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Peculiarities Of Taking Into Account The Impact Of Anomalous Variations Of Geodynamic Stress To Well Logging Parameters

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Abstract
The South Caspian basin is the regional depression characterized by complex geological and tectonic setting, active geodynamic processes, earthquakes and mud volcanoes, the thickness of sedimentary cover is over 5-25 km and the area divided by faults into blocks. It has been displayed the importance of use of more advanced methods for oil and gas exploration, to study in more detail the setting of oil and gas targets, to study oil horizons by use of geophysical, oil-field geophysical data taking into account the geodynamic stress situation.
The method has been developed for consideration of anomalous variations of geophysical parameters (seismic wave velocity, resistivity, magnetic, radiation, etc.) in oil and gas layers under the impact of geodynamic stress and earthquakes.
It has been indicated that in case of earthquakes with magnitude M≥*5 occurred at various depths the changes are observed in geological environment, geophysical parameters of rocks depending on hypocentral distance and the impact of geodynamic stress accumulated in the earthquake focuses. Variations in logging parameters acquired in oil layers are within 15-25% range.*
It is recommended to take into account the impact of geodynamic stress accumulated in the earthquake focuses while fulfilling well logging works in oil and gas fields.
Key words: *Hydrocarbon fields, anticlinal-synclinal structures, faults, sedimentary units, geodynamic-seismic activity, anomalous geophysical fields, resistivity, magnitude, hypocentral distance, geology, etc.*

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The actuality of the topic The South Caspian basin is the regional depression characterized by complex geological and tectonic setting, active geodynamic processes, earthquakes and mud volcanoes. According to the maps compiled based on the gravity, magnetic, seismic and electric survey data acquired in the region the thickness of sedimentary cover is over 5-25 km and the area is divided by faults into blocks [1, 2, 12].

The South Caspian basin has rich hydrocarbon reserves and for the last 25 years here such oil and gas fields as Azeri, Guneshli, Chirag, Bahar, Bulla deniz, Shahdeniz, Umid, Babek, Absheron, Garabagh, etc. were discovered. Geological and geophysical services conducted in this region allowed to predict vast oil and gas reserves presence in perspective structures [2, 7, 10].

Currently among the *crucial problems* are the need to conduct exploration for oil and gas by more advanced methods, appply new technologies and study in more detail the geological setting of oil and gas bearing units, more accurate evaluation of oil horizons by use of acquired well logging parameters taking into account the geodynamic stress.

Aim of the study The aim of this study consists in scientific substantiation of importance to take into consideration the excess variation of geophysical parameters (seismic wave velocity, resistivity, magnetic, radiation, etc.) in oil and gas layers under the influence of geodynamic stress, earthquakes while interpretation works aimed to evaluate hydrocarbon presence.

Magmatic processes, development of intrusives, seismo-geodynamic activity related to earthquakes, geotectonic motions, intensive activity of mud volcanoes and other phenomena taking place while geological evolution of the South Caspian basin have left the characteristic traces in geological environment of the region and these processes intenisvely continue now causing anomalous variations in layers.

If case of earthquakes with magnitude M≥5 are taking place at various depths, various changes are observed in geophysical field parameters of rocks depending on hypocentral distance [3, 5]. Taking into account

that in Azerbaijan the oil and gas presence is more observed in geological sections of Productive Series the major attention has been paid to variations observed in log diagrams of these layers.

Problems to be solved:

1. Consideration of allocation characteristics of depths of earthquakes hypocenters on the territory of Azerbaijan.
2. Study allocation of earthquake focuses within Productive Series.
3. Apply the method of consideration of earthquakes with magnitude M≥5 occurred at various depths to evaluate their impact within Productive Series.
4. Recommendations to take into account the peculiarities of geodynamic stress variation while identification of missed oil and gas targets.

Seismic activity of Azerbaijan territory of the South Caspian basin has always been high and the earthquakes with M≥5 magnitude are taken place here since the historic past. The depths of earthquakes focuses in this region are evaluated as within 60-100 km depth interval [1, 4, 6].

In the territory of Azerbaijan, the depth of the Mokharovichich boundary is 40-55 km, the depth of the Konrad boundary is 20-35 km, and the depth of the bottom boundary of the sedimentary cover – the boundary of basement is more than 25 km as reflected in geophysical fields. The large morfostructures have very complex geological-tectonic setting [2, 11]. The depth of surface of the basement in Gabyrry-Alazanda area is 9-14 km, in Yevlakh-Agjhabadi trough, Low Kur depression is 14-16 km, in Oghuz-Ismayilli-Shamakhy area is 4-7 km, in Low Kur depression is 12-18 km and the uplifts and troughs are featured by characteristic isolines. The thickness of sedimentary cover from Low Kur towards the South Caspian basin increases up to 25-30 km [2, 9, 11].

