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Focal and Dynamic Parameters of Strong Earthquakes on the Territory of Azerbaijan for the Period 2005-2015

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Abstract

The article presents a method for calculating the focal and dynamic parameters of strong earthquakes in Azerbaijan for the period of 2005-2015 based on broadband entries (BH) of modern digital stations and statistical analysis of the produced solutions. Analysis of compressed axis orientation showed NW-SE orientation in Zagatala region, NS in Sheki and then gradually changing in a clockwise direction to the NE-SW direction in the Caspian Sea. Stretching axis is mainly oriented NE-SW and NS directions, due to the area of immersion of Kura depression under the Greater Caucasus zone. On the basis of the averaged data for each station was organized spatial amplification factor distribution map for the territory of Azerbaijan. The total value of the factor varies within the range of 1,5-4,6. Maximum is observed in the Kura River valley area and Zagatala region, indicating that the layer of the earth's crust under the stations of these regions, strengthen the impact of transverse wave through the source-receiver.

Keywords: Seismic moment tensor; Amplification factor; Nakamura method

Introduction

It is well known that the nature of the movements recorded on the seismogram is defined as a medium in the path of the seismic waves, and the source, requires a comprehensive analysis of the recording, which will allow receiving further information about the earthquake, for better understanding of the source mechanism [1].

An important consideration in the calculation of dynamic parameters is the transition from the station range to alopecia. For such a transition effect of the environment must be considered ("weakening") and amplification factor in the path of the seismic ray. There are various methods for determining the station amendments, which are described in studies [2,3]. The study of the conditions of formation of the earthquake source action mechanism is of great importance for the understanding of seismic phenomena and the development of methods of forecasting of seismic hazard. In this study the main parameter is the seismic wave. At present, the dense network of high-sensitivity digital still seismic stations, allowing to record all seismic events with magnitude of ml> 0.1 within Azerbaijan, as well as the extensive factual material obtained according to the network, have allowed to develop many new methodological issues and outline new ways in forecasting earthquakes. The aim of this paper was to determine the source parameters, including focal mechanism solution and dynamic parameters based on seismic signal analysis using the method of Nakamura in the past 10 years [4].

The Methodology of Calculation of Seismic Moment Tensor and the Preparation of the Actual Seismograms

In this study was used algorithm by the method of inverse waveform - Time-Domain Moment Tensor INVerseCode (TDMT INVC) [5]. The principal source of seismograms is Republican Seismic Survey Center of ANAS. Broadband seismograms are selected in compliance with the distance limitations (80-350 km). Preparation of seismograms for the inversion involves: removal of the entry of P-wave; deconvolution (restoration of the true ground displacements); definition of epicentral distance, forward and reverse azimuths; calculation of radial and transverse components; filtration. Deconvolution is performed in the time domain. For band pass filter is applied Butterworth filter 4. Although the source of a strong earthquake is an extended entity, in the study of its characteristics as a first approximation is used a model of a point source. This is justified in considering the wavelength of much larger geometric source sizes and time periods, significantly exceeding the processing time break within the source. In practice, these provisions are fulfilled only approximately.

Thus, on the basis of the mentioned above were developed and analyzed the mechanisms of strong earthquakes foci occurred in the years 2005-2015 with a magnitude more than 5.0 and were installed characteristic features of seismotectonic deformation in the individual seismogenic zones of the Republic, namely in Zagatala, Shaki, Gabala, Oguz, Hajigabul, Ismayilli regions, as well as in the Caspian Sea region (Figure 1).

