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SEISMIC GEODYNAMICS OF MINGACHEVIR WATER RESERVOIR

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In article are submitted data on a relief, the geomorphological analysis, climatic conditions and also seismicity of the territory of the Mingachevir reservoir. The analysis of communication of a water level is carried out to a reservoir with seismicity of the territory and influence on activization of landslides. It is established that filling of a reservoir has impact to emergence of weak earthquakes directly around the Mingachevir reservoir and in adjacent territories. When flooding valley level of ground waters in radical breeds raises that causes formation of landslides.

Key words: Mingachevir water reservoir, earthquakes, focal mechanisms, water level, landslide.

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СЕЙСМОГЕОДИНАМИКА МИНГЯЧЕВИРСКОГО ВОДОХРАНИЛИЩА

Республиканский Центр Сейсмологической Службы при Национальной Академии Наук, Баку, Азербайджана

В статье представлены данные о рельефе, геоморфологическом анализе, климатических условиях а также сейсмичности территории Мингячевирского водохранилища. Проведен анализ связи уровня воды в водохранилище с сейсмичностью территории и влиянии на активизацию оползней. Установлено, что заполнение водохранилища оказывает влияние к появлению слабых землетрясений непосредственно в районе Мингячевирского водохранилища и на смежных территориях. При затоплении долины уровень грунтовых вод в коренных породах повышается, что вызывает образование оползней.

Ключевые слова: Мингячевирское водохранилище, землетрясения, механизмы очага, уровень воды, оползни.

Introduction

As it is known the territory of Azerbaijan is under influence of natural disasters which occur occasionally, they are: landslides, earthquakes, mudflows, floods, etc. the most dangerous and unpredictable among them are earthquakes.

In world practise it is known when earthquakes were caused by different technogenic activity of people. Water is efficient instrument in man’s impact on seismicity and seismic conditions in seismoactive regions, that is building large water reservoirs and other hydrotechnic constructions caused seismic activity growth. This problem is urgent for our republic as the republic is one of the seismoactive regions in Caucasus.

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Several water reservoirs are functioning on Azerbaijan territory including Mingachevir water reservoir and they are able to change seismic conditions of region.

Study of earthquake – prone factors of Mingachevir water reservoir is of practical and theoretic importance, it allows to study both tectonic structure and seismicity of region in details. Moreover research of these factors permits to withstand undesirable consequences during natural disasters and optimal exploitation of hydrotechnical constructions.

This article mainly focuses on study of earthquake-prone factors on territory of Mingachevir water reservoir, on definition of connection between seismicity and water condition in reservoir, and also determination of influence nature of hydrostatic impact on landslide activization within studied region.

General description of Mingachevir water reservoir

Mingachevir water reservoir is located in natural tectonic mouldlike depression of Kura valley passing into thick anticlinal uplifts framing Bozdag ridges from South and Kojashen from north (fig. 1).

Fig 1. Schematic map of Mingachenir water reservoir region.

Water reservoir extends from NW to SE along Kura r. valley approximately 75 km including partially Alazani r. valley. The area of water reservoir aquatorium is about 625 km^2, and average width 6-8 km. Length of coastline is 215 km. Volume of water reservoir is 16 km^3. Mingachevir water reservoir surrounded by high ridges is located in favourable conditions and represents natural tectonic bowl having the same morphological surface Khanabad valley is the only low area where saddle connects ridges Bozdag and Kojashen with the higher mark. Khanabad dam is constructed here which takes Aljiganchai valley from water breakout of water reservoir.

Mingachevir water reservoir was filled in 1953 when Mingachevir hydroknot appeared covering Kura r. in area of Mingachevir throat.

Relief of Mingachevir water reservoir area can be characterized by complexity and diversity. The main geomorphological structure of studied region – Bozdag ridge represented by anticlinal fold of flat-topper type. Bozdag consists of chiefly sandy-clayey rocks of Absheron and only in crestal part akchagyl dark–grey, almostly black clays [1] can be found as sports.

This main geomorphological structure is added by inclined piedmont foreslopes overlapping two large erosion steps. Piedmont foreslopes added the main structure are terraced. This terrace is represented by numerous denudation steps.

North-eastern slope of Bozdag ridge is of typical landslide structure while the upper part of slope with beds of very steep fall, and in arch part steepness reduces and stair-stepping becomes noticeable.

