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PERIODICITY OF EARTHQUAKES IN THE CASPIAN SEA

(Представлено членом редакційної колегії д-ром геол. наук, ст. дослідником О. І. Меньшовим)

The Caspian Sea is the largest closed reservoir in the world. The strongest earthquake in the Caspian Sea was the 7.9 magnitude, the 1895 Krasnovodsk earthquake. The parameters of earthquakes with different magnitude in recent years in the Caspian Sea were analyzed and the characteristic depth was determined based on statistical data. Attempts to determine their periodicity and attempts to predict for the future have been made on the basis of statistical data of earthquakes occurred within the last 50 years in the Caspian Sea and surrounding regions. In the data taken from the earthquake catalog, parameters of earthquakes whose magnitude is above 5.0 were used. In recent years, earthquakes with a magnitude below 5.0 have been accompanied in the Caspian Sea. The characteristic depth of earthquakes is considered ±60 km. The probability of recurrence of an earthquake with a magnitude of 6.8 occurred in 2000 is likely to occur in 2050.

Keywords: Caspian Sea, earthquake, magnitude, depth, seismicity.

Introduction. The Caspian Sea is the largest closed reservoir in the world. The reason why earthquakes occur in the Caspian Sea is clear according to 3-D geodynamic model of the Caspian region after V.I.Ulomov (Fig. 1). The largest of the "coastal" seismic events known to have occurred there include 1895 Krasnovodsk, western Turkmenia magnitude 7.9 earthquake and the 1868 magnitude 7.8 event which occurred on the opposite coast of the Caspian Sea (*Ulomov et al., 2003*). The Caspian Sea region presents earthquakes with a variety of focal mechanisms including lateral faulting, large and small angle thrusting and also normal faulting, all of which have the potential to be affected by crustal flexure (Fig. 2) (*Ansari et al., 2020*). Fig. 3 and Fig. 4 illustrates epicenters of earthquakes occurred different years in the Caspian Sea region. Let's try to determine the periodicity of earthquakes by paying attention to the time of occurrence, the magnitude, using statistical data.

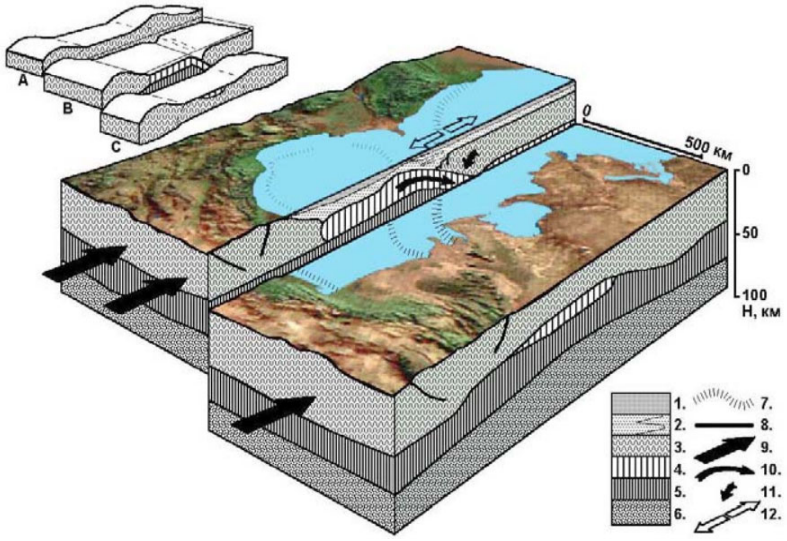

Fig. 1. 3-D geodynamic model of the Caspian region (after V.I. Ulomov).
Bottom: 1 – water layer; 2 – folded and faulted seafloor sediments; 3 – "granitic" layer; 4 – relicts of oceanic crust; 5 – "basaltic" layer; 6 – subcrustal substratum; 7 – highs in the gradient of isostatic anomalies; 8 – major tectonic faults; 9 – irection of pressure exerted by Arabian plate; 10 – direction of subduction for the southern Caspian oceanic lithosphere pluging under the Turanian-Scythian plate; 11 – direction of motion for the northern Caspian lithosphere as this is being involved into subduction; 12 – horizontal tension in the bending northern Caspian lithosphere producing normal slip movements in local earthquakes. Top-schematic dynamic three-block model: A – Caucasus block, B – Albourz Mountain – Caspian block, C – Kopet Dag – Turanian block (*See Ulomov et al., 2003*, fig. 3)

