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STRESS-STRAINED STATE OF THE EARTH'S CRUST OF AZERBAIJAN FOR 2004-2016 YY.

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ABSTRACT. The article analyzes the connection between strong and catastrophic earthquakes (M≥5.5) with an activity of Alpine-Himalayan belt on the territory of Azerbaijan. According to the data from 35 digital seismic stations were studied seismic regime, earthquake focal mechanisms, and the spatial and temporal distribution of earthquake sources. The sequence of seismic processes indicated a definite connection. Analysis of all earthquakes showed that nearly 80% of the extension axes shocks and 40% compression axes shocks deflection in PL do not exceed 20°. Orientation of extension axes generally dominates in the SW-NW direction, but the orientation of compression axes is detected in the NE-SW direction (67%) and in the NW-SE direction (33%).

Introduction

Hundreds of natural and technogenic disasters occur annually in the world. Seismic disasters have a special place and are more than 50% of the total number of natural disasters. In recent years, there is an increase of seismicity around the world. In different parts of the globe occur strong and catastrophic earthquakes, which are accompanied by great destructions and human losses. It suffices to give an example of the devastating earthquake near the Japanese island of Honshu on March 11, 2011 (M=9), the earthquake in Nepal on April 25, 2015 (M = 7.8), a series of earthquakes in the Pacific Ocean near Chile, Peru in 2015-2016 (M = 7.8-8.3). (Fig. 1).

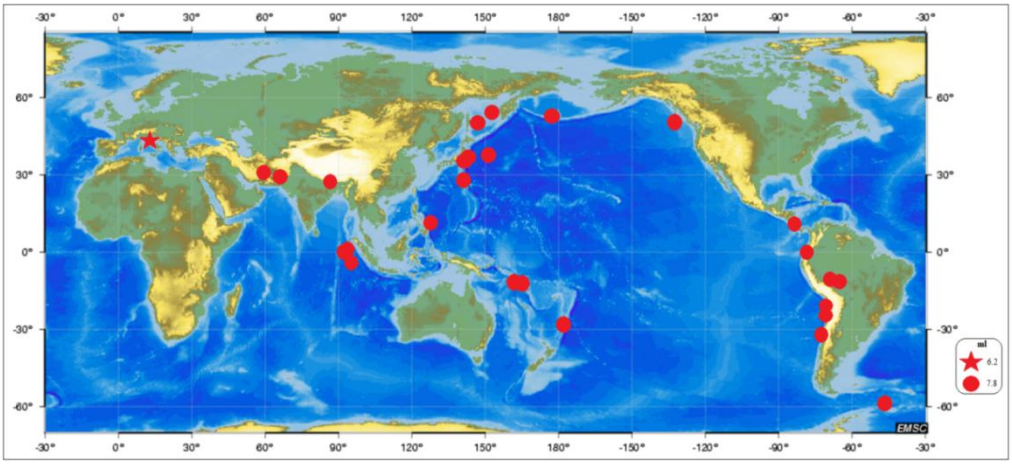

Figure 1. Map of the epicentres of strong earthquakes occurred in the world during 2011-2016.

It had a smaller magnitude compared to the above mentioned earthquakes, but depth of earthquake was small H = 4 km and this is resulted in almost complete destruction of the city of Amatriche, the death toll reached nearly 300 people. The sources of all mentioned earthquakes are located in the Pacific (Ring of Fire) and the Alpine-Himalayan fold belts. The last destructive earthquake in 2016 occurred on August 24 in the central part of Italy (Fig.2).

[1] The Republican Seismic Survey Center of Azerbaijan National Academy of Sciences

