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Analysis of Formation, development and Contemporary Morphodynamic Processes of Batumi Cape

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Abstract

The presented work mainly relies on the data and materials of 1834–1980 and, importantly, the materials of the last 50 years of regime studies of the coastal zone of the Cape, as well as reports from various organisations and published articles. The work includes the natural conditions of the formation of the cape, its development under the influence of anthropogenic factors, and the assessment of its actual stability, taking into account the expected risk factors. The work discusses the active influence of the submarine canyon existing along the cape on the stability of the coastal zone. Its underwater slope (slopes of 300 and more) directly follows the entire shape of the cape. Consequently, large volumes of beach-forming material are permanently lost at great depths. This process is well studied and presented in the paper. The work also considers the stability of the aquatic area of a small floating craft shelter (referred to as the "Yacht Club") arranged in the Cape area. Recently, a growing sediment accumulation zone has been formed along the coastal section of its enclosing structures (moles). Its parameters and morphological markers indicate the formation of a destabilisation process of the accumulative form, with a correspondingly negative result. The issues listed in the paper are discussed based on the factual results of many years of research, with the inclusion of relevant graphic and photo materials.

Keywords: Beach-forming material, alongshore sediment transport, lithodynamic system, submarine canyon

Introduction

The problem under consideration is much broader than we discuss it today. This study is part of a large geoecological problem that exists on the Black Sea coast of Georgia: the problem of accelerating the rise in the level of the world's oceans, as well as powerful man-made pressure on the coastal zone, which causes an imbalance in sediment equilibrium in the coastal zone, beach erosion, and so on. Batumi Cape is located in the central part of the town, where there are many modern hotels, tourist attractions, and visitor entertainment facilities. Also in its area are a yacht club and the northern section of the famous boulevard of Batumi. Accordingly, the coastal zone of the cape in all seasons of the year is crowded with both visitors and the local population. In Adjara, resort and tourist infrastructure is being developed on a large scale, which requires thoughtful development of the coastal zone and, most importantly, maintaining its sustainability. Based on the current reality, a comprehensive study of the formation, development conditions, and reasons for degradation of the seacoast zone has become urgent.

The Batumi Cape coastal zone (above-water and underwater slope), as well as the canyon intruded within it, are well studied. Observations on the morphodynamic processes taking place here and research in various directions were carried out here along with the formation and development of the cape (mostly after the construction of the Batumi port at the end of the 19th century). Their frequency has been increasing since the 1970s of the previous centuries.

It is clear that it is not appropriate to carry out detailed studies within the entire Adjara coastline, considering both our resources and the uneven sustainability of individual areas. According to the findings of a thorough, long-term study, a part of the Batumi Cape was found to be where the conditions were right for bad things to start happening. In particular, the most likely destabilisation of the stability of the coastal zone.

Methods and Materials

In the presented work, mainly the materials of the 1834–1980 unpublished reports and, importantly, the materials of the last 50 years of regime studies of the Cape coastal zone are used. also reports from various organisations and published articles. It includes the natural conditions of the formation of the cape, the stages of its development under the influence of anthropogenic factors, and the assessment of modern sustainability taking into account the expected risk factors. There is discussion of the negative impact of the underwater canyon, located along the cape, on the stability of the coastal zone and the

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preventive measures taken to mitigate its activity. Additionally, the sustainability of the yacht club water area and its surrounding construction (breakwaters and groynes) in the cape area the issues listed in the paper present the analysis of the results of many years of research, their combinations, and their conclusions. In connection with the mentioned problem, morphodynamic, lithodynamic, statistical, hydrometeorological, cartographic, comparative geographical, and general scientific methods were used.

Results

Conditions of formation and development of the cape

The seacoastal zone of Adjara and the entire Kakhaberi plain (including the Batumi area) are mainly formed by the solid sediment of the Chorokhi River. Under natural conditions, the beach-forming material of the river, which fell into the sea estuary under the influence of storms in the prevailing direction, formed an alongshore stream of alluvium (a unified lithodynamic system) from Cape Kalendere to the sea confluence of the River Natanebi.