It is assumed that the relief of the basement and the internal structure of the sedimentary cover are so complex due to the influence of magmatic (plume mantle) processes in deep layers, geodynamic stress and earthquakes. Anomalous features of stress deformation conditions, seismogeodynamic activity and dynamic activity of mud volcanoes within sedimentary cover are also observed at presence. The amplitude of tectonic faults between blocks in the sedimentary cover is within 1500-2000 m ranges, while in some places they are observed with larger displacement [2, 8, 9, 10].

In geological sections in the South Caspian basin the deformations, stress, seismic activity and tectonic faults presence increases in the upper layers, the areas of complicated seismic records and various values of the same layer parameters are observed on log diagrams[3, 4].

Methods of the study In the process of exploration for oil accumulations, production works from the fields the crucial importance consists in analysis of geophysical field parameters taking into account the geodynamic stress in order to fulfill accurate processing and interpretation of geophysical data.

The oil and gas fields, which are currently under production, have been covered by 2D, 3D and 4D seismic survey. In fields and perspective structures a large number of wells down to 7 km depths have been drilled with futher downhole logging operations. It must be noted that abnormal variations of geophysical fields are not taken into account while the analysis of acquired geophysical data and as a result the incorrect data are gained about the reference boundaries and evaluation of oil and gas presence in the layers. In some cases, the reference boundary is evaluated as 10-100 meters, the oil and gas target is evaluated as non-producing layer or vice-versa [3, 4, 5].

In order to trace the impact of earthquakes on geodynamic stress on depth seismic sections and on logging diagrams acquired from the wells drilled through the periods when geodynamic activity is observed the following order of earthquakes impact is selected:

1- The parameters of earthquakes, which effect is observed in geophysical survey field, formations (time of event, coordinates of earthquake focus, depth of hypocenter, sizes of the focus, time of energy accumulation, etc.) are selected by use of catalogue of Seismological Service Center of Azerbaijan Republic [12, 15].

2- Geophysical fields variations (resistivity, spontaneous potential, etc.) are defined according to the magnitude (M) and energy (E) accumulated in the focus of the earthquakes, which may abnormally change lithological and physical propeties of rocks in well sections.

The distances refferring to the impact of earthquakes and possible abnormal changes in layers, in other words, the radius of impact according to the strength of the earthquake is calculated according to the methods of V.I.Ulomov, I.P.Dobrovolski, S.I.Zubkov and V.N.Myachkin:

$\Delta\rho = 10^{0,43\,M}$, km.

Here, $\Delta\rho$ - hypocentral distance from the area of potential stress energy accumulated in the earhquake center, km; M – magnitude of the earthquake.

The time period of potential stress energy accumulation up to the moment of earthquake strike in the focus is calculated

$$\Delta t = 10^{0.74\ M-4.60}, \text{ year.}$$

To define the hypocentral distance according to the earthquake magnitude the grid has been designed (Figure 1) and the earthquake impact radius ($\Delta\rho$) is calculated. The time (Δt) of energy accumulation in earthquake focal zone is also calculated.

The abnormal increase of geodynamic stress in areas falling under the effect of earthquakes cause variation of elasticity module – E, resistivty in reservoir layers - $\rho_{süx}$, porosity - m, permeability coefficient – k, water saturation coefficient – K_{doy}, resistivity ratio - $\rho_{süx}/\rho_{doy}$ and other variations. In our previous studies it has been indicated that the mentioned parameters vary prior and after the earthquakes in some oil fields of the Low Kur depressions (Mishovdagh, Kurovdagh, Kursyanga, etc.) [4].

