The Sea Cliffs Exposure and Management in 2 Mai – Vama Veche Shore Sector *Elena Vlăsceanu, Dragoș Niculescu, Liliana Rusu, Răzvan Mateescu*	"Cercetări Marine" Issue no. 53 Pages 19-29	2023
DOI: 10.55268/CM.2023.53.19		

THE SEA CLIFFS EXPOSURE AND MANAGEMENT IN 2 MAI – VAMA VECHE SHORE SECTOR

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ABSTRACT

A major concern for coastal communities is shoreline change. This leads to the progressive loss of beaches. In order to anticipate the development of coastal management plans, it is important to understand the causes of coastal erosion. In the absence of development and consolidation works, the Tourist Area of National Interest, 2 Mai - Vama Veche, is undergoing progressive degradation. Due to the advanced erosion areas, the coastal cliffs are in danger of collapsing more quickly. The delineation of the affected coastal area, as well as the highlighting of methodological criteria, especially at the sea-land interface, assumes the use of the coastline as a key element in the delineation of beach and cliff areas, and the use of the crest of the cliff slope in the delineation of cliff areas. This takes into account the natural variability of geomorphological processes, but also the vulnerability of sectors and subsectors of the southern Romanian coast.
Keywords: coastal cliffs, shoreline vulnerability, wave exposure, erosion, climate change

AIMS AND BACKGROUND

The Romanian coastline is over 244 km long (between Musura and Vama Veche). This represents 6% of the total length of the Black Sea coastline. Geographically, the Romanian coastline is made up of the natural coastline (beaches and cliffs - about 84%) and the man-made coastline (harbours, coastal protection structures - about 16%). Two geomorphological units characterise the coastline: The northern unit, comprising the Danube Delta and the Razim-Sinoe lagoon complex, extends for 170 km from the Ukrainian border to Midia. It is characterised by a deltaic lagoon shoreline formed by fluvial accretions, recent shell sands arranged as beach deposits and littoral belts of relatively low elevation, often below 2m (Giosan, 2005). The southern unit, from Cap Midia to Vama Veche, near the Bulgarian border, is about 74 km long. It has a relatively high coastline with cliffs, most of them active, with a maximum height of about 35 m, and small beaches arranged in cordon-like formations along the fluvial-marine limans: Tașaul, Sutghiol, Techirghiol, Costinești, Neptun, Saturn and Mangalia (Bondar, 1973). The 2 Mai sector belongs to the southern unit of the Romanian coastline. It is an area with a well-developed coastal cliff, south of the old beach-barrier type coastline, in the area of the old Mangalia Liman. Fossil soils, limestone Sarmatian deposits at the base with successive Quaternary loess and paleoloess, form the coastal area of 2 Mai (Fig. 1).