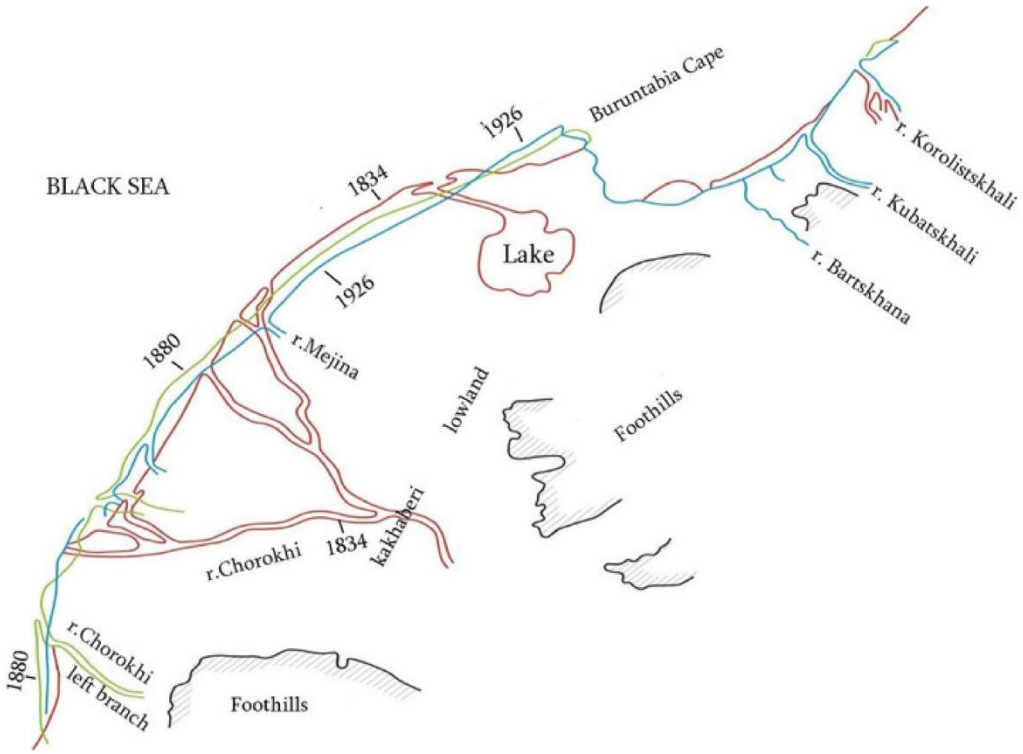


Figure 1. Stages of development of Kakhaberi Plain 1834-1926 (Depository 1)

The length of the beach was approximately 50 kilometres [1, 2]. Batumi Port (1872–78), which completely stopped the movement of alluvium to the north, drastically altered the unified system [3]. An autonomous coast was separated from the south of the system; its length was 15–16 km. Unpublished reports, such as Manganar 1834, the first piece of cartographic data used by Svishevski in 1939 [4], reflect these processes. The displacement of the main bed of the Chorokhi River and its mouth (delta) from north to south is considered, which is directly related to the redistribution of the alluvion drawn from the river into the sea [5–11]. Additionally, the influence of the Batumi port on the development of the coast and the stages of the formation of the cape to protect the water area of the port from sedimentation, at the beginning of the last century, the famous boulevard of Batumi spur was constructed with an initial length of 170 m, which was filled from the south with material from the Chorokhi River brought by stormy waves. In the formation stage, the growth rate of the cape was approximately 4 m/year. The spur was filled for 30–40 years (Depository 2), and the cape reached the extreme form of its development; it approached the depths of 4-5 m of the submarine canyon heads by the extreme distance. The movement of a large volume of alluvion to the depths leads to the erosion of the slopes of the underwater canyon and further activation of its headwaters. Periodically, a large volume of drift and alluvion accumulates in the coastal zone of the cape, mainly in the local areas of

the underwater slope. In the case of the formation of a critical mass, it moves to great depths together with part of the above-water beach and is practically analogous to an avalanche or landslide process. The process can be provoked by any insignificant disturbing factor: storm duration, direction, strength, different conditions of dewatering of nonuniform drift in the critical mass (in previous years, in many cases, the content of household garbage and construction waste), and many others.