North-eastern slope of Bozdag coinciding with arc part of anticline gradually passes in area of hilly relief development on flattened Bozdag top. South-western slope of Bozdag ridge is represented by bush relief area.

Relief forms during relatively dry climate. Sea transgressions from south-east abraded south slopes of Bozdag and eliminated southern slope of the main fold.

Mingachervir water reservoir silting

Building of Mingachevir dam and construction of large water reservoir provided change of rate regime of Kura r. This disturbed recorded regime of sediments movement and created conditions for their bedding in water reservoir. There were situations in practise of hydrotechnical building when newly built water reservoirs became silty fast. So, study of conditions of sediments accumulation and definition of silting duration of Mingachevir water reservoir is of great importance.

Within water reservoir one can determine morphologically area of piedmonts and mountains of surrounded ridges, average height of which is 200-250 m. The higher water levels in water reservoir can be found in summer months and this is connected with hydrometeorologic phenomena in area of water reservoir. Increase of water level in water reservoir continues usually 5 months – from March till July and maximum intensity is in May-June. In August fall of water occurs; at the beginning-slowly and then-rapid. In January-March level fluctuations are insignificant. Spring and summer increase of water level is caused both by water coming from Kura, Ioru and Alazan rivers and by sediments in water reservoir. Reduction of water level in water reservoir during autumn-winter period is caused on the one hand – by drought type of supply, and on the other hand – regime of water reservoir work on energetic schedule.

Spring overflow in Mingachevir water reservoir is the consequence of two factors relationship – melting of snow gathered in mountains and spring sediments. Gradual coming of spring water starts in March. Average duration of overflow is from 2,5 till 3 months. Start and finish terms of overflow on three rivers coincide. Moreover, artificial distribution of water on irrigation influences greatly on flow regime. Correspondingly expenditure of suspended sediments depends on change of water expenditure.

Ground waters of Absheron and Akchagyl deposits are confined to root sandstones but as a result of strong and deep erosion of ridges components are heavily drained and aquifers of Absheron are more drained.

Seismicity of studied region.

At present RCSS of ANAS includes 35 seismotelemetric stations, seven of which are located on territory of Middle Kura depression.

Thanks to improvement of monitoring system now it is possible to register earthquakes with ml>0.1 without interruption. According to map of earthquakes epicenters for three period 427-1953, 1954-2017 and 2003-2017. The Mingachevir focal area can be defined as zone with 6-7 M (fig. 2, 3).

On the basis of the macroseismic and instrumental data analysis collected in the Azerbaijan territory for the period of the last 400 years, it has been determined that the strong and weak earthquakes foci in Azerbaijan are mainly situated within the crust and correspond to 10-30 km depths. Thereby relatively small amount of these events is connected with deep depths (fig. 4) [5].

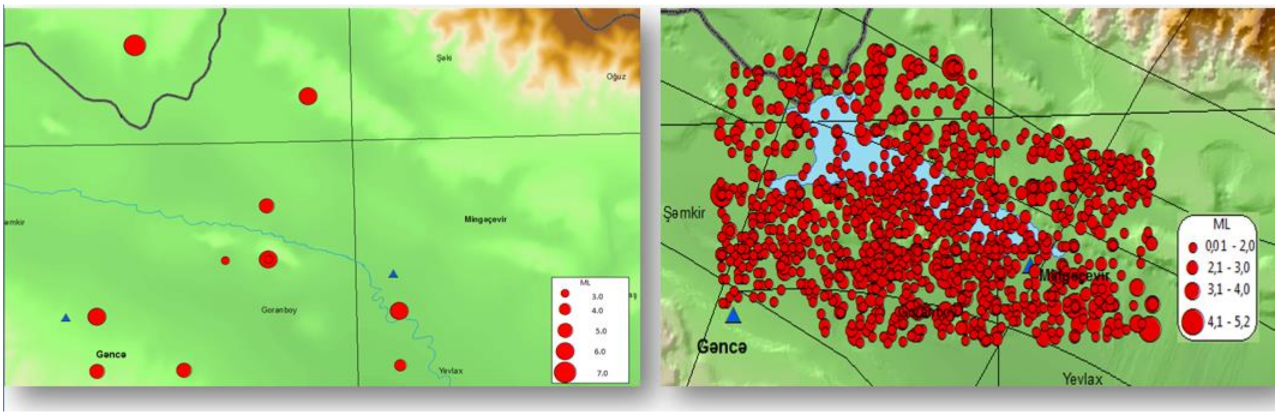


Fig. 2. Map of Mingachevir region epicenters and adjacent areas for the period 427-1953 and 1954-2017.