Note that one of the most powerful earthquakes in the past 10 years is the earthquake that occurred in Oguz region on September 4, 2015. Earthquake occurred under the influence of almost equal tensile and compressive stresses. The first nodal gap plane extends in the SE direction (153°) with a fall in the SW at an angle of 90°, the second nodal plane has a NE trending (63°) with a fall in the SE at an angle and 90°. According to this compressive stresses in the earthquake source were oriented in a NE direction (azimuth 18) and acted sub horizontally (angle to 0° horizon), and the tensile forces were oriented to the west-south-west direction (287°) at an angle of 0° to the horizon. Type of the earthquake motion is the shift to the left-side horizontal component (Figure 2). The epicenter of Oguz earthquake is timed to Samur-Arpa fault and can be interpreted as a left-sided shear deformation in the zone of geodynamic influence of left-sided Arpa-Samur fault (Figure 2).

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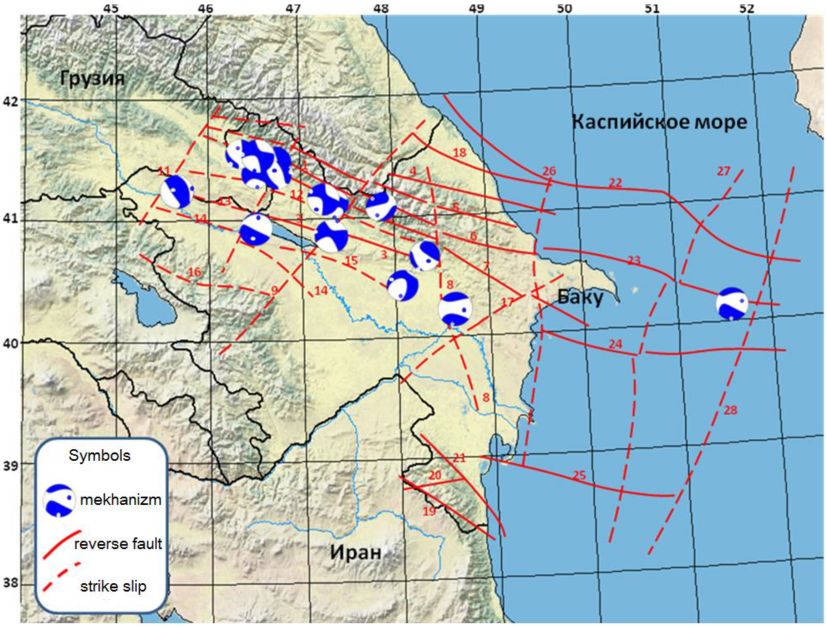

Figure 1: Scheme of the fault structure and earthquake focal mechanisms 2005-2015 with ml ≥5.0.
Faults: 1: Dashgil-Mudresinsky, 2: Vandamsky, 3: Geokchai, 4: Siyazan, 5: Zangi-Kozluchayskу, 6: Germiansky, 7: Adzhichay-Alat, 8: West Caspian, 9: Arpa-Samur, 10: Ganjachay-Alazan, 11: Kazakh-Signagi, 12: North Adzhinoursky, 13: Iori, 14: Kura, 15: Mingachevir-Saatli, 16: Bashlybelsky, 17: Palmiro-Absheron, 18: Akhty-Nyugedi-Kiliazinsky 19: Talysh, 20: Yardimli, 21: Predtalyshsky, 22: Central Caspian, 23: Apsheron-Balkhan, 24: Sangachal-Ogurchinsky, 25: Mil-Chikishlyarsky, 26: Jasper flexure, 26a: Gizilagach, 27: Shakhov-Azizbayov, 28: Karabogaz-Safidrudsky.

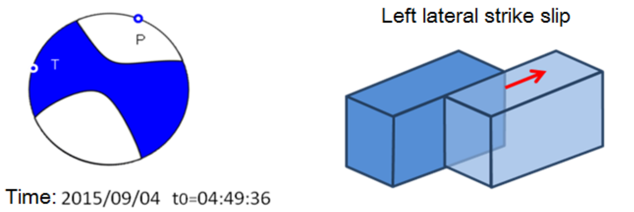

Figure 2: Mechanism of Oguz earthquake source in 2015 and a block diagram of the offset.

Discussion and Results

Separation of samples of discharges, shifts and reverse faults revealed significant differences and close matches of focal parameters shocks with different types of shifts in the source.