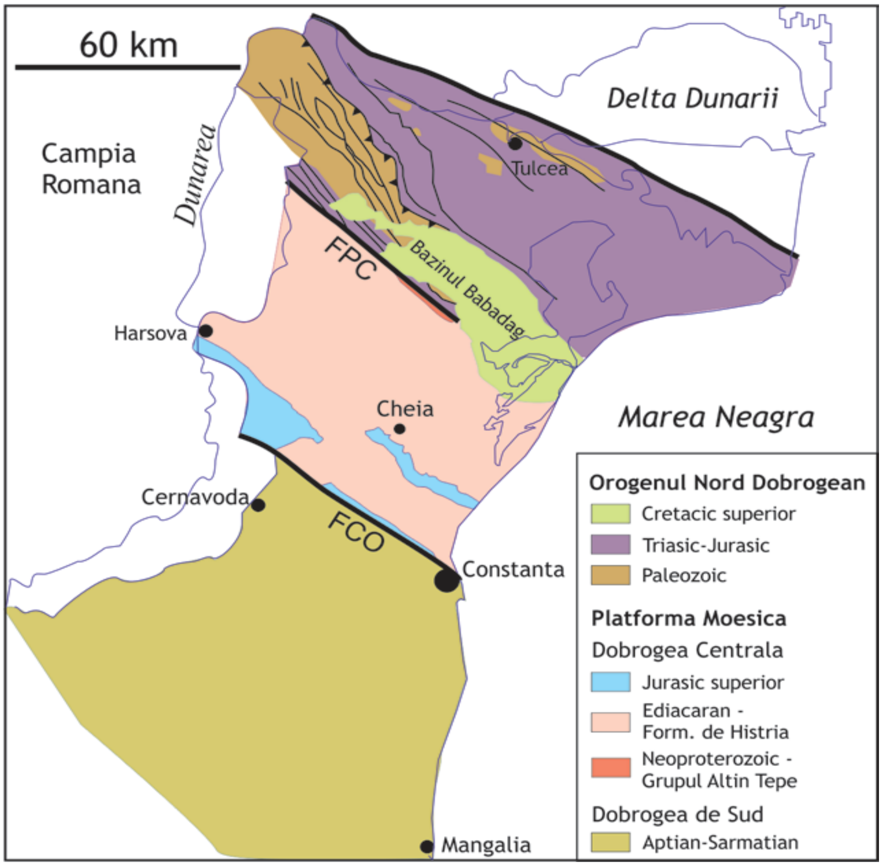

Fig. 1. Geological map of Dobrogea (Melinte-Dobrinescu *et al*, 2020)

The southern coast has a structural plateau relief with altitudes below 100m. It is located at the eastern end of the Prebalkan platform - Southern Dobrogea (Fig. 2). The sea shore is high. The cliff was formed in Sarmatian and Quaternary deposits (loess and paleosols), where gravitational subsidence occurs.

The Sarmatian plate, which is below sea level, the lack of hardness of the exposed loess deposits, the configuration of the coastline, which causes wave diffraction, and the anticyclonic circulation induced by the enclosing dikes of the port of Mangalia, are all responsible for the energetic abrasion of the active areas of the 2 Mai cliff.

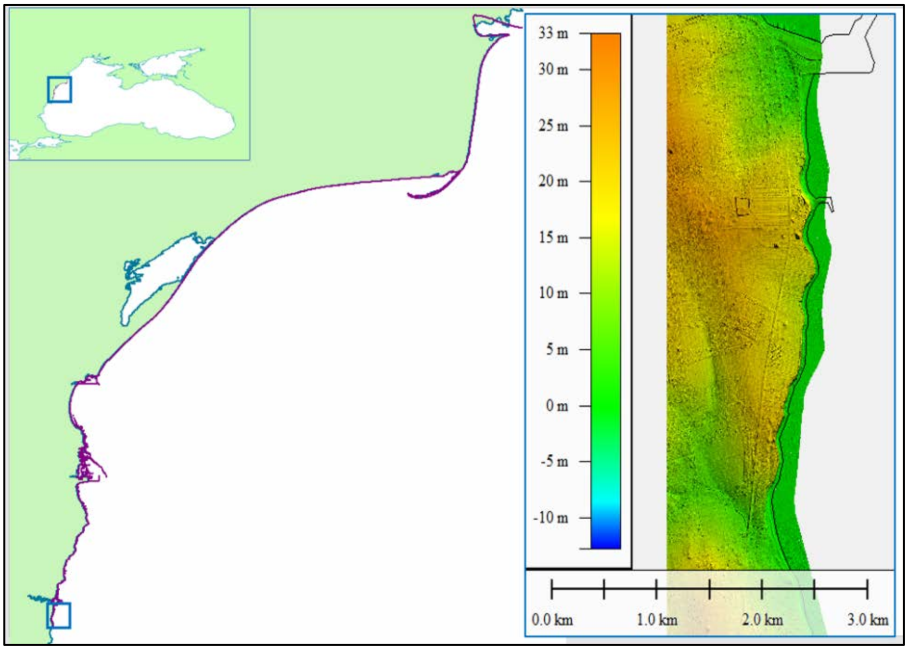

Fig. 2. Southern unit of the Romanian Littoral and the area of interest

As a result of the geological structure, in particular the position of the hard substrate of the limestone platform below sea level, and the hydrometeorological conditions specific to the area, the 2 Mai sector has undergone intense changes, especially towards the south of the site (Constantinescu, 2012) (Fig. 3).