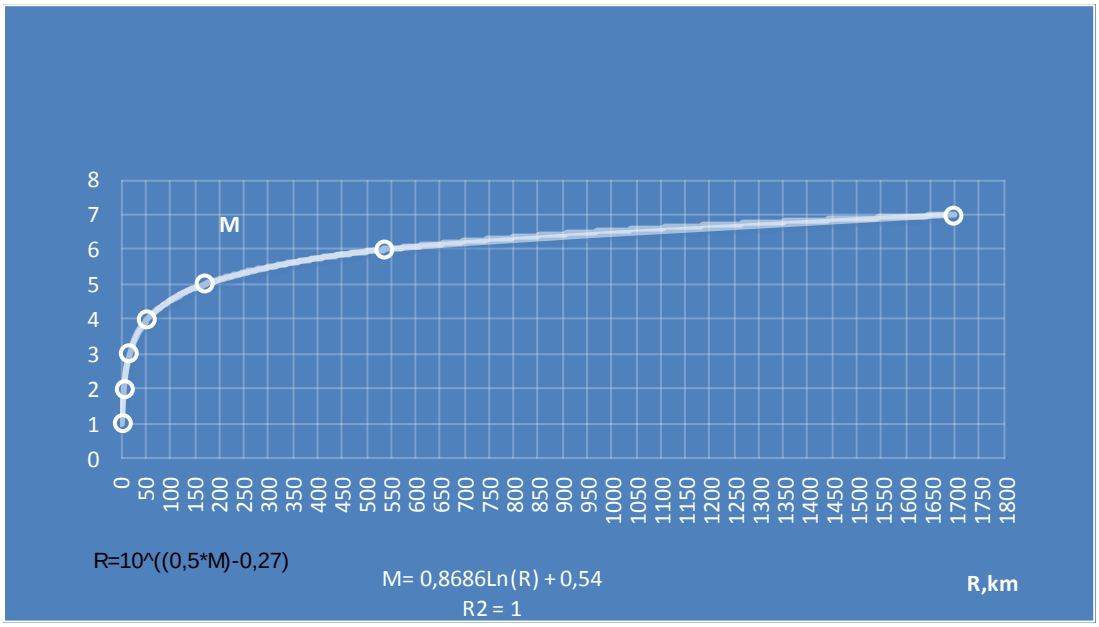

Figure 1. The grid for evaluation of hypocentral effect distance according to the magnitude of the earthquake.

The following table has been drawn for evaluation of epicentral distance -ΔR and energy accumulation time - Δt according to the earthquake magnitude

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Table 1

Magnitude, M	1.5	2.1	2.7	3.3	3.8	4.4	5.0	5.5
Epicentral distance ΔR, км	4.5	8.0	15.0	26.0	43.0	80.0	140,.0	230.0
Energy accumulation time Δt, time period	3 hours	8 hours	1 day	2,5 day	6 day	17 day	50 day	180 day

Despite that in some layers the logging parameters are low (2.0-2.5 Ohm m) under the impact of geodynamic stress, later the oil and gas presence have been identified in these layers [4]. In some cases the logging parameters in some layers are high (8-12 Ohm m) and these layers are evaluated as producing targets, however the testing does not support the opinion [4]. These may be caused by several reasons and one of the most effective causes of these the seismo-geodynamic activity has been scientifically substantiated by us.

Laboratory tests and analysis of geophysical fields variations observed in geodynamic test sites display that under the impact of earthquakes the geophysical fields parameters (seismic wave velocity, electric conductivity, gravity and magnetic field parameters, radioactive field parameters, etc.) of rocks vary. In fields depending on the impact radius and magnitude of the earthquake this may vary as 15-25 % or even more [3, 14].

Geophysical fields variations depending on the hypocenters depths, the hypocentral distance and allocation of focuses of earthquakes has been studied for Miocene and Pliocene, especially for Productive Series, which have high oil and gas potential in the territory of Azerbaijan.

The data on epicenters (Figure 2a) and focuses of the earthquakes ($ml \geq 3.0$) recorded in 35 observation points of Republican Seismological Service Center through the period of 2003-2018 by digital seismic stations manufactured by "Kinemetrics" company of the USA were analyzed (Figure 2b).

