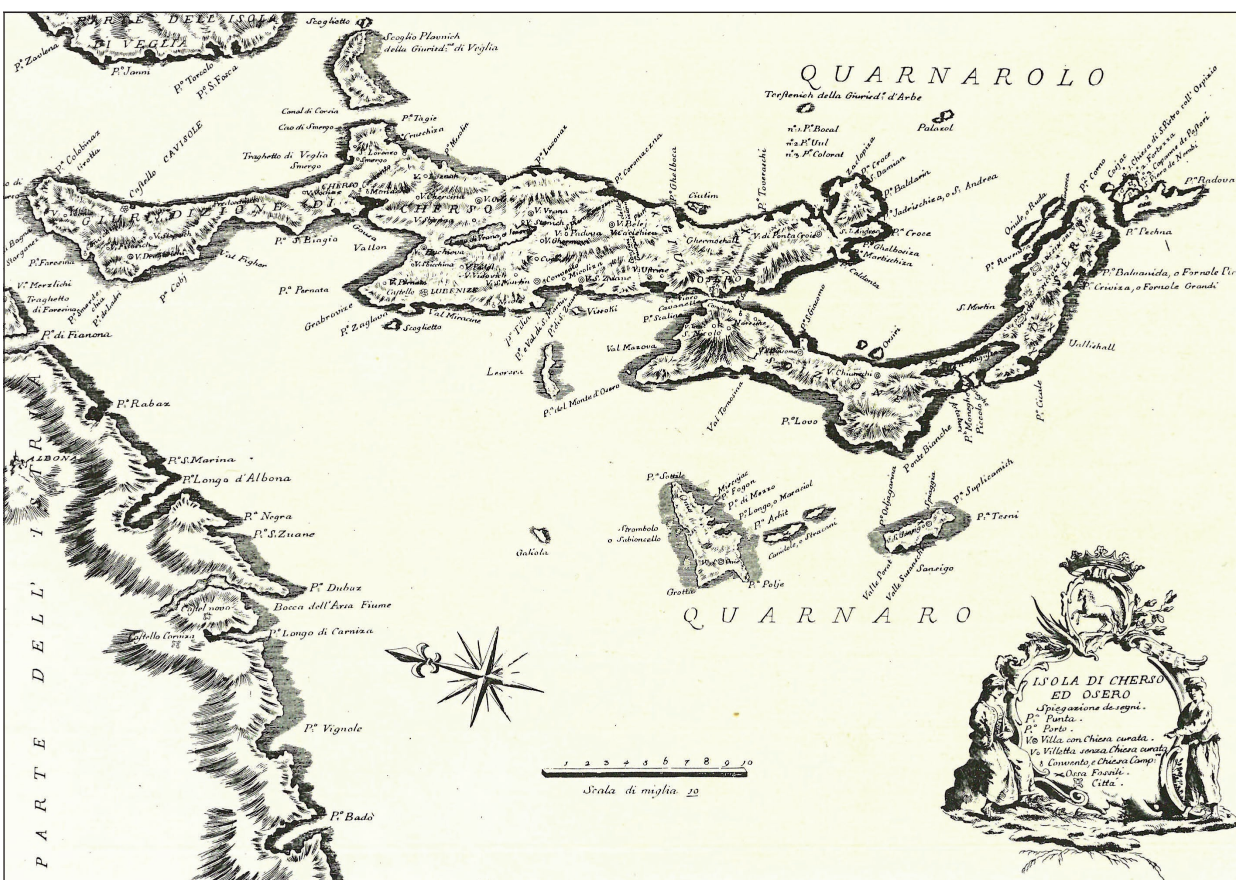

Figure 4: Fortis' map of the Cres Island showing Vransko jezero Lake (1771) (source: Fortis, 1771).