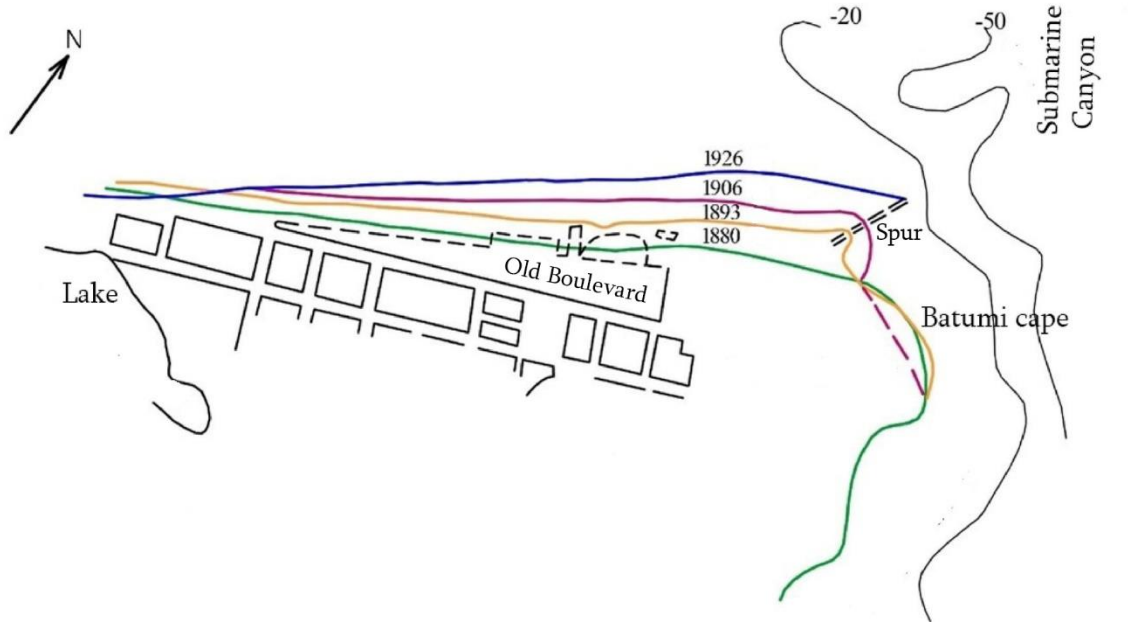


Figure 2. Spur influence on the variation in the sea edge line in 1880-1926 (Depository 2)

Modern conditions of Batumi Cape

Active studies, with the use of different methods, of the ongoing morphodynamic processes within the Batumi Cape limits have been conducted since 1979 using various methods. The latest data are figs. 1 and 2 of 2022. According to their study, there are two sections that pose a risk: the first is between the old and new spurs, where a large amount of material that had been accumulating on the coast was released into the depths in 1999. The second, along the marina/seacoast groyne of the yacht club, is where a process similar to the first is in the stage of formation.

On January 14, 1999, in the central area of the Batumi Cape (the first area), within the limits of two spurs, in absolutely calm sea conditions, an event developed when the accumulated material on the underwater slope instantly broke off and went to depth, taking with itself a 200–250 m long and 50–60 m wide above-water beach strip with a total area of approximately 12 thousand m2. The process was provoked by small earthquake resonance tremors (magnitude 3, data from the Turkish side) that occurred in the Trabzon region of Turkey (250–270 km from the city of Batumi). The process developed in winter, at night, when the beach was deserted. If the same thing happened in the summer, during the daytime, when there are hundreds of bathers and vacationers on the beach, it is not difficult to imagine what fatal consequences we would have.

In the second area, along the jetty of the yacht club, there is an increasingly accumulative form of drift that has been forming for the last 10 years. Unlike the first one, the movement of excess material from the coastal zone to great depths, with the scenario of instantaneous development of landslides or avalanches, was not observed. Currently, the morphological parameters of the site and the analysis of the comparison of sections from different years indicate that the alluvion accumulation has reached a critical phase.

If we take into account the catastrophic variant of the negative process of the previous century (14.01.1999) (with a nonfatal result), it is most likely expected to be repeated in both areas (Figs. 3, 4) (sections 2-2, 3-3, 4-4, 5-5).