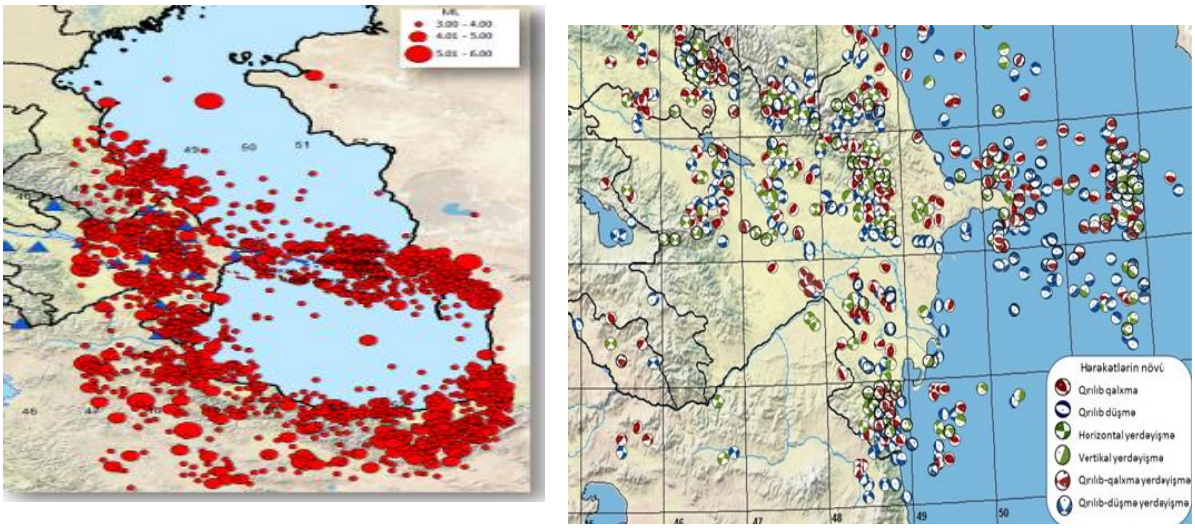
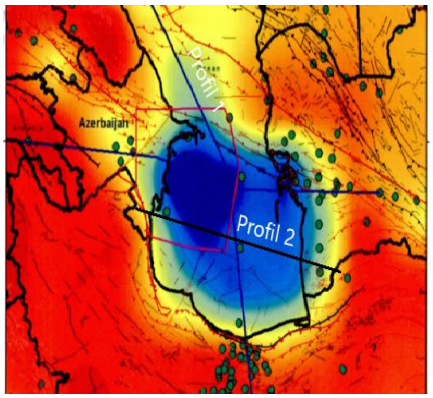
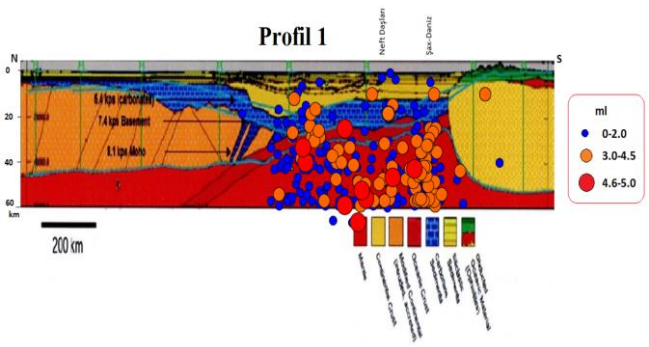


Figure 2. The map of epicenters (a) and focuse mechanisms (b) of earthquakes occurred through the period of 2003-2018 in Azerbaijan and surrounding regions (G.C.Yetirmishli, 2020).

Despite the large number of earthquakes occurred in the upper 3-5 km interval of the earth crust in territory of Azerbaijan the magnitude of earthquakes does not exceed M≥4 (Figure 3b). In this interval the deformations in sections are intensive and horizontal movements, tectonic fractures lead to decrease of stress energy.

In 7-20 km interval of land area of Azerbaijan (in low parts of Sedimentary cover and upper part of Granitic layer) the relatively strong earthquakes of M≥6-8 take place causing severe destructions and human life losses [1, 11, 12]. The earthquakes of magnitude M≥4-6 in the South Caspian basin are observed in places with lower thickness of Granitic layer [2, 11, 13], conjugation areas of blocks and fault zones in the areas surrounded by intrusive masses within blocks (Figure 3).