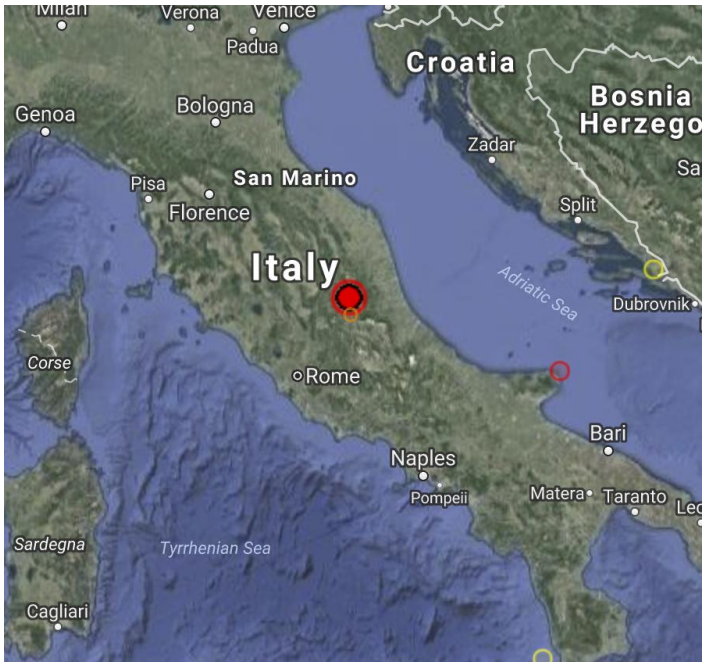

Figure 2. The epicentre of the strong earthquake with a magnitude of M = 6.2 occurred in Italy on August 24, 2016

Seismic study of Azerbaijan

The territory of Azerbaijan is also a part of seismically active zone of the Alpine-Himalayan fold. Here have repeatedly occurred strong earthquakes with M≥5. The intensity of the tremors in the epicentre of separate earthquakes reached J0 = 8-9 points. A significant part of the territory allocated on the seismic zoning maps to the 7, 8, 9-point zones [Ahmedbeyli et al., 1987].

The activity of geodynamic processes occurring on the territory of the republic is caused by the collision of the Arabian and Eurasian continental plates.

Strong earthquakes also occur at the present stage. During the last years the outbreak of seismic activity is registered on the territory of the republic. To represent the character of the distribution of earthquake sources in Azerbaijan and the Caspian region there is a map of earthquake epicentres for 2004-2016, with ml ≥4 and ml ≥5 (Fig. 3,4).

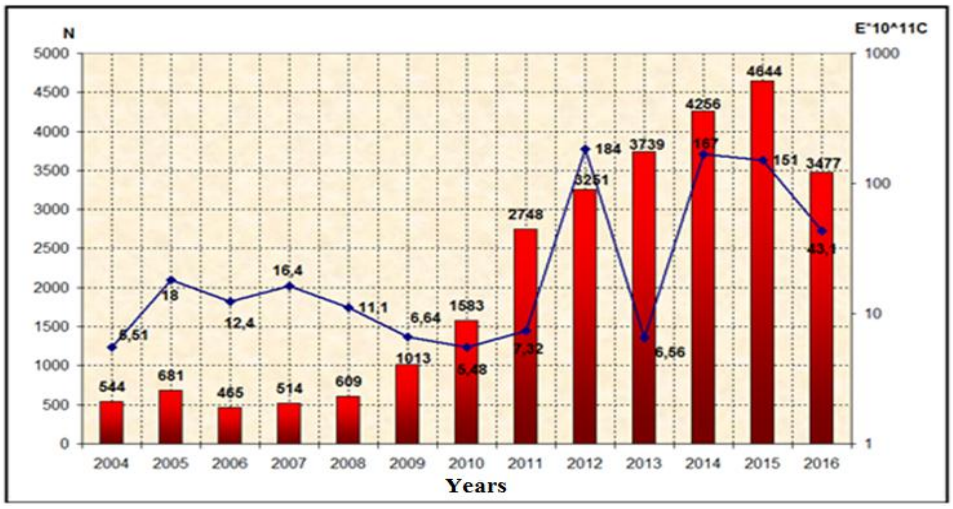

Figure 3. Histogram on distribution of the number of earthquakes and selected seismic energy by years

For a visual representation of the seismicity of the territory of Azerbaijan and the Caspian Sea was compiled a map of earthquake epicentres with ml ≥4 for the years of 2004-2016 (Figure 4).