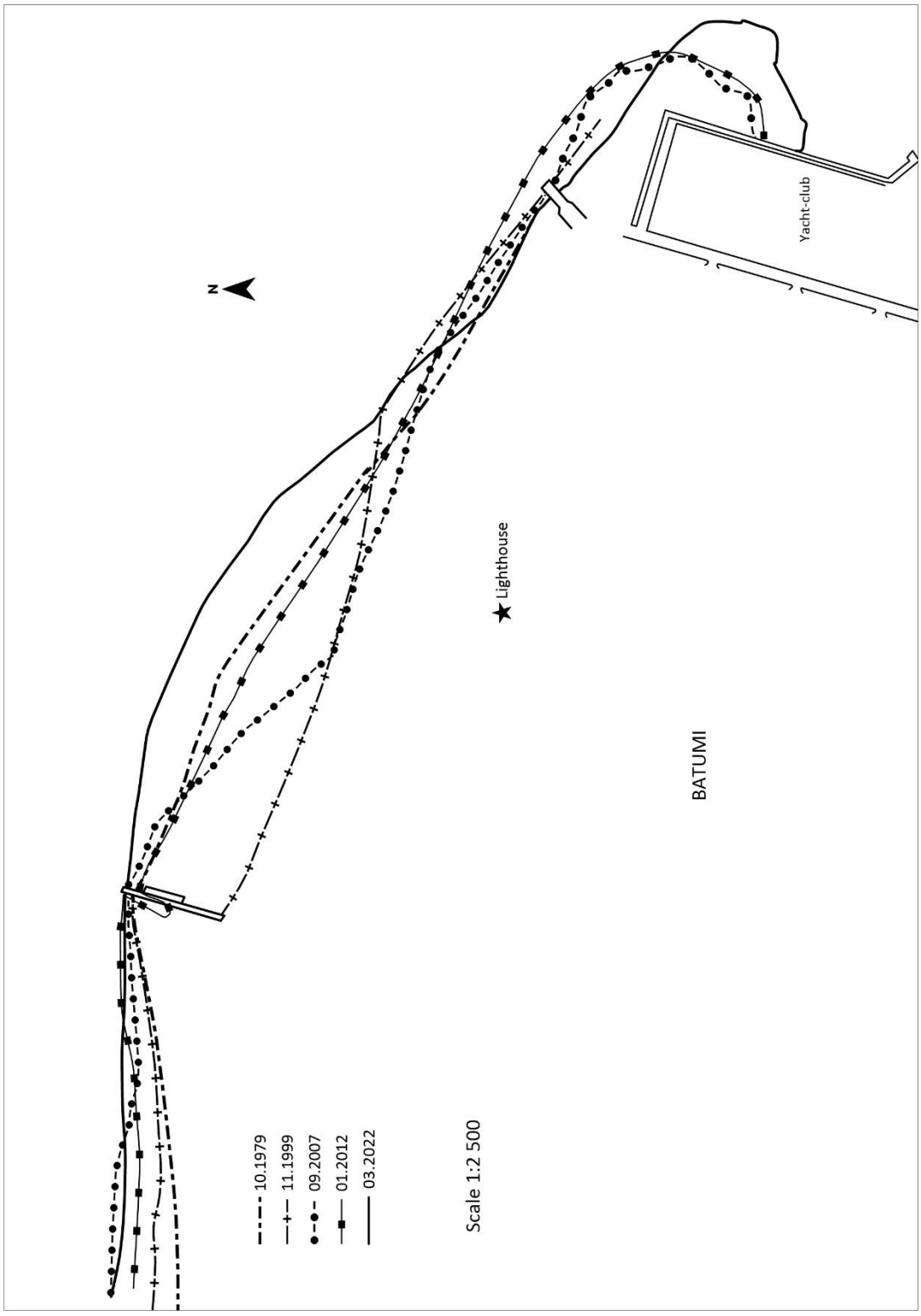


Figure 3. Coastline changes (Batumi cape)

