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Stress Field Pattern in the Northeastern Part of Azerbaijan

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Abstract—Azerbaijan is characterized by a strong level of seismicity with earthquakes concentrated within several active areas. In this study, we calculated the source mechanism of earthquakes occurring in the northeastern part of Azerbaijan, by using the digital waveform data recorded by the Republican Seismic Survey Center (RSSC) at the Azerbaijan National Academy of Sciences (ANAS) during the period from 2003 to 2017. Polarity of the first motion of a P-wave was the main criteria for focal mechanism solutions with high reliability. In investigation of the different tectonic deformations and modern stress field pattern in the tectonic areas of the northeastern part of Azerbaijan, the focal mechanism solutions were applied. The results show mainly a thrust faulting mechanism with few events displaying also normal faulting or strike-slip faulting. The World Stress Map (WSM) Create A Stress Map Online (CASMO) and Cataclastic Analysis Method are used in the current research for defining the regional stress field orientations. Western and central parts of the Greater Caucasus ridge are mainly characterized by northeastern–southwestern (NE–SW) tension. In the eastern part, the tension reverses into intensive compression. Additionally, the transformation of sinistral strike-slip motion into predominant right-lateral strike-slip motion can be obviously traced southward from mountain ridges of the Greater Caucasus. The differences between these characteristics are considered for the large tectonic zones (Balaken–Zagatala, Sheki–Oguz–Gabala, Ismailli–Shamakhi). In the Zagatala region of the studied area, the NW–SE orientation of the compression axes is observed, while in the Sheki region, orientation stretches towards N–S and smoothly extends clockwise towards NE–SW orientation in the Caspian Sea. The tension axis is mostly directed towards NE–SW and N–S which is linked with the heat of the Kur depression under the zone of the Greater Caucasus. Significant spatial variations in orientations of the axes of principal stresses in the shear zone and their local weak gentle variations are evidence of a consistent general stress in the NE–SW direction.

Keywords: Azerbaijan, Greater Caucasus, seismicity, tectonics, stress state, Lode–Nadai, WSM CASMO.

1. Introduction

The northeastern part of Azerbaijan is influenced by tectonic activity driven by plate tectonic boundaries. In the current research, we concentrate on the region with coordinates from 40° N to 42° N latitudes and 46° E to 50° E longitudes (Fig. 1), which comprises Balaken–Zagatala, Sheki–Oguz–Gabala, Ismailli–Shamakhi (Fig. 1: I–III, respectively), and is characterized by a relatively strong seismicity. The seismic event occurring in Shamakhi in 1668 ($M \approx 7.0$; $I_0 = 9$–10), in fact, can be considered one of the strongest events to strike the Caucasus. On the basis of historical documents, this earthquake induced landslides and resulted in more than 80,000 human lives lost. Actually, Shamakhi area was struck by several strong earthquakes with intensity up to $I_0 = 8$ (according MSK-64) in 1828, 1859, 1869 and 1872 and the last one ($M = 6.9$; $I_0 = 9$) occurred in 1902. The other area in this part of the region is Ganja, where historically strong and destructive earthquakes occurred in 427 ($M \approx 6.7$; $I_0 = 9$), in 1139 ($M \approx 6.8$; $I_0 = 9$) and in 1235 ($M \approx 5.7$; $I_0 = 8$). Through the years, the Zagatala, Balaken, and Sheki areas were also shaken by a number of strong earthquakes with intensities of less than $I_0 = 6$–7, but causing severe destruction (Babayev 2010; Babayev et al. 2010, 2014; Gasanov 2003, Yetirmishli et al. 2015). On May 7th, 2012, an M5.6 earthquake struck Zagatala, Gakh and Sheki. More than 3000 private and public buildings collapsed or were severely damaged. On May 18th, another event ($M = 4.8$) occurred, causing the collapse of more than

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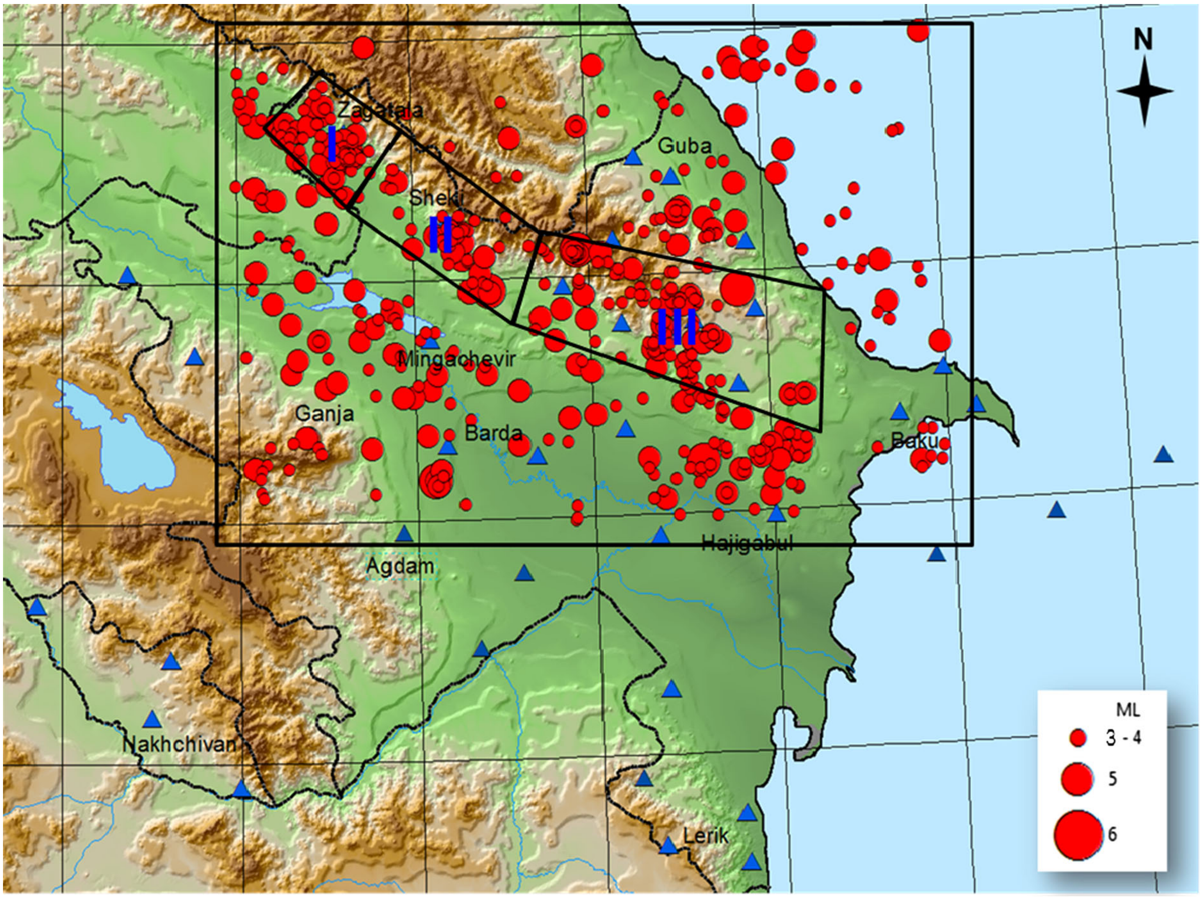