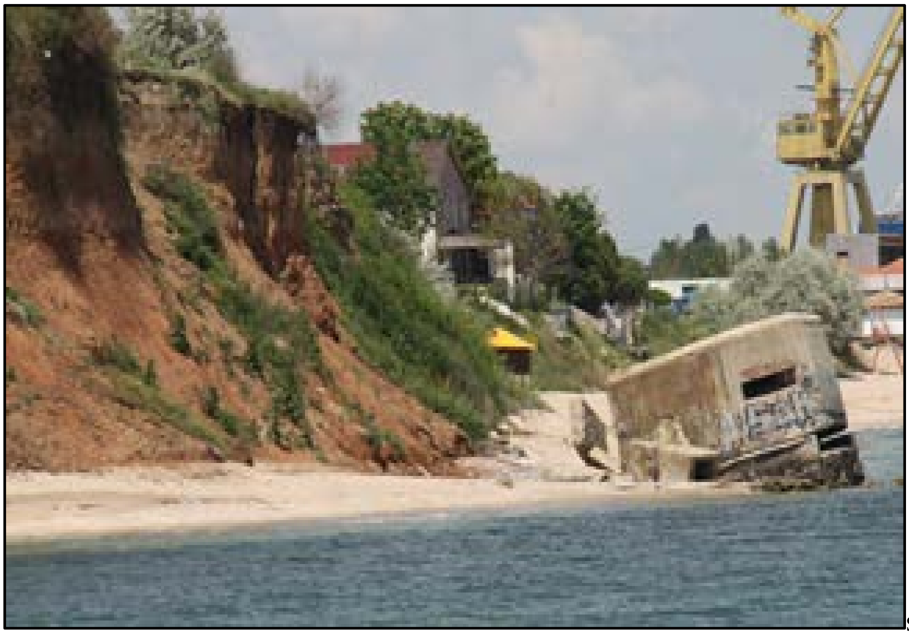
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Fig. 3. The active cliff of the 2 Mai sector

The geomorphological changes in the coastal area of 2 Mai can be analysed comparatively using maps and historical images, especially those relating to the development of the Port of Mangalia, which began in the 1950s. At that time, the dredging of the coastline and the construction of the surrounding breakwaters caused significant changes in the coastal geomorphology, both locally, through the effect of wave diffraction, and sectorally, through the interruption of sediment flow (Figure 4). The port of Mangalia, like other ports along this stretch of coastline, represents an impermeable boundary for sediment transport (Omer, 2015).

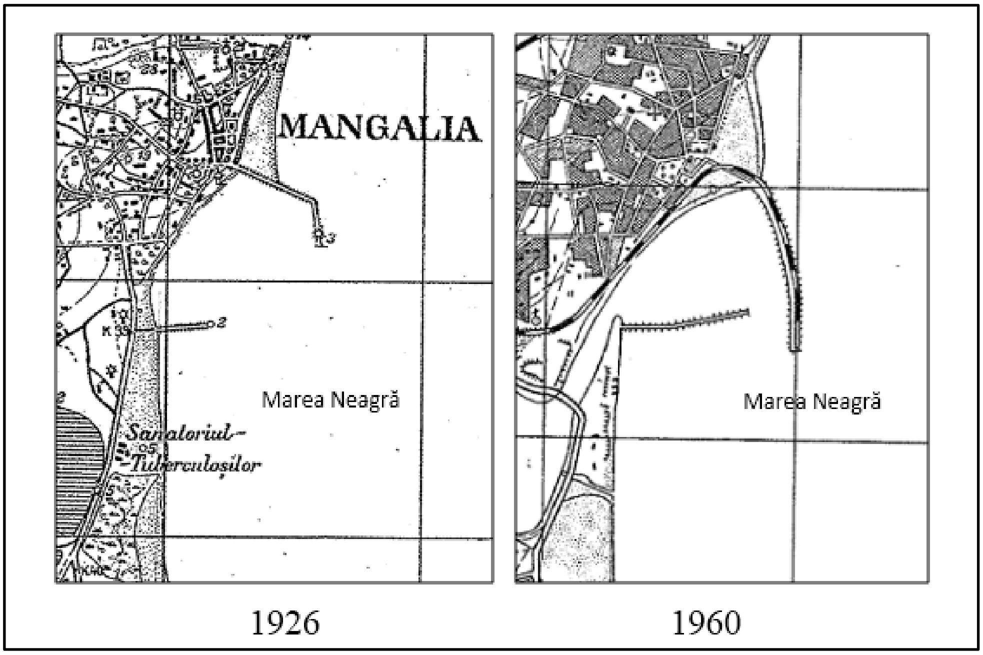

Fig. 4. Evolution of works at Mangalia Port between 1920-1960
(image source: Stefan Constantinescu, 2012)