Analysis showed that nearly in 80% of the stretching axis shocks and in 40% of compression deflection axis shocks deviations in PL do not exceed 20°. Orientation of stretching axis generally dominates in SW, NW direction, but for the compression axis is detected orientation in the NE-SW direction (67%) and in the NW-SE direction (33%). The angles of incidence for the different types of movements exceed 45°, which show quite a steep dipping fault zones. This is consistent with the fact that the most of transverse fractures in studied area has angles of incidence in 50-90°, i.e. the angles sufficiently close to the vertical. Analysis of the dive angles SLIP showed for the first nodal plane 27% varies within -15°-(-43°) and 40% within -57°-(-180°). For the second nodal plane 60% of foci varies within -62°-(-171°). Variations of immersion angles of the principal stresses axis in conjunction with significant standard deviations indicate significant spatial heterogeneity of the lithosphere.

On the basis of the obtained results was built a schematic map of the orientation of the compression and stretching axis of studied strong earthquakes. Analysis of the orientation of compression axis showed NW-SE orientation in Zagatala region, NS in Sheki and then gradually changing in a clockwise direction to the NE-SW direction in the Caspian Sea. Stretching axis is mainly oriented NE-SW and NS directions, due to the area of Kura depression immersion along the main Caucasus thrusts under the Greater Caucasus region (Figure 3).

By analyzing the sequence of seismic processes can be seen that the considered sources have definite connection. It should be noted that matching angles of incidence DP, SLIP modules and stretch azimuths STK reverse faults and discharges do not exclude the possibility of these motions along the planes of some faults. Perhaps Zagatala earthquake was the first impulse, which caused a series of strong earthquakes in Balakan, Sheki, Oguz, Gabala and Ismayilli regions. All of these zones are in similar seismotectonic conditions. The geological structure of these zones involves structural elements of Tfanski anticlinorium, Zagatala-Govdag Synclinorium, Vandam anticlinorium and imposed Alazan-Agrichay deflection. These structures of all-Caucasian areas are separated by deep sub latitudinal faults [6].

Method of Computing the Impact of the Environment ("amplification") on the Way of a Seismic Ray

It is known that the Earth's crust displacement is measured in three directions: North-South (NS), East-West (EW) and vertical (Z). Nakamura's method consists of finding the spectrum ratio of the horizontal component (H) to a vertical range (V). This requires the use of measurement of 3 seismogram components E, N, Z (Figure 4) [7,8]. Calculating the H component occurs as the mean-square spectrum of E and N components, the vertical component V corresponds to spectrum of Z component. Further, the ratio is calculated directly H/V (1):

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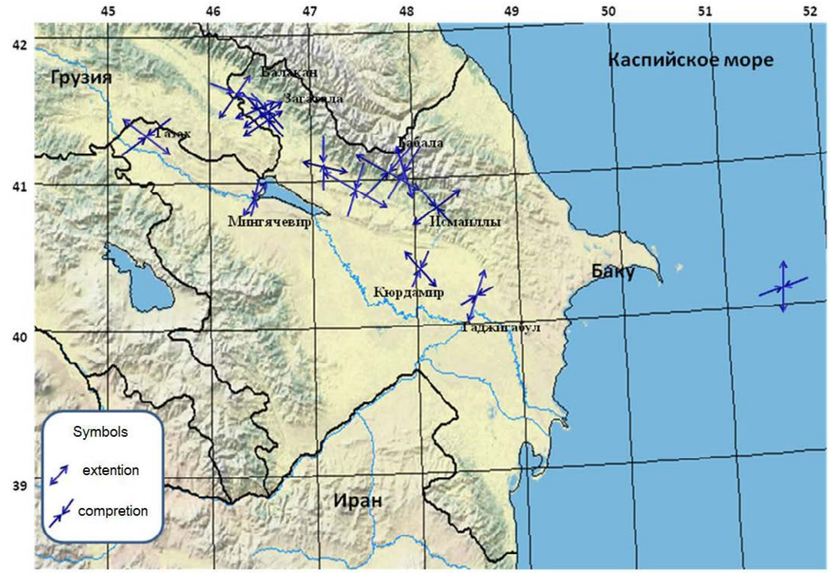

Figure 3: The scheme of distribution of compression and stretching axes of foci mechanisms 2005-2015.