Figure 1
Location of the study area in a quadrangle with distribution of earthquake epicenters (2012–2017). Blocks: I—Balaken–Zagatala, II—Sheki–Oguz–Gabala, III—Ismailli–Shamakhi. Note: Earthquakes were selected from the Republican Seismic Survey Center (RSSC) at the Azerbaijan National Academy of Sciences (ANAS) catalogue. Triangles indicate the seismic station. Three sea bottom stations mapped in the Caspian Sea will be installed in 2019

7000 houses and the evacuation of more than 9000 families.

Analysis of seismicity of Azerbaijan in 2012–2016 has led to the distribution of seismogenic zones along the Caucasian fault pattern, shown in Fig. 2.

Activation of seismicity is due to the accumulation of stresses and their subsequent discharge in the tectonic zones of the studied region. Studying the conditions to solve the mechanism of earthquake sources is very important for understanding the nature of seismic phenomenon and developing methodologies for estimating stress regime and constructing stress field pattern. Estimating the stress field is crucial to understand seismic effects produced by large-scale plate tectonics and the relative deformation field (Mohamed et al. 2015).

There are various methods to solve earthquake focal mechanisms, such as polarity of arrival of the first P-waves, analysis of amplitude ratios of P-wave over S-wave (Kisslinger et al. 1981) and moment tensor inversion (Stein and Wysession 2003; Mohamed et al. 2015).

In this study, we aim to find the source mechanism of earthquakes occurring in the northeastern part of Azerbaijan during 2003–2017, in order to investigate the state of fault displacements and contemporary stress orientation model in the tectonic

Figure 2

Fault map of the study area. Some faults are compiled from geologic maps and divided into thrusts and remaining fault types. Some faults are interpreted from gravity data (from Kadirov 2000; Nemčok et al. 2011). Faults: 1–1 Makhachkala-Krasnovodsk, 2–2 Akhty-Nyugedi-Kiliazin, 3–3 Siyazan, 4–4 Zangi-Kozluchay, 5–5 Vandam, 6–6 Alazan-Agrichay-Alat, 7–7 Kur, 8–8 Pre-Caucasus, 9–9 Bashlybelsky, 10–10 Gektana-Akerinskiy, 11–11 Sharur-Ordubad, 12–12 Gizilagach, 13–13 Arpa-Samur

areas of the studied region, by using the World Stress Map (WSM) Create A Stress Map Online (CASMO) approach (Heidbach et al. 2004, 2008) and cataclastic analysis method (Rebetsky-Yu et al. 2012).

1.1. Tectonics and Seismicity

The study area is the central part of the Crimean–Caucasian–Kopetdag Alpine fold system, which comprises three large geo-blocks: the Deshte-Lut block in the east of Iran, the Middle Caspian-Turan plate on the eastern coast of the Middle Caspian and the Main Zagrosky over thrust on the south for the fall of Iran (Yetirmishli and Kazimova 2018). These large geo-blocks comprise the main geo-structural elements of Azerbaijan (Khain and Alizade 2005). The northern part of Azerbaijan encompasses the eastern section of the intricate southern wing of the mega-anticlinorium of the Greater Caucasus, as well as the area of its southeastern immersion (Yetirmishli and Kazimova 2018). The central part of Azerbaijan belongs to the region of the Kur intermountain basin, characterized by the accumulation of a powerful sequence of Neogene-Anthropogen Molasses (Alizadeh et al. 2016; Babayev et al. 2014; Kadirov et al. 2012; Khain and Alizade 2005; Yetirmishli and Kazimova 2018). In order to investigate the earthquake source mechanism, it is necessary to select the appropriate regional tectonic map. Consequently, having studied the works by Kadirov (2000, 2004), Kangarli (2007), Nemčok et al. (2011), Shikhalibeyli (1996) and the Tectonic map of Azerbaijan (Ali-Zadeh et al. 1980), we compiled a fault map for the study area (Fig. 2).

Seismically, the territory of Azerbaijan belongs to Alpine folded system and is characterized by a high level of seismicity. Historically, strong earthquakes occurred in this area. Those historical earthquakes are characterized by high number of casualties and failures. The most intense events were mainly recorded in Shamakhi and Ganja (Babayev 2010; Babayev et al. 2010, 2014; Kadirov et al. 2013, 2015; Telesca et al. 2013, 2017; Yetirmishli et al. 2013).

The analysis of earthquake distribution demonstrates that most of the strong earthquakes ($M \geq 5.0$) are confined within the crystalline basement (Mammadly 2012), including Zagatala and Balaken earthquakes. Ismailli earthquake, however, occurred on 7th October 2012 year with $ml = 5.3$, with the focal depth of $H = 41$ km. The surface of the crystalline basement reaches the depth of 10 km. This is not the only earthquake in the Ismailli region with such a focal depth; before it, several other less intense events were recorded at about 40 km depth (Fig. 3).

1.2. *Focal Mechanism*

The seismic information obtained from 35 seismic stations allowedto explore the seismic regime of the territory of Azerbaijan, to identify areas of high seismic activity, the spatial distribution of the focal areas, and the mechanisms of earthquake sources. Polarity of the first motion of P-wave was the main criteria in focal mechanism solution with high reliability (Fig. 4). Seismograms are downloaded in SEED format. Broadband seismograms are chosen with a constraint on the distance (20–350 km) (Yetirmishli and Kazimova 2018).