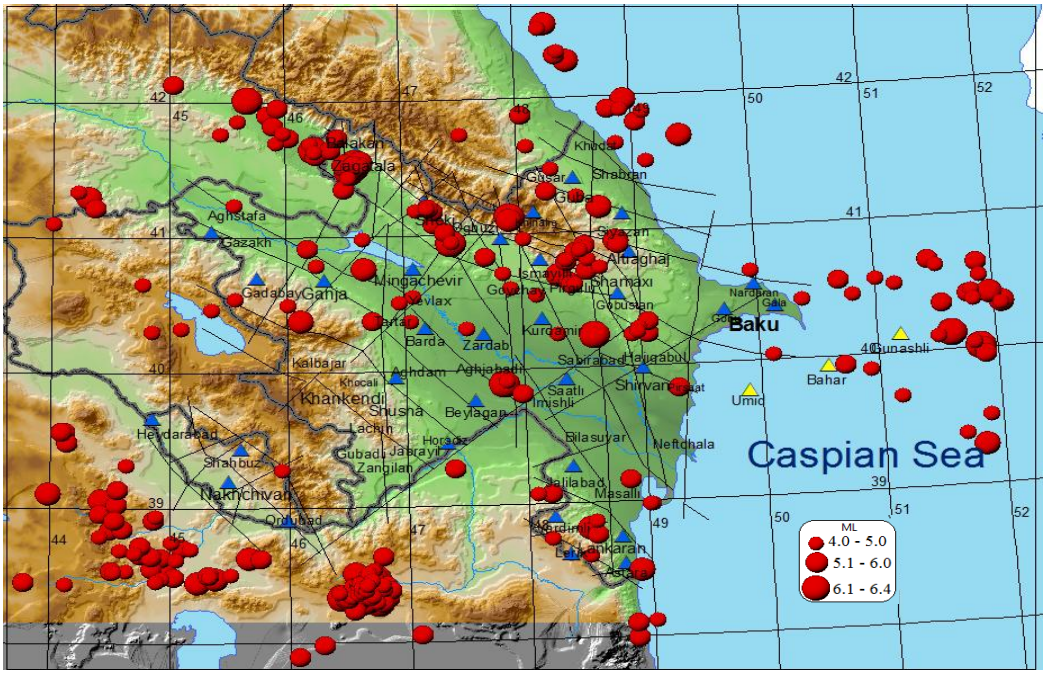

Figure 4. Map of the epicentres of earthquakes with ml ≥4 in Azerbaijan and the Caspian Sea for the years of 2004-2016 ▲ - seismic stations; ▲ - will be installed

Here are allocated separate seismically active areas. This, above all, Shamakhi, Ismayilli, Sheki-Zagatala, Talish zones and water area of the Caspian Sea region.

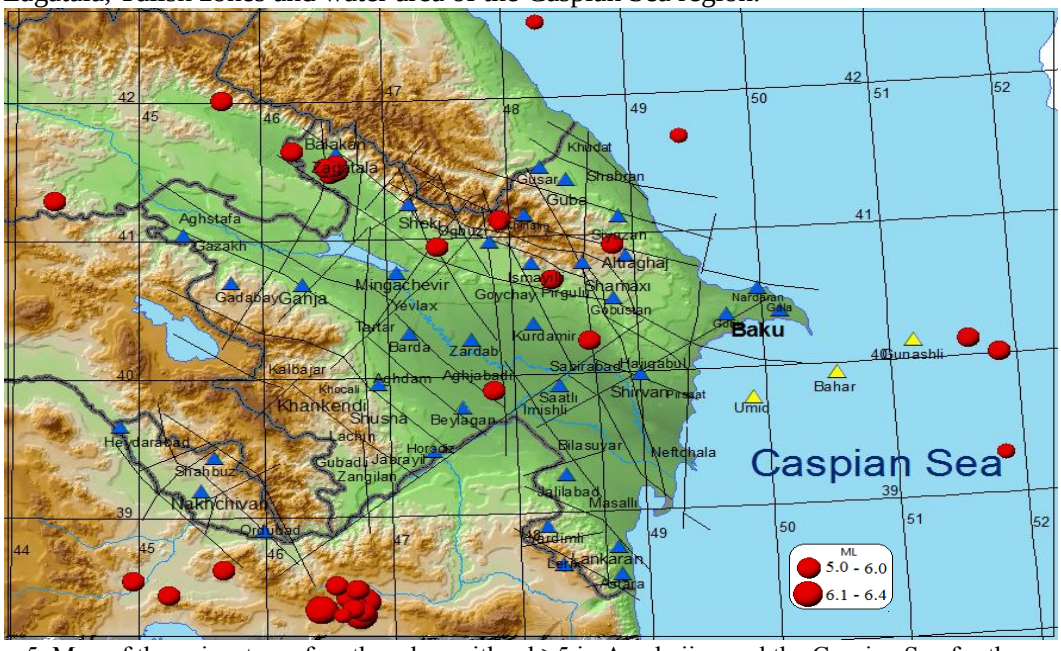

Figure 5. Map of the epicentres of earthquakes with ml ≥5 in Azerbaijan and the Caspian Sea for the years of 2004-2016

In 2012 and after a lull in 2014-2016 years here occurred a series of strong earthquakes: Zagatala on May 7 with ml = 5.6, 5.7; Balakan in 2012 with ml = 5.8, which were felt in the epicentre with J0= 7 point; Ismayilli on October 7, 2012, with ml = 5.3; Caspian on January 10, 2014 with ml = 5.0; Hajigabul on February 10, 2014 with ml = 5.8; Zagatala on June 29, 2014 with ml = 5.3; Caspian on June 07, 2014 with ml = 5.6; series of earthquakes in Gabala on September 29 and October 04,2014 with mlmax = 5.5; Oguz on September 4, 2015 with ml = 5.9 and Imishli on August 1, 2016 with ml = 5.6. They were felt at the epicentre with an intensity of 6-7 point.(Fig.5)