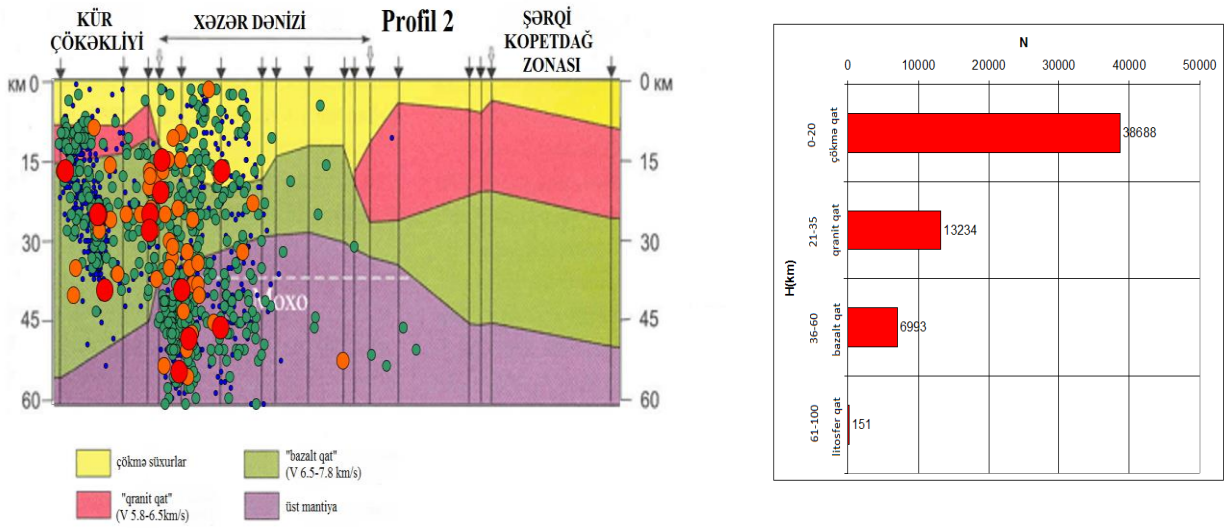


Figure 3. The graphs of hypocenters distribution (a) along the lines of Iran, Neft Dashlary directions (line 1), and Kur depression, Caspian sea and Eastern Kopetdagh directions (line 2) and the graph of hypocenters-versus-depth distribution for the earthquakes (ml≥3.0) through time period of 2003-2018 (b) on territory of Azerbaijan (H.O.Veliyev, S.E.Kazımova 2020).

The nature of motion in the focus zone of the earthquake is the instantaneous fall or rise and reflects the movement of tectonic block [11, 12]. In transition zones from the Middle Caspian to the South Caspian the dynamics of activity is always observed in basalt layer and sedimentary cover and the depth of earthquake hypocenters here is between 40-70 km (Figure 3, line II).

The epicenters of earthquakes (ml≥3.0) occurred in territory of Azerbaijan through 2003-2018 and epicenters on the map of tectonic faults are observed in zones of tectonic faults and areas of their intersections (Figure 4). The type of distribution of the earthquakes once more supports the accumulation of geodynamic stress according to modern models and corresponds to the mechanism of occurrence of tectonic type of earthquakes [1, 11, 12].

The epicenters of earthquakes striken in oil and gas regions of Azerbaijan and the major activity on map of tectonic faults are observed within 15 km interval of sedimentary cover and relate to tectonic faults (Figure 4).

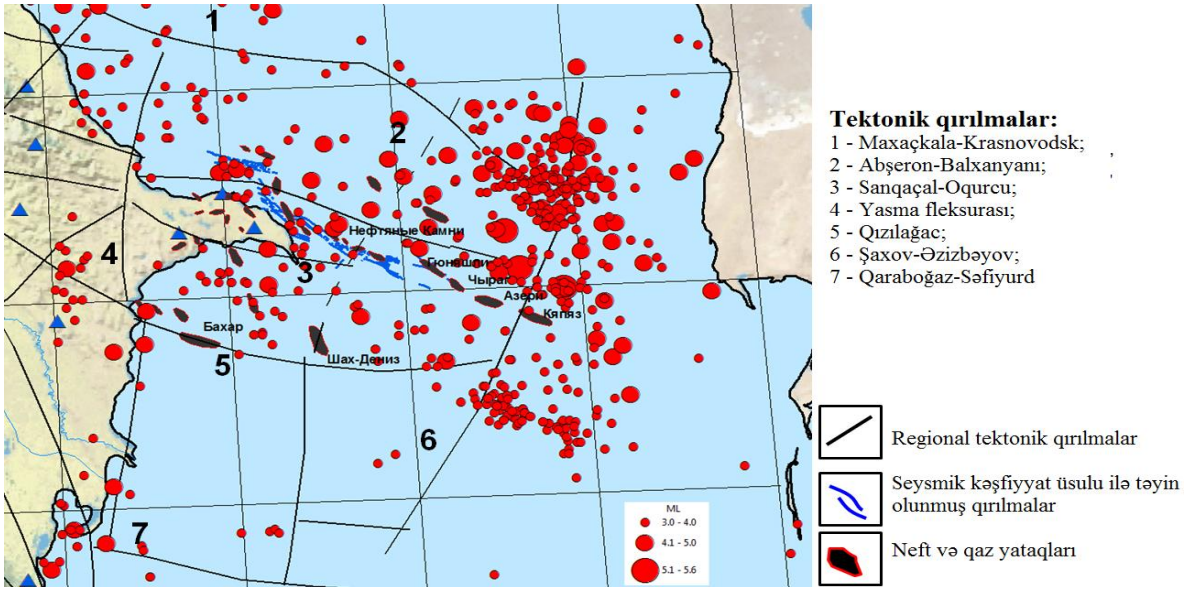


Figure 4. The epicenters of the earthquakes (ml ≥ 3.0) occurred in Azerbaijan in 2003-2018 and the map of faults (G.J.Yetirmishli, H.O.Veliyev, S.E.Kazimova 2020).