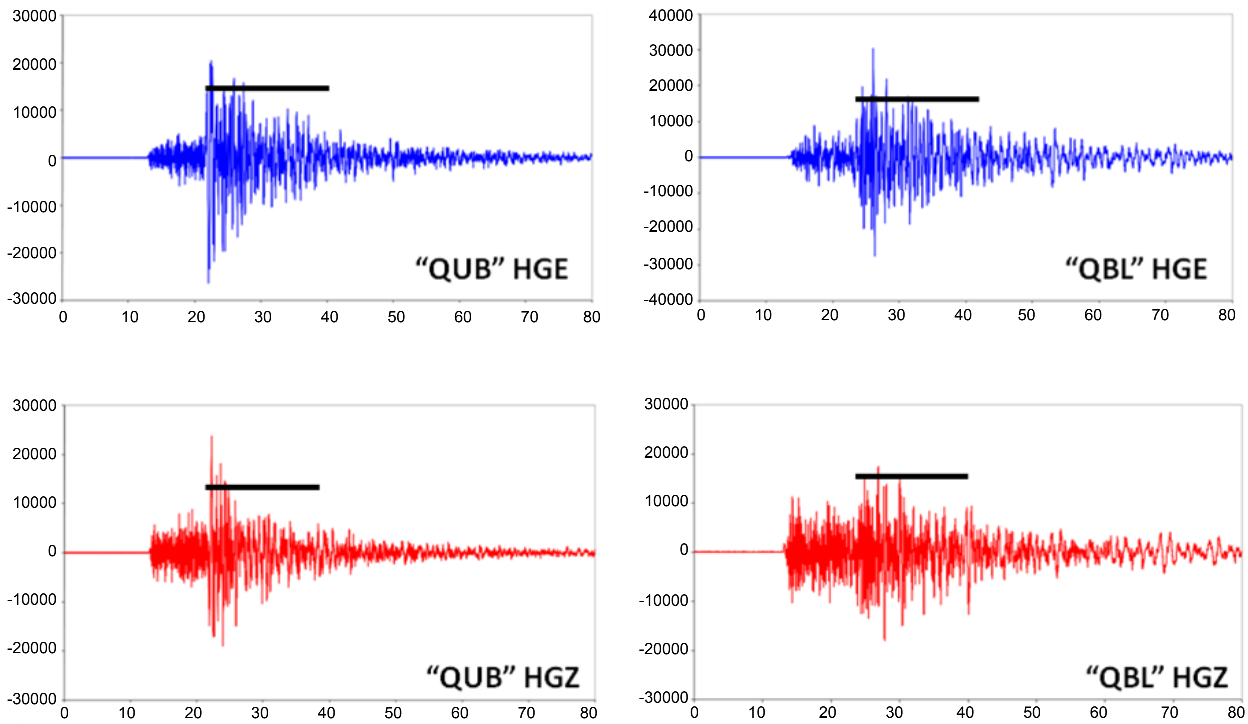

Figure 4: The horizontal and vertical components of the seismic signal on stations «QUB» and «QBL».

$$H(f) = \frac{\sqrt{N^2(f) + E^2(f)}}{2} \quad (1)$$

$$H/V(f) = \frac{H(f)}{V(f)}$$

Thus, was analyzed data of digital records of the transverse wave for three components HGE, HGN, HGZ from 21 stations of strong earthquakes with a magnitude above those earthquakes occurred in 2005-2015. During the study the duration of the recording time window was 60 seconds.