The mechanisms of strong earthquake foci with a magnitude of more than 3.0 occurring in the period 2003–2017 (Fig. 5) were calculated and analyzed. We analyzed the focal mechanisms of the strongest earthquakes (with $M > 5.0$) occurring in the Greater Caucasus, during the period 2012–2015 (Fig. 6).

The Zagatala seismic zone is located in the extreme northwest of the Azerbaijani part of the Greater Caucasus. Its eastern boundary should conditionally be considered the Zagatala–Shamkir shear uplift. The zone merges with seismically active zones of Southern Dagestan and Western Georgia in the north, west and south. Two strong earthquakes occurred in Zagatala district on May 7, 2012 at 04^{h} 40^{m} ($\varphi = 41.50°$ N, $\lambda = 46.58°$ E, $M = 5.6$, depth $h = 8$ km) and at $14^{h}15^{m}$ ($\varphi = 41.68°$ N, $\lambda = 46.63°$ E, $M = 5.7$, depth $h = 12$ km). The Zagatala earthquake ($ml = 5.6$) occurred on 7 May 2012 and was characterized by near-lateral ($PL_P = 10°$) compressive and stretchin g ($PL_T = 14°$) stresses. The type of movement along both steep (DP1= 87°, DP2= 72°) planes is a strike-slip. The plane *NP1* has a southeast (STK1= 152°) strike with a dextral strike-slip, and *NP2*—southwest (STK2 = 216°), with a strike-slip. On the same day, another earthquake of $ml = 5.7$ occurred. The earthquake occurred under the influence of near-horizontal stretching stresses ($PL_T = 1°$) and near-vertical compressive stresses

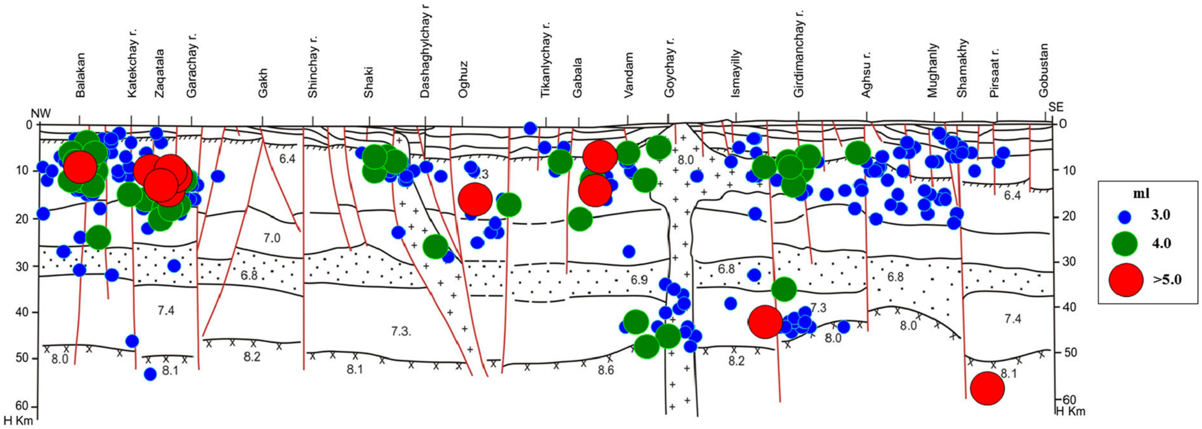


Figure 3

Seismo-geological section in the direction of NW–SE along the Greater Caucasus for the period 2012–2017. From Kangarli (2007)

