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8. Tectonic and geomorphological remarks resulted from bathymetric measurements. Noviodunum Fortress, Isaccea, Tulcea County, Romania

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Abstract: The banks of Danube near Noviodunum, represented an important strategic area in history. This area was used as a crossing point of the Danube by the Scythians, Getae?, the Persians of Darius the 1st, the Macedonians of Alexander the Great, Romans, Goths, Mongols, Ottomans or by the armies of the Tsarist Empire. But still, why did, these nations choose to pass the great Danube right here? The answer is simple: due to the geomorphological, geological and tectonic configuration, the Isaccea - Noviodunum region appears as a promontory that ends exactly near the Danube. The Lower Danube Sector all away to the Black Sea was quite inaccessible in the past for the various armies that crossed these territories at one time. However, the narrowest part of the Lower Danube (approx. 5 km) is located in the Noviodunum - Isaccea region a fact that can be linked to the advancement of the Isaccea Promontory caused by tectonic processes.
The bathymetric measurements performed by the DDNI Tulcea, highlighted a fault that correlates perfectly with the already known fault system. Also on this occasion, geomorphological aspects related to the old level of the Danube were highlighted.
Keywords: bathymetry, Noviodunum, tectonics, geomorphology

INTRODUCTION

The study area is located in the Northern Dobrogea, on the Danube, in front of the Noviodunum fortress - 2 km East of Isaccea Town, Tulcea County. Due to the bathymetric measurements performed by DDNI Tulcea in the area, it was possible to outline some aspects related to tectonics and local geomorphology.

Unfortunately, the theories regarding North Dobrogea Tectonics are not supported by seismic measurements, which would complement the tectonic models issued by various scientists. These tectonic models are the result of interpreting deep geological boreholes that have been drilled over time in the region, correlated with surface geology. However, of these models, the most commonly used is that of Mirăuță, Mirăuță, 1964, and which has since been improved by other researchers like Grădinaru, 1988, Seghedi et al., 1990, Baltreș, 1993 (Seghedi, 2001), outlining new tectonic elements.

Starting from the tectonic map issued by Seghedi, 2001, by taking into account the approximately parallel directions of the tectonic system near the Isaccea-Noviodunum-Niculițel area, and correlated with the pit direction highlighted by the bathymetric measurements, it is obvious that we are dealing with a fault. on the Danube. Of course, the geology of the region also give us precious insights, as the Isaccea Promontory vanishes on the right bank of the Danube, North of Noviodunum, and does not appear on the left bank, in Ukraine. It is clear that this can be attributed only to tectonic activity.

Panait et al, 2018 suggested that the 1st terrace of the Danube, from the Getic - Early Roman period (1st - 3rd Centuries AD) was located at approx. 45 m further North of the current right bank of the Danube. The bathymetric measurements carried out by DDNI Tulcea successfully highlighted a terrace at 30 - 60 m from the actual bank of Danube (depending on the water levels), confirming this aspect.

MATERIALS AND METHODS

DDNI Tulcea carried out within the national projects (***NP DDNI Tulcea, 2015), (***NP DDNI Tulcea, 2016), bathymetric measurements meant to outline the Danube floor. The method consists in the use of a multibeam sonar which maps the submerged terrain. A multibeam echo sounder attached to a boat sends different kind of beams to the waterfloor. The beams are reflected by the waterfloor and in the same time the information is collected by the sensors attached to the boat. The data is processed in real time during measurements.

The device used in the bathymetry survey is a Teledyne Odom multibeam equipment (Figure 1), composed of Multibean Echo Sounder (Teledyne ODOM Hydrographic ES3), Sound Velocity Sensor (Valeport Mini-SVS), Professional Heading and Positioning Compass (Hemisphere Vector V103), Motion Sensor (SMC IMU-108), Heading Sensor (Airmar H2183), GPS (Javad GNSS Triumph-1), Workstation (Laptop). ES3 Control Software provided by Teledyne ODOM Hydrographic (for field data use) and Hypack Max & Hysweep Software (for acquisition and processing) were used as data processing software.