It is clear from the previous pictures that Mangalia liman was originally a fluvio-marine liman, which was transformed into a military bay/harbor basin by the removal of the sand ridge (coastal cordon) separating it from the sea in the 1950s. (Romanian coastline - Wikipedia). Although the 2 Mai sector is relatively protected by the southern breakwater of Mangalia harbour, waves reaching the shore from the northeastern side of maximum fetch rise up the beach slope to the base of the cliffs (Fig. 5). Thus, it should be noted that during the study period, the storm that occurred on 9-14 January 2023, with a maximum significant wave height of 2.60 m at the coast in the Eforie area (measured at the SofarOcean/Spot 1622 buoy, located in the 19 m depth isobath - Fig. 5), generated a wave advance to the base of the cliff, with deposition of plastic waste and marine vegetation debris in the area of interest (Fig. 6). Storms with return periods of 10 years can generate waves of 5-6 m in the coastal area.

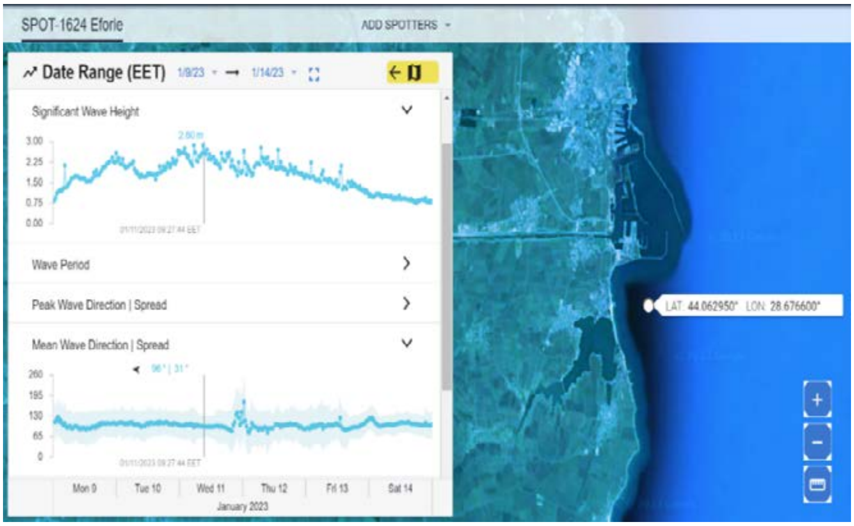

Fig. 5. Wave data recorded at Eforie station
(significant wave height 2.60m, Wednesday 11.01.2023)

Fig. 6. Fragments of marine vegetation/weed beds on the beach slope immediately adjacent to the study area are evidence of storm surges

EXPERIMENTAL

This paper is based on NIMRD research and studies, including updated geomorphological data collected through field measurements, and reference papers published by various experts in the field of coastal geography and geomorphology.

Historical topographical plans and maps at appropriate scales, aerial photographs - analogue or digital, UAV data and orthophotos obtained from the

ANCPI (National Agency for Cadastre and Publicity), satellite images - in digital format, topographic profiles and DTMs (Digital Terrain Models) measured in the field with total stations, DGPS and airborne LIDAR were analysed (Niculescu *et al*, 2017).

A Global Mapper and an ArcGIS 12 (GIS/Geographic Information System) application were developed to assimilate the geographic data, including topographic measurements, GPS, orthorectified aerial photographs obtained from ANCPI (Constanta), and in-situ photographs obtained by drone/UAV (Unmanned Aerial Vehicle) (Niculescu *et al.*, 2017). ArcGIS spatial analysis techniques were developed to represent the geomorphological data (GPS/topographic section data) in a preferred plan/pattern model. This allows the assessment of the location of the sites in relation to the cliff slope line, i.e. the assessment of the slope variations of the cliff surfaces. This technique facilitates data management for better managing the abiotic resources of the coastal system, as well as providing informed support for decision making (Mateescu, 2016). The method used to visualise the cliff limits was based both on GPS measurements of the physiographic, geomorphological elements of the unprotected/natural semi-built cliffs (unprotected by hydrotechnical works such as embankments, drains, etc.) and on laboratory analysis through processing, editing and spatial/GIS analysis.