From the selected recording area the linear trend is eliminated and for preventing leakage of the spectrum the signal is smoothed at the ends with a 5% cosine window. The corrections are applied to error of the instrument measurements and the spectrum is calculated using Fourier transform.

Based on the above was calculated factor of amplification of 21

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wideband digital stations (Figures 5-7). The obtained result we divided into three classes: the stations for which the maximum amplification factor value ranges in the frequency range of 0.2-1.0 Hz (stations «ALI», «GBS», «GLB», «LKR», «PQL», «QBL», «QSR», «XNQ», «ZKT»), the stations for which the maximum amplification factor value ranges in the frequency range of 1.0-4.0 Hz (stations «ATG», «HYR», «IML» «MNG», «QUB»,«SIZ»), and in the range of 3.0-7.0 Hz (stations «AST», «GAN», «LRK» «ORB», «SEK»,«BRD»).

In the basis of this method was put the notion that the effect of the thin layer (a small layer of the earth's crust directly under seismic station) of the studied object for the most part refers to the transverse waves (S-waves), which are enhanced by this structure, and virtually do not change longitudinal waves (P-wave). Then the ratio of the spectral characteristics of the two horizontal components to the spectrum of vertical component will characterize the so-called transfer function, which is strongly dependent on a thin layer under the considered object [9]. It was found that the maximum amplification factor is characteristic for the stations of «QBL»=3.6, «AST»=4.3, «GAN»=4.3, «SEK»=3.6, «BRD»=3.4.

Further, taking into account all the above mentioned was compiled a distribution map of amplification factor of transverse seismic waves on the digital stations according to the data of strong earthquakes occurred in the years 2005-2015 (Figure 8).

Conclusions

Thus, on the basis of the algorithm by the method of inversion of waveforms Time-Domain Moment Tensor has been calculated seismic moment tensor of earthquakes in Azerbaijan for the period of 2005-2015, based on the records of broadband (BH) modern digital stations, which allowed to identify the characteristics of seismotectonic deformation in the individual seismogenic zones of the Republic, namely in Zagatala, Shaki, Gabala, Oguz, Hajigabul, Ismayilli regions, as well as in the Caspian Sea area.

According to above mentioned, it can be concluded that the seismic activity in the Greater Caucasus and the central part of the Caspian water area in 2012-2015 is connected with the intensification of Kazakh-Signakh to fall at an angle of 72° to the SE, Ganjachay-Alazan

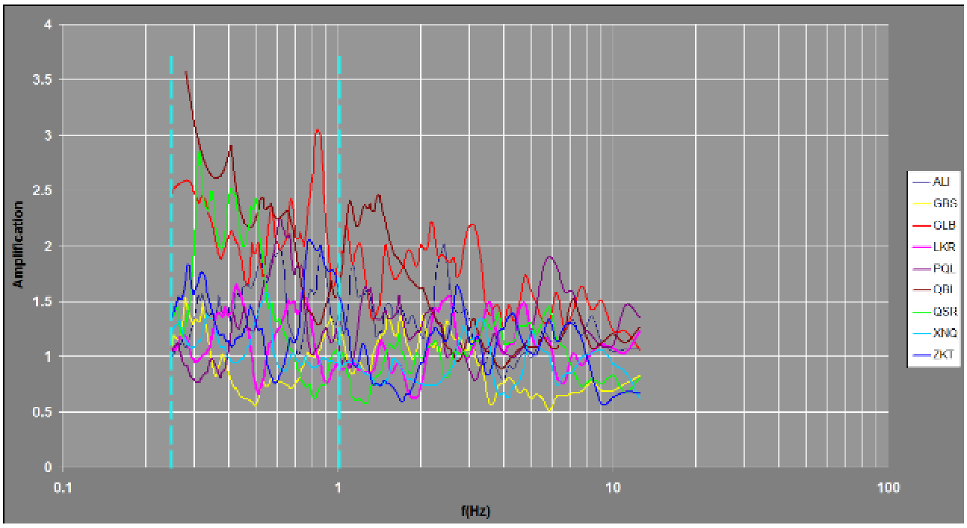

Figure 5: The amplification factor of the seismic wave on the stations of «ALI», «GBS», «GLB», «LKR», «PQL», «QBL», «QSR», «XNQ», «ZKT».

