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## Analysis of the fluvial delta evolution in Chilia Levee area by correlating archaeological study with remote sensing data

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**Abstract:** Within this paper the evolution of the area around the Chilia Levee was studied, using the information obtained by studying the evolution of the natural environment and human settlements in the entire area bounded by the branches Chilia and Sulina on the north and south, as well as by Letea sand bank on east and Ceatalul Izmail on west. Based on archaeological studies made on the Danube Delta an interesting correlation between the data related to soils type distribution and the traces of settlements were found. The study of the area around the Chilia Levee highlighted interesting aspects related to the evolution of the Chilia Delta in its whole.

**Keywords:** Chilia Levee, Chilia Peninsula, Neolithic Period, Bronze Age, Iron Age, soils type distribution, human settlements evolution

### INTRODUCTION

Within this paper the evolution of the area around the Chilia Levee was studied. But to achieve its purpose, the data relating to the area of interest were obtained by studying the evolution of the natural environment and human settlements in the entire area bounded by the branches Chilia and Sulina on the north and south, as well as by Letea sand bank on east and Ceatalul Izmail on west.

Based on archaeological studies made on the Danube Delta as well as the data related to soils type distribution in the area around the Chilia Levee an interesting observations about the evolution of Chilia Delta were found. A correlation between the soils type distribution and the traces of settlements brings to attention some phases and stages in the evolution of the area around the Chilia Levee in particular and the Chilia Delta in general.

### MATERIALS AND METHODS

Within this paper we used digital data (data that are not available commercially in many cases) and paper scientific studies from different sources, as follows:

- Digital GIS / SGI data:

1. Raster format

- Romanian Geological Map, scale 1: 200000;
- ASTER GDEM Ver2 (produced by METI and NASA in cooperation with the Japan-US ASTER Science Team);
- Shuttle Radar Topography Mission (SRTM), highest-resolution topographic data generated from NASA's;
- Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+).

2. Vectorial format

- Relief Map Units (shapefiles format) provided by geo-spatial.org;
- CORINE Land Cover maps (shapefiles format) accomplished by European Environment Agency at scale 1:100000;

3. Derivative work from Aster GDEM Ver.2

- The contour lines of 5 to 5 meters vectorial map;
- The contour lines of 10 to 10 meters vectorial map;
- The elevation classes;
- The slope classification after gradient and exposure;
- The triangulated irregular network (TIN);

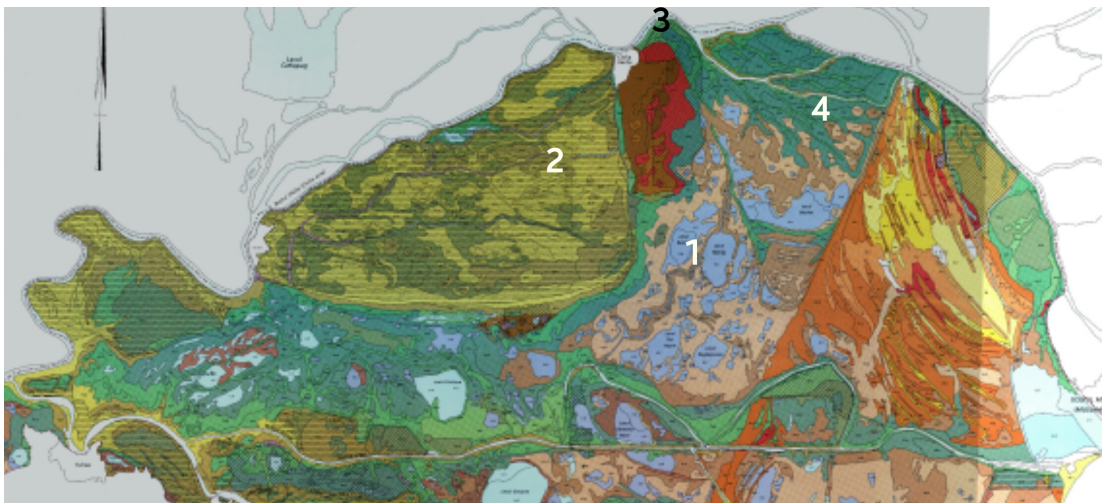
- The vegetation classification map (intersection between elevation, sloping gradient and exposure classes TIN and CORINE Land Cover maps).
- 4. Derivative work from SRTM:
  - The contour lines of 10 to 10 meters vectorial map;
  - The contour lines of 1000x1000 meters resolution vectorial map (including the Black Sea);
  - The elevation classes;
  - The triangulated irregular network (TIN).
- 5. The Danube Delta's archaeological sites distribution map.
- 6. Digital scientific papers:
  - The Danube Delta Evolution During The Holocene: Reconstruction attempt using geomorphological and geological data, and some of the existing cartographic documents (Panin, Overmars, 2012);
  - Man made deltas (MASELLI & TRINCARDI, 2013);
  - Early Anthropogenic Transformation of the Danube-Black Sea System (Giosan *et al*, 2012).
  - River Basin (The International Commission for the Protection of the Danube River, 2015, <http://www.icpdr.org/main/danube-basin/river-basin>)
- 7. On paper scientific studies
  - Geology platform units and North Dobrogea Orogen/ Geologia unităților de platformă și a orogenului nord-dobrogean (IONESI, 1994).
  - GIS data were obtained partly from the Internet, such as: Romanian Geological Map (scale 1: 200000), ASTER GDEM Ver2, Shuttle Radar Topography Mission (SRTM), Landsat 7 ETM+, Relief Map Units (shapefiles format), CORINE Land Cover maps.

