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On the origin of the "Ikantalaka" landslide – the Balchik coast

Dimcho Evstatiev, Yordan Evlogiev

Geological Institute, Bulgarian Academy of Sciences, 1113 Sofia, Acad. G. Bonchev St., Bl. 24;
E-mail: dimcho_e@geology.bas.bg

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Д. Эвстатиев, Й. Эвлогиев – Происхождение оползня "Иканталака" (черноморский берег около г. Балчика). Оползень Иканталака возник в начале Карангатской трансгрессии (рисс-вюрм) в результате сильных землетрясений. Структура оползающих масс показывает, что его большая часть представлена затопленным оползнем. Основными факторами, которые привели к его становлению, были локальные гидрогеологические обстоятельства (по большому оврагу с плоскогорья в тело оползня поступала вода) и локальные тектонические условия (по всей вероятности здесь проходил разлом с простиранием, поперечным к простиранию береговой линии). Тело оползня сложено главным образом арагонитовыми глинами (сарматская свита Топола – верхний бессараб-нижний херсон). Эти глины отличаются высокой чувствительностью и легко поддаются размягчению. Зона, по которой осуществлялось скольжение, включает контакт между свитой Топола и подстилающей Эвксинградской свитой (сармат – верхний караган-средний бессараб). Эвксинградская свита сложена диатомовыми глинами, которые переслаиюваются тонкими глинистыми песками. Ее поверхность падает к морю под углом 3–4°.

Abstract. The Ikantalaka landslide emerged in the beginning of the Karangatian transgression (Riss-Würm) under the effect of strong earthquakes. The greater part of it represented a submerged landslide, the evidence for this being the structure of the slided masses. The main factors for this were the local hydrogeological circumstances (a big gully mouthed the landslide from the plateau) and the local tectonic conditions (probably a fault existed in perpendicular direction to the coastline).

The landslide body is built mainly of the aragonite clays of the Topola Formation (Sarmatian: Upper Bessarabian – Lower Hersonian, which are characterized by high sensitivity and susceptibility to softening. The zone, along which the sliding occurred, comprises the contacte between this Formation and the Euxinograd Formation embedded underneath (Sarmatian: Upper Karaganian – Middle Bessarabian). The latter is represented by diatomic clays, intercalated by thin clayey sand layers. Its surface is inclined at 3–4° towards the sea.

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Key words: landslide, earthflow, seismo-gravitational phenomena, geodynamic, aragonite clay, diatomaceous clay.

Introduction. State-of-the-art of the problem

The "Ikantalaka" landslide is one of the biggest landslides along the coastal area between the towns of Balchik and Kavarna. It has drawn the attention of researchers for a long time with its peculiar form of a landslide-earthflow, distinguishing it from the predominantly step-like/block landslides on the coast around it (Kamenov and Demirev, 1965).

Kamenov et al. (1972) describe the landslides between Balchik and Kavarna, considering not only their structure, rock composition and geomorphology, but also the factors provoking the sliding process: marine abrasion, groundwater, earthquakes, rock weathering, etc. The authors think that the main landslides of the block type occurred during the Pleistocene and their dismemberment, including the origin of landslide-earthflows, took place during the Holocene and in the present days. An earthflow or debris flow implies the flow along the slope of overmoistened clayey mass, which may be triggered by the effect of seismic forces. It is inferred that the "Ikantalaka" landslide is exactly such an earthflow, set up in motion probably by an earthquake.

In the considered paper are mentioned also the level fluctuations of the Black Sea during the Pliocene and the Pleistocene, the presence of marine terraces, the positive neotectonic movements in the region and the existence of young faulting.

The influence of the earthquakes along the regarded coast is considered by Iliev (1973). He collected the available information about landslides and rockfalls provoked by strong earthquakes from the antiquity till the present days. The role of the earthquakes is considered by the author together with the influence of rock composition, marine abrasion and groundwater level fluctuations.

On the basis of the analysis of the geomorphological specificities and historic documents for the Balchik landslide, Evstatiev and Rizzo (1984) consider that the earthquakes are the most important factor for the origin of the landslides of the block type.

The effect of the rising groundwater level on the landslide activation along the Northern Black Sea coast is studied by Stoykov et al. (1981) and Stoykov and Evstatiev (1983). Evstatiev and Petrova (2006) analyze the stability coefficient of a landslide, adjacent to the "Ikantalaka" one, for different groundwater levels and different seismic coefficients.