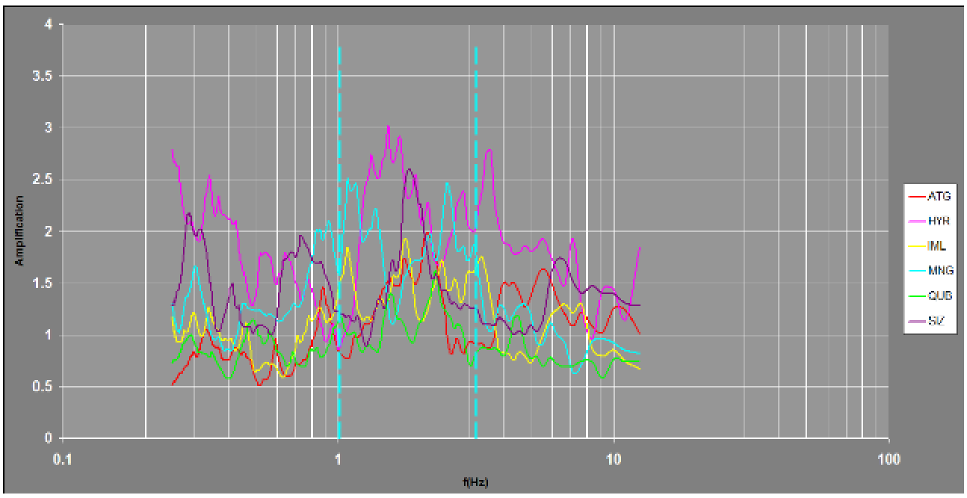

Figure 6: The amplification factor of the seismic wave on the stations of «AST», «GAN», «LRK», «ORB», «SEK», «BRD».

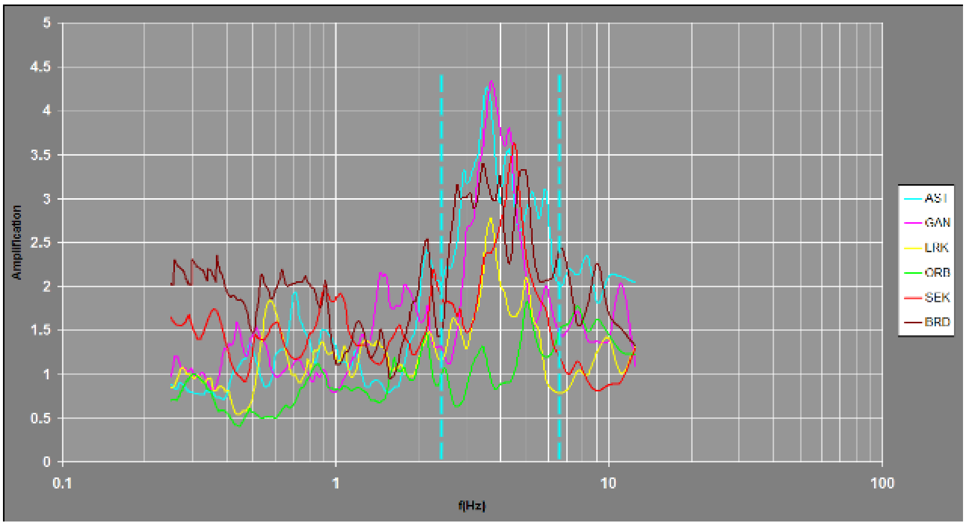

Figure 7: The amplification factor of the seismic wave on the stations of «ATG», «HYR», «IML», «MNG», «QUB», «SIZ».

