Study of structural-tectonic discreteness of abrasion-landslide bench in a segment of Odesa coastline

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Introduction. The study of landslides in the north-western Black Sea area has revealed significance of structural-tectonic peculiarities of rock massif for landslide scale, mechanism and slopes stability. Different methods were used to spot structural-tectonic weakness zones of different types. Dense disjunctive net (at characteristic tectonic intervals of 20-60 m) makes itself evident in two kinds of relief forms: in grating pattern of thalweg fragments of many small beams and gully and outlines of blocks of slip rocks and as outlines of slope edges at landslide sites (Kozlova, 2001; Freiberg et al., 2010, 2012; Kozlova et al., 2013). It has in particular been established that separate elements of landslides and erosion systems are most often regularly 'organized' in geological space. They rather develop in certain directions and with certain spatial interval indicating that they prepare some structural canvas of geological space. Monitoring of some buildings' and engineering facilities' state also shows that their deformations are caused by the reasons, which are regularly distributed in time and geological space (Cherkez et al., 1997, 2006; Shmouratko et al., 2013). With that, publications dedicated to studies of underwater slope of landslide coast from engineering-geological viewpoint are scares (Kozlova et al., 2017). Interest in underwater part of landslide slopes is caused by the need in both engineering assessment of conditions for building of different facilities and forecasting of engineering-geological system behaviour. The latest cannot be reliable without knowledge of landslide slopes evolution regularities.

The purpose of the work is to reveal structural-tectonic discreteness of abrasion-landslide bench in a segment of the Black Sea landslide coastline in the area of Marine Hydrobiological Station of Odesa National I.I. Mechnikov University.

Data & Methods. The study has been performed in the north western part of the Black Sea region (see Cherkez, 1996; Kovalova et al., 2010; Freiberg et al., 2012; Medinets & Medinets, 2012) and comprises Odesa coast segment from the cape near Chkalov Sanatorium to Marine Hydrobiological Station of Odesa National I.I. Mechnikov University (Figure 1a).