Materials and Methods. According to the official website (www.seismology.az) of the Azerbaijan Republic Seismic Survey Center, the periodicity of the earthquakes in the Caspian Sea was investigated using the catalogues of earthquakes from 01.01.2018 to 31.06.2021. During the analysis, parameters such as the moment of earthquakes, coordinates, depths, magnitudes were taken as the basis. On the basis of these materials, 4 graphs were drawn and these parameters were described in graphs. Each of the 4 graphs presents individual years. In the first graph describing 2018, earthquakes in the Caspian Sea were very few. This year the region had a quiet period. The graph, which presents the earthquakes in 2019, clearly shows that it is characterized by greater activity in comparison with other years. If we look at 2020, we can see that the hypocenters are mainly in excess of 50 km in depth. In the first 6 months of 2021, we again see hypocenters deep within 50 km. Overall, if we take into account the earthquakes that occurred in these 4 years, we can see that earthquakes occurred mainly at a depth of ±60 km. Over the years, the magnitude has been below 5.0 (Fig. 5, 6, 7 and 8).

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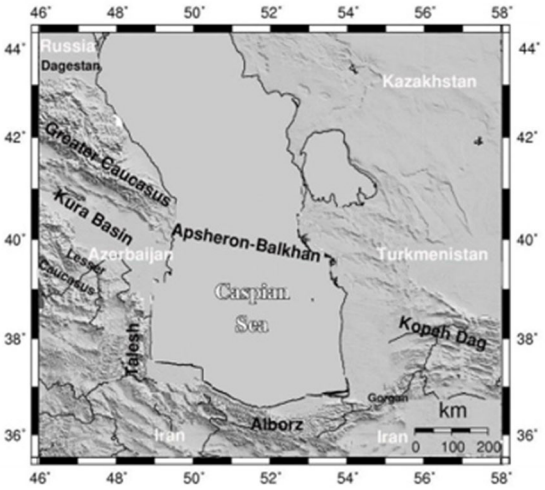

Fig. 2. The Caspian Sea surrounded by active seismic belts of earthquakes (after *Jackson et al., 2002*)

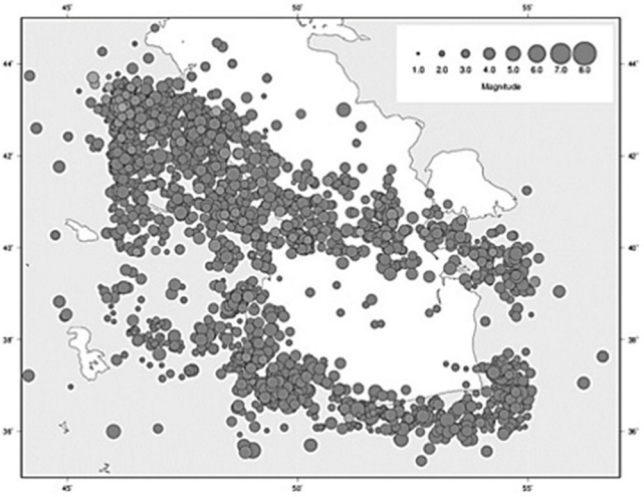

Fig. 3. Earthquake events occurred from 1931 to 2009 in the Caspian Sea region (*Ansari et al., 2020*)