and took a short boat tour along its coasts. He argues that the lake is formed in limestone depression (Fortis actually erroneously refers to limestone as *marmo* (marbel); see Surić et al., 2007) and that its *clayish bottom* is favourable for water accumulation. In reality, lake is formed in dolomite depression and the lake bottom is covered with 30 m thick lake sediments (Biondić et al., 1995). Interestingly, Fortis states that the lake water originates from hills surrounding the lake (Figure 4). Origin of the lake water was intensively debated throughout late 19th and most of the 20th century. Lorenz (1859) suggested that the lake water comes from the neighbouring Istrian peninsula via underground channels while Mayer (1873) argues that the lake is fed through local island catchment area. Poljak (1947) supports Lorenz's theory and for the next few decades, land-based origin of water was generally accepted in the literature. Finally, Bonacci (1993) proved that the lake receives water from local catchment area, which corroborated Fortis' claim. Furthermore, Fortis writes about periodical changes of the lake water level, and through communication with the local inhabitants, he found out that lake level is changing in roughly 5-year cycles. These cycles of lake level changes were proved during extensive research of the lake's hydrological properties in the early 1990's and are caused by lake's slow response time to seasonal rainfall changes due to its relatively large volume. Furthermore, lake also displays significant annual water level changes, with average annual amplitude of 81 cm (Ožanić & Rubinić, 1995). In contrast to other, mostly accurate observations, Fortis' notes on lake's depth is somewhat confusing. Namely, he states that the depth of the lake is 12 and 14 feet. It is not clear why he gives two values in the first place. Perhaps Fortis meant that the lake's depth ranges from 12 to 14 feet, or those numbers were simply the only data he could obtain on how deep lake actually is. Since the Venetian foot equals to 0.34 m, lake's depth would fall within 4-4.7 m range, which is far less than 74.4 m, which is actual depth of Vransko jezero Lake (Biondić et al., 1997). One explanation of this unusual mistake by Fortis' standards could be that he simply confused Vransko jezero Lake on Cres Island with the aforementioned lake of the same name near Zadar. Proof for such claim is the fact that the Vransko jezero Lake near Zadar has maximum depths between 4 and 6 m (Šuljić & Rubinić, 2010) which is very close to the Fortis' data.

4. KARST POLJES, PONORS AND VRULJAS

Within karst hydrology and hydrogeology underground water circulation is particularly challenging to study because of the complicated network of subterranean fissures, fractures and conduits. Even with modern methodology (i.e. dye tracing and piezometric wells), it can be hard to determine an exact direction of groundwater flow in karst areas. For the late 18th-century scholar such as Fortis, intensive fieldwork combined with the observations of local people (which were often unreliable because of the various superstitions of the locals regarding anything underground) was the only way to collect data and to come up with scientific conclusions.

Poljes are perhaps one of the most interesting features of the karst landscape as they are displaying a plethora of geological, geomorphological, hydrological and hydrogeological processes typical for the karst. The hydrology and hydrogeology is particularly interesting with springs and ponors often located just few hundred meters apart and with poljes transforming into lakes within few hours. In few of his accounts, Fortis proved that he understood that part of karst hydrology and hydrogeology very well. He wrote about the karst polje near the town of Vrgorac in the southern Croatia, which (according to Fortis' account) was intentionally turned into lake by the Ottomans who closed the ponors when they were retreating from that area. He also stated that the lake sometimes disappears and turns into fertile land. He also mentioned the nearby river of Trebižat, which disappears into the underground as well as the flooding of surrounding poljes. Fortis further wrote about springs and ponors near the village of Kokorić, and he made remark that the floods occur after heavy rains in the Bosnian interior and that water erupts from springs few meters high. It is evident from that remark that Fortis understands that the floods are not caused only by local rains and that the water definitely flows underground before reaching the springs.

When Fortis writes about Lika River he corrects earlier writings of Danielle Farlati (1690-1773) who claims that the mouth of Lika River is in the coastal town of Karlobag at the foothills of Velebit Mt. Fortis correctly stated that the Lika River is sinking in ponors in Kosinjsko Polje. He also writes about *Gaščica* or *Guščica* River (today's Gacka River) which sinks near the town of Otočac. He gives an explanation about the directions of the groundwater flow and he argues that the water from

Gacka River appears in submarine springs (*vruljas*) along the coast near the town of Senj. As a proof of this claim, he mentioned some wooden dishes, which ended up in the Gacka River and later appeared in the sea on the other side of the Velebit Mt. Modern studies corroborated Fortis' ideas about the direction of the groundwater flow. Indeed, the analysis of satellite thermal images and dye tracing showed complex relations between the springs and vruljas along the coast and rivers in the hinterland and proved that water from Gacka River appears in vruljas near Senj (Stroj, 2010 and references therein).