The effect on oil and gas fields of 47 earthquakes of magnitude M≥4 striken through 2003-2018 time period in Azerbaijan has been studied. The epicentral distances have been taken into account and analysis of parameters of earthquakes striken in oil fields has been done (Table 2).

It has been identified that various values of resistivity are observed in Productive Series during the periods of geodynamic activity in the considered field (Figure 5). Under the effect of the earthquakes with high magnitude and short epicentral distance the resistivity in the same layers varied as 15-25% from the normal values (Figure 5).

№	Date	Time h.m.s.	Coordinates of the focus			κ	M_{pv}	MI	J_0 (bal)	Notes
			φ°, N	λ°, E	h(km)					
1	20.01.2003	16:38:51.9	40.20	50.00	44	10.6	4.8	4.2	4.0	Baku 3-4b
2	08.05.2003	15:02:26.3	41.24	48.67	37	10.9	4.7	4.4	4.0	Guba 4b, Siyazan 3-4b, Qusar 3b
3	01.06.2003	06:09:42.3	41.05	47.27	22	12.4	5.4	5.1	5-6	Shaki,Oghuz 5b; Mingechevir 4b, Gabalə 3b
4	18.06.2003	14:39:37.6	39.75	48.98	17	10.7	4.8	3.6	3.5	Shirvan 3b
5	25.07.2003	23:59:28.5	40.00	50.25	41	10.7	5.0	4.3	3.5	Baku 3b
6	04.10.2003	09:10:58.1	40.19	49.84	36	10.5	4.8	3.8	4.0	Baku 3b
7	24.10.2003	20:47:24.7	40.68	50.15	43	10.7	5.0	3.6	4.0	Nardaran3b
8	10.11.2003	08:43:38.0	40.72	48.74	13	10.8	5.0	3.9	4.5	Pirqulu4b, Shamaxı 3.5b
9	03.07.2004	06:57:29.5	39.90	49.01	46	10.7	5.1	3.9	3.0	Shirvan3b, Sabirabad2-3b
10	05.01.2005	05:27:35	39.95	50.73	27	11.3	5.4	4.6		Neft daşları3b
11	05.03.2005	19:45:02.6	39.85	48.22	11	9.7	4.3	3.5	3.5	Saatlı3.5b, Sabirabad3b
12	04.04.2005	13:46:25	40.74	50.01	15	9.5	4.1	3.1	4.0	Sumqayıt 3b, Nardaran 3.5b, Baku 2-3b
13	11.04.2005	14:50:26	39.43	49.18	32	10.3	4.6	3.9	3.5	Salyan, Neftchala 3b
14	03.06.2005	14:31:36.0	40.72	50.07	23	10.0	4.5	3.7	4.0	Nardaran 4b, Sumqayıt 3.5b, Baku 2-3b
15	12.06.2006	16:21:54.5	40.34	49.08	39	10.8	5.1	4.3	4	Qobu, Baku2-3b
16	11.07.2007	06:51:13.9	38.66	48.61	30	12.3	5.7	5.0	6.0	Yardımlı, Lerik 6b; Lankaran 4b, Masallı 3.5b, Astara 3b
17	24.07.2007	13:41:34.7	41.92	48.82	41	11.3	5.0	4.9	4.5	Yalama 4b, Khudat, Khachmaz3b
18	23.08.2007	01:52:19.1	40.58	48.49	12	11.6	5.4	4.6	5.0	Aghsu 5b, Shamakhy 4.5b, Pirqulu 4b, Qonaqkend 3b
19	03.05.2009	14:17:26.6	40.19	49.96	38	9.7	3.7	3.48	3	Baku 2-3b
20	04.06.2009	14:20:3.1	40.40	50.64	44	11.0	5.0	4.63	3-4	Baku 2-3b
21	03.06.2010	4:53:30.89	40.47	50.42	60			4.16	3	Pirallahı2-3b
22	14.03.2011	07:52:15	40.25	49.07	18			4.3	3.5	Shirvan 3b
23	14.03.2011	08:14:41	40.29	48.99	4			4.0	3.5	Shirvan 3b
24	14.03.2011	20:57:59	40.24	49.14	22			4.0	3.0	Shirvan 2-3b
25	25.03.2011	09:52:13	39.29	47.41	4			4.3	4.5	Fizuli 3b, Jalilabad, Yardımlı 2-3b