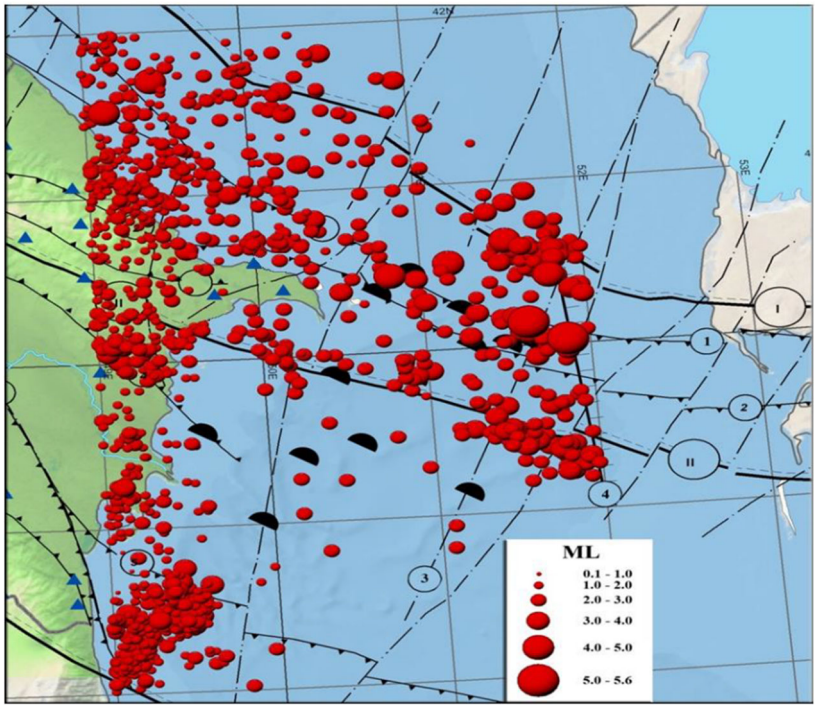

Fig. 4. Map of epicenters of earthquakes occurred in the Caspian Sea and nearby regions in 2014–2016 (*Abdullayeva et al., 2016*)