The GPS measurements were performed with the GeoXH6000 GPS system (centimetre accuracy class). The system consists of a data collector with a 12-channel (D)GPS/SBAS receiver (L1 C/A code and carrier phase/L2) and an integrated GPS antenna. The system incorporates multipath error correction technology. It provides real-time SBAS (WAAS/EGONOS) data acquisition and differential data post-processing (using data from L1/L2 dual-frequency or L1 single-frequency reference stations). The horizontal accuracy of the system used for real-time solutions or for differential post-processing of the coded signal is in the centimetre range. For the determination of the shoreline in inaccessible areas, processing (vectorisation/scanning) was carried out in ArcGIS. This was supported by orthophotos obtained from the local cadastral office/ANCPI (2004) and spatial data from Ikonos and Spot (at 2019 level). It was therefore possible to make an estimate of the current changes in the active 2Mai cliff based on the resolution at which the in-situ images were taken.

RESULTS AND DISCUSSION

As far as the current situation is concerned, the existing orthophotos from 2011, updated to January 2023 (Figures 7.a, 7.b and 8), show that in the area of the 2 Mai Cliff, a low annual rate of shoreline retreat can be observed due to the relative protection provided by the walls of the demolished structure. However, this does not prevent the cliff from sinking and sloping towards the sea. The existence of an active cliff slope, as defined (Vespremeanu, Golumbeanu, 2018), is shown by the slope map associated with the area of interest, determined on the Digital Terrain Model (DTM), expressed in degrees (Fig. 9).

Fig. 7. Orthophotoplan 2011 a) and b)

Fig. 8. Orthophotoplan updated by drone

On this slope map (Fig. 9), about 250 m south of the breakwater that encloses the port of Mangalia, the appearance of cliffs can be observed, representing the southern shores of the former fluvio-marine liman that existed before 1950, north of the locality of 2 Mai, later developed as a port basin.