Bringing raster data into shape file format was made in Quantum GIS (QGIS) application (free distributed under GNU license) and Saga GIS. Vector data were finally stored in three types of shape file files corresponding to the three types of vector geometry data, such as: point vectors type shape file, polyline vectors type shapefile and polygon vectors type shape file.

Of course, satellite images were processed in their turn depending on needs. The Landsat images were assembled for each spectral band separately and then the satellite images from three bands were combined together. In accordance with historical and archeological studies the Danube Delta's archaeological sites distribution map was carried out in the final stage.

## RESULTS AND DISCUSSIONS

The evolution of the area around the Chilia Levee was analyzed using data obtained from study of the natural environment and human settlements evolution in the entire area bounded by Chilia branch on north, Letea Sand bank on east, Sulina branch on south and Ceatalul Izmail on west. Helpful in studying the evolution of the area around the Chilia Levee was the soil map. Based on the analysis of soil and archaeological sites distribution in the area around the sand bank Chilia, four phases have been identified (Fig. 1 and 2).

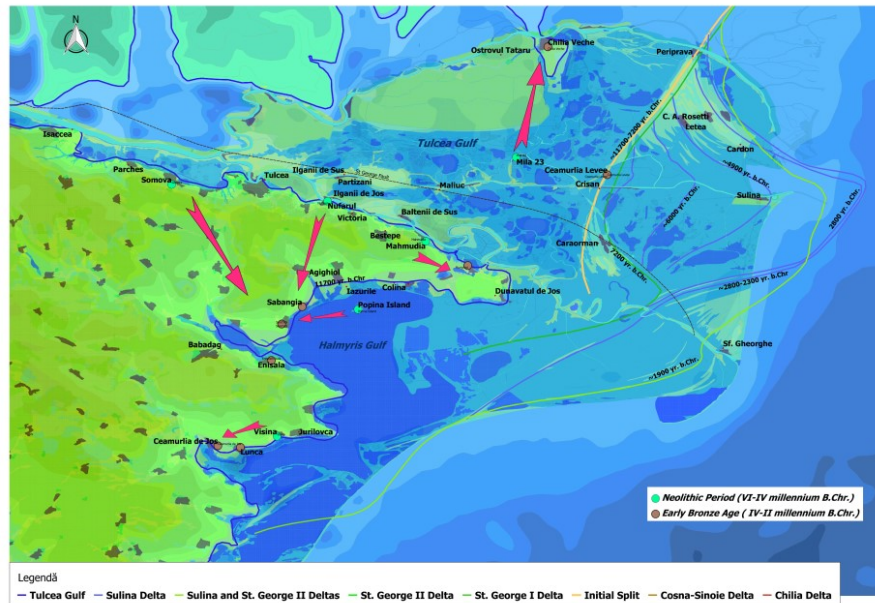


**Figure 1** The evolution of Chilia Levee area reflected in the four phases on the soil map

Giosan *et al* (2005) suggest younger ages for the initial stages of delta development (for example, in their view, the St. George I Phase could not be much older than ~5,500 – 6,000 yr. BP). This hypothesis seems to better correlate with the present-day understanding of water-level changes in the Black Sea during the Pleistocene Holocene time.

New age determinations are now in progress and, probably, they will give a new understanding of the Danube Delta development timing during the Holocene (Panin, Overmars, 2012).