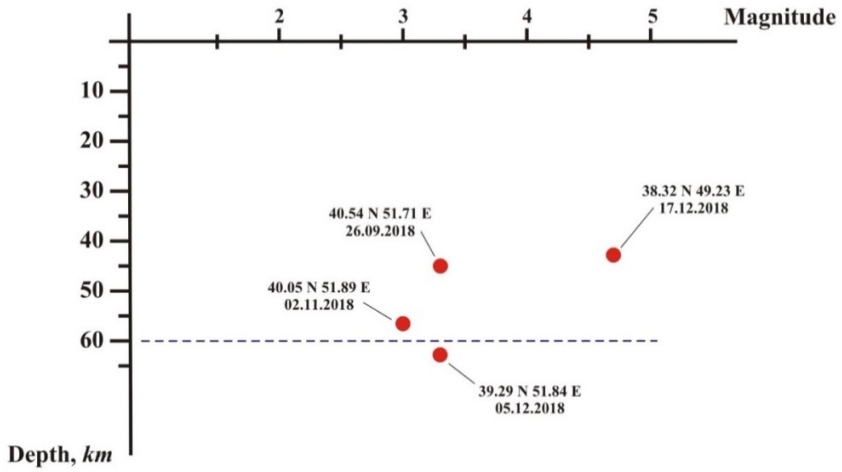

Fig. 5. Parameters of earthquakes in the Caspian Sea in 2018

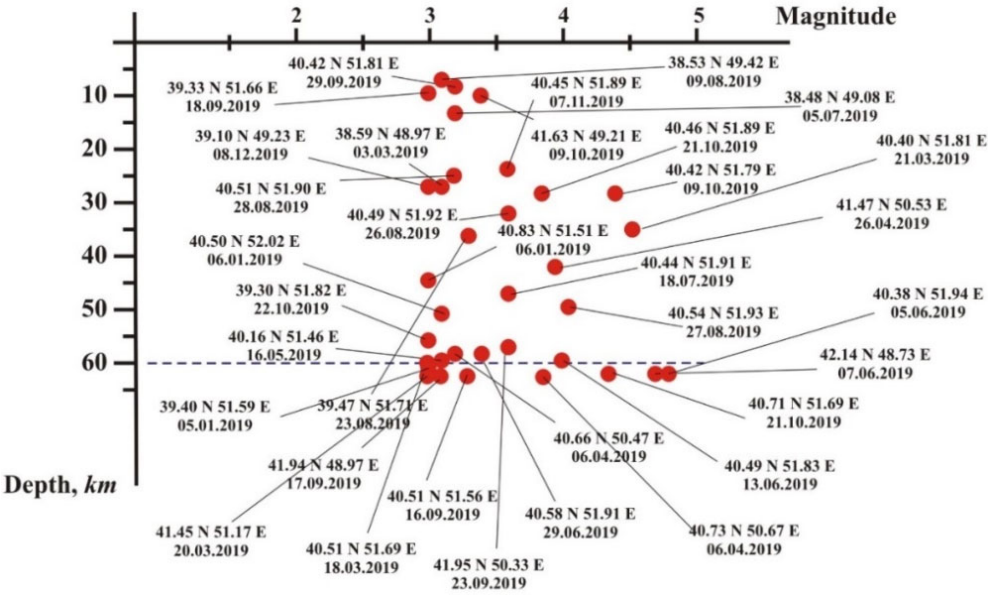

Fig. 6. Parameters of earthquakes in the Caspian Sea in 2019

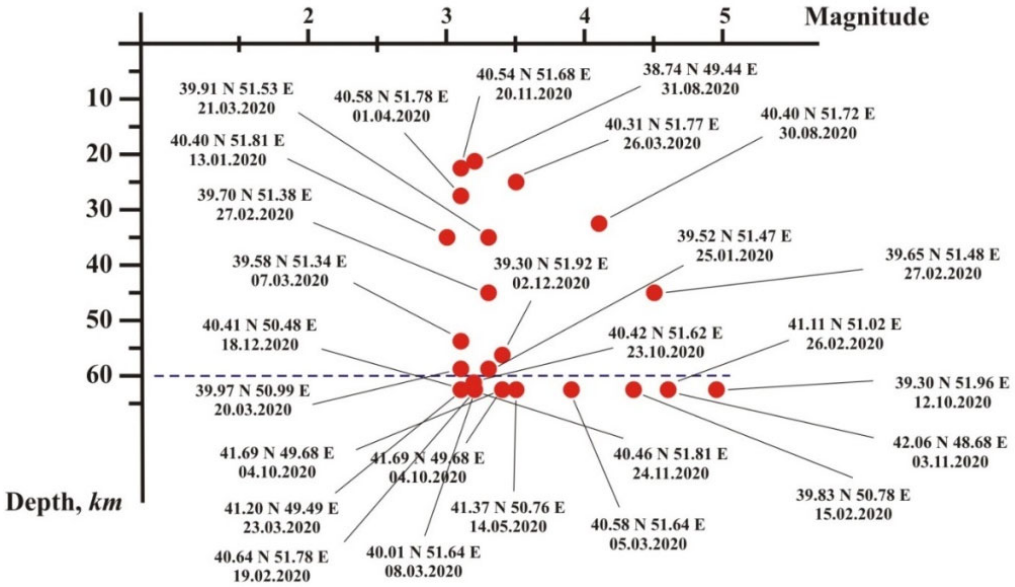

Fig. 7. Parameters of earthquakes in the Caspian Sea in 2020

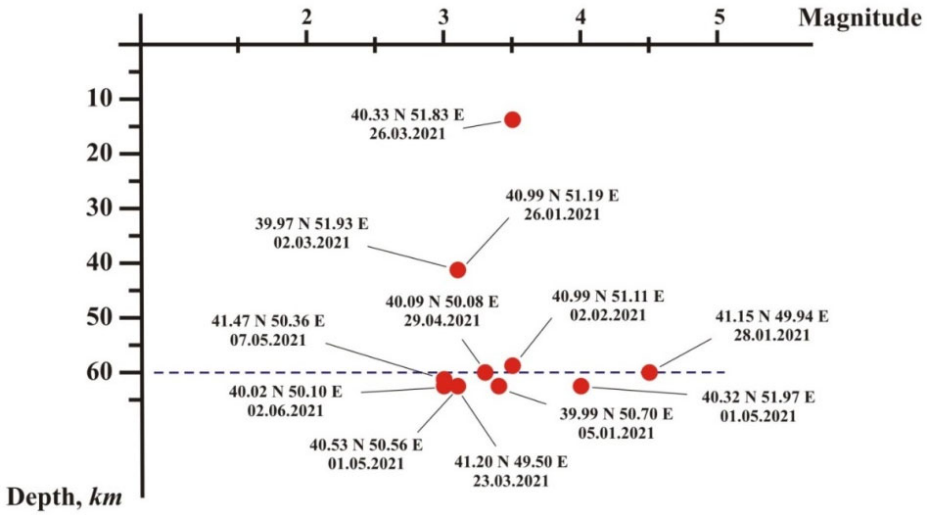

Fig. 8. Parameters of earthquakes in the Caspian Sea in 2021 (from 01 January to 31 June)

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The table 1 below presents the earthquakes in the Caspian Sea and nearby regions. Let's pay attention to the 49 earthquake parameters given in the table. This table includes earthquakes with M≥5.0. In these earthquakes, we can see only one earthquake with the highest magnitudes. It is an earthquake that occurred in 2000 with a magnitude of 6.8. A total of 7 earthquakes close to the magnitude of this earthquake have been observed since 1953. It also shows a repetition of several years of earthquakes with the same magnitude. Earthquakes of this type do not occur frequently in this region. But earthquakes with a magnitude of up to 5.0 frequently occur. If we pay attention to the depth of earthquakes, we can see that over the years the depth has been between 10–80 km.

Table 1

Parameters of earthquakes in the Caspian Sea and nearby areas, M≥5.0 (1953–2020) (www.earthquaketrack.com)