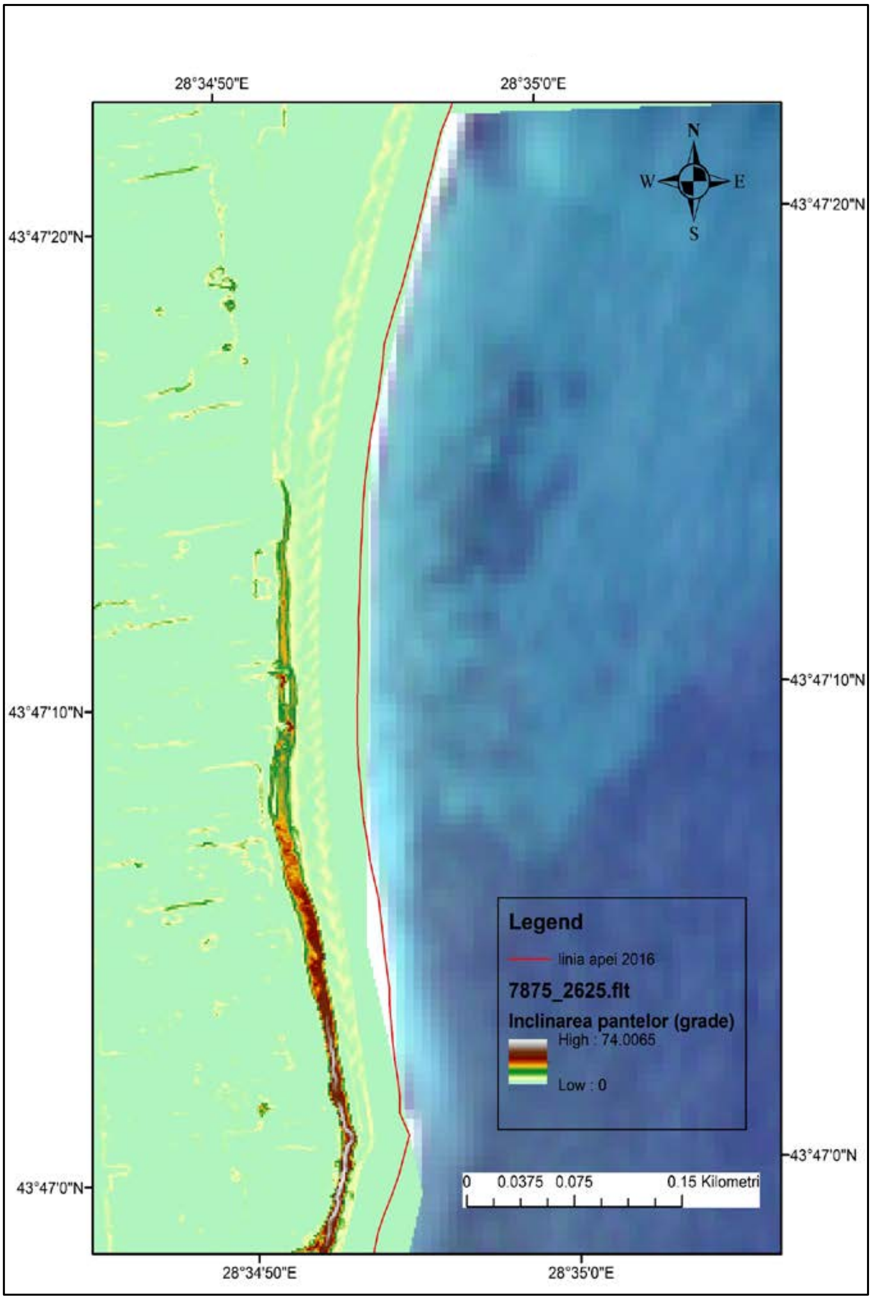

Fig. 9. Slope map (in degrees), derived from digital terrain model (DTM/2011), ArcGIS representation (coordinate system: Stereo 70)

The cross-sectional profile of the cliff slope plotted on the DTM data shows that the area of interest is likely to have been developed, possibly collapsed, without embankment reinforcement and/or wave attenuation works on the cliff slope (Fig. 10 and Fig. 11).

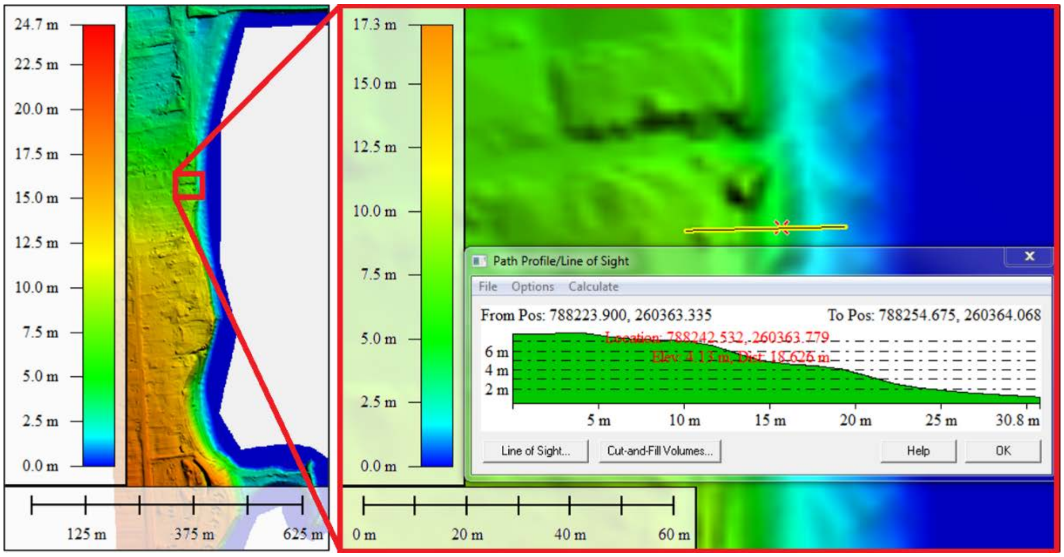

Fig. 10. Area of interest represented on the Digital Terrain Model (DTM) for 2 Mai, and (b) Cross-section of the cliff slope