Figure 1. **Workstation and the Teledyne Odom multibeam equipment**

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The ES3 Multibeam echo sounder is a portable system that can be installed on vessels, and collects bathymetric data over a 120° swath at a water depth of up to 60 meters. The external sensors which can be interfaced to the ES3 include GPS receiver, Motion Receiver Unit and Sound Velocity Probe.
The Motion Reference Unit is the most important external sensor input to the ES3. If a MRU is not interfaced directly to the ES3 the data will not be fully roll compensated. When the ES3 is receiving data from a MRU, the beams are roll compensated in real time. This means the data output to the data acquisition software will be roll compensated but still must be compensated for pitch and heave.
The ES3 is able to accept real time sound velocities from a sound velocity probe attached to the head. This is important in areas where the sound velocity at the head is constantly changing as a result of temperature changes through out the day.

The Hypack Hydrographic Survey Software together with the Hysweep module allows for the configuration, calibration, collection and processing of multibeam transducer sonar systems. The software can also create planned lines for the surveys. It can display the vessel in 2-D or 3-D shapes, highlights the location of all sensors, generate a water level correction, and creates 2-D and 3-D images that can be converted into various file formats for further data processing.

RESULTS AND DISCUSSIONS

The bathymetric map compiled within (*** NP DDNI Tulcea, 2015) (Figure 2), point out the presence of a pit almost parallel to the right bank of the Danube at approx. 30 - 40 m offshore (bathymetric measurements were carried out at low water levels). Starting from the waterside, the bathymetric measurements noticed a slow descent on approx. 30-40 m to a depth of 5-7 m, resulting in a slope of 17-18%. Here, the slope becomes more abrupt, on an average length of 30 m to a maximum depth of 17 m meaning a slope of approx. 40% (in the Northeast part). The pit has smaller depths to the North of the fortress: -13 m. At this depth the pit floor extends laterally about 15-25 m in the Northern part of the fortress, and 30-50 m in the Northeast. Starting from the bottom, the last sector of the pit begins to rise to a depth of -9 m to -8 m, with a slope that varies between 12 and 20%, the steeper slopes being noticed in the North-West.

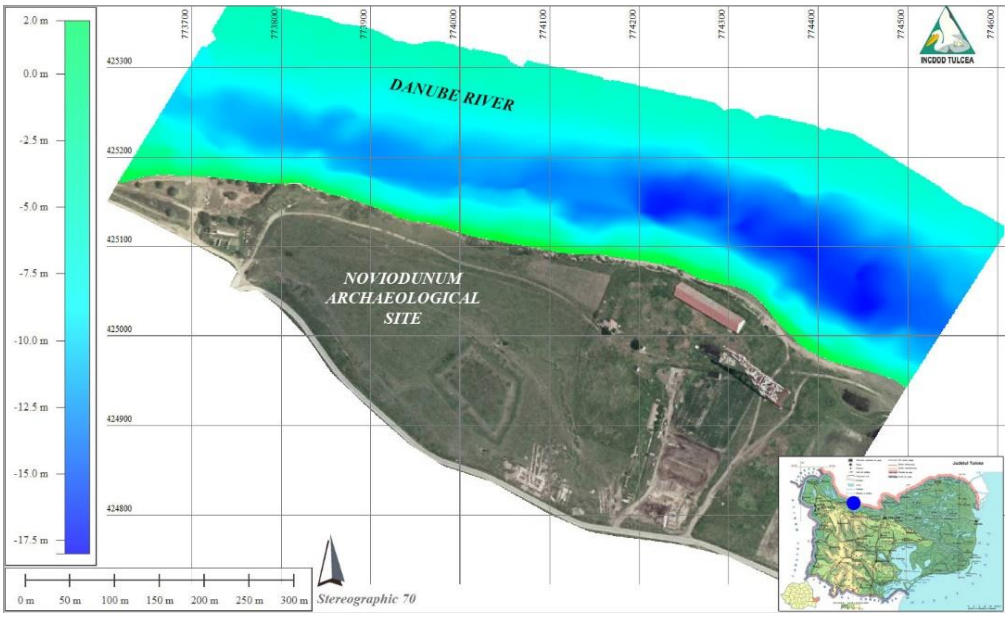

Figure 2. **Bathimetric measurements.** The dark blue colour highlights the pit in front of the Noviodunum Fortress (***NP DDNI Tulcea, 2015)