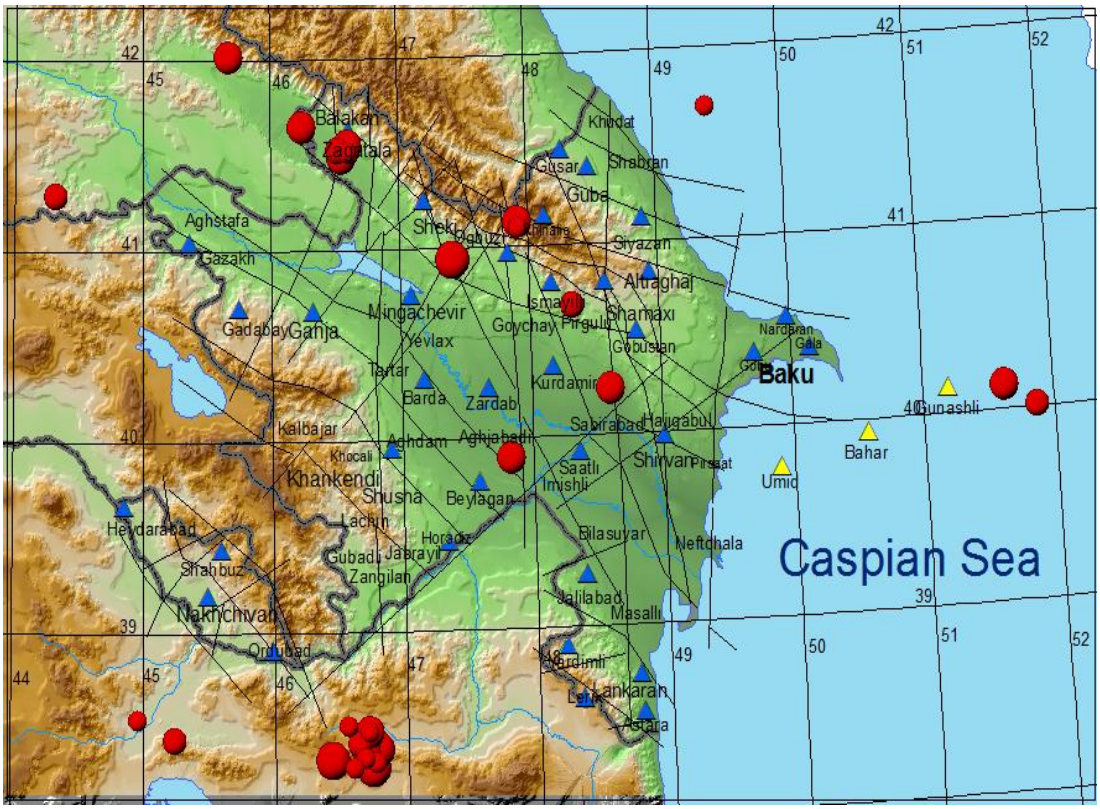

Figure 6. Map of the epicentres of earthquakes with ml ≥5 in Azerbaijan and the Caspian Sea for years of 2012-2016

As you can see, most of the earthquakes' sources are located in the joint area of the Kura depression and south-east dipping of Greater Caucasus. These are Zagatala, Sheki, Gabala and Ismayilli sources. As an example, is shown a macroseismic field of a strong earthquake, which occurred on February 10, 2014 (Fig.6).

Activation of 2012, 2014 - 2016 years is due to the accumulation of stresses and their subsequent discharge in the band of under thrust adjacent of Middle-Kura and Vandam tectonic zones along Ganikh Ayrichay-Alat deep thrust. Discharge occurs along the deep thrust in the most weakened areas of intersection of violations among themselves. Analysis of seismicity on the territory of Azerbaijan in recent years has shown that there is a general consideration of the distribution of seismogenic zone along the Caucasian structures, however, in each of them there is a migration of epicentres in the anti-Caucasian direction (Fig. 7) [Rzayev et al., 2013].