26	15.11.2011	19:33:55	40.04	50.13	55			4.0	3.0	Baku 2-3b
27	27.01.2012	04:22:31	40.75	49.48	5			3.0	3	Sumqayıt3b
28	07.05.2012	04:40:25	41.50	46.58	9			5.6	7.5?	Zaqatala, Qakh, Balakən 6b; Shaki, Oghuz 5b; Mingechevir, Shamkir, Ganjə, Qazakh- 4b; İsmayıllı, Shamakhy, Dashkesen, Gedebey 3b
29	07.05.2012	05:38:02	41.56	46.67	16			4.8	4	Zaqatala 4b; Qakh, Oghuz, Shaki 3.5b; Mingechevir, Gedebey, Shamkir 2.5b.
30	07.05.2012	05:40:29	41.37	46.52	5			4.4	4	Zaqatala 4b; Qakh, Oghuz, Shaki 3.5b; Mingechevir, Gedebey, Shamkir 2.5b
31	07.05.2012	08:36:21	41.53	46.67	16			4.2	4	Zaqatala 4b; Qakh, Oghuz, Shaki 2-3b.
32	07.05.2012	14:15:13	41.56	46.63	12			5.7	7	Zaqatala, Qakh, Balaken 6b; Shaki, Oghuz 5b; Mingechevir, Shamkir, Ganja, Qazakh- 4b; İsmayıllı, Shamakhy, Dashkesen, Gedebey 3b
33	07.05.2012	16:58:55	41.55	46.60	19			4.3	3-4	Zaqatala 3.5b,Balaken3b
34	18.05.2012	14:46:33	41.52	46.62	13			5.0	6	Zaqatala 5b, Balaken, Qakh4b
35	18.05.2012	14:47:20	41.52	46.64	10			5.0	6	Zaqatala 5b, Balakən, Qakh 4b
36	10.14.2012	10:13:36	41.66	46.27	8	12.6		5.6	6	Zaqatala, Balaken 6b; Qakh5b, Shaki4b; Mingechevir, Shamkir, Qazakh, Ganja, Gedebey, Shamakhy, Yevlakh, Gabala 3b.
37	09.09.2013	04:35:47	40.68	49.98	7			4.1	4	Nardaran 4b, Baku, Sumqayıt 3b
38	10.02.2014	12:06:47	40.25	48.63	46			5.7	6	Saatlı 5b, Hajıqabul, Shamakhy, İsmayıllı, Imishli 4b; Ganja, Mingechevir 3.5b; Baku, Guba, Shaki 3b
39	07.06.2014	06:05:29	40.14	51.65	61			5.6		Oil platform 4-5b, take recommendations from the dwellers of,
40	29.06.2014	17:26:07	41.54	46.54	9			5.3	6	Zaqatala5b; Balakən, Qa — Cədvəl 4.2-nin ardı.
41	04.09.2015	04:49:37	40.97	47.43	15			5.9	7	Oghuz 6b; Shaki, İsmayıll , Mingechevir 5b; Pirquli , Shamakhy , Ganja , Zaqatala 4b; Guba , Qazakh, Shirvan 3b; Baku 2-3b
42	01.08.2016	04:46:35	39.91	47.85	28			5.6	5	Imishli, Beylagan, Zardab 5b; Aghdam, Kurdamir, Ucar 4b; Shamakhy , İsmayıllı, Ganja 3-4b; Shaki, Guba, Zaqatala, Baku, Lankaran, Nakhchyvan 3b
43	11.05.17	03:24:19	39.72	48.42	48			5.4	5	The earthquake was recorded 24 km to the south-east from Saatly in Saatly region. In the epicenter the magnitude of earthquake was 5 points, in surrounding areas 4-3 points.
44	16.06.2017	13:41:13	40.55	47.59	34			4.4	4	The earthquake was recorded 32 km to the north-west from Zardab station in Ujar. In the epicenter the magnitude was 4 points, in surrounding areas 3 points.
45	20.07.2017	6:22:34	39.91	48.34	54			4.4	4	Imishli 4b; Zardab 3b
46	15.11.2017	19:48:02	40.17	47.11	25			5.7	6	Barda, Ter-ter 5b; Ucar, Mingechevir,Ganja 4b
47	28.08.2018	12:57:14.8	38.72	48.63	15			5.0	5-3	The earthquake has been recorded 13 km to the west from Lenkoran station in Lerik