№	Earthquakes	Date	Location	Magnitude	Depth (km)
1.	Caspian Sea, Offshore Azerbaijan	25.11.2000 18:09	Epicenter at 40.245, 49.946 15.2 km from Baku (Baki, Azerbaijan)	6.8	50
2.	Caspian Sea, Offshore Azerbaijan	25.11.2000 18:10	Epicenter at 40.167, 49.954 23.2 km from Badamdar (Baki, Azerbaijan)	6.5	33
3.	Caspian Sea	16.09.1989 02:05	Epicenter at 40.337, 51.534 103.2 km from Pirallahı (Baki, Azerbaijan)	6.5	54
4.	Caspian Sea, Offshore Turkmenistan	06.03.1986 00:05	Epicenter at 40.368, 51.555 105.2 km from Pirallahı (Baki, Azerbaijan)	6.5	33
5.	Caspian Sea, Offshore Turkmenistan	17.09.1989 00:53	Epicenter at 40.203, 51.749 104.2 km from Türkmenbaşy (Balkan, Turkmenistan)	6.2	51
6.	Northwestern Iran	28.02.1997 12:57	Epicenter at 38.075, 48.05 24.2 km from Omidcheh (Ardabil, Iran)	6.1	10
7.	Northwestern Iran	09.07.1998 14:19	Epicenter at 38.717, 48.507 10.2 km from Lerik (Lerik, Azerbaijan)	6.0	26
8.	Caspian Sea	20.04.1966 16:42	Epicenter at 41.703, 48.238 3.2 km from Gereykhanovskoye (Dagestan, Russia)	6.0	20
9.	Caspian Sea, Offshore Azerbaijan	27.01.1963 19:35	Epicenter at 41.013, 49.732 30.2 km from Şuraabad (Xızı, Azerbaijan)	5.7	45
10.	Caspian Sea	21.03.1956 04:54	Epicenter at 40.932, 48.382 19.2 km from Basqal (İsmayıllı, Azerbaijan)	5.7	15
11.	Caspian Sea	04.08.1981 18:35	Epicenter at 38.072, 49.34 48.2 km from Hashtpar (Gilan, Iran)	5.6	27
12.	Caspian Sea, Offshore Turkmenistan	07.06.2014 06:05	Epicenter at 40.373, 51.574 106.2 km from Pirallahı (Baki, Azerbaijan)	5.5	30
13.	Caspian Sea, Offshore Azerbaijan	10.02.2014 12:06	Epicenter at 40.288, 48.803 21.2 km from Mughan (Hacıqabul, Azerbaijan)	5.4	64
14.	Caspian Sea	07.10.2012 11:42	Epicenter at 40.747, 48.437 3.2 km from Basqal (İsmayıllı, Azerbaijan)	5.4	17
15.	Northwestern Iran	03.01.1996 08:42	Epicenter at 38.994, 48.72 6.2 km from Masally (Masally, Azerbaijan)	5.4	56
16.	Caspian Sea, Offshore Azerbaijan	18.09.1961 11:01	Epicenter at 40.974, 50.107 45.2 km from Bilajer (Baki, Azerbaijan)	5.4	53
17.	Caspian Sea	30.04.1953 15:45	Epicenter at 41.13, 48.129 28.2 km from Qutqashen (Qəbələ, Azerbaijan)	5.4	15
18.	Caspian Sea	01.08.2016 04:46	Epicenter at 40.07, 48.069 22.2 km from Imishli (İmişli, Azerbaijan)	5.3	10
19.	Caspian Sea	29.09.2014 01:38	Epicenter at 41.197, 48.1 24.2 km from Kurush (Dagestan, Russia)	5.3	13
20.	Northwestern Iran	27.01.1986 16:35	Epicenter at 38.885, 48.62 9.2 km from Boradigah (Masally, Azerbaijan)	5.3	71
21.	Caspian Sea	13.08.1959 00:33	Epicenter at 39.786, 48.4 10.2 km from Əhmədbəyli (Saatlı, Azerbaijan)	5.3	35
22.	Northwestern Iran	11.07.2007 06:51	Epicenter at 38.751, 48.598 14.2 km from Haftoni (Lənkəran, Azerbaijan)	5.2	25
23.	Caspian Sea, Offshore Azerbaijan	07.01.2001 06:49	Epicenter at 40.171, 50.143 22.2 km from Türkan (Baki, Azerbaijan)	5.2	33
24.	Caspian Sea	21.03.2000 14:07	Epicenter at 39.949, 48.23 12.2 km from Saatlı (Saatlı, Azerbaijan)	5.2	59
25.	Caspian Sea, Offshore Turkmenistan	07.05.1997 16:16	Epicenter at 40.338, 51.633 112.2 km from Pirallahı (Baki, Azerbaijan)	5.2	50
26.	Caspian Sea, Offshore Azerbaijan	24.08.1989 18:55	Epicenter at 41.687, 49.273 46.2 km from Xaçmaz (Xaçmaz, Azerbaijan)	5.2	33
27.	Caspian Sea, Offshore Turkmenistan	11.06.1986 20:15	Epicenter at 40.245, 51.665 112.2 km from Türkmenbaşy (Balkan, Turkmenistan)	5.2	47
28.	Caspian Sea	03.02.1976 16:40	Epicenter at 39.933, 48.415 3.2 km from Saatlı (Saatlı, Azerbaijan)	5.2	58
29.	Caspian Sea	05.02.2019 19:31	Epicenter at 40.933, 48.624 26.2 km from Basqal (İsmayıllı, Azerbaijan)	5.1	10
30.	Caspian Sea	11.05.2017 03:24	Epicenter at 39.865, 48.602 17.2 km from Əhmədbəyli (Saatlı, Azerbaijan)	5.1	62

