Project TE 110/2018

Reconstruction of the waterways connections in the Danube delta since the Antiquity until the Middle Age

Scientific report 2019

Elaboration of the spatio-temporal patterns of navigation in the Danube delta and the assessment of their impact on local human communities.

The working hypothesis of our research, which was formulated after thorough documentation of navigation practices in the Black Sea basin and particularly at the mouths of the Danube, highlights the switch of the naval traffic distribution among the Danube's arms since the Antiquity to modern times. According to the historical and archaeological sources, functional, navigable routes during the Antiquity were first set up to the Greek colonies founded on the coastline: Histria, Orgame, Tomis, and Callatis. From Polybius, we know that after the 3rd c. BC, the people living in Histria city were facing major siltation problems associated with nearshore sandbanks or barriers formation, which started to impede ship access. This geomorphologic situation was recently confirmed by preliminary geoarchaeological studies (Preoteasa et al., 2013, Vespremeanu-Stroe et al. 2013), which further support the hypothesis from historical documents (Pârvan, 1923, Pippiddi, 1967) according to which that the navigation activities have been maintained on a southern arm of the Danube (Peuce). Roman and Byzantine times witnessed navigation decline at Histria while settlements along the Sf. Gheorghe arm (Halmyris, Salsovia, Periaslaveț, Aegyssus, Noviodunum, Gărvan) were flourishing as most of the commercial and military activities were concentrated along this branch. An interesting change seems to have had occurred during the 9-14th centuries AD as most of the Genoese commercial centers (Chilia, Vicina) and anchorage points (Lycostoma) were settled on the northern Danube's arm, Chilia. Excepting Chilia, the other two settlements, despite the abundant references in historical sources attesting their existence, they are still not identified in the field.

During the second phase of this project, new investigations have been performed integrating sedimentary (mean grain size, total organic content), geochemical, microfaunistic, palynologic analyses together with radiocarbon datings.

In the northern part of the Danube delta four new cores: Sir 1, Par 1, Par2 and Kil1 of 8m, 10m, 4.5m and 4m deep were added to another four already published cores (i.e. F16, F15, F18 in Vespremeanu-Stoe et al., 2017 and KP1 and KP2 in Filip and Giosan 2014) which provide new sediment texture, organic matter content data and new radiocarbon ages. Geochemical and microfauna analyses have been undertaken on Kil 1 which provide information on the nature (i.e. fluvial, lacustrine or marine: open coast, sheltered coast or closed/semienclosed lagoon) of depositional environment and associated hidroenergetic characteristics. Sediment cores have been retrieved with the Eijkelkamp Cobra TT percussion corer system, which were topographically positioned using Leika DGPS.

Grain-size analyses were undertaken using Horiba LA950 (Laser Diffraction Particle Size Analyzer). The samples were treated with acetic acid (CH3COOH, 20%) and hydrogen peroxide (H2O2, 30%) to remove the organic content, then washed with distilled water. The samples were centrifuged with distilled water to prevent flocculation of fine sediments. Before each reading, several milligrams of sodium polyphosphate were added to each sample to disperse the particles. Subsequent calculations on raw data were made in the GRADISTATv8 program (Blott, 2010) using equations developed by Folk and Ward (1957) for the grain-size parameters.

Loss of Ignition (LOI) is a fast method to determine the content of organic matter (OM) and inorganic carbonates (Cinorg). OM burns at temperatures between 200 and 550°C while Cinorg begins to ignite at temp. of 800°C (except for dolomites, where Cinorg burns at ~ 700°C) (Dean, 1974). 37 samples collected from the EN3 core, weighing between 2.7 and 4.1 g, were dried at room temperature for four days. The crucibles were dried at 150°C for 1.5 hours, then cooled and weighed. The crucibles were filled with sediment and burnt in three steps, in a Caloris CD 1011 oven: 105°C for 12 hours; 550°C for 6 hours and 950°C for 2 hours. After each combustion, they were weighed to an accuracy of 0.0001g. To find out the percentage of OM and Cinorg Heiri equations were used (Heiri, 2001).

Magnetic susceptibility (MS) measurements were performed on half split EN3 core at 143 depth points using a Bartington MS3 magnetic susceptibility meter and an MS2K Surface Sensor. The sensor has a 25.4 mm diameter area of response, depth of response of less than 10 mm, and a

maximum resolution of 2x10-6 SI. For each measurement point, we used a measurement period of 10 s and drift correction.