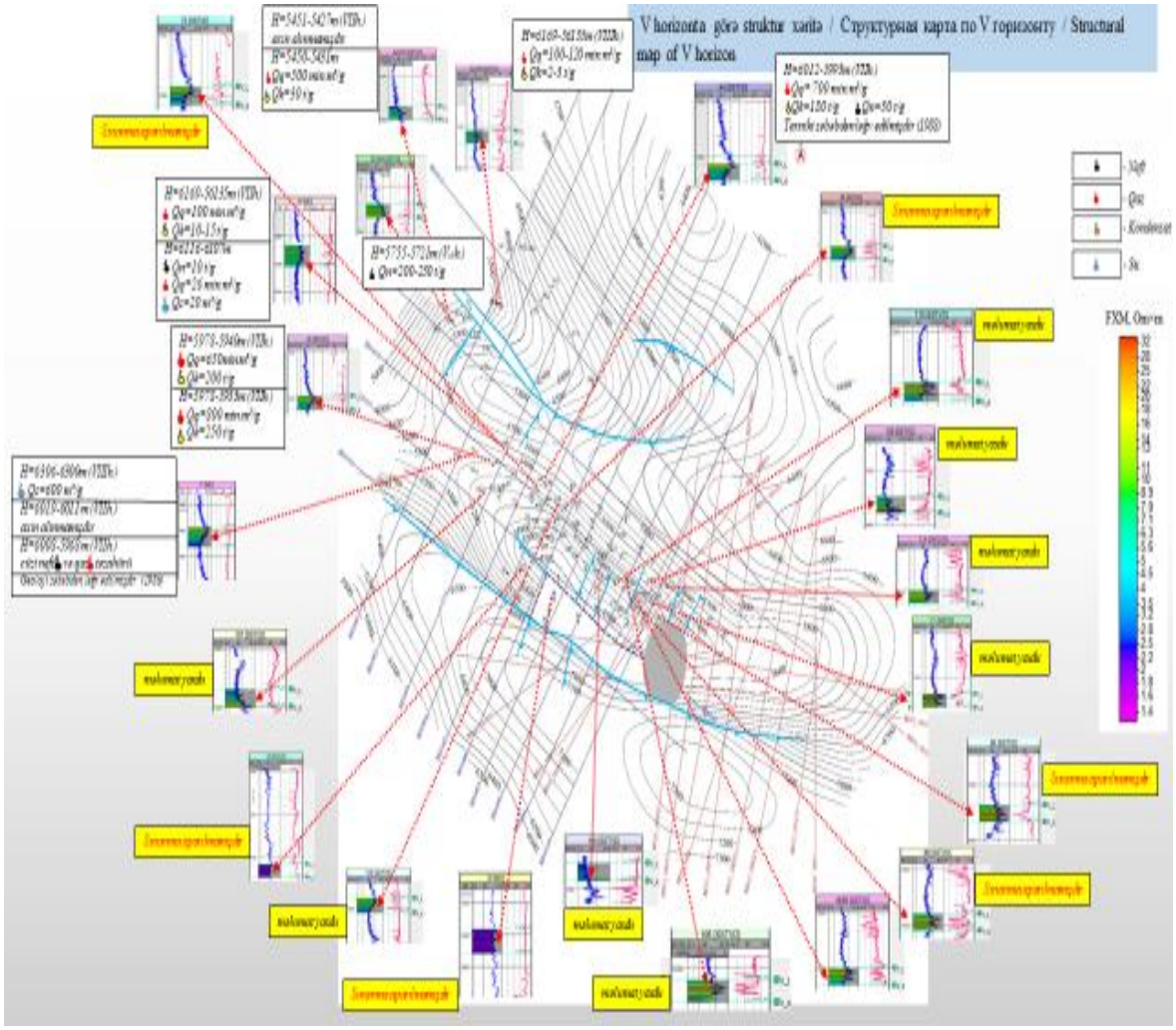


Figure 5. The comparative analysis of logging parameters acquired in oil horizons in wells in the field chosen conditionally (*SOCAR, Abasova P.J., Abilhasanova L.J., Shıkhmammadova T.N. at al., 2017*).

SUMMARY

1. It has been noted that due to the impact of geodynamic stress accumulating in the earthquake focal zones, the logging parameters of the oil and gas fields change as 15-25%.
2. The method is proposed for evaluation of geodynamic stress accumulated in the earthquake centers depending on the magnitude of the earthquake and the distance from the hypocenter.
3. It has been determined that the logging parameters acquired from the same oil-gas formations, from oil fields and from wells drilled nearby, were observed with an anomalous effect during the activation of the earthquake.

RECOMMENDATIONS

1. It is recommended to take into account the impact of geodynamic stress accumulated in the earthquake focuses while fulfilling well logging works in oil and gas fields.
2. The study of geological sections and oil and gas layers by use of geophysical parameters can be more effecient if to take into account the geodynamic stress leading to avoiding cases of missing oil and gas layers.

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