№	Earthquakes	Date	Location	Magnitude	Depth (km)
31.	Caspian Sea, Offshore Turkmenistan	12.11.1990 16:00	Epicenter at 40.254, 51.621 112.2 km from Pirallahı (Baki, Azerbaijan)	5.1	53
32.	Caspian Sea, Offshore Turkmenistan	17.09.1989 09:39	Epicenter at 40.259, 51.652 114.2 km from Türkmenbaşy (Balkan, Turkmenistan)	5.1	33
33.	Caspian Sea	02.12.1981 00:51	Epicenter at 40.926, 48.09 16.2 km from İsmayıllı (İsmayıllı, Azerbaijan)	5.1	33
34.	Caspian Sea	29.11.1981 23:37	Epicenter at 40.836, 48.078 8.2 km from İsmayıllı (İsmayıllı, Azerbaijan)	5.1	44
35.	Caspian Sea, Offshore Azerbaijan	07.02.1976 03:38	Epicenter at 40.345, 51.12 68.2 km from Pirallahı (Baki, Azerbaijan)	5.1	80
36.	Caspian Sea, Offshore Azerbaijan	14.12.1973 09:11	Epicenter at 41.876, 49.028 39.2 km from Xudat (Xaçmaz, Azerbaijan)	5.1	79
37.	Caspian Sea, Offshore Azerbaijan	28.08.2018 12:57	Epicenter at 38.834, 48.857 8.2 km from Lankaran (Lənkəran, Azerbaijan)	5.0	10
38.	Caspian Sea, Offshore Azerbaijan	26.01.2015 03:30	Epicenter at 41.292, 48.875 13.2 km from Divichibazar (Shabran, Azerbaijan)	5.0	50
39.	Caspian Sea, Offshore Azerbaijan	11.02.2002 16:18	Epicenter at 40.102, 50.211 29.2 km from Türkan (Baki, Azerbaijan)	5.0	54
40.	Caspian Sea	05.06.2001 15:33	Epicenter at 42.472, 48.634 53.2 km from Derbent (Dagestan, Russia)	5.0	60
41.	Caspian Sea, Offshore Azerbaijan	29.11.2000 10:44	Epicenter at 39.856, 50.209 56.2 km from Türkan (Baki, Azerbaijan)	5.0	33
42.	Northwestern Iran	02.11.1994 12:31	Epicenter at 38.152, 48.315 11.2 km from Ardabil (Ardabil, Iran)	5.0	10
43.	Caspian Sea	21.05.1991 17:37	Epicenter at 42.867, 48.028 30.2 km from Manaskent (Dagestan, Russia)	5.0	10
44.	Caspian Sea, Offshore Turkmenistan	17.09.1989 01:21	Epicenter at 40.243, 51.694 110.2 km from Türkmenbaşy (Balkan, Turkmenistan)	5.0	53
45.	Caspian Sea, Offshore Turkmenistan	11.06.1986 12:41	Epicenter at 40.302, 51.673 113.2 km from Türkmenbaşy (Balkan, Turkmenistan)	5.0	33
46.	Caspian Sea, Offshore Turkmenistan	01.05.1986 03:31	Epicenter at 40.242, 51.657 113.2 km from Türkmenbaşy (Balkan, Turkmenistan)	5.0	48
47.	Caspian Sea, Offshore Turkmenistan	23.03.1986 14:26	Epicenter at 40.346, 51.629 111.2 km from Pirallahı (Baki, Azerbaijan)	5.0	33
48.	Caspian Sea, Offshore Turkmenistan	07.03.1986 02:21	Epicenter at 40.366, 51.559 105.2 km from Pirallahı (Baki, Azerbaijan)	5.0	40
49.	Caspian Sea, Offshore Azerbaijan	19.11.1981 14:10	Epicenter at 40.734, 49.193 19.2 km from Kilyazi (Xızı, Azerbaijan)	5.0	33

To see earthquakes in more detail, Fig. 9 and Fig. 10 come to our aid. Fig. 9 shows that the last 20 years have been accompanied by relatively still periods. During the years of 1980–2000, there was a noticeable activity. This resulted in the occurrence of the highest magnitude earthquake (M=6.8) in 2000. Fig. 10 shows that over the past 20 years, earthquakes below magnitude 6.0 have been observed. This can be explained by the fact that after the earthquake in 2000, there was a sufficient discharge of energy. If we look at the preparation process of the earthquake in 2000 based on these data, we can say that the probability of an earthquake with this magnitude or an earthquake with a magnitude above it is not expected in the coming years.