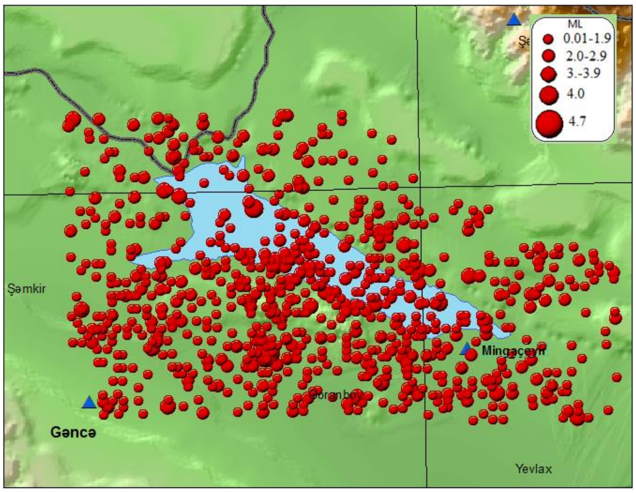


Fig. 3. Map of Mingachevir region epicenters and adjacent areas for the period 2003-2017.

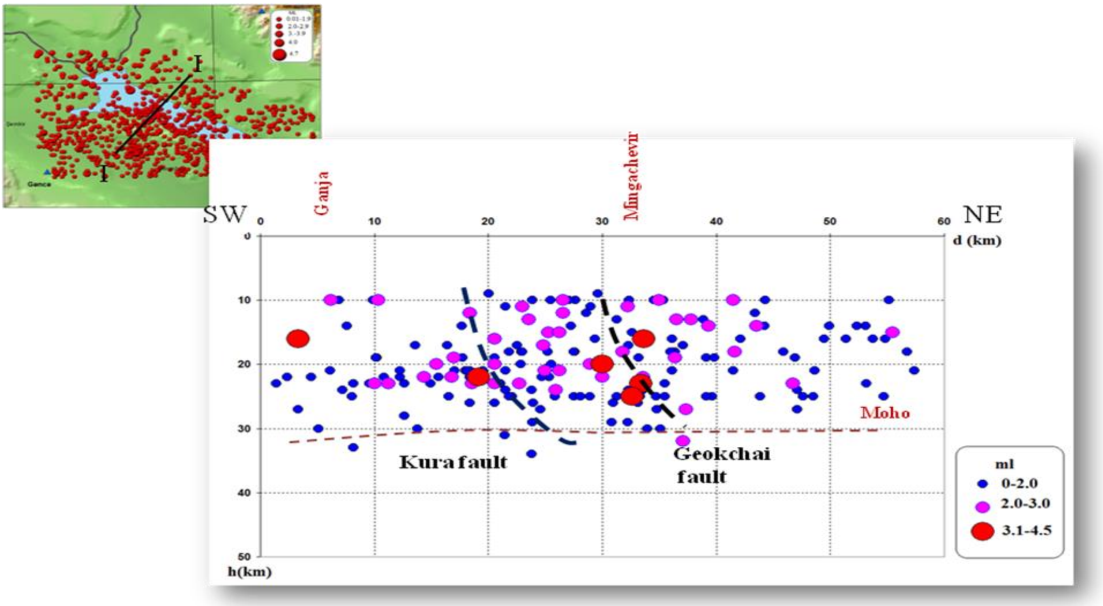


Fig. 4. Depth section of earthquakes hypocenters in Mingachevir water reservoir zone.

On the basis of the macroseismic and instrumental data analysis it was determined that both strong and weak earthquakes occurred in Mingachevir water reservoir. But small earthquakes happen most often. In spite of this there is a necessity for monitoring of seismicity in this territory because of these small earthquakes eventually form small fractures in Mingachevir water reservoir. This can not only cause strong earthquakes but also lead to environmental hazards of Mingachevir water reservoir [5].