The stratigraphic and sedimentological investigations of Popov et al. (1986), Popov and Kodjumdjieva (1987), Koleva-Rekalova (1997) and other authors have contributed substantially to elucidating the mechanism of the landslides between Balchik and Kavarna. It has turned out that the so-called in the past "middle lithological formation", in which the landslides in the region were developed, was not built of "marls, clayey marls and calcareous clays", but mainly of aragonites – chemical precipitates of magnesium carbonate (named Topola Formation, Sarmatian age, Upper Bessarabian – Lower Hersonian). In the same way the "lower marl-clayey" formation, on which the sliding occurs, does not consist of marls but of diatomaceous clays, intercalated with thin layers of clayey sand and calcareous stacks (named Euxinograd Formation, Sarmatian, Upper Karaganian – Middle Bessarabian).

The aragonites differ from the alumosilicate soils with respect to their physico-mechanical properties and behaviour. They are characterized by low bulk density of the dry mass, high water content, easy washing away and softening in water, high sensitivity of the structure (Kamenov et al. 1972), which consists of interwoven and slightly bonded small crystals (Koleva-Rekalova et al., 1999). Under natural conditions the aragonite massif contains thin (up to 20 cm) intercalations of strong micritic limestone that play a reinforcing role. The influence of the specific properties of aragonites on the origin of landslides of the earthflow type, is considered by Koleva-Rekalova et al. (1996).

The interest in the landslide terrains along the Balchik coast has been increased during the last years due to the attempts for determining the possibilities of using at least some of them for resort construction. In this connection the Geological Institute of the Bulgarian Academy of Sciences carried out in 2005–2006 an engineering geological investigation of the coastal area to the west of the Topola village, which included also the "Ikantalaka" landslide. New information has been obtained that enriches and broadens the existing scientific knowledge and provides the opportunity of amending and specifying the present ideas about this interesting landslide[1].

Basic results from the explorations

The studied landslide has impressive sizes: width in the upper part exceeding 900 m and length of 1.2 km. Its broad circus in the upper end is narrowed, forming a fan-like train after the narrowing (Fig. 1, Photo 1 and Photo 2). This train was initially protruding to two hundred – three hundred meters into the sea, the evidence for this being the limestone block scattered on the bottom.

The general inclination of the slope, from the base to the main slide slope to the road to Balchik, in the eastern part of the circus is about 8°, and in the central and western parts – 12°. This inclination diminishes to 5–6° from between the road to Balchik and the sea.

The main slide slope is steep, almost vertical, with a height of 50 m and starts from the elevation of about 160 m at the edge of the plateau (Fig. 1, Fig. 2 and Photo 1). The Euxinograd Formation, representing an alternation of diatomaceous clays and thin clayey sand layers is embedded in the landslide base. Almost the entire main slide slope is built of the Topola Formation sediments — aragonites with micritic limestone intercalations. The profile ends with the cavernous limestones and calcareous clays of the Karvouna Formation.

A thick sliding zone has been obtained by the slide on the contact between the Topola and Euxinograd Formations (thickness of up to 28 m, Fig. 2). The zone consists of wavy layered clay with yellow-rusty, gray-black to greenish colour (photo 3). Its lower end is usually situated at 15–20 m from the surface but reaches the depth of 50–55 m in the higher part of the landslide. It starts from the base of the main slide slope with

[1] Geological Institute of BAS. 2006. Engineering Geological Report for the preliminary arrangement plan of the real estates in terrains 3, 4 and 5 of Litex Commerce AD, the Topola village, Kavarna municipality, Dobrich district.