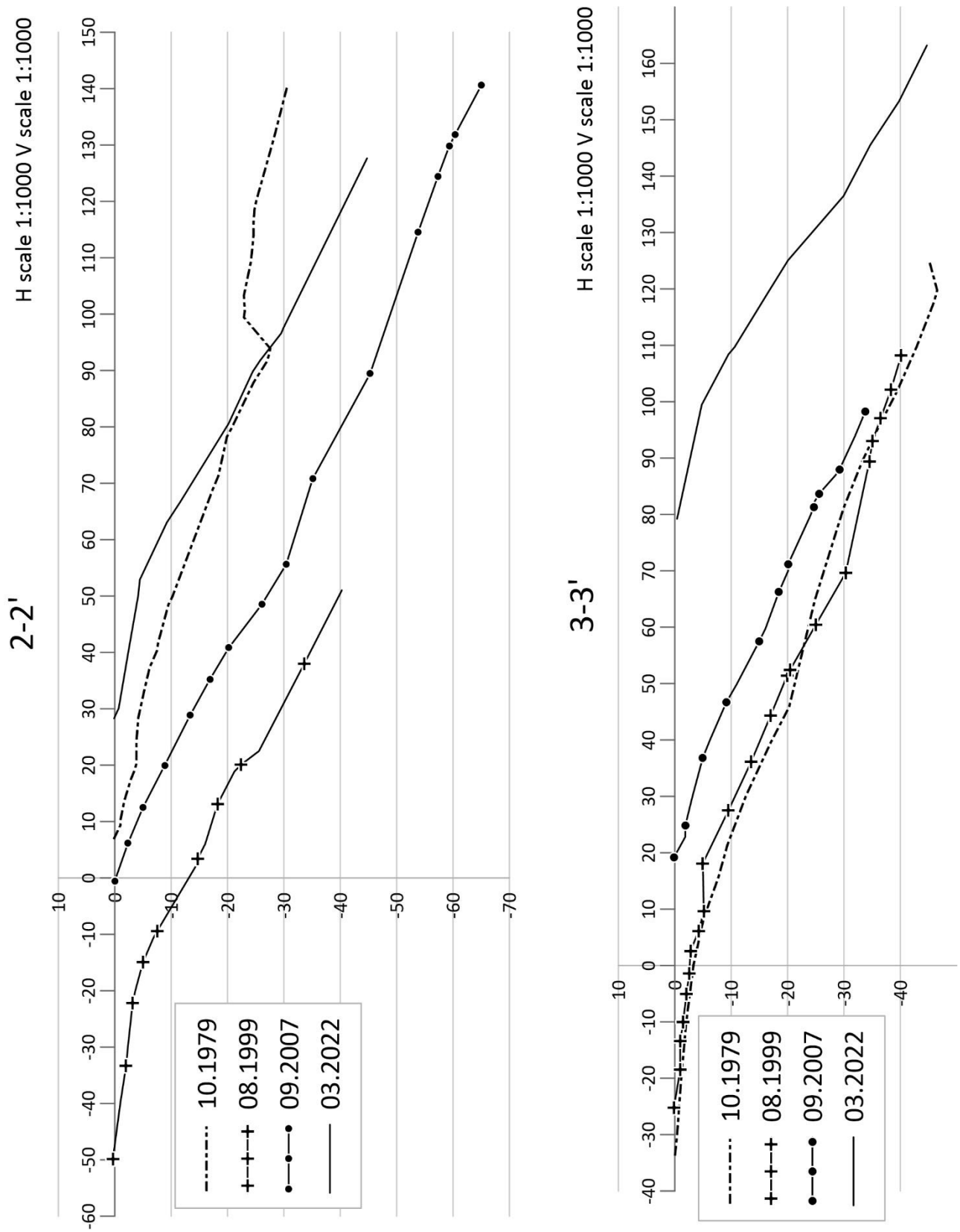


Figure 4. Cross-section

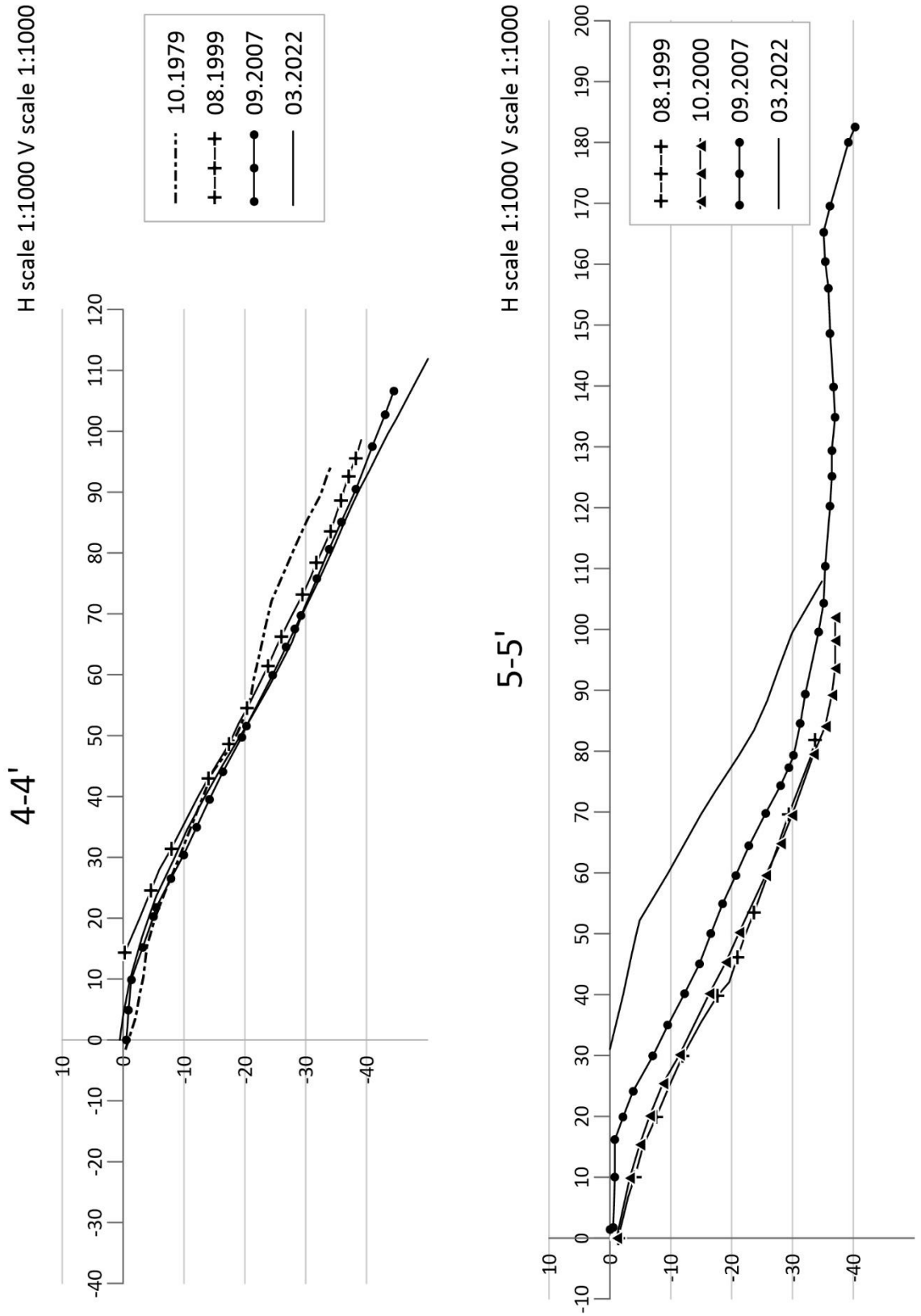


Figure 5. Cross-section

The characteristic sections of the first area are 2-2 and 3-3 (Fig. 4), and those of the second area are section (5-5) (Fig. 5). Additionally, a graph of the comparison of sea edge lines (Fig. 3.). To simplify the visualisation of the sections, the data of 4 different years are compared, unlike the information in (Fig. 3.) (1979-2).