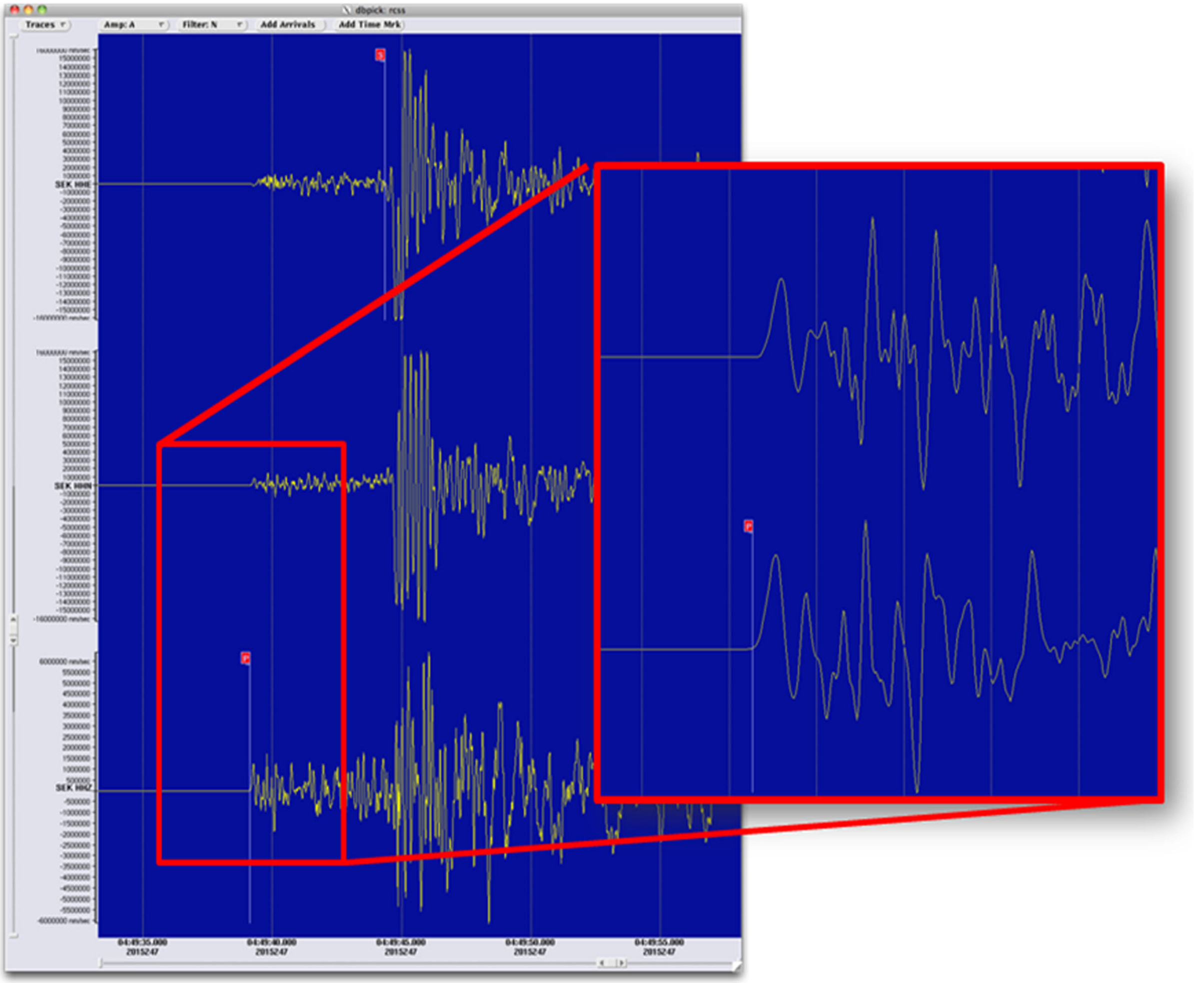


Figure 4
P-wave phase selection with software dbloc2 by Antelope 5.6

(PL_T = 69°). The type of displacement along the first nodal plane NP1 is a normal fault with dextral strike-slip, the second NP2 is sinistral strike-slip. On 18 May 2012, another two earthquakes occurred in the same region with local magnitude ml = 5.0. The mechanisms of these two earthquakes are not identical to the previous two and the type of movement was normal fault with strike-slip shift. Zagatala earthquakes are a consequence of the geodynamic situation in the Zagatala focal zone. The focal mechanisms are interpreted as due to movements of the earth's crust along a system of longitudinal (general Caucasian stretches) and transverse ("anti-Caucasian") faults. The main role belongs very probably to a pair of dextral strike-slip along the NNE trending: Alazan-Agrichay part of fault 6–6 (Fig. 2) (Rzayev et al. 2011; Yetirmishli et al. 2015).

It should be noted that in addition to a large number of aftershocks with magnitude between 3 and 4, on May 18th, two more earthquakes with $M = 5$ occurred in the Zagatala region. The type of focal mechanisms was normal faulting with sinistral strike-slip.

In the same year on October 7th, two stronger earthquakes occurred in the Ismailli region with $m_L = 5.3$ and in the district of Balaken with $m_L = 5.7$. The Balaken earthquake was characterized by the lateral (PL_P = 0°) southwest trending stretching

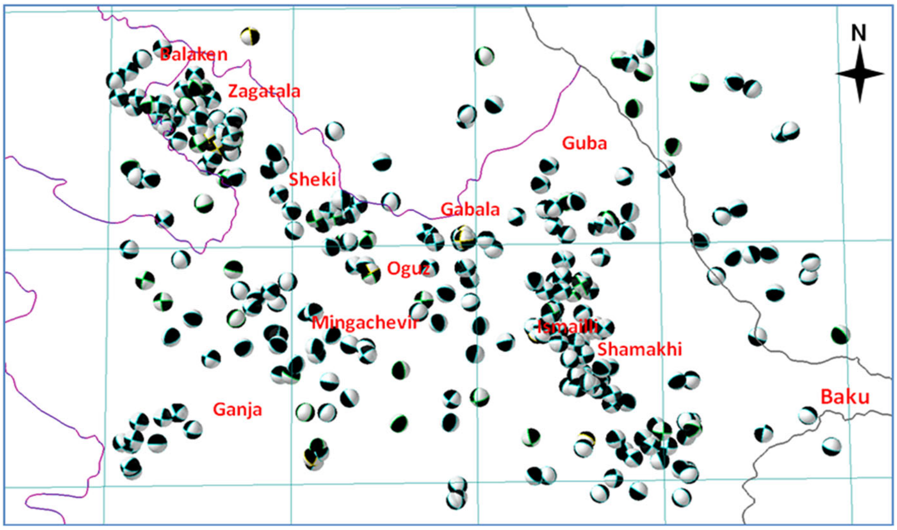
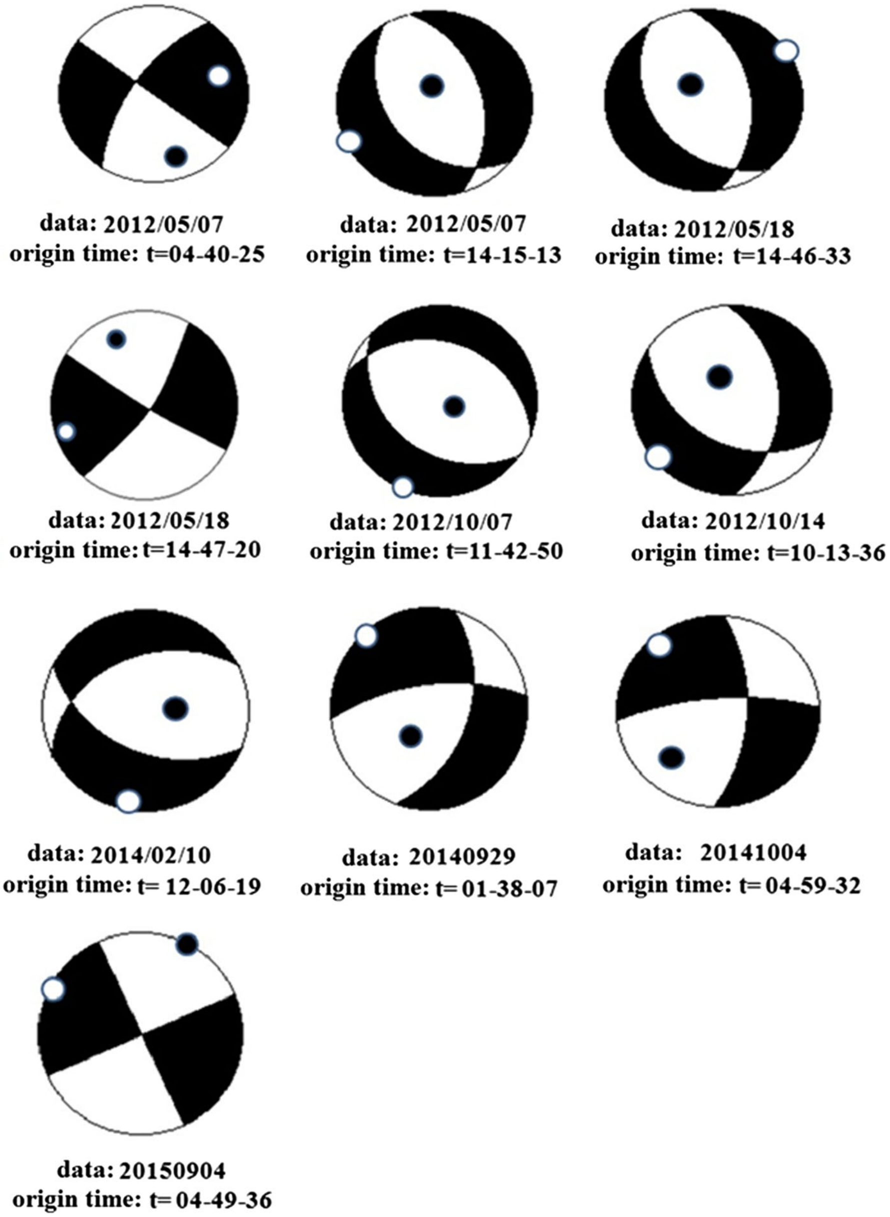