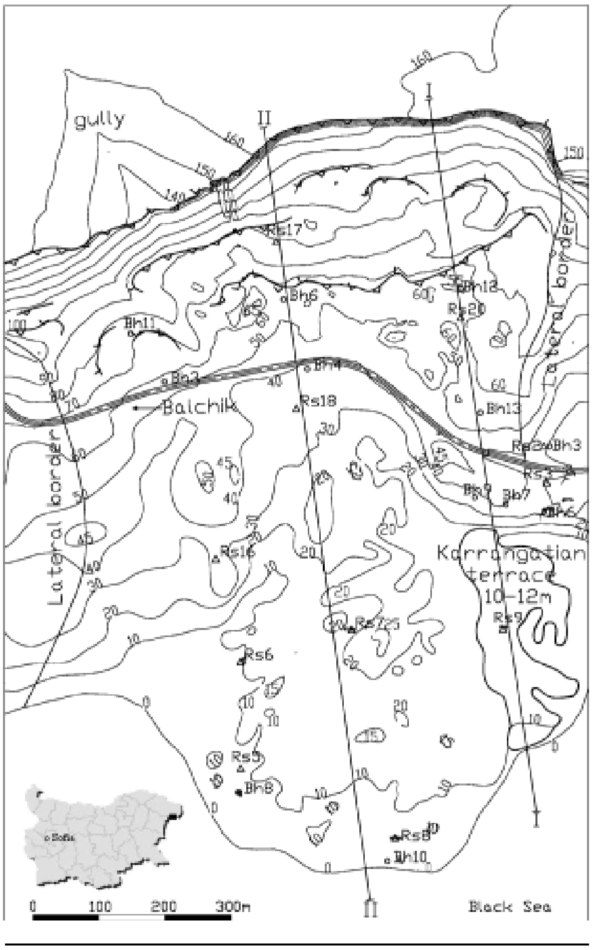

Fig. 1. Map of the landslide “Ikantalaka”

Photo 2. View of the landslide from the sea

Photo 3. Sample from the wavy layered main sliding zone

Photo 1. View of the landslide from the plateau (western border)

a circular-cylindrical form and is gradually transformed to a plane with an inclination of 2–3° in the direction to the sea. The considerable depth of the sliding zone is a result of the pressure of the huge blocks torn from the plateau that have passed over it.

The landslide body consists of three main elements:

– Blocks of aragonite with micritic limestone intercalations, more or less turned around during the sliding, but with relatively well preserved structure. The limestone layers have played a reinforcing role, since the block integrity has been preserved under conditions of such significant displacements;

– Deluvial filler between the aragonite blocks, single layers of it being with soft consistency, causing the closure of the boreholes;

– Aragonite clay flows with rock limestone plates and pieces, deposited on the blocks in the lower part of the landslide.

The landslide is incised by gullies but regardless of this 3–4 landslide steps are distinguished in it, which are not visible in the attached small-scale profiles.

Flat areas are established to the east and to the west of the landslide at elevations 90–120 m, 60 m, 30 m, 10–12 m and 5 m, which represent remains from marine terraces. Only the last two terraces are found within the range of the landslide.

The groundwater level in the low flat part, outside the blocks, is at a depth 7–10 m from the surface. The diatomaceous clays of the Euxinograd Formation serve as a watertight barrier. The level gradually lowers in the direction to the main slide slope, reaching 17–18 m from the surface. However, no water level has been established in some of the boreholes.

According to the stability analyses the “Ikantalaka” landslide is in a provisionally stabilized state but

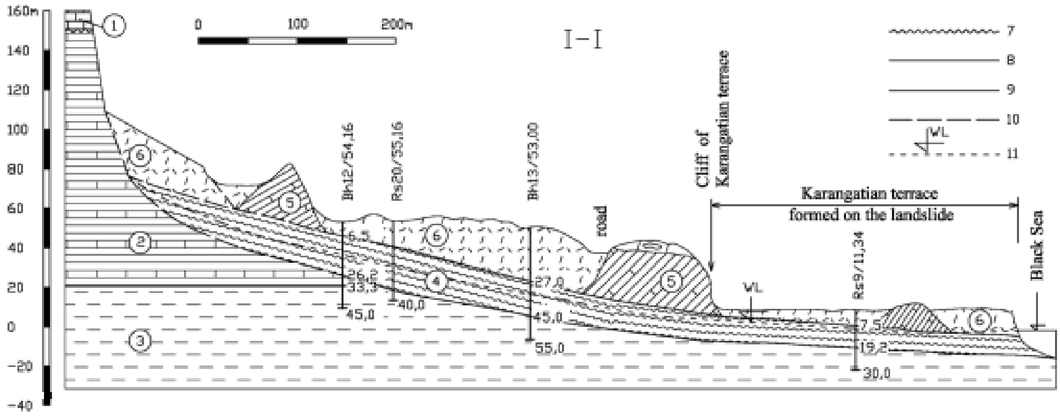

Fig. 2. Geological profile I — I
1 – limestone, with reddish clay intercalations (Karvouna Formation); 2 – aragonite clay, intercalated by carbonate layers (Topola Formation); 3 – diatomaceous clay with fine strips of clayey sand (Euxinograd Formation); 4 – old landslide zone of wavy stratified clay; 5 – landslide blocks of the Topola Formation, with preserved structure but outlevelled; 6 – delluvial – landslide aragonitic deposits; 7 – erosion surface; 8 – lithological boundary; 9 – established sliding surface; 10 – supposed sliding surface; 11 – water level; Other designations: Bh12 – borehole; Rs9 – Resistivity surveys point