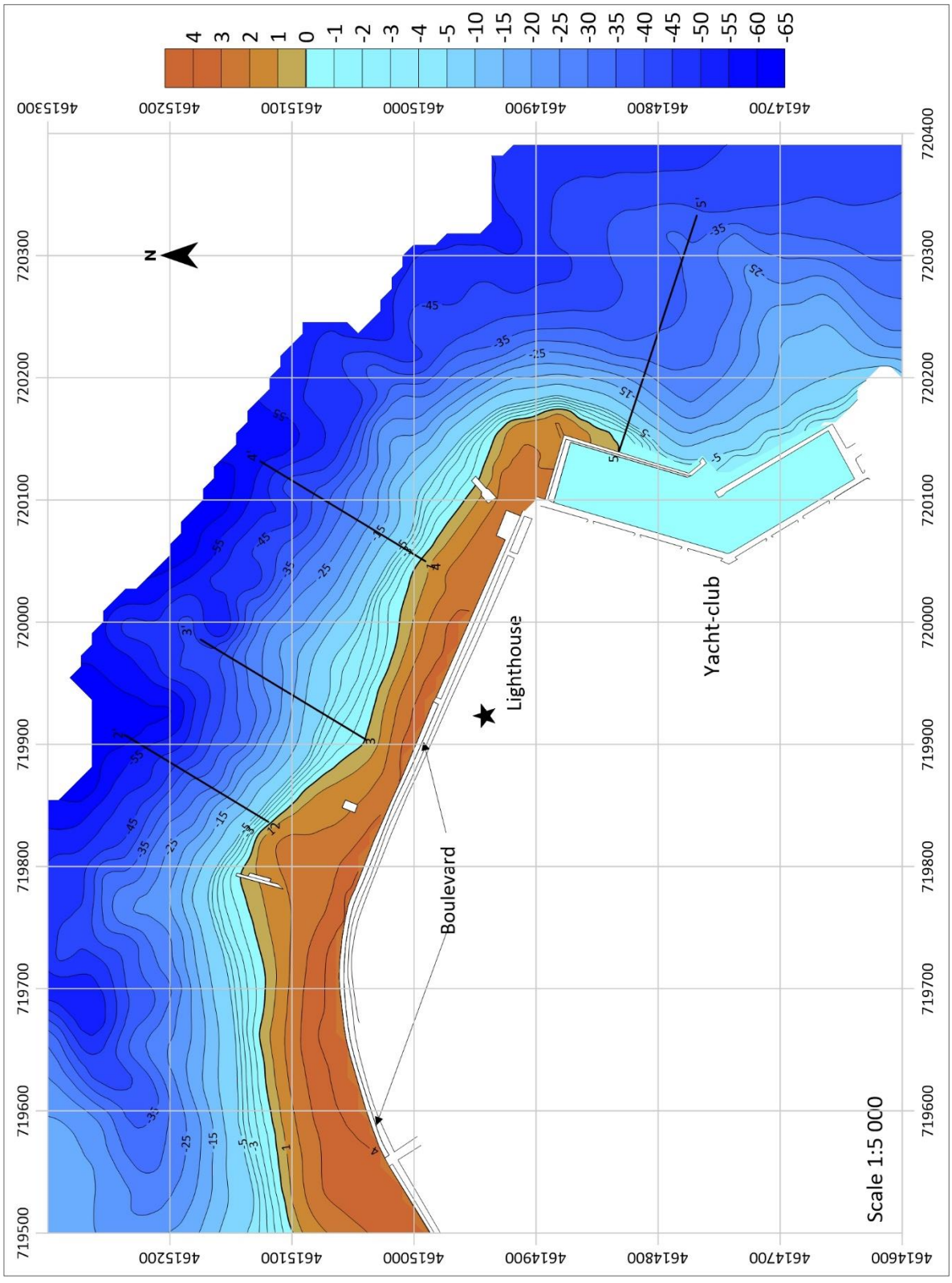


Figure 6. General topo-bathymetric map of the cape and layout of 4 cross-sections

In the first area, a wide accumulation zone of alluvion was distinctly formed between the old and new spurs (Fig. 3). The increase in the sea edge line was approximately 60 metres during the last 20 years (08.1999–03.2020). On the slope of the submarine canyon, a depth of 30 metres moved forward by 45–50 metres (section 3-3). (Fig. 4.). Accordingly, the volume of the accumulative mass exceeds the amount of drift lost in the underwater canyon on January 1, 1999. In this area, during the development

of the expected negative process, it is difficult to predict what area of the above-water beach will turn out to be in the sea.