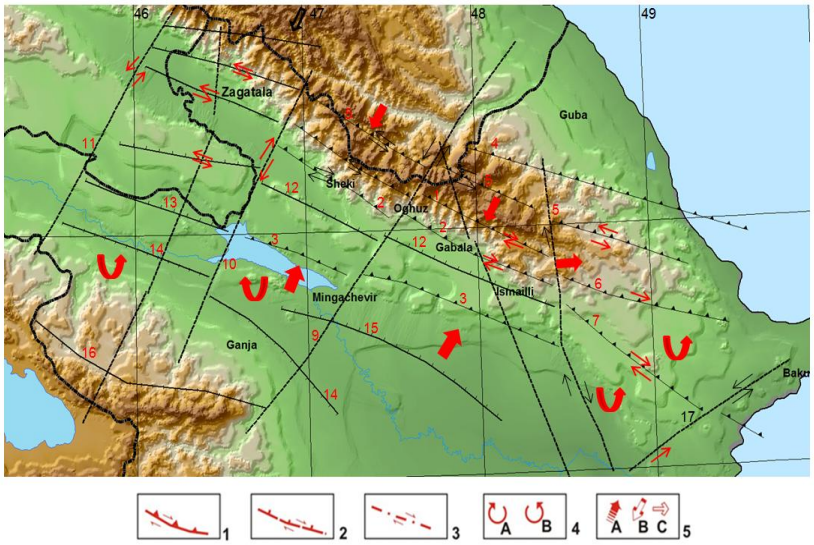

Figure 7. Scheme of the fault structure and features of geodynamic regime of the southern slope and the south-east dipping of Greater Caucasus

Main seismogenic faults, defining features of geodynamic regime of the earth crust: 1 - reverse faults, 2 - normal faults, 3 - strike-slip faults (arrows indicate the direction of horizontal movements). Uplift: 1- Dashgil-Mudresi, 2 - Vandam, 3 - Geokchai, 4 - Siyazan, 5-Zangi-Kozluchay, 6 - Germian, 7 - Adzhichay-Alat. Strike-slip: 8-West-Caspian, 9-Arpa-Samur, 10-Ganjachay-Alazan, 11 - Gazakh-Signagi. Normal faults: 12-North-Adzhinour, 13-Iori, 14-Kura, 15 –Mingachevir-Saatli, 16 - Bashlybel, 17 - Palmiro-Absheron. Elements of geodynamics: 4-Torsion units: A-clockwise, B-counter clockwise. Horizontal shifts: A- underthrust, B – in thrusting, C-move aside.

As an example are shown source zones of earthquakes occurred during 2012-2014 years in the north-west of Azerbaijan (fig. 8).

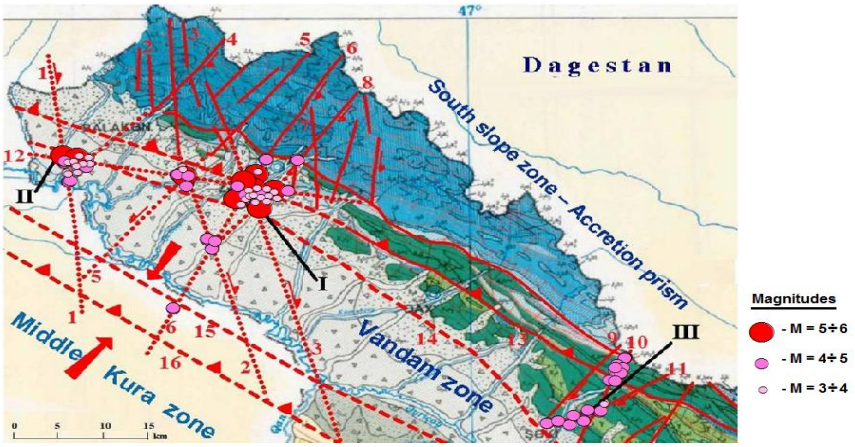

Figure 8. Focal zones of earthquakes that occurred in 2012-2014 in the north-west of Azerbaijan.

Activation in 2014 began on January 10, when the earthquake with ml = 5 happened in the sea, in the north of the Azerbaijani part of the Caspian Sea; then, on February 10, a strong earthquake in Hajigabul with ml = 5.7 was registered. These earthquakes had great depth, the latter was felt not only in the territory of republic but also far beyond its borders. They had no aftershocks. These earthquakes may have played a role in the further activation, i.e., acceleration of seismotectonic processes and the implementation of preparing sources of earthquakes, the epicentres of which are

located on the south-east of Greater Caucasus dipping. Those earthquakes happened on June 29 in Zagatala-Balakan region with ml = 5.3, and two earthquakes – on September 29 with ml = 5.5 and October 4 with ml = 5.0, respectively, to the north-east of Gabala (Vandam structure).