Based on these data, it can be concluded either about supposed fault or about existence of medium nonhomogeneity of stress fields at this depth and earthquakes of this focal area can be coincided with them.

Scientists investigating the seismicity of this focal zone made a conclusion that both shallow earthquakes connected with the sedimentary cover and enough deep ones related to the "basaltic" layer and even to the transient formations from crust to mantle are characteristic of Mingachevir focal area [2].

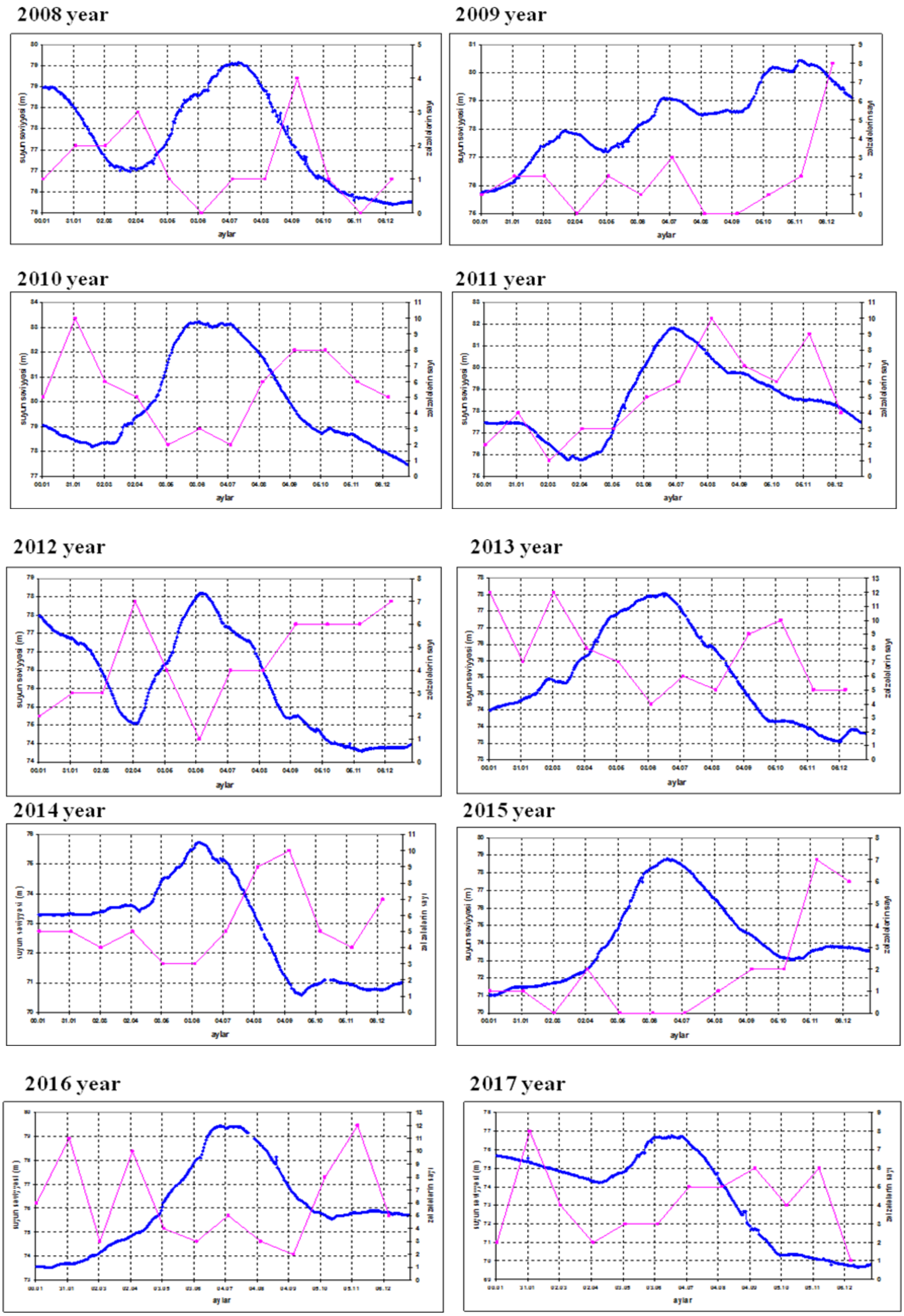
The hypocentres distribution within investigated area for the period of 1980-2010 indicates an increase of seismic activity in 1980-1986, 1999-2004.