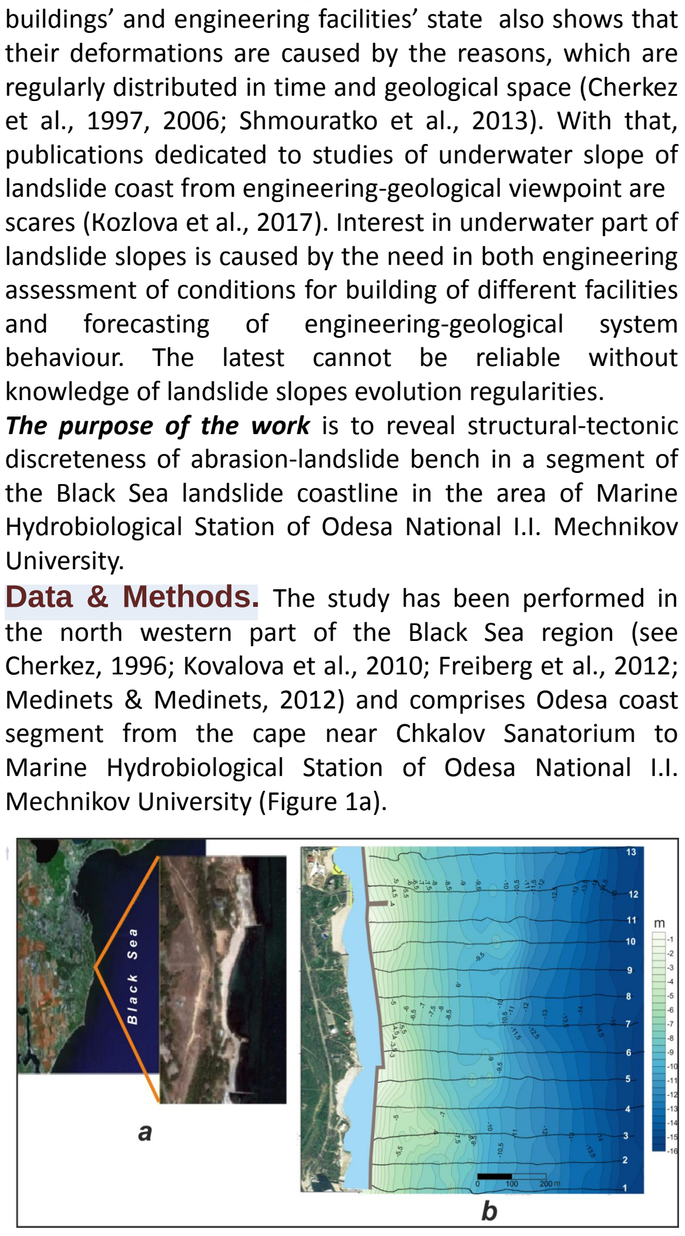

Figure 1 *- Scheme of studied area location (a) and bathymetric map of the Black Sea coastal shelf near Odesa (b). Continuous horizontal lines (b) – bathymetric profiles, figures – their numbers.*

The climate is temperate continental, with a mean annual temperature of 10.5°C (period of 2000-2014) and mean annual precipitation of 432 mm; total annual atmospheric nitrogen deposition varies between 114 and 224 kg N km-2 on-shore and off-shore respectively, ca. 66% of which is organic, associated with marine aerosol formation (Medinets, 2014; Medinets et al., 2016). Study area is exposed by freshened waters via riverine input of the Dniester River.The results of bathymetric surveys performed by the authors in 2016, 2009 and 2006, as well as remote underwater video recording of 2008 have been used in the study (Kozlova et al., 2017). The basic and most detailed bathymetric survey performed by us in 2016 comprised 13 profiles down to 16 m depth in the 1200 m long area along the coastline (Figure 1b). All the profiles from the coastal side started at breakwater line located ca. 100 m from water edge. The breakwaters together with artificial beaches and groins are a part of coast protection works of the landslide-protection complex of Odesa coast. The 700–800 m long profiles were orientated perpendicular to the coastline; the distance between them made ca. 100 m. "SeaCharter 640 cDF" echo-sounder comprising GPS for position determination was used to measure depth. Distance between depth measurement points along each profile did not exceed 1.0 m. SonarViewer 1.2.0.2.A software was used to convert data from echo-sounder records format for processing. Different software packages were used to filter noises and build digital models of relief: ArcGIS Desktop with Spatial Analyst and Golden Software Surfer. The data was statistically processed with MATLAB and Statistica software. Methodology of data from bathymetric surveys processing consisted in deriving of sea bottom elevation digital models and its relief characteristics for 2006, 2009 and 2016. Moving averaging method with 30 m window was used to establish trend component of bottom depth, as well as the reminders for lineament analysis and determination of periodical component of spatial variability of relief characteristics using spectral analysis method (Fourier transform).

Results. In the study area block landslides are developed, deeply deforming the Meotian rock with displacement surface situated down to -15.0 m below the current sea level (Figure 1a). Landslide dislocations in this segment of coastline were registered in 1856, 1858 and 1963, at that the length of disconnected massif was 420-500 m (Kozlova et al., 2017). Bottom elevation model built using sizes of deviation from depths trend surfaces shows evident hilly and ridged character (Figure 2a). To find and identify hidden tectonic dislocations the lineament analysis was used, which proved to be an effective (on results) and operative (on time) method of modern geological studies.

The analysis performed has revealed regularly orientated lineaments with prevailing north-eastern and, to a lesser extent, north-western direction (Figure 2B), which enables us to connect them with the common for continents and oceans planetary tectonic-lineament regmatic net.

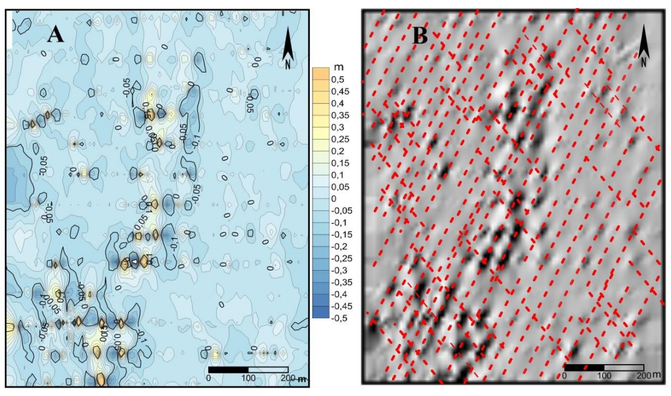

Figure 2 *- Model of sea bottom relief after removal of linear trend on the results of bathymetric survey of 2016 (A) and bottom lineaments (B) [red dotted lines] in the Black Sea coastal shelf area near Odesa.*

The results of depth measurement along the profile No. 3 in 2016 and bottom relief after removal of depth trend component on the results of bathymetric surveys of 2006, 2009 and 2016 are presented on Figure 3. Strong periodical character of reminder series of deviation from trend surface of depths points to regular disposition of ridges in bottom relief.