Fortis' remarks on submarine springs (vruljas) are also a proof of his exceptional understanding of groundwater flow in karst. Since he had a habit of interrogating the local people about their environment he was able to conclude that the word *vrulja* is rooted in the word *vrilo* meaning spring, and that vruljas are, in fact, submarine springs. He writes about vruljas near the town of Makarska and states that the water in those springs originates from the hinterland, from some sort of underground reservoirs of from water that disappears in ponors. According to Fortis, earlier scholars were suggesting that vruljas could be considered as underwater mouths of rivers sinking in the coastal mountain hinterland, but Fortis disproved such ideas.

5. WATER SUPPLY

Fortis discussed the remains of the Roman aqueduct, which was used for the water supply of nearby Roman colony of Jader or Iader (today's Zadar). He argued that earlier authors (Šimun Ljubavac and Ivan Lucius) were wrong about the source of the water for the aqueduct which they believed was Krka River. Their claims were based on the remains of the canal found along the banks of the Krka River, but Fortis sees that canal as too small and in such poor condition that it could not transport water further than the nearby town of Skradin. He also

Figure 5: An example of preserved pond, possible Fortis' muddy reservoir (Šolta Island).

wrote that the Krka River is too far from Zadar and that terrain itself, with numerous hills and mountains, would make construction of such aqueduct impossible. Instead, he believed that the Kakma Spring near the Vransko jezero Lake might have been actual source of water for the aqueduct but he concludes that without firm evidence he cannot make any definite conclusion. Only in the 1980's Ilakovac (1982) made a most comprehensive study of Roman aqueducts in North Dalmatia, and he concluded that the source of water for aqueduct was, in fact, Biba Spring ca. 2 km to the north-east of the Vransko jezero Lake and some 40 m above sea level. However, Fortis' assumption is not without a foundation since Kakma Spring has few advantages over Biba Spring: it is several kilometres closer to Zadar and is much more abundant in water so it is used today in water supply of nearby coastal zone with substantial summer tourism. Nevertheless, Kakma Spring has one major setback compared to Biba Spring; it is only 15 m above sea level which does not give enough slope for standard Roman gravity-feed aqueduct given its substantial distance from Zadar (ca. 25 km). Both springs provide high-quality fresh groundwater in contrast with often muddy lake water which turns brackish during high tides when seawater flows in the lake through canal.

Fortis mentions *swampy rivers* and *muddy reservoirs* which were used as a water sources by the *Morlachs* (a name by which the inhabitants of the Dalmatian hinterland were known in the time of Fortis' travels). It is unclear what Fortis means by swampy rivers since swamps are rare in predominantly karstic region of East Adriatic, but swamps and marshes might have existed in Fortis' time near Vransko jezero Lake (Zadar) and along the lower course of Krka River.

Muddy reservoirs may refer either to water tanks similar to those that are preserved in many coastal and insular towns, or to the ponds, which are also still visible in the local landscape (Figure 5). Since Fortis repeatedly states that, the people he encountered are often extremely poor and that they live in simple, low-quality homes, it is unlikely that they would build expensive water tanks like those that existed in economically more developed coastal townships, so the muddy reservoirs that he refers to are most likely ponds. Additionally, water in stone-build reservoirs tends to be clear and not muddy like in the ponds. Because of the permeability of karstic terrain, it was always a challenge for the local population to obtain and preserve enough water particularly during the summer droughts. Usually, the only impermeable material available was clay. They would often build ponds in small natural depressions using compressed clay which would unable the rainwater to infiltrate underground. It is worth noticing that up until the recent times water from ponds was intensively used for agriculture and for the human consumption. Most of these ponds are now overgrown with dense vegetation, but some of them are still in use today (Lončarić et al., 2011). The scarcity of water sources was evidenced by Fortis during his visit to Ugljan Island where he remarked that the local population suffers from the water shortages which is common in almost whole *Illyric archipelago* particularly during the summer. Therefore, locals are forced to transport water from far away or to use the poor quality water from the local ponds (Figure 5).