Figure 5
Focal mechanism solutions for the period 2003–2017 (Yetirmishli and Kazimova 2017) for earthquakes with $M > 3$ (many earthquakes overlap and, thus, they are not visible)

and the near-vertical northwest trending compressive ($\mathrm{PL_T}$ = 48°) stresses; the *NP1* plane had a southeastern strike ($\mathrm{STK_1}$ = 115°) and the *NP2* plane had a northern strike (STK_2 = 2°). The comparison of nodal plane strikes with fault lines for Balaken earthquakes indicate as compliance with Alazan-Agrichay part of fault 6–6 (Fig. 2). The Ismailli earthquake was characterized by the lateral ($\mathrm{PL_P}$ = 0°) southwest (AZM= 212°) orientation of tension axis and the vertical southeastern (AZM= 122°) orientation of compression ($\mathrm{PL_T}$ = 83°) axis; the movement type along both (DP= 75–40°) planes was a down throw with faulting elements. *NP1* had south–southeastern ($\mathrm{STK_1}$= 172°), and *NP2* had west–northwestern ($\mathrm{STK_2}$ = 280°) strike. Comparing nodal plane strike with fault strikes determines their conformity with Gizilagach (*NP1*) and Alazan-Agrichay part of fault 6–6 (Fig. 2) (*NP2*) deep rupture dislocations. Both earthquakes indicate normal faulting.

Activation in 2014 began on February 10, a strong earthquake with ml = 5.7 was registered. These earthquakes had large focal depth. The latter was felt not only in the territory of Azerbaijan, 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 seismo-tectonic processes and the implementation of preparing sources of earthquakes with the epicentres located on the southeast of the Greater Caucasus thrust. Those earthquakes occurred on June 29 in the Balaken-Zagatala region with ml = 5.3. On 29th September and 4th October, 2014, two seismic events with ml = 5.5 and ml = 5.0 hit the NE from Gabala. Compressive stresses ($\mathrm{PL_P}$ = 48°) oriented towards the southwest (AZM = 265°) characterized the event with ml = 5.5. The displacement along two steep (DP1= 64°, DP2 = 53°) planes was strike-slip. The plane *NP1* was latitudinal ($\mathrm{STK_1}$ = 265°), and *NP2* meridional ($\mathrm{STK_2}$ = 17°). Comparing the strike of nodal planes with fault lines suggests the link of the second nodal plane *NP2* with Arpa-Samur (Fig. 2) fault. Second seismic event is characterized by near-horizontal (PLP= 23°) compressive stresses. The displacement along two planes was the shift with the reset elements (Yetirmishli and Kazimova 2018). The plane *NP1* was latitudinal ($\mathrm{STK_1}$ = 268°), and NP_2 is meridional ($\mathrm{STK_2}$ = 1°).

The strong earthquake with the magnitude of m_L = 5.9 occurred on the border of Sheki–Oguz–Gabala region of Azerbaijan on 4th September, 2015. The epicenter was 29 km southeast of Sheki. This earthquake occurred under the influence of almost equal tensile (Pl = 16°) and compressive (Pl = 18°) stresses.



data: 2012/05/07
origin time: t=04-40-25

data: 2012/05/07
origin time: t=14-15-13

data: 2012/05/18
origin time: t=14-46-33

data: 2012/05/18
origin time: t=14-47-20

data: 2012/10/07
origin time: t=11-42-50

data: 2012/10/14
origin time: t=10-13-36

data: 2014/02/10
origin time: t= 12-06-19

data: 20140929
origin time: t= 01-38-07

data: 20141004
origin time: t= 04-59-32

data: 20150904
origin time: t= 04-49-36

Figure 6
Earthquake focal mechanisms in 2012–2015 with magnitude $M > 5$

Table 1 shows that the first nodal plane (*NP1*) extends in the southeast direction (STK = 153°) with a fall in the southwest direction with DP = 90°, and the second nodal plane (*NP2*) has a NE trending (STK = 63°) with a fall in the southeast direction with DP = 90°. (See Supplementary file Supp1.txt) Shift types of this earthquake can be interpreted as a left-lateral strike-slip deformation in the zone of influence of geodynamic left-lateral Arpa-Samur fault (Yetirmishli et al. 2016).

The results allow plotting the schematic map showing the orientations of the compression and extension of the focal mechanism of the researched earthquakes. These are projections of the P and T axes on the horizontal plane, built in the epicenter of the earthquake. Considering the variations of the

Table 1

The focal mechanism parameters of 2012–2015 earthquakes with ml ≥ 5.0 to evaluate the stress orientation (see details in the Supplement files Supp1.txt)