A more precise shaping of this pit was made within (*** NP DDNI Tulcea, 2016). It is observed that this pit extends in the North-West / South-East direction, the total length being approx. 2 km. The depths are higher in this case due to the fact that the bathymetric measurements were made at high water levels.

As mentioned earlier, this pit is approximately parallel to the right bank of the Danube near the fortress of Noviodunum. What is unusual is the fact that this pit appears suddenly near the waterside, suggesting a tectonic origin. It is known that most watercourses are linked to tectonic fractures, therefore some connections can be made between the Danube flow direction and local/regional tectonics.

Analyzing the local geology, the Isaccea Promontory, formed by geological formations of the Triassic age, suddenly disappears to the North of the Noviodunum fortress and only recent Holocene deposits can be seen on the left bank of the Danube. Such a complete disappearance of an important geological structure can only be possible due to intense tectonic activity.

The Regional Tectonic Map (Isaccea - Niculițel area) shape an important system of faults and geological structures approximately parallel to each other in the NW - SE direction (Seghedi, 2001), the same as in the case of the pit identified near Noviodunum. Figure 3 shows the evident correlation between this fault and the regional tectonics. It should be noted that this pit (fault) appears only in front of the Isaccea Promontory.

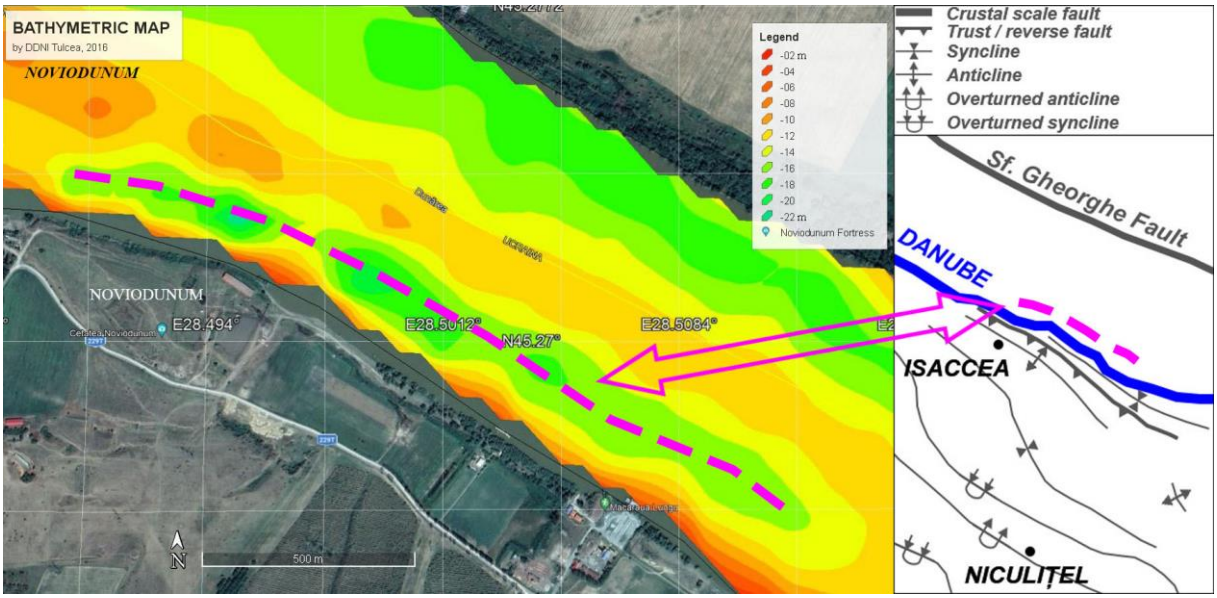

Figure 3. **Correlations between bathymetric measurements (left) and regional tectonics (right)**. The fault identified by bathimetry (magenta) can be linked to the local tectonics (***NP DDNI Tulcea, 2016), (Seghedi, 2001)