The concentration of 26 geochemical elements has been detected by means of Energy Dispersive X-ray Fluorescence (ED-XRF) analyses, which were performed using a portable Bruker Tracer S1 Titan spectrometer. This spectrometer uses a Rhodium (Rh) anode tube to generate an X-ray beam to probe the samples. The generated beam has maximum energy limited at 40 keV. The laser shaft is passed through a collimator, resulting in a spot with 8 mm in diameter on the selected samples. A Silicon Drift Detector (SDD) positioned backward at an angle of approximatively 45° to the Rh-anode tube, was used to record the spectra. One point randomly selected was analyzed on each sample; each point was exposed to the beam for 60 s. Each characteristic spectra was later analyzed to obtain elemental concentrations. The results obtained are expressed in parts-per-million (ppm).

To obtain a correct set of results, up to 10 g of material from each depth were collected and reduced mechanically. The material was homogenized, and a portion of 2g was collected and compressed into a pellet using a 25 ton automated hydraulic press (Specac). The resulting pellets were placed into a plastic holder until the analysis.

The newly obtained high-resolution data characterizing Chilia arm fluvial activity and human settlements' socio-economic dynamics were used to draw the landscape configuration at key historical moments.

Sediment characteristics and stratigraphy of Kil 1 and Par 1cores

The sediment texture (mean grain size) and organic matter (LOI, TOC) characteristics and stratigraphy intercepted in cores Par1, Par2, together in the published in F18 (Vespremenau-Stroe A. et al., 2017 and KP1 (Filip and Giosan, 2014) reflect the sedimentation pattern in the northwestern part of the delta. At the deepest part of Sir 1 core, from -4 to -8 m, an alternce of fine veneers of sand and silts (ca. 1-2 cm thick), with numerous intertwined (ca. 1cm thick) laminae of organic material accumulated roughly from 9 ka BP, at a mean rate of 0.72 mm/yr. The MS values are highest at these depths, reaching mean values of 4,5 ppu with numerous and large amplitudes (standard deviation). After 25 cm thick layer of massive sand, placed between -4,25 and -4,5 m, a new cycle installed starting from ca. 5.4 ka onwards when sedimentation turned to mainly fine silts and clay deposition. Thin laminae of sands and sandy silts (i.e., cm size) re-appear at -2,4 m, until -2 m when thin laminae of organic matter are intertwined veneers of sands. A 1 m thick peat layer

was intercepted from-1,2m to -0,7 m capped by silt and soil. The MS values are comparatively lower and more constant.

The sedimentation regime at Par1 core location is characterized by relatively compact packages of sands (ca. 1-1,5 m) deposited in between 1-1.5 m thick layers of silts and clays all through the core. After a 15 cm thick veneer of sand intercepted between -9,55 and -9,7 m, the next sand laminae was deposited between -7,9 and 8,1 m and at -7,6 m, followed by the thickest sand package, of 1,4 m, between -7,4 and -6m. The MS values record an increasing trend from -9.5m to 6.95 where it reaches the most significant peak along the entire core. The next sand layers are thinner, of 0.30 m at -5.8 to -5.5m, of 1 m at -4.6 to -3.6 m and about 0.5 m, from -3.1 to -2.4m. The MS values are lower than those recorded downcore, averaging 1.3 ppu, and are characterized by a slightly decreasing trend, reaching the minimum -3,7m wherefrom it resumes lager values, averaging 1.8 ppu up to the surface.

The cores F18 and Par2 were positioned as close to small fluvial secondary channels formed within the previous Pardina Lake, which course can still be traced on high-resolution aerophotographs and satellite images. The sand layers intercepted upcores mark the fluvial activity related to secondary channel development.

Geochemical analysis

The elemental concentration of the K is usually associated with the finest sediment input, such as clays. Its diminishing upward trend between -4 m up to -2m might be related to the installation of an environmental regime characterized by coarser fraction advent. The abrupt decrease between -2 and -1.5 m reflects the input of sand fraction as also supported by textural data and the Zr/Rb ratio for which bigger values reflect more energetic depositional conditions. Variability of elemental K concentration and Zr/Rb ratio reflects three main tendencies that distinguish different layers between -4...-1.85m, -1.85...-1.50m, and -1.50...0cm. Si/S ratio varies in parallel with Mn/Fe showing relatively high values averaging 6, respectively 0.025 up to -1.55m, followed by a sudden decrease upcore. The same trend but with more ample fluctuations is depicted by the Ca/S ratio, which accounts for the salinity conditions.