No	Data, year/month/day	t_0, h/min/s	h, km	ml	Mw	PIT (deg)	PIP (deg)	Coordinates		Nodal plane					
										NP1			NP2		
								Lat (deg)	Lon (deg)	STK (deg)	DP (deg)	SLIP (deg)	STK (deg)	DP (deg)	SLIP (deg)
1	20120507	04-40-25	9	5.6	5.9	14	10	41.5	46.58	152	87	162	216	72	2
2	20120507	14-15-13	12	5.7	5.3	0	69	41.56	46.63	130	48	− 117	349	48	− 62
3	20120518	14-46-33	13	5	5.1	0	74	41.53	46.62	354	47	− 68	144	47	− 112
4	20120518	14-47-20	10	5	5.0	5	10	41.52	46.64	117	86	− 169	27	79	− 4
5	20121007	11-42-50	41	5.3	5.1	0	83	40.7	48.35	128	45	− 81	295	45	− 98
6	20121014	10-13-36	8	5.7	5.6	0	48	41.66	46.27	116	58	− 141	2	58	− 39
7	20140210	12-06-46	46	5.7	5.5	8	61	40.23	48.62	125	59	− 57	253	44	− 132
8	20140929	01-38-07	11	5.5	5.1	7	48	41.13	47.94	265	64	− 43	17	53	− 146
9	20141004	04-59-32	6	5	4.9	11	23	41.11	47.94	268	82	− 25	1	65	− 171
10	20150904	04-49-36	16	5.9	5.5	16	18	40.97	47.43	153	90	− 180	63	90	0

angles of principal stresses axis in line with the significant standard deviations (Yetirmishli and Kazimova 2018), one can imply the large spatial lithosphere heterogeneity. Study of the direction of the compression axis proves the northwest–southeast orientation in the Zagatala region, while in Sheki it is north–south. Towards the northeast–southwest direction, the orientation gradually changes clockwise towards northeast–southwest in the Caspian Sea. The tension axis is mostly directed towards northeast–southwest and north–south because of the immersion of the Kur depression along the Main Caucasus Thrust under the Greater Caucasus region (Figs. 7, 8, 9).

Greater Caucasus area is a compression zone where the Kura depression sinks under the Greater Caucasus. So many diverse tectonic faults. There are both NF and RF and SS. Tension orientation predominates southwest–northeastward, but compression orientation is directed towards northeast–southwest with 67% domination, while northwest–southeastward has 37% predominance. The incidence angle for displacement of various type exceed 45° which means a rather steep dip in the failure zone. This is consistent with the fact that in the investigated zone, the majority of transverse faults have incidence angles of 50–90°, that is, angles sufficiently close to the vertical (Yetirmishli and Kazimova 2018). This is mainly the Arpa-Samur cross fault whose incidence angle at depths of 9–20 km varies between 58° and 87°.

1.3. Stress State Pattern by WSM CASMO

WSM CASMO is a visualization technique which allows plotting stress orientations on a map knowing the focal mechanism solution of earthquakes (Barth et al. 2008). In this study, the stress orientation was evaluated on the basis of the source parameters of 1990–2017 earthquakes with $M_w \geq 5$ (Fig. 10).

The results from this approach demonstrate mainly a thrust-faulting with a number of normal-faulting and some strike-slip faulting. These results indicate that mainly western and central parts of Greater Caucasus ridge are characterized by north-eastern–southwestern tension. In the eastern part, the tension reverses into intensive compression.

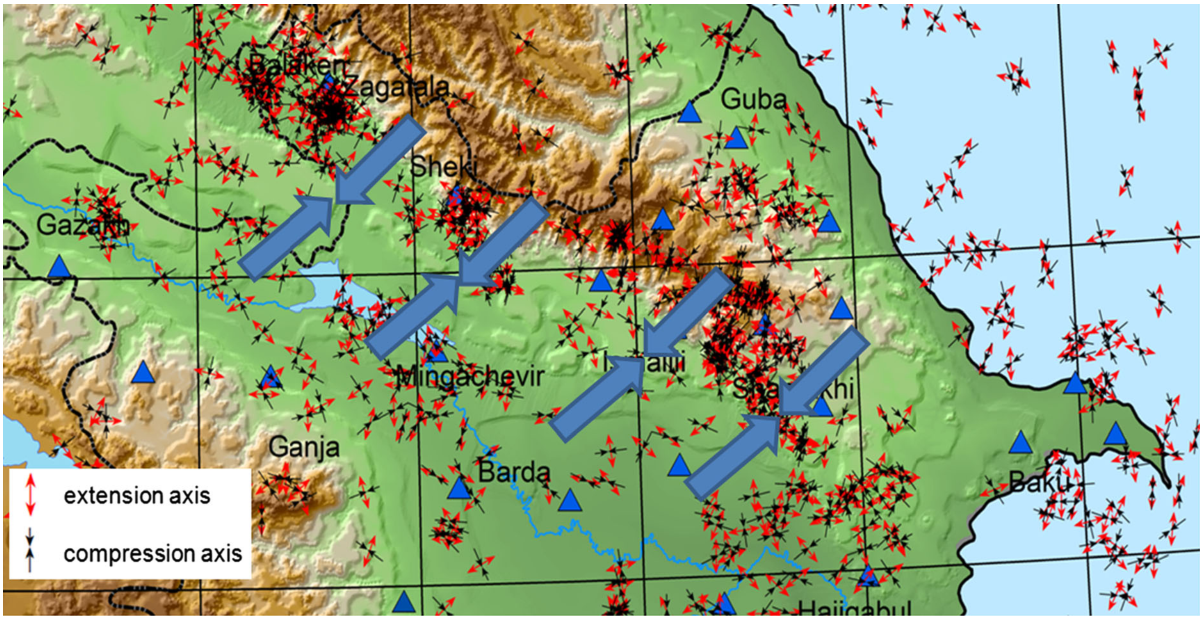


Figure 7
Distribution of the horizontal projections of the P and T axes for events occurring during 2003–2017 for Azerbaijan

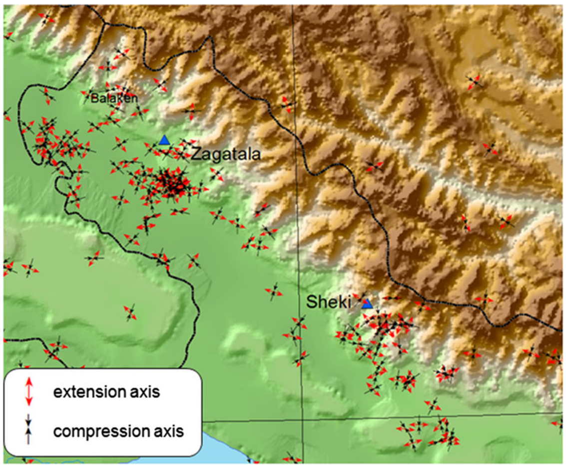


Figure 8
Distribution of the horizontal projections of the P and T axes for events occurring during 2003–2017 for Balaken–Zagatala–Sheki zone