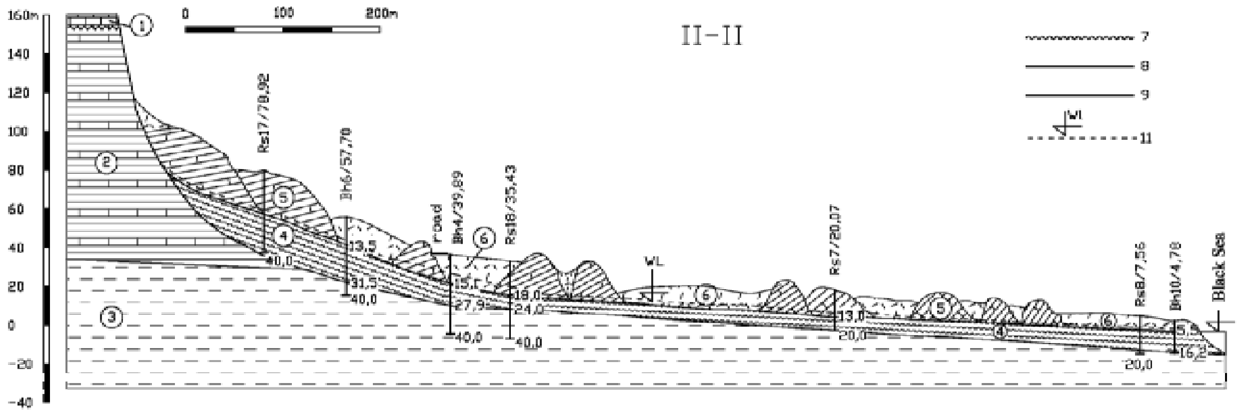

Fig. 3. Geological profile II — II
1 – limestone, with reddish clay intercalations (Karvouna Formation); 2 – aragonite clay, intercalated by carbonate layers (Topola Formation); 3 – diatomaceous clay with fine strips of clayey sand (Euxinograd Formation); 4 – old landslide zone of wavy stratified clay; 5 – landslide blocks of the Topola Formation, with preserved structure but outlevelled; 6 – delluvial – landslide aragonitic deposits; 7 – erosion surface; 8 – lithological boundary; 9 – established sliding surface; 10 – supposed sliding surface; 11 – water level; Other designations: Bh12 – borehole; Rs9 – Resistivity surveys point

it might be disturbed by rising of the groundwater level, a strong earthquake or both.

Analysis of results from the viewpoint of the landslide origin

The new explorations confirm that the Ikantalaka landslide represents a seismo-gravitation earthflow. Except for this result of affirmative character, they provide the possibility of finding answers also to other questions namely: when did the landslide occur; why it has the character of an earthflow; what is the probable mechanism of the sliding process, etc.

The answers of these questions are related with the geodynamic development and the cyclic paleoclimatic changes in the Euxinian basin during the late Pliocene and the Quaternary.

The Black Sea area is under the influence of two cooling periods in the late Pliocene and five glacial periods in the Quaternary, which provoked lowering of the sea level. This lowering reached up to 90 m and caused the isolation of the Black Sea from the Mediterranean Sea. During the glacial periods the

Black Sea coast was raised and subjected to active erosion. The valleys were deeply incised due to the high aptitude of the rocks to washing away and due to the lowering of the erosion basis.

The sea transgressions took place during the warm climate optima (interglacials, interstadials). During each of them the sea flooded the coast, forming a transgressive terrace, situated at a lower level than the old one due to the rising of the land.

The rising of the sea level was accompanied by intensive abrasion of the over-moistened Sarmatian sediments and formation of high cliff. All this, together with the strong earthquakes had provoked the emergence of big landslides of the block type along the strongly dismembered seacoast. These landslides were cyclically activated during the next fluctuations of the sea level. Most probably, they or big parts of them were submarine landslides. Marine terraces were formed on top of them with accumulated at their surface limestone plates and pieces "floating" in the aragonite clay.

The analysis of the terraces, established in the sections adjacent to the studied landslide, shows that the step-like/block landslides are old and their origin can be traced back to the late Pliocene (2.59 Ma). The oldest landslides with a marine terrace on top of them at the elevation of 120 m were formed during the first transgression, after the sea level lowering.

During the early and middle Pleistocene the landslide process was cyclically renewed and transgressive terraces were formed on the landslides at the elevations of 60, 30, 10–12 and 5 m.

The Ikantalaka landslide emerged most probably during the late Pliocene and was developed during the early and middle Pleistocene, being initially of the step-like/block type. The block remains within the landslide body and the very thick (up to 28 m) sliding zone provide the evidence for this.

During the late Pleistocene there were events, which changed the outlook of the landslide. As a result there are no terraces older than the Karangatian one (10–12 m).