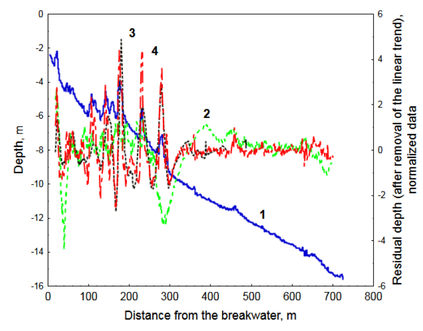

Figure 3 *- Underwater slope relief along the profile No. 3 according to bathymetric surveys of different years. 1 – depth of sea bottom, 2016 (scale to the left); 2, 3, 4 – sea bottom relief after removal of linear trend (scale to the right): 2 – 2006, 3 – 2009, 4 – 2016*

Spectral analysis of temporal sets of sea bottom relief after removal of trend component of 13 bathymetric profiles showed high-frequency periodic components. Harmonics with periods of 30, 40 and 60 m had the highest amplitude. It should be pointed out that underwater relief structure stays practically unchanged in surveys of different years. It would appear natural to assume that harmonics with 30….60 m period determine tectonic pitch of the identified regmatic lineament net, which could serve a natural framework for landslide processes occurrences. Conclusion that there are landslide ridges of limestone, prepared during abrasive processing, in the underwater part of coastal slope is proved by remote video recording of 2008. On the results of the video recording ridges of limestone were found, which can be traced down to 6-10 m depth and at the distance of 250-400 m from the coastline, some limestone blocks rise 2 m above the sea bottom. It should be noted, that such landslide relief was also found in other areas of coastal part of the north-western Black Sea shelf using geological and geophysical data (Cherkez, 1996; Freiberg et al., 2012). A set of features enables us to believe that sea bottom area adjacent to the coastline down to the 12-m isobath is a bench worked out in the Upper Neogene landslide-faulted rocks. Its surface is presented by Meotian clays with Pontian limestone blocks dented into it; the blocks spaced in chains form a set of ridges. The configuration of landslide ridges – relics of ancient landslides – are approximately equivalent to the 'traces' of intersection of landslide displacement surfaces with sea bottom plain of abrasion. Spatial modifications of landslide motions kinematics are pronounced at orientation of landside ridges on the bench and are subject to structural-tectonic regmatic net. Morphometric analysis of underwater slope relief done using the data from bathymetric surveys and instrumental observations of current deformation processes in supraaquatic part (Kozlova, 2001; Freiberg et al., 2010; Kozlova et al., 2013) enabled us to reveal stability of dimensions of landslide blocks and strike directions of ancient and contemporary landslides in the northern Black Sea region.

Conclusions and recommendations. Morphometric analysis of sea bottom relief in the coastal shelf area with well represented landslide processes, adjacent to Odesa coast, helped us find: a) relics of ancient landslides on the rock bench, thus confirming widespread development of abrasion and landslide bench of the landslide segments in the north-western Black Sea coast; в) identity of size of landslide blocks and strikes of landslide dislocations in ancient (Pleistocene-Holocene) and modern pressing-out landslides; c) geohistorical reconstructions provide not only qualitative characteristics of geological processes but also averaged quantitative estimation of their intensity in spaces of time which exceed significantly the period of direct observations in-situ; d) evident influence of structural-tectonic factor on landslide processes development, both late Pleistocene-Holocene and modern. Building and reconstruction of different facilities in the coastal zone area, coast protection works, as well as development of new and reconstruction of existing landslide prevention and coast protection works should be done taking into account the revealed morphometric peculiarities of slide relics on the subaqueous slope.

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