The studies show that the seismic activity has associated with the water reservoir level change. Maximum seismic activity and a large number of shocks occurred in 1982. The earthquake with M = 6 magnitude happened on 3 May of the same year. Time shift between the water level peaks and seismic activity was several months.

The great repetition frequency of local earthquakes in Mingachevir region and its geological conditions taking into account modern tectonic movements create a real threat for construction sites.

A comparative analysis of reservoir water level changes against the energy released during earthquakes have been conducted by us for research of the background seismicity and seismic hazard determination. The graphics for the period of 2008-2017 are presented as an example (Fig. 5).

Observational data analysis for seismic activity showed existence of water level dependence in the water reservoir on the seismic activity of small earthquakes which is non-linear except for each years. Seismic energy increase is observed in the interval of 1-3 months after reaching of maximum water level. The seismic activity increase can also be connected with other influencing factors: additional load, tectonic faults existence, flooding, pore pressure change and etc. [8].



2008 year

2009 year

2010 year

2011 year

2012 year

2013 year

2014 year

2015 year

2016 year

2017 year

Fig. 5. Graphic of the reservoir water level change against energy released during earthquakes in 2008-2017.

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Earthquakes influence area on Mingachevir water reservoir zone was estimated accordingly the happened earthquakes magnitude within investigated region.

Stress Orientation Distribution by Lode-Nadai Method

Methods of analysis of seismological data on earthquake source mechanisms and geological information on orientation of slip fault sets are well-known in inverse problem of tectonophysics. These methods of stress inverse problem make it possible to calculate four out six components of tectonic stress tensor based on data on discontinuous dislocation: orientation of three principal stress axis (σ_k, k=1,2,3), determined by three Euler's angles and Lode-Nadai or ratio coefficient characterizing shape of stress tensor (fig 6.).