Correlating these data with those related to soils type distribution and the traces of settlements from the Neolithic Period were found in the central part of the Delta (Mila 23 and the Ceamurlia Levee) or Popina Island (Fig. 2), the first two phases have been identified.



**Figure 2** The human settlements evolution between Neolithic and Bronze periods

The human settlements evolution between Neolithic and Bronze periods according to The Danube Delta's archaeological sites distribution map as well as the vegetation classification map and Contour lines of 1000x1000 meters resolution

Based on archaeological studies made on the central part of the Delta, an absence of habitation traces dating from the Late Neolithic and Bronze periods was observed. Basically, settlements disappear from the central part of Danube Delta (Mila 23) and Popina Island to reappear in the higher areas such as Chilia Levee (Fig. 2).

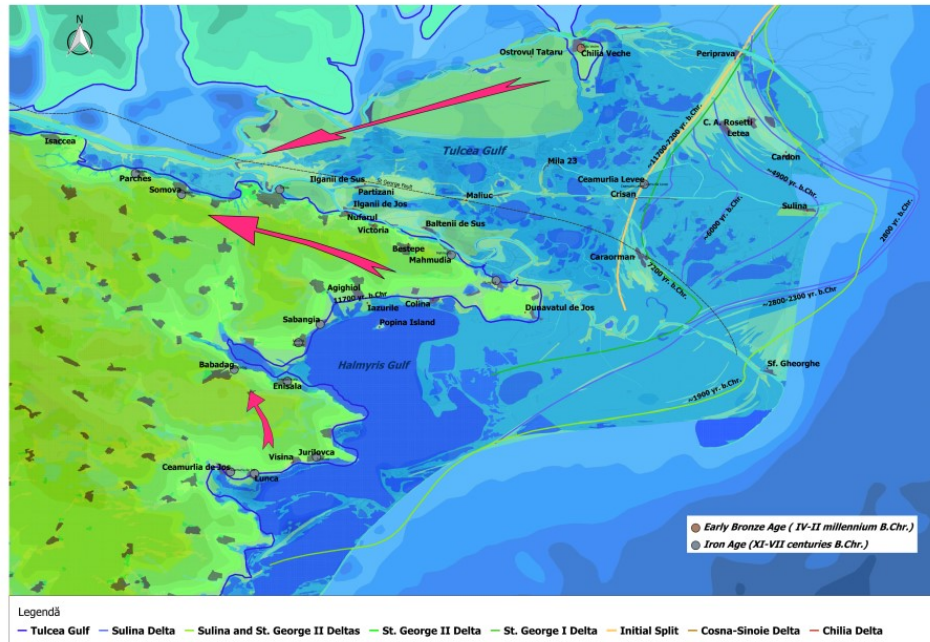
Based on data provided by the soil map, decay of the human settlements at the end of Neolithic may be related to activation of the Sulina branch. With the activation of Sulina branch the area around the Chilia Levee enters a first phase of transformations.

**Phase 1.** Initially Chilia Levee was an extension of the Bugeacului plain in the form of a peninsula. This situation changes in the late Neolithic period by changing the Danube River way to the north. Sulina develops its own delta on two directions: first on the main way (along the Big M) and the second to north. Thus the late Neolithic period from the first loop of the Big M starts to develop a channel to north. This channel will reach on the middle of Bronze age the south limit of the Chilia Peninsula. These processes have negatively influenced the development of human settlements in the late Neolithic Period and early Bronze Age (see Fig. 2 and 3).





The channel descends southward from Tătaru branch and delineate the Chilia Peninsula in the west (A) and the strip of Semisubmerged-Histic Alluvial Gley Soils halfripened (Gh) in the eastern part of Chilia Levee (B)



**Figure 4** The human settlements evolution between Bronze and Iron periods

The human settlements evolution between Bronze and Iron periods according to The Danube Delta's archaeological sites distribution map as well as the vegetation classification map and Contour lines of 1000x1000 meters resolution

## CONCLUSIONS

Based on all this information a model of the historical evolution of the region was obtained. Simple study of the area around the Chilia Levee highlighted interesting aspects related to the evolution of the Chilia Delta in its whole.

Of course, the image obtained by using these data types must be filled with data acquired from stratigraphical, sedimentological, geomorphological and hydrological studies. For this reason, the conceptual model obtained by correlating historical and archaeological data with those obtained through remote sensing techniques represents a starting point for future research.

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