The comparatively high values the Si/S ratio reflects a predominantly siliciclastic depositional environment. In contrast, the high amounts of Mn/Fe and Ca/Sr ratio indicates the sediment deposition occurred in oxygen saturated conditions of a shallow brackish environment. The sudden increase of the K concentration paralleled by the decrease of the Zr/Rb ratio in the upper part of

the core, starting from -1.4m, might be related to a change toward finner and slower sediment productive environment.

2.3. Paleontological analysis

The paleontological analysis identified a sterile layer at the bottom of the core, at depths greater than 3 m. From -2.9 m upwards, there are predominantly Black Sea fossil species, the specimen density increases, but the diversity is low. A change in microfossils composition occurs at 1.8m, where the monospecific population of Ciprideis torosa abounds next to several forams. Between 1.52-1.70 m despite the low diversity of the ostracods and forams assemblage, the abundance of species adapted to brackish conditions increases, allowing for only ca. ¼ for the freshwater species. The microfauna content changes from -1.40 m upwards with freshwater species becoming prevalent.

These investigations were employed to build up spatio-temporal models of navigable waterways through the history of the Danube delta inhabitation. These models are relevant to assess the interactions between sensitive geomorphic systems and humans.

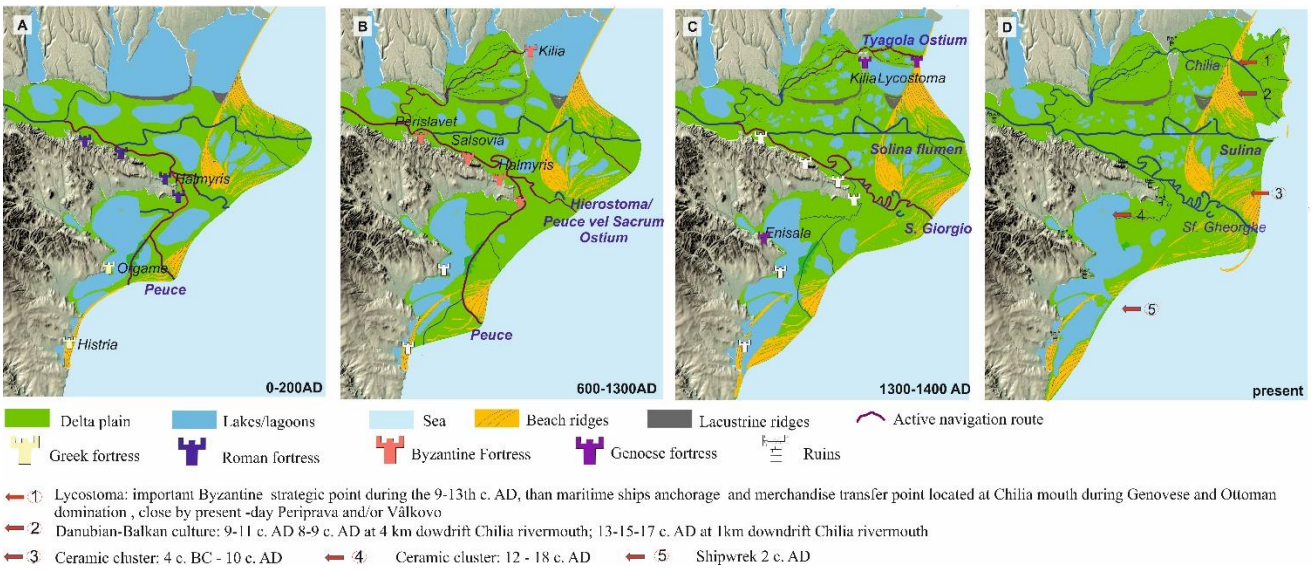

Fig. 1 Morphological and fluvial configuration of the Danube delta at various moments during the Roman, Byzantine and Late Byzantine/Genoese and present times