The beach, adjacent to New Spurs, and the yacht club do not fall within the area of stormy influence of the prevailing direction on the cape—the westerlies or western rhumbs. In addition to the mentioned azimuth, the breakwaters of the Batumi port shield it from uncommon N.W. storms. Nevertheless, the conditions of formation and development of their coastal zone (Fig. 5 and sections 4–4; 5–5) are different from each other. Section 4-4 is taken within the Batumi Cape scopes, and during our observation period (40–45 years), no forms of excess alluvion accumulation are observed. In the above-water part of the section, the fluctuation of the sea edge line is 10-15 m, and that of the underwater slope is 20–35 m within the depth scope of approximately 100 m. Accordingly, Section 4-4 actually shows that this area is a transit zone for drift movement. However, this does not mean that the transit drift does not fall into the great depths of the submarine canyon. [12] Unlike other sections, where the alluvion moves under the conditions of accumulation of excess and critical mass formation, in Section 4-4, the process is permanent, mainly by floating the drift on the subaqueous slope.

As we mentioned, the form of excess drift accumulation along the yacht-club jetty (Section 5–5. Fig. 5) has been observed since 2000 and its activation in the last 15 years; currently, the increase in the beach above the water has reached 30 m. The bottom of the cone of excess mass (depth 30–35 m) is approximately 100–110 m away from the shore. There are various reasons for the formation of such a shape; however, it is interesting that this period coincides with the construction of the yacht club jetty as well as with the natural events of January 1999, which developed within the cape limits. Fig. 6 shows the layout of the abovementioned cross-sections.

Influence of the Batumi submarine canyon on the formation and stability of the cape

As we mentioned, the final stage of the formation of the cape can be considered the approach of its previous accumulation zone to the heads of the canyon, and the reason for the activation of the canyon is the construction of the spur. Based on various sources and our research, approximately 100–120 thousand m3 of large bottom fractional sediment-alluvium from the Chorokhi River was and is being lost in the depths of the underwater canyon. If we take into account the losses of sand, the volume will increase at least 10 times. The displacement of material on an underwater slope causes its depth to deepen. The development of the corresponding morphological forms of the slope expresses the areas of development of this process. The most dangerous zone on the cape is shown in Fig. 7.