6. THE SEA-LEVEL RISE

Perhaps one of the most interesting parts of Fortis' scientific observation are his observations about the sea-level rise. He has absolutely no doubts that the sea level is rising for which he founded numerous evidences along the Adriatic coast. When he climbed at the top of Biokovo Mt. in the south of Croatia, he was observing the islands of Brač and Hvar and the surrounding channels and he imagined how that part of the Adriatic must have looked when the sea level was lower. He later looked towards east where he saw Dinaric mountains in Bosnia and Herzegovina and the imagined that those mountains would appear as islands if the sea level would increase in the future.

Fortis mentioned the case of Zadar in which the remains of the old town's square are now below the sea level, as well as the remains of the ancient buildings founded on the bottom of the harbour. Furthermore, he stated that the sea is *constantly conquering the shores*, despite the accumulation of the alluvial sediments in the shallows. He wrote that the seawater is intruding ever further up the rivers, eroding and *destroying boulders and mountains* along the way. Fortis disagreed with the then predominate opinions on the causes of the sea-level rise which were that the sea-level is rising either due to the subsidence of the land or that the rise is just ostensible and it is caused by the *accumulation of the land* in the sea. Remarkably, Fortis correctly concluded that

the sea-level changes occurred in cycles, although he did not provide any explanations on causes of these rise.

In his description of the Vransko jezero Lake near Zadar, he mentioned that the seawater will eventually flood the lake weather because of the land subsidence or because, as he believed, the sea level changes in cycles and thus will inevitably rise above the lake level in the future. He also understood very well that the rise would affect local population because of the saltwater intrusion in coastal rivers, springs and lakes.

Fortis also speculated that the Skradinsko jezero Lake (today's Prokljansko jezero Lake) at the mouth of the Krka River was in the past a plain occasionally flooded by the river before the rising sea level pushed the river flow further inland (Figure 6). He mentioned the remains of Roman mosaics and a peer two feet (ca. 0.7 m) below the sea surface.

Furthermore, after extensive fieldwork he concluded that the Neretva River flew through what is today a sea channel between the mainland and the Pelješac Peninsula in the south of Croatia. He believed that the evidence for such a claim could be found on the small island of Šćedro where he found a quarry of tufa from a *limestone river*. Fortis also discusses the case of Hvar Island where he found limestone with *sea shell fossils* which, according to him, are of the same origin as the ones on the neighbouring mainland. He saw that as the evidence that the Hvar Island used to be part of the mainland and that at some point the whole island was flooded by the sea since he found the marine fossils at the summit of the island's hills. He further stated that the tufa deposits can also be found on the Hvar Island and that those deposits are of younger age than the *marine-marble* rock which cover most of the island surface, but are older than the last sea-level rise.

When writing about Neretva River Fortis correctly stated that due to the sea-level rise seawater is entering the course of the Neretva River, which prevents the river water to flow into the sea and creates floods in the river's delta. He further claimed that the seawater can sometimes be tracked 12 miles up the stream and that this seawater causes troubles for local agriculture. Interestingly, in the last 60 years the problem of saltwater intrusion into Neretva River has become one of the main concerns for both local ecosystem and agriculture. Apart from the sea-level rise (particularly during the strong SE wind), the construction of several dams and reservoirs in the upper part of the river course from late 1950's onwards changed the hydrological regime of the river downstream, significantly decreasing the river