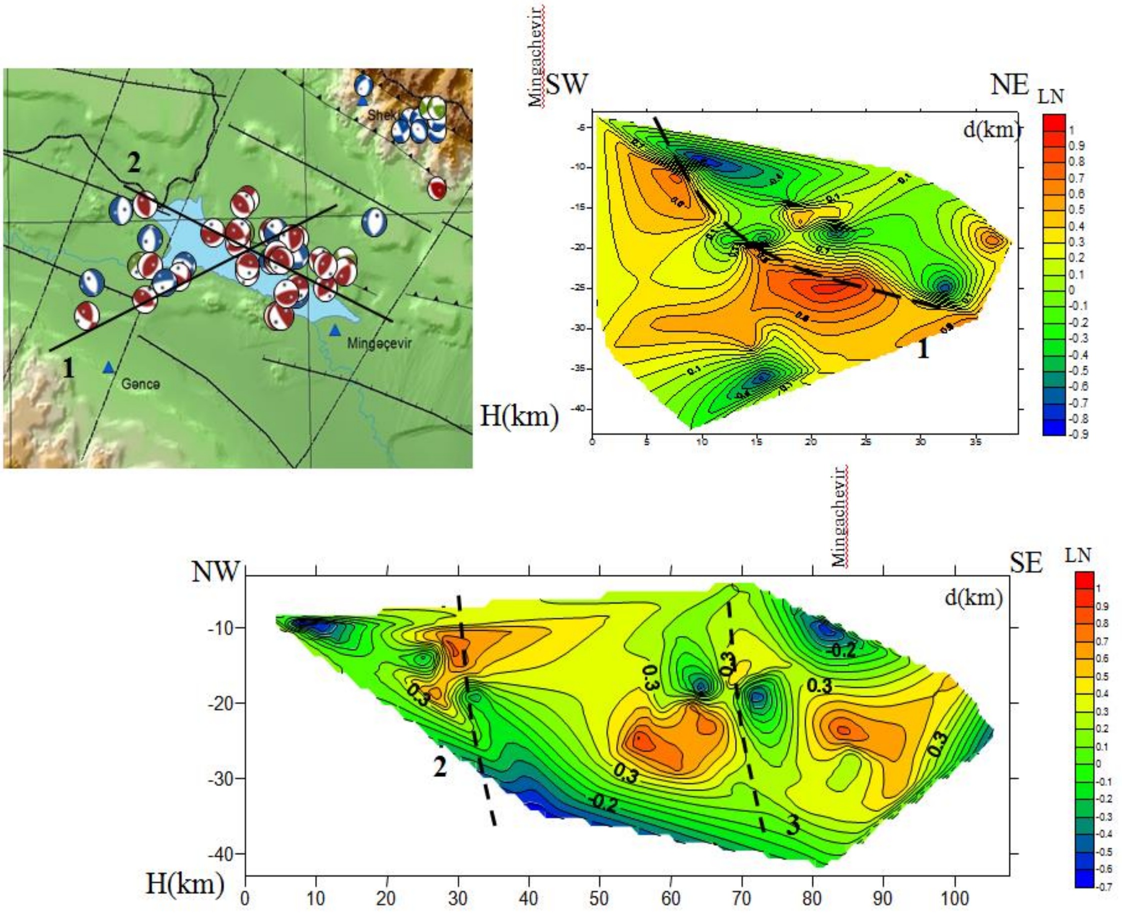

Fig. 6. Stress orientation by Lode-Nadai coefficient for the Mingachevir reservoir.

A high value of the Lode-Nadai μ_σ coefficient indicates tension, a low value indicates compression. The Lode-Nadai μ_σ coefficient within the study area almost everywhere corresponds to a stress tensor of pure shearing (deviatoric stresses of maximum compression and tension have almost equal absolute values). In the transition zone from Kur basin toward NE zone of Greater Caucasus, the stress tensor type corresponds to uniaxial compression (absolute value of deviatoric compression is two times larger than the other two principal stresses, which have almost the same value).

Physical and geological conditions on the Mingachevir reservoir banks

Periodically horizons fluctuations of the Mingachevir reservoir while in service create the conditions for the change of existing physical-geological conditions of the water reservoir bowl slopes. The wave-cut processes, storm flows having argillaceous karst on the slopes contribute to the slopes dissection intensification of the water reservoir basin bowl, which in its turn causes the landslides during periodic fluctuations of water line [7].

The numerous wave-cut notches of different sizes are formed under the waves slaps in the basis of coastal cliffs. These wave-cut notches in large quantities are observed above the dam on the south slope of the water reservoir. During high water level these positions are injected by water forming small inlets with vertical walls.

The banks are often broken by deep vertical cracks along which the large masses failure of ground occurs.

As a result of conducted surveys following banks types are distinguished in the coastal zone of Mingachevir water reservoir: 1. accumulative areas; 2. abrasion bank: a) abrasion-collapse bank; b) abrasion-landslide bank, c) table bank of flooding, and d) table bank of flooding [1].

Accumulative areas are essentially developed in the piedmont plain region**,** between ridge branches, downward to the water reservoir. In particular, they are occurred on the south-eastern and south-western areas.

Abrasion banks having dissected nature of the scalloped type bank are observed to the east from the Gyanjachay inflowing to the water reservoir.

Abrasion-collapse bank type is typical for the south-south-eastern bank of the water reservoir where the branch tips of the Bozdagh ridge, jutting out deeply into the sea**,** are exposed to the intense undercutting and caving.

Abrasion-landslide bank type is developed on the south bank of the water reservoir, directly at the HPS neck.

In the studied region the collapses play role of constant factor of the slopes formation. In addition, the ridges slopes, bordering the water reservoir, are covered by landslides. Landslides are represented a complex phenomenon, conditioned by cohesion forces change. It is known that the landslides occurred on the right bank of Mingachevir water reservoir, within Bozdagh ridge, in 1985, 1987, 1989, 1996, 2000, 2006 and 2012. With the purpose to study the hydrostatic impact effect on landslides activation within the studied region, we have been conducted a comparative analysis of water level changes of water reservoir with the energy released during earthquakes and landslides processes in 1985, 1989, 1996, 2000 and 2006 (fig. 7, 8).