As an example is shown a macroseismic map of Hajigabul earthquake which occurred on February 10, 2014 (fig. 9)

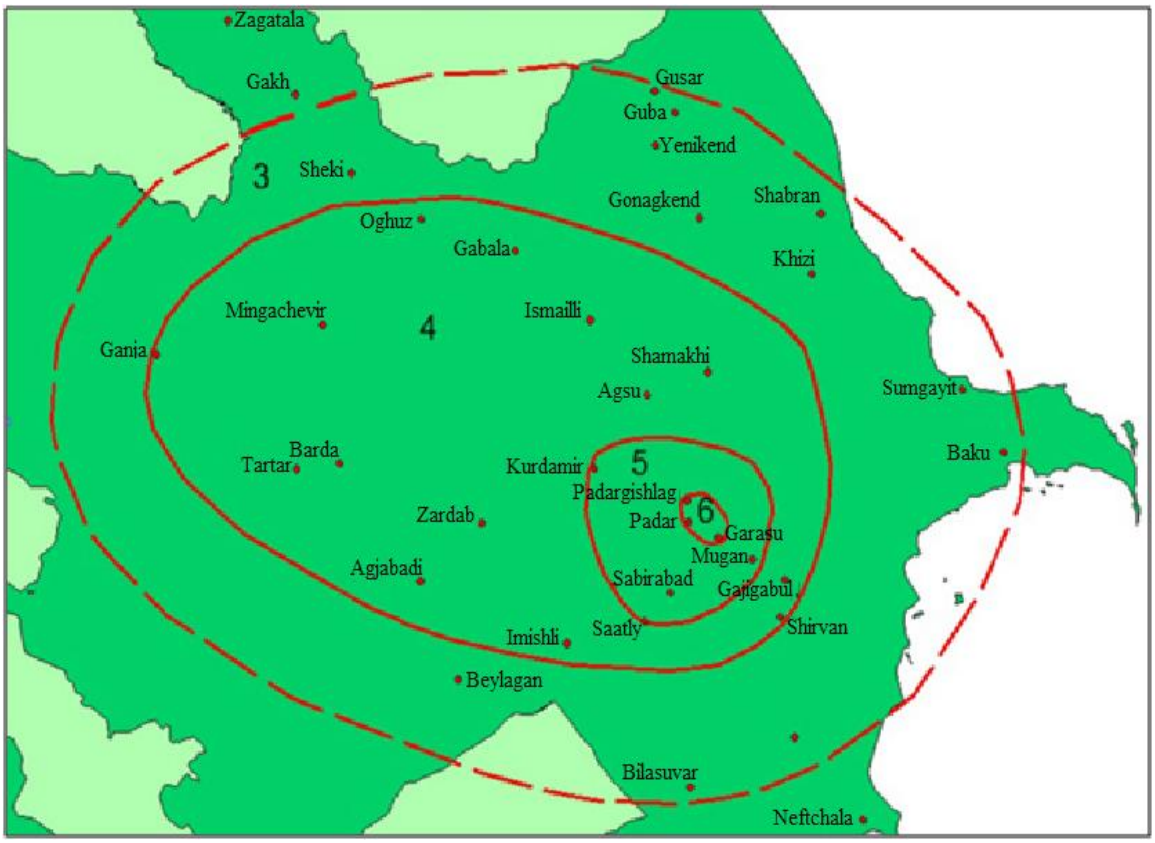

Figure 9. Macro seismic field of earthquake occurred on February 10, 2014 in Hajigabul (Comp. by Yetirmishli G.J., Garavaliyev E.S.)

Analysis of results of seismicity in Azerbaijan in recent years has shown that there is a general consideration of the distribution of seismogenic zones along the Caucasian structures, however, in each of them there is a migration of epicentres in the anti-Caucasian direction. That is, during activation along the adjacent zone of Kura depression and the Greater Caucasus (underthrust zone) longitudinal faults occur disruptions with respect to transverse faults. Statistics show that the earthquake hypocenters in most cases are in the upper part of the Earth's crust, where the elastic stress accumulation processes lead to the formation and growth of new structures in the crust itself.

Stress-strained state of the Earth's crust of Azerbaijan

The seismic information obtained from 35 seismic stations, allows investigate the seismic regime of the territory of republic, to identify areas of seismic activity, the spatial distribution of the focal areas, as well as the mechanisms of earthquake sources.

In order to study the stress-strain state of the Earth's crust in Azerbaijan were compiled mechanisms of earthquake sources [Dreger, 2002] with ml≥5, which happened in 2012-2015 years (fig. 10).