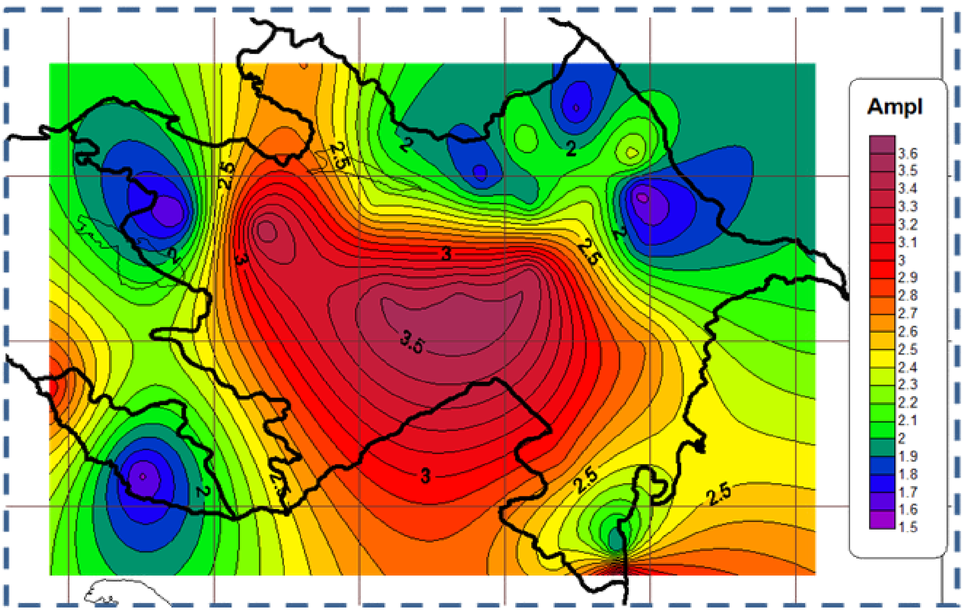

Figure 8: A distribution map of amplification factor of the transverse seismic waves on the digital stations, according to the data of strong earthquakes occurred in the years 2005-2015.

with the fall at an angle of 58° to the NW, Arpa-Samur with a fall at an angle of 85°-90° (at depths of 16-25 km) to the SE, Ismayilli-Gabala with the fall at an angle of 44° to the SE (at a depth of 46 km) and 53° (at a depth of 11 km) and cross, Geokchai with the fall at an angle of 81° to the NE, Mingachevir, Saatli with the fall at an angle of 53° to the NE and Absheron-Balkhan with the fall at an angle 66° to the SW of longitudinal faults. Perhaps Zagatala earthquakes occurred under the influence of right-sided Kazakh-Sighnaghi and Gandjachay-Alazani lateral faults were the trigger of the subsequent earthquakes in the area. Statistical analysis of the mechanisms of strong earthquakes foci showed predominance of tensile stresses mainly related to the activity of cross-sectional and orthogonal faults throughout the territory of Azerbaijan.

In addition, had been calculated station corrections (determination of amplification factor) based on analysis of seismic signal of earthquakes with a magnitude above 5 occurred in 2005-2015 years with Nakamura's method. It has been found that stations ATG, NAX and GLB from the earthquakes located in SSW direction are characterized by the enhancement in 2.5-3.0 times in the frequency range of 4-10 Hz. Stations ZKT, LKR, QSR, QZX, ALI are characterized by increase in 2.5-3.0 times in the frequency range of 0.3-1 Hz. For stations IML and AST abnormalities are not observed. Stations AST, LRK, QZX, XNQ are characterized by the increase in 2.5-3.0 times in the frequency range of 3-10 Hz.

On the basis of the averaged data for each station was compiled a distribution map of spatial amplification factor for the territory of Azerbaijan. The total value of the factor varies in the range of 1,5-3,6. Maximum is observed in the Kura River valley area and Zagatala region, indicating that the layer of the earth's crust under the stations of the region strengthen the impact of transverse waves through the source-receiver.

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