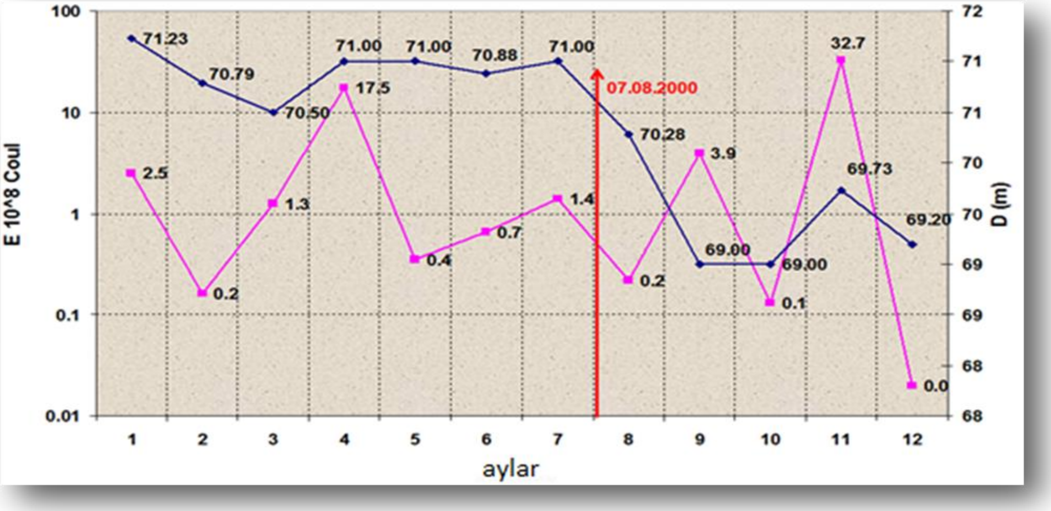

Fig. 7. Dependence diagram of the water level change of water reservoir with energy released during earthquakes by landslides activation for 2000.

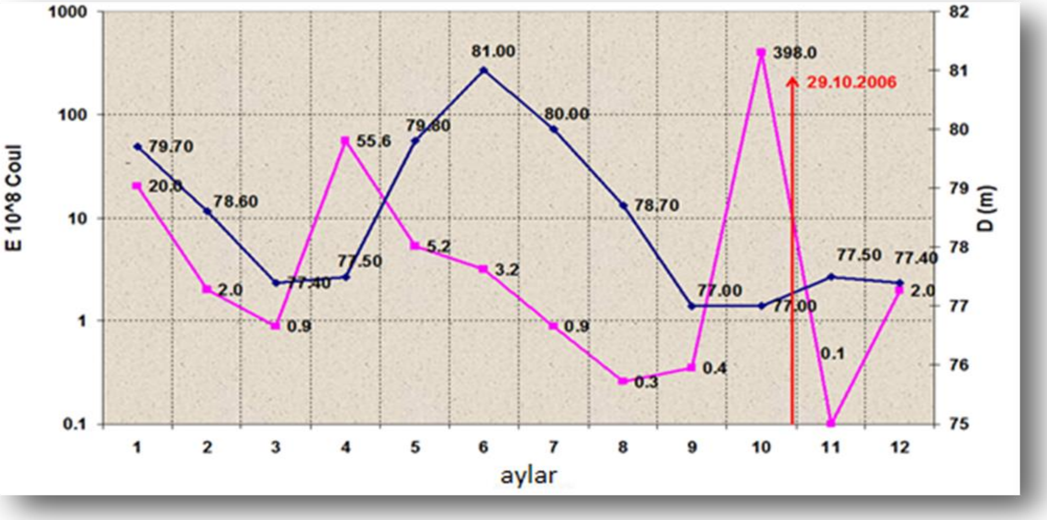

Fig. 8. Dependence diagram of the water level change of water reservoir with energy released during earthquakes by landslides activation for 2006.

The analysis showed that the landslides occurred mainly in the summer-time during the fall in water level on 5-10 m, which is associated with the hydrostatic pressure decrease, change of argillaceous rocks plasticity, heavy rains and water seepage through water reservoir cracks.

Conclusion

Reservoir filling influences the small earthquakes appearance directly on the Mingachevir water reservoir region and on the adjacent territories. During plain flooding the underground waters level rises in the basement rocks that induces the landslides formation. Moreover the right bank of water reservoir is the most probable place where one would expect the landslide phenomena. In addition, it should be noted that the high terraces in the cliffs areas and on the mountain slopes will collapse and adapt to the new conditions, which will cause the local origin drifts accumulation in the water reservoir.

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