1.4. *Stress Orientation Distribution by Cataclastic Analysis 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 problems of tectonophysics. In our work, to

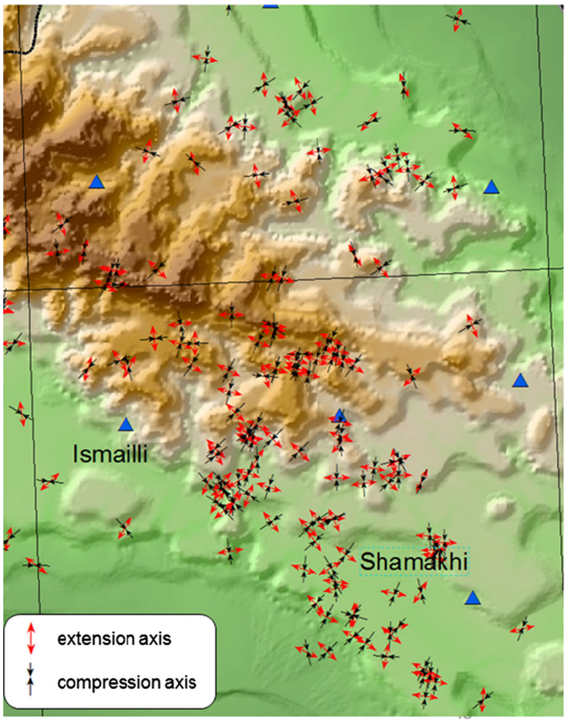


Figure 9
Distribution of the horizontal projections of the P and T axes for events occurring during 2003–2017 for Ismailli–Shamakhi zone

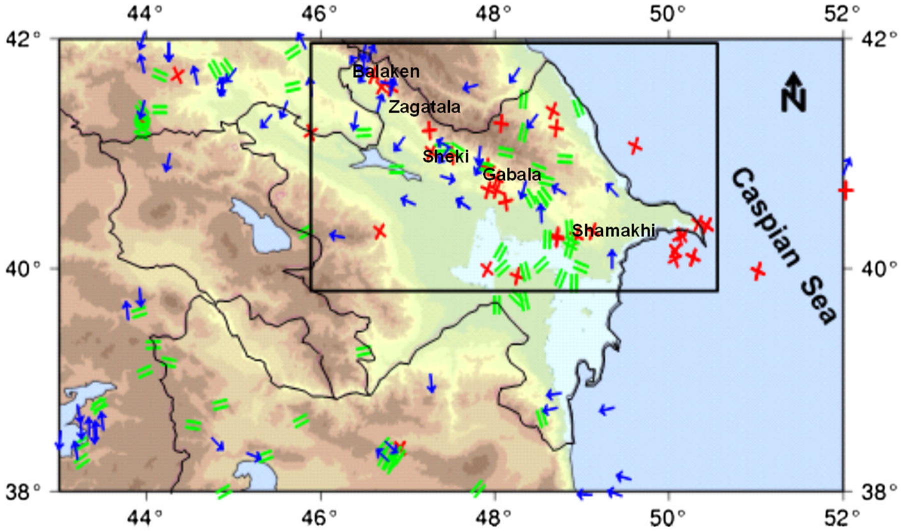


Figure 10

Stress map based on the principal axes of focal mechanism solution databy CASMO WSM (Heidbach et al. 2004, 2008) for the period 1990–2017 with Mw ≥ 5 (Babayev et al. 2017). Blue arrows indicate thrusts and thrusts with strike-slip elements; green mark indicates strike-slip mechanism; red symbols indicate normal faults and normal faults with strike-slip elements. Notes: Focal mechanism solutions were done based on catalogues of the Republican Seismic Survey Center, Azerbaijan National Academy of Sciences (RSSC ANAS), United States Geological Survey (USGS), Global Centroid-Moment-Tensor (CMT), GeoForschungsZentrum (GFZ), Incorporated Research Institute for Seismology (IRIS), World Stress Map (WSM) and European-Mediterranean Seismological Centre (EMSC)