If we analyze a NE - SW profile (Figure 4) that crosses the two major North Dobrogean tectonic units (North Dogrogean Orogen and Scythian Platform), even if farther from the studied area, but taking into account that the North Dobrogean tectonic units are largely homogeneous, we can associate this profile with the existing situation in the Noviodunum-Isaccea-Niculițel area. From the beginning, one can observe the parallel system of faults between the two major faults (Noviodunum and Sf. Gheorghe Faults), a situation very similar to the one in the studied area (Popescu et al., 2016).

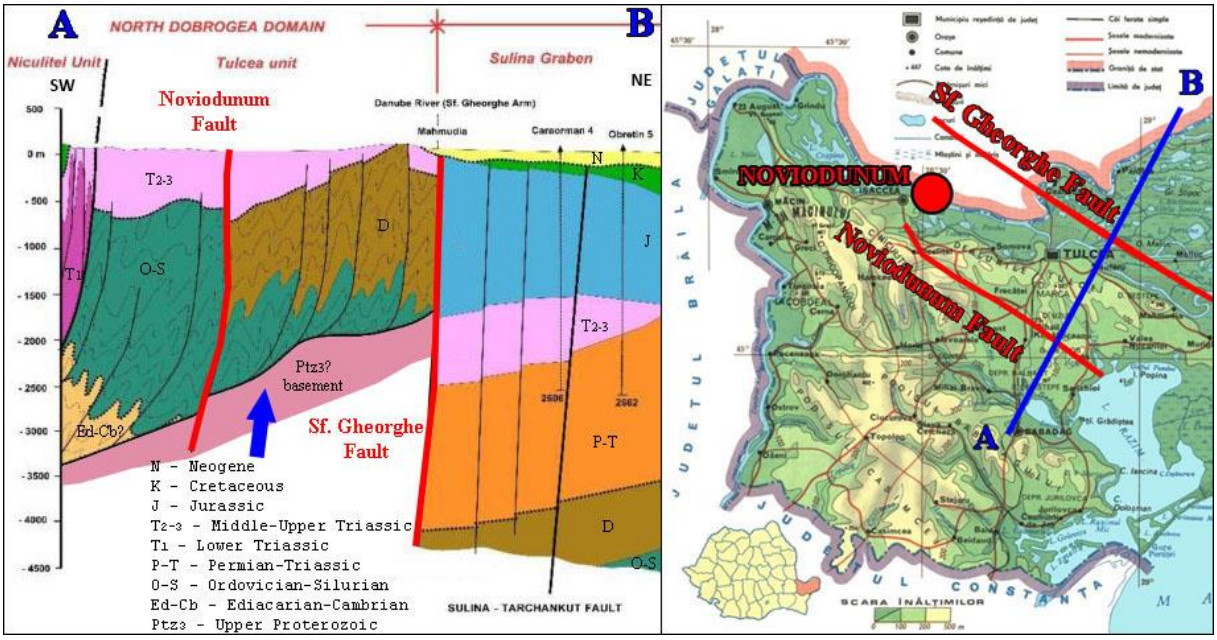

Figure 4. **SW - NE section through Niculițel and Tulcea Nappe** (Popescu et al., 2016)

We have shown that this area has been affected by intense tectonic activity. Their traces can be seen to the North-West of the fortress where the turbiditic limestones of Triassic age bears visible tectonic marks (Figure 5). Here one can find folds, strike-slip faults, or dip-slip faults.

Figure 5. **Tectonic structures identified on the right bank of the Danube.** The original (left) and the processed photo (right) with visible tectonic activity: folds, faults - NW of Noviodunum (Photo by the author, 2019)

In addition to the tectonic aspects derived from the bathymetric measurements, some geomorphological remarks can also be issued.
As mentioned above, these measurements showed a sudden descent of the right bank of the Danube after about 30 - 40 m (at low levels of the Danube) and 50 - 60 m (at high levels of the Danube). Regarding this aspect, Panait et al., 2018 considers the existence of the first terrace of the Danube at about 45 m from the current bank, which could date from the Getic-Early Roman period (1st - 3rd Centuries AD), when the Danube level was 3 m lower than the current one.