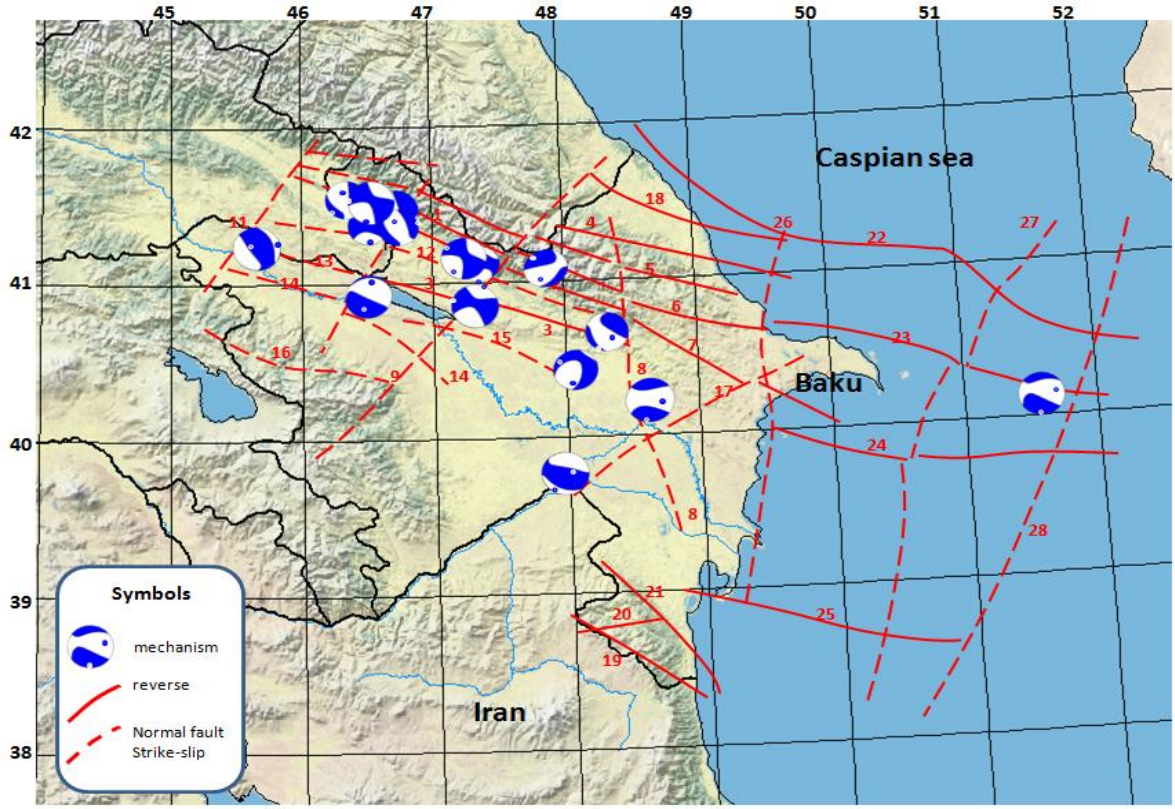

Figure 10. The scheme of the fault structure and mechanisms of earthquake sources in 2012-2015 with ml≥5.0

Let's highlight the most important of them. Earthquake that occurred in Zagatala on May 7, 2012 with ml = 5.6 was characterized by nearly horizontal (the PLP = 10°) of compressive and tensile (PLT = 14°) strains. The type of motion along both steep (DP1 = 87°, DP2 = 72°) planes - shift. The plane NP1 has south-east (STK1 = 125°) stretch with the type of rightward shift and NP2 - southwest (STK2 = 216°), with the type of leftward shift. Comparison of the trending of nodal planes with the fault lines shows the consent of the first nodal plane NP2 with right Kazakh-Sighnaghi and Ganjachay-Alazan transverse faults, that allows to consider NP2 plane to be active. On the same day there was another tangible earthquake with ml = 5.7. The mechanism of this earthquake source occurred under the influence of nearly horizontal tensile stresses (PLT = 1°). Type of shift on the first nodal plane NP1 – discharge with the elements of right lateral strike slip, on the second - discharge with the elements of left lateral strike slip. On May 18, 2012 in this area was recorded another earthquake with ml = 5.0. The mechanism of this earthquake is identical to the previous one, the type of shift discharge with elements of left lateral strike slip (Fig. 11).