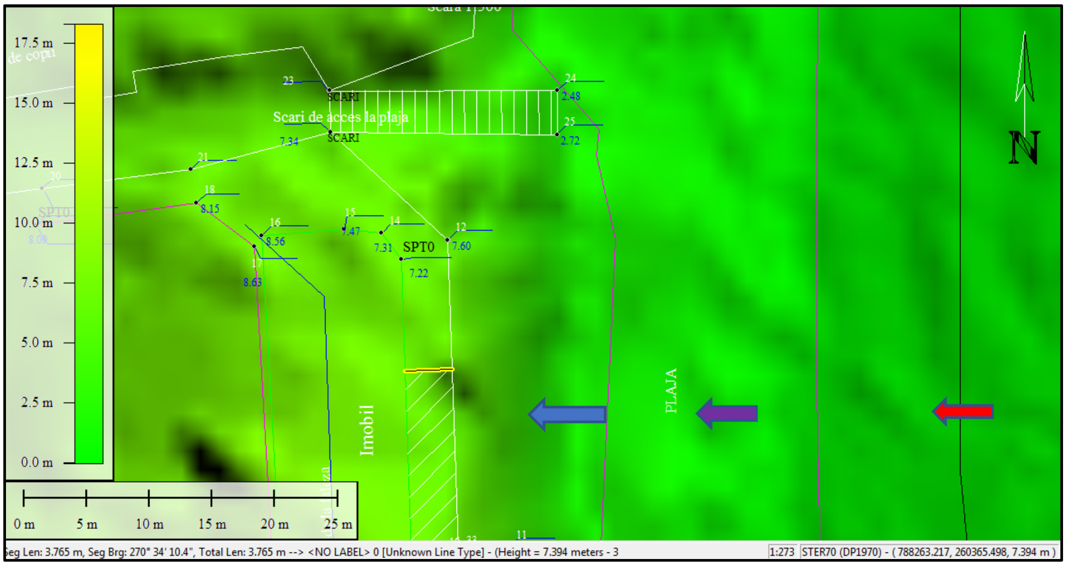

Fig. 11. Detail of the main components of the cliff-side shoreline in the 2 Mai area: in yellow, the distance of 3.7m from the crest of the cliff-side to the wall of the existing building on the cliff (red arrow – swash line, purple arrow - the cliff'foot, bleu arrow - the cliff's apex)

Given the specific and irreversible nature of the changes in the high cliff coastline, the rates of change in the 2 Mai area are negative, with annual averages between 0.1 and 0.5 m and multiannual retreats between 1.6 and 24 m, due to the combined action of natural factors represented by the action of the sea, hydrodynamic entrainment and precipitation, in the absence of coastal defence development.

CONCLUSIONS

Some conclusions can be drawn about the main characteristics of the 2 Mai sector based on the data and information used in the study. In terms of geological characteristics, the cliff is part of the former southern shore of the Mangalia fluvio-marine lake. In terms of geomorphological characteristics, the area of interest is an active cliff subject to coastal erosion, with a shoreline variation of about 1m/year, the coastal drift being blocked by the breakwaters of Mangalia harbor. From a geodynamic point of view, the rate of retreat of the cliff apex is about 10 cm/year. The hydrological elements, the rainfall regime, the wave and coastal current regime, the sea level rise and the rainwater run-off increase the risk of infiltration due to the lack of drains, canals and sea defense systems.

In the 2 Mai - Vama Veche sector, in order to avoid the loss of territory belonging to the national heritage, the destruction of communication routes and the irreparable loss of the uniqueness / specificity of the natural landscape, it is urgent to establish a baseline of the public domain, with reference to the crest of the slope, to be demarcated by administrative/territorial planning solutions, but also by technical protection solutions (earthworks/consolidation) to be implemented.

Like most active/unprotected cliffs, the 2 Mai Cliff is in a process of slow retreat in the natural regime, at a rate of about 10 cm/year. Therefore, a 10 m limit from the cliff top to the land is relatively appropriate for the delineation of the retreat and the lifespan of some private buildings/developments in the coastal area, about 30 years under conditions of non-intervention or lack of coastal protection. In summary, the spatial extent limits can be related to the various local environmental problems or types of socio-economic pressures associated with the extension of a public space boundary, as well as to certain elements of marine ecology and coastal landscape.

It is recommended that the 10 m landward boundary from the cliff edge along the entire coastal strip to Vama Veche be demarcated and implemented in the urban planning of the local municipality. Another recommendation is to extend the protection of the cliffs with reinforcement columns, drains and retaining walls (in vulnerable areas / with concave cliffs at high risk of collapse / collapse - deposit of accumulated material at the base of the slope as a result of surface washing, erosion, gravitational processes) within the coastal protection schemes, respecting the carrying capacity of the environment.

It is advisable to consider the variability of sea level and the limit of storm surges in cadastral measurements, including beach and cliff areas, in urban planning documents and in the demarcation of public and private boundaries, and to make the necessary corrections in the cadastral plans accordingly.

Acknowledgement. This work was carried out in the framework of the research project CLIMEWAR (CLimate change IMpact Evaluation on future WAve conditions at Regional scale for the Black and Mediterranean seas marine system), supported by a grant of the Ministry of Research, Innovation and Digitization, CNCS - UEFISCDI, project number PN-III-P4-PCE-2021-0015, within PNCDI III.

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