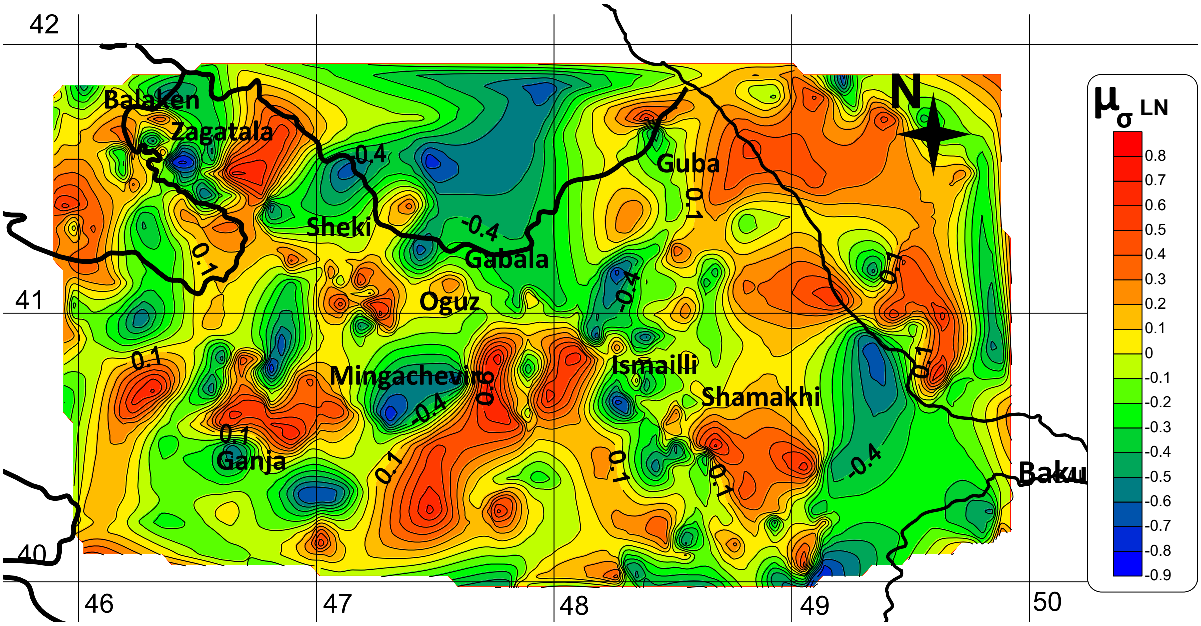


Figure 11

Lode–Nadai coefficient for the Greater Caucasus

study the stress state of the region, we used the method developed by Rebetsky (1996) which is a method of cataclastic analysis of earthquake focal mechanism sets, by which data on the orientation of the principal stress axes and the Lode–Nadai coefficient, which determines the shape of the stress ellipsoid, can be calculated (Bergerat 1987; Chernykh 1988; Solonenko et al. 1993; Yamaji 2000; Rebetsky-Yu et al. 2012; Rebetsky-Yu and Polets-Yu 2018) . The values of the Lode–Nadai coefficient ranging from -0.2 to 0.2 calculated for Greater Caucasus region correspond to the stress tensor of pure shear, while the large spatial domains where the Lode–Nadai coefficient is close to $+1$ and -1 indicate regimes of uniaxial compression and tension (Fig. 11). The Lode–Nadai μ_σ coefficient within the study area almost everywhere is in relationship with a stress tensor of pure shearing. In the transition zone from Kur basin toward NE zone of Greater Caucasus, the stress tensor type corresponds to uniaxial compression (the absolute value of deviatoric compression is double of the other two principal stresses that are almost equal).

In Figs. 12 and 13, we show the stress orientation distribution in 3D model to determine the best-fit of stress orientation distribution with depth using Lode–Nadai method with the respective faults in the Greater Caucasus and adjacent Low Kur depression zone. The length of profile shown in Fig. 12 is 340 km and 317 earthquakes were used to determine the parameters of the stress tensor. The grid size along the x-axis is 3.4 km, along the y-axis is 2 km, and along the z-axis 0.1, with an average of three earthquakes per grid node. The profile depth is 50 km.

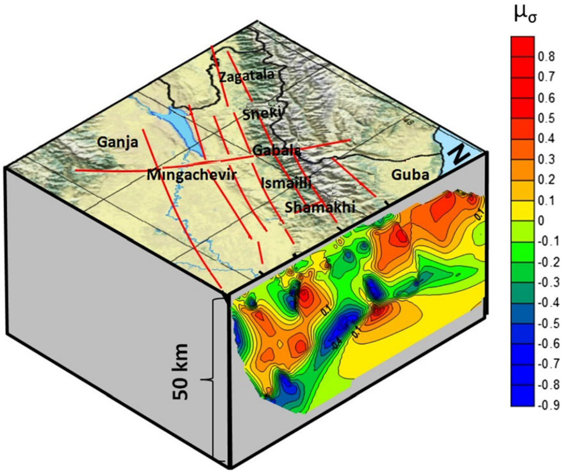


Figure 13
Lode–Nadai coefficient for the Greater Caucasus

The length of the profile in Fig. 13 is 240 km and 250 earthquakes were used to determine the parameters of the stress tensor. The grid size along the x-axis is 2.4 km, along the y-axis is 2 km, and along the z-axis is 0.1 km, with an average of two earthquakes per grid node. The depth of the profile is 50 km.

2. *Conclusion*

There are three seismic zones affecting the northeastern part of Azerbaijan: Balaken–Zagatala,

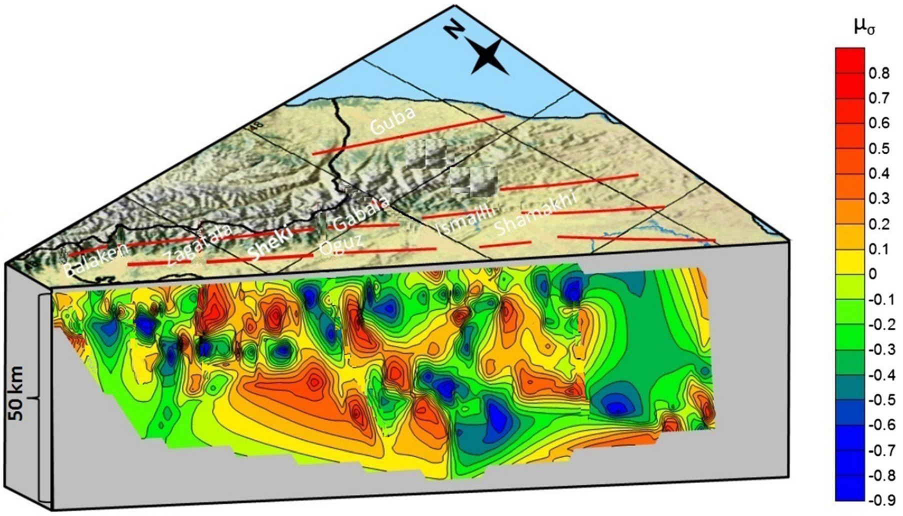


Figure 12
Lode–Nadai coefficient for the Greater Caucasus

Sheki–Oguz–Gabala, Ismailli–Shamakhi. The results of the stress tensor by means of focal mechanisms of the recent earthquakes suggest that the zone is stretching and their mechanism is determined as a result of right-lateral shear deformation in the zone of geodynamic influence of left-lateral faults, creating clockwise torsion of the block. Stress orientation of extension axis generally dominates in southwestward, northwestward, but for the compression axis is detected orientation in the northeast–southwestward (67%) and in the northwest–southeastward (33%). The results from the proposed methods demonstrate mainly a thrust-faulting with a number of normal-faulting and some strike-slip faulting.

As stated above, this contribution represents a second attempt to reconstruct the pattern of the crustal stresses (Rebetsky-Yu et al. 2012), by assembling most of the RSSC seismic network data on earthquake focal mechanisms collected over a 14-year period. An updated focal mechanism catalogue was used to refine the results of the stress reconstruction and obtain the parameters of the stress state forecast crust domains where such data were missing. As demonstrated in the paper, using World Stress Map (WSM) Create A Stress Map Online (CASMO) and Lode–Nadai coefficient techniques gives the possibility to solve the problem of stress generation mechanism in the crust based on a new approach. The set of stress tensor parameters obtained within this approach enables determining both the orientation and the relationship between spherical and deviatory components. This set of parameters of natural stress essentially enlarges analysis power of modern geodynamics. From this basis, relying upon principles of plasticity theory, parameters of stress tensors are defined which ensure the best fit to the observed displacements in terms of energy, i.e. dissipation of energy through slip faults.

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