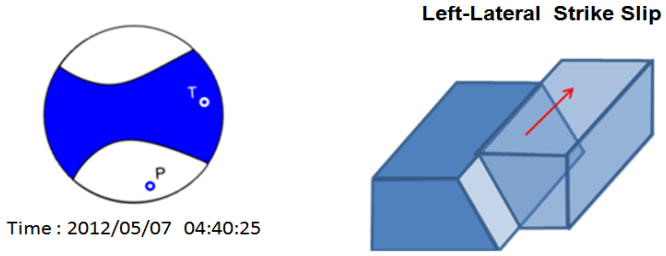

Figure 11. Mechanism of source of Zagatala earthquake occurred on May 7, 2012 (t0 = 14:15:13)

Later in the same year happened two noticeable earthquakes - in Ismayilli, on October 7 with ml = 5.3 and Balakan, with ml = 5.7. Both of these earthquakes occurred under the influence of nearly horizontal tensile stress (PLT = 0°). Type of earthquake normal fault with left lateral strike slip elements (Fig.12). Ismayilli earthquake shift is connected with the activity of the North Adzhinour fault.

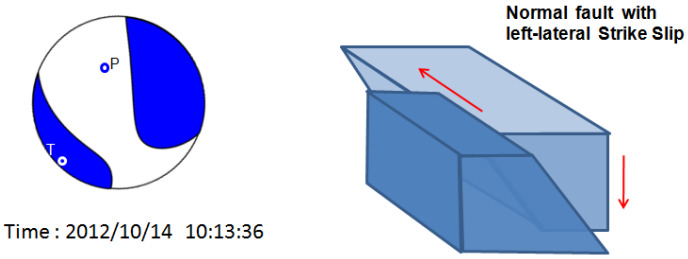

Figure 12 The mechanism of Balakan's earthquake source occurred on October 14, 2012, as well as the block diagram of the offset.

One of the most powerful earthquakes in the past 10 years is the earthquake that occurred in Oguz on September 4, 2015 with ml = 5.9. The type of shift of the earthquake - the strike slip with left lateral horizontal component. The epicentre of Oguz earthquake is timed to Samur-Arpa fault and can be interpreted as a left lateral shear deformation in the zone of geodynamic influence of left lateral Arpa-Samur fault.

Analysis of all earthquakes showed that nearly 80% of the stretching axes earthquake sources and 40% of compression axes earthquake sources deflections do not exceed 20°. Orientation of extension axes generally dominates in SW, NW direction, but for the compression axes the orientation is detected in the NE-SW direction (67%) and in the NW-SE direction (33%). The angles of incidence for the different types of shifts exceed 45°, which shows quite a steep dipping of fault zones. This is consistent with the fact that in the studied area most of transverse faults have incidence angles of 50-90°, that is, angles sufficiently close to the vertical. Analysis of dive angles SLIP showed for the first nodal plane 27% that vary within -15º - (- 43º) and 40% within -57º - (- 180º). For the second nodal plane 60% of sources that vary within -62º - (- 171º). Variations of dive angles of principal stress axes in conjunction with significant standard deviations indicate a significant spatial heterogeneity of the lithosphere [Hain et al., 2005].

Conclusion

It was found that seismic field of strong and disastrous earthquakes (M≥5.5) tends to focal areas of the Alpine tectonic belt of the Earth.

Developed and equipped with a digital telemetry network (35 stations) provided observations and analysis in real time for seismological and geophysical changes in the stress state of the geological environment of the Caspian Sea and territory of Azerbaijan.

Analysis of the seismic regime of the country revealed major seismically active areas. These are the south-eastern part of Greater Caucasus, mainly Shamakhi-Ismayilli zone, as well as Oguz-Gabala and Sheki-Zagatala zones. Epicentral area of most mentioned earthquakes is located in the foothills of Vandam structural zone. The spatial distribution of epicentres shows that events in 2014 with ml≥5 confined to the cross (the north-western, north-eastern and submeridional stretches) disjunctive dislocations, but the epicentral areas as a whole have a "common Caucasian" elongation and are located along Vandam tectonic zone through Ganikh-Ayrichay-Alat deep thrust. The cause of the seismic activity of this area is a combination of lateral compression forces with tensile forces. The epicentres of Gabala and Oguz earthquakes are confined to the stretching zone and their mechanism is

determined as a result of right lateral shear deformation in the zone of geodynamic influence of left lateral Arpa-Samur and Ismayilli-Sygyrli faults, creating clockwise torsion of the block.

The angles of incidence for the different types of shifts exceed 45°, which shows quite a steep dipping of fault zones. This is consistent with the fact that in studied area most of the transverse faults have incidence angles of 50-90°, that is, angles sufficiently close to vertical.

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