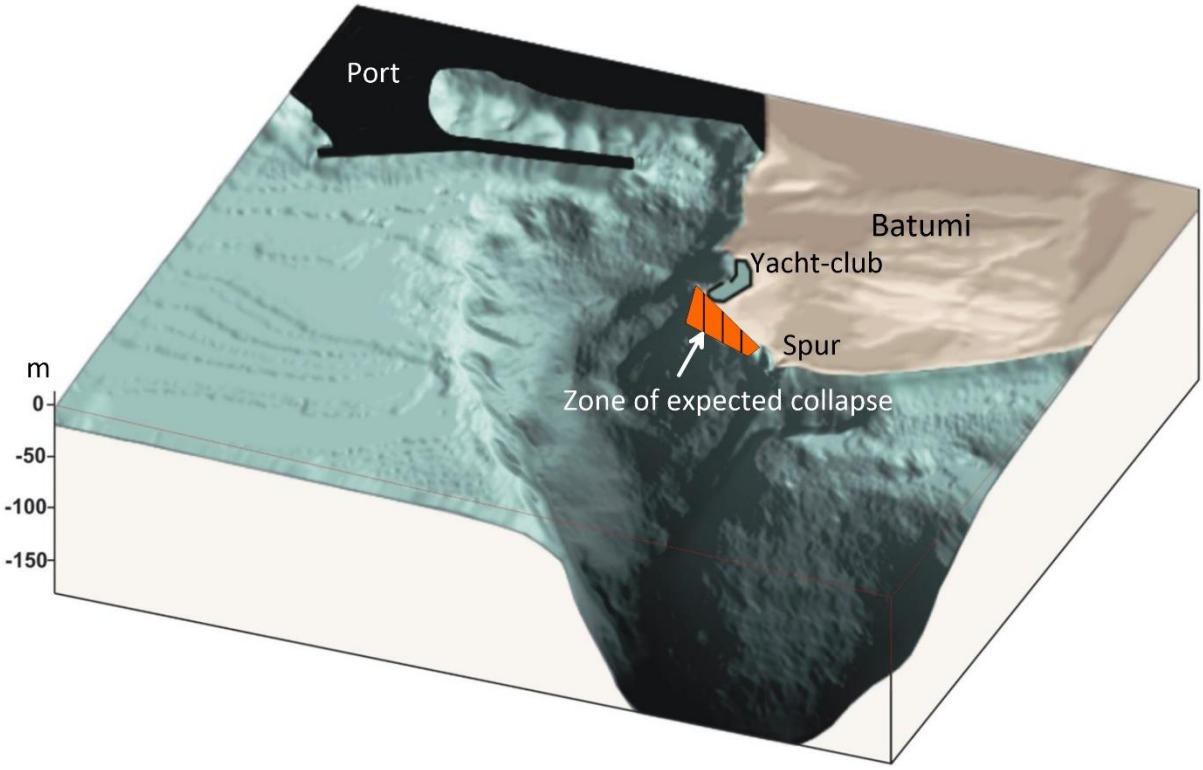
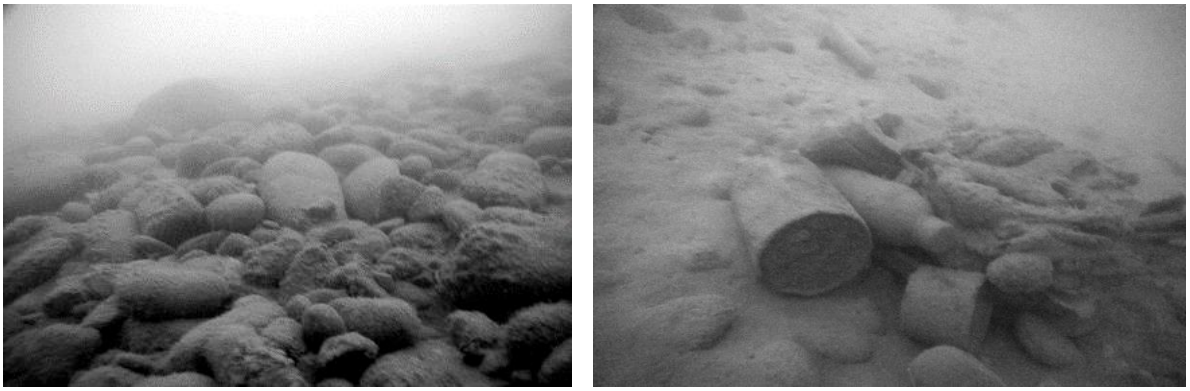


Figure 7. Batumi Submarine Canyon



(**a**) (**b**)

Figure 8. An underwater slope facing the old spur. Tilt 30° depth 6-7 m. (a). In front of the yacht club. Depth 15-17 m. (b)

The photos (Fig. 8) were taken by scuba divers and a special underwater pilot, who measured the direction, inclination, and depth of the slope. Accumulating cape-building material of various grades as well as household garbage (mainly in front of the yacht club) are observed everywhere. The photos show only the surface of the slope, which is mainly covered by pebbles, sand, and silt. The same structure exists in the lower layers, at the points we have randomly measured, in layers 1.0–1.5 m deep from the surface [13, 14]. Thus, the combination of sections and photos of the underwater slope reflects the active period of development of the cape, which can be a prerequisite for the development of the negative process. Here, for comparison, photos of the Cape Coast from different years are shown.

Conclusion

It is impossible to predict the development time and scale of negative processes with great probability. However, we deem it appropriate to consider several options: 1. Permanent discharging of an underwater critical mass of material in smooth sea conditions; in this case, the central area of the cape is practically safe, but in front of the yacht club, where the critical mass is directly adjacent to the seaside groyne, destabilisation of the stability of both the club's surrounding buildings as well as the infrastructure of its water area and the vessels ported there is most likely to be expected. 2. In the event that processes similar to those of 1999 develop, the results could be more or less catastrophic for both districts; 3. From the point of view of the development of catastrophic processes, it is very important to know in which season of the year to expect the unpredictable processes discussed above. It is necessary to temporarily prohibit the presence of vacationers, fishermen, or people just walking or working in the areas designated by us for their safety. Obviously, this ban will continue until, in agreement with the local authorities, the options and timelines for the preventive measure are decided. The issue cannot be resolved only on the basis of our many years of observations and experience.

It is necessary to carry out detailed measurements of underwater (bathymetry up to 15 m depth) and above-water (topography to the end of the beach) areas from Batumi Boulevard to the entrance of the yacht club. It is important to include experts studying the sustainability of the coastal zone in cape development plans. On the one hand, future facilities should not provoke negative processes, and on the other hand, the facilities themselves should not fall into the destabilisation area.

Competing interests

The authors declare that they have no competing interests.

Authors' contribution

G.R. and G.L. conceived of the presented idea and wrote the manuscript. G.K. performed the analytic calculations, created the maps and design. All authors provided critical feedback and helped shape the research, analysis and manuscript.

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