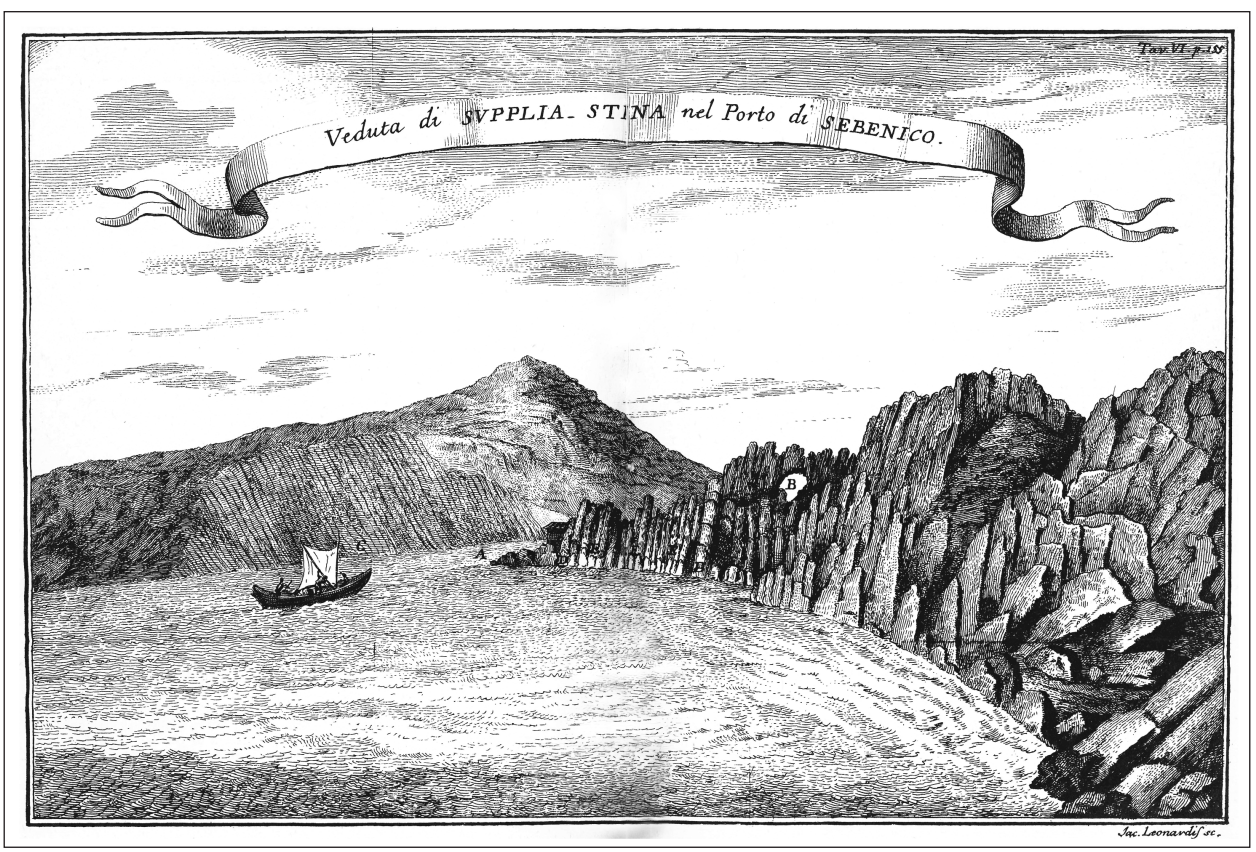

Figure 6: Submerged canyon of the Krka River near the town of Šibenik (source: Fortis, 1774).

discharge, which allowed more inflow of the seawater (Ljubenkov & Vranješ, 2012).

Conclusively, Fortis strongly believed that the sea-level changes occurred many times over the Earth's past but he admitted that he cannot explain how and when, and he admired anyone who would try to do the *hardest task of all*, i.e. explaining all the changes that occurred on surface of the Earth.

7. CONCLUSION

Alberto Fortis was in many ways a true representative of the Enlightment era scholars with wide variety of interests ranging from various Earth sciences (geology, geomorphology, hydrology, etc.) to social and human sciences such as history, demography and even ethnology. He firmly believed that the fieldwork is a cornerstone of any good scientific effort. Therefore, his works offer extensive source of information for all who wish to study the development of scientific ideas. His observations are not just simple description of things that he encountered, as he frequently seeks to understand the mechanisms behind certain processes (i.e. sea-level rise) often comparing his theories with those of earlier observers.

In the two books which had been used as a base for this paper, hydrological and hydrogeological features of karst were by no means the central part of the Fortis' study maybe simply because the surface appearance of the water in karst is so scarce. But, when Fortis' was writing about the karst lakes, rivers, springs or ponors, or when he tried to explain why there is shortage of water on the Adriatic islands, he is doing that with remarkable accuracy which can only be explained by his thrall understanding of natural sciences, his knowledge of the literature and his inquisitive nature. In many ways, his explanations of karst hydrology can be considered as an important step in the emergence of the science of karstology in the Dinaric karst.

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