Drawing a parallel between these mentioned aspects, it can be said that the boundary at which the right bank of the Danube become steep is the approximate location of the first terrace of the Danube in the 1st - 3rd Centuries AD (Figure 6).

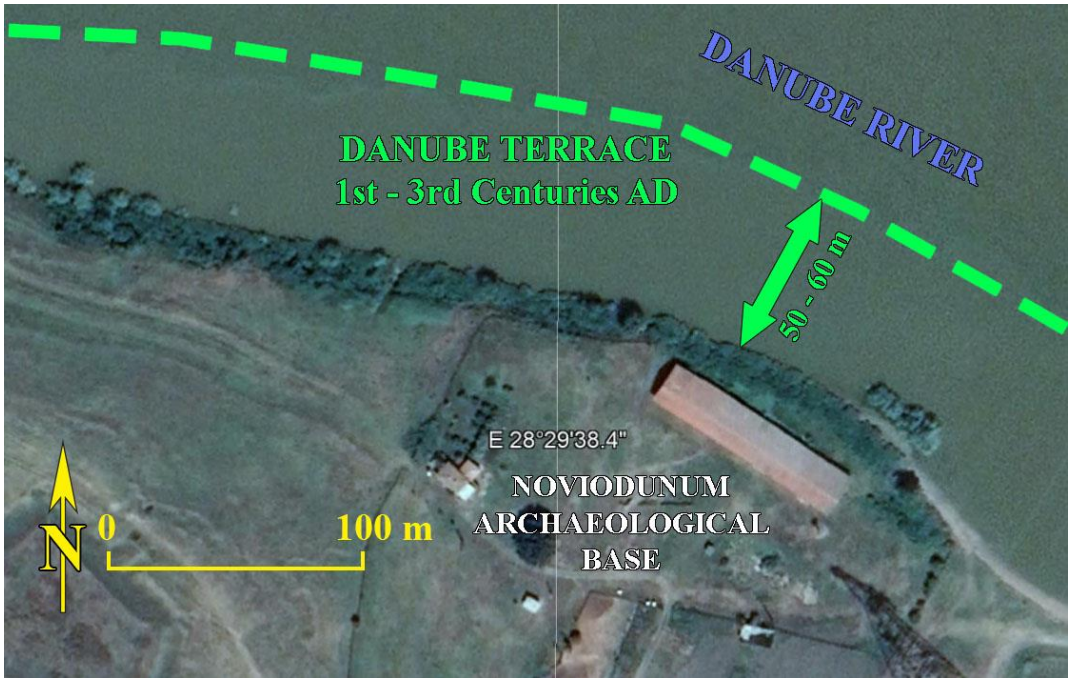

Figure 6. **The probable limit to the first terrace of the Danube River** (Panait et al., 2018)

CONCLUSIONS

The results of the bathymetric measurements performed by DDNI Tulcea, were successfully correlated with local or regional geological, tectonic and geomorphological studies. The existence of a new fault on the Danube completes the tectonic structures identified in Northern Dobrogea. Also, geomorphological aspects regarding the location of the old course of the Danube, in the first centuries of the first millennium, were confirmed.

It should be noted that this area is generally not sufficiently researched, especially from a geophysical point of view. Geophysical measurements, especially the seismic ones, can bring light regarding tectonic interpretation. But even so, we believe that theories regarding regional tectonics are relatively well defined in Northern Dobrogea.

In the future, we consider that additional studies are needed to complete and improve local and regional tectonics and geomorphology.

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******* National Project NP 09 26 04 08, 2016, Phase II. Morpho-fractal analysis of the hydro-morphological dynamics of the 3 main branches of the Danube Delta. *DDNI Tulcea*

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