There are sufficient reasons to presume that in the beginning of the Karangatian transgression (Riss-Würm) earthquakes with high magnitude occurred that led to the formation of a seismo-gravitation landslide-earthflow, which included the older step-like/block landslide. Under the conditions of transgression and seismic effects the aragonite clays yielded forming a submerged mud-stone flow in the sea. The structure of the slide masses, in which an aragonite clay matrix enveloping big pieces and blocks of crushed micritic limestone stacks is distinguished, provides evidence for the possibility of a similar mechanism (photo 4).

In addition there are traces of secondary stratification at some places in the sliding mass. The inclination of the Euxinograd Formation surface of 3–4° towards the sea facilitated the propagation of the debris flow.

The particular hydrogeological conditions at this place had contributed to the formation of such a landslide type. The water of a big gully flows into the landslide from the plateau (Fig. 1). This water could form a lake at the highest step under the main slide slope, maintaining the slope over-moistened. A similar lake existed in the closely situated Momchilski Rid landslide (also developed in the aragonites of the Topola Formation) and was the main reason for its revival in the middles of the nineties.

Photo 4. Structure of the earthflow deposits

Photo 5. View of the Karangatian terrace

The local tectonic conditions could also be a prerequisite for the landslide origin. The geophysical explorations in the region have established the existence of faults that are parallel and perpendicular to the seacoast. However, the small scale of the schemes showing the faults (Kuprin et al., Ed. 1980) does not allow their exact localization. It is possible that some of them were seismo-conductive.

During the maximum of the Karangatian transgression a 10–12 m terrace, which is well expressed in the lower part of the peninsula protruding into the sea, was formed on the landslide body (photo 5).

Conclusion

The new investigations support the opinion that the "Ikantalaka" landslide represents a seismo-gravitation landslide-earthflow. It was developed at the background of an older landslide of the block type. The evidence for this is the deep (up to 28 m) sliding zone, formed along the contact between the Topola and Euxinograd Formations, as well as the block remains, encountered within the landslide body. The studied landslide originated in the beginning of the of the Karangatian transgression as a submarine landslide as a result of strong earthquakes. The 10–12 m Karangatian terrace was formed in its lower fan-like end, the higher marine terraces being destroyed in the course of the sliding.

The origin of the landslide-earthflow was enhanced by the easy softening and high sensitivity of the aragonite clays of the Topola Formation, the inclined surface of the embedded underneath Euxinograd Formation towards the sea, the overmoistened slope at this place by the gully, which drain considerable areas of the plateau. It is possible that the local tectonic conditions had also exerted their impact but this will be a problem of future research.

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Д. Евстатиев, Й. Евлогиев – Върху произхода на свлачището „Иканталъка" – Балчишко крайбрежие. Свлачището „Иканталъка" отдавна привлича вниманието на изследователите със своята форма: широк циркус с висок главен свлачищен отстъп, стеснение в долния край на циркуса, под което следва ветрилообразно разширение, навлизащо в морето.

Описват се новите резултати, получени от сондажно проучване на свлачището и от геоморфоложки анализ на района, които позволяват да се допълнят и актуализират представите за неговия произход и развитие, като сеизмогенно свлачище-поток.

Свлачищното тяло е изградено предимно от арагонититните глини на Тополската свита (сармат: горен бесараб – долен херсон), които се характеризират с висока чувствителност и размекваемост. Зоната, по която е станало свличането, обхваща контакта между тази свита и залягащата под нея Евксиноградска свита (сармат: горен караган – среден бесараб). Последната е представена от диатомейни глини, прослоени с тънки слоеве глинест пясък. Нейната повърхност е с наклон 3–4° към морето.

От анализа на морските тераси в района се прави заключение, че свлачището „Иканталъка", подобно на другите свлачища около него, отначало е било от блоков тип, за което свидетелствува дебелата хлъзгателна зона (до 28 m) и остатъците от блокове в свлачищното тяло. Произходът на свлачищата от блоков тип е свързан с трансгресиите и регресиите на морето през плейстоцена, с особения геоложки строеж и с геодинамичната обстановка.

Разглежданото свлачище е възникнало в началото на Карангатската трансгресия (рис – вюрм) под влияние на силни земетресения. Доказателство за това е отсъствието в неговото тяло на морски тераси по-стари от Карангатската. По всяка вероятност, по-голямата част от това свлачище е било подводно свлачище, за което свидетелствува структурата на свлечените маси. За да се получи подобен тип свлачище на даденото място принос имат и конкретната хидрогеоложка обстановка (в неговото тяло от към платото се влива голямо дере) и локалните тектонски условия.