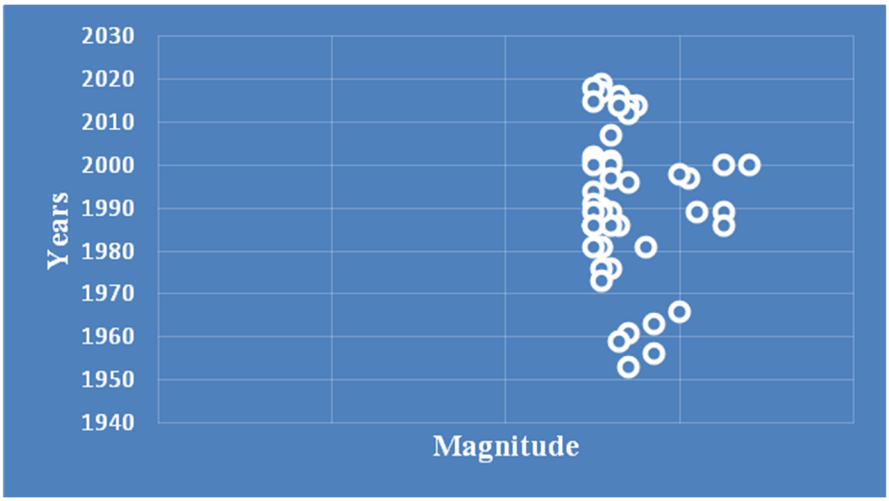

Fig. 9. Description of earthquakes with magnitude above 5.0 in the Caspian Sea and nearby areas over the years of 1953–2020

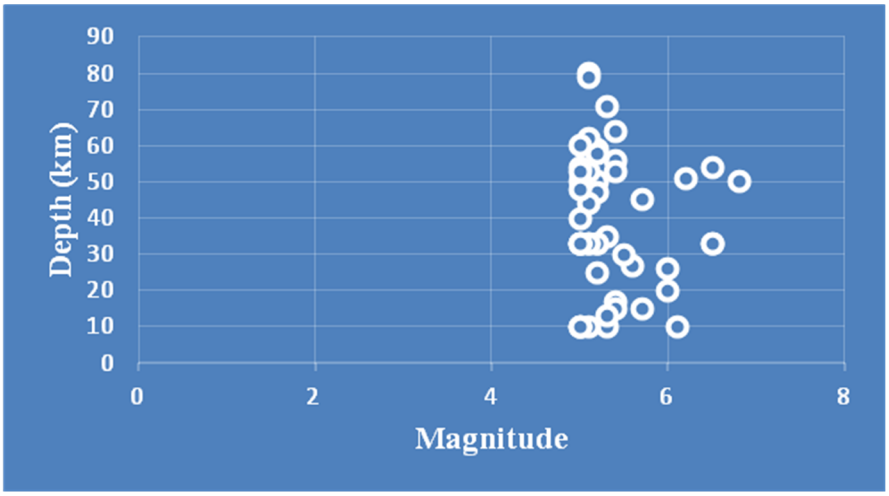

Fig. 10. Distribution of earthquakes over 5 magnitude by depth in the Caspian Sea and nearby areas during 1953–2020

Results and discussion. The periodicity of the earthquakes in the Caspian Sea in 2018–2021 was considered. 2018 was observed with relatively quiet seismicity. 2019 was accompanied by more earthquakes than in previous years. But over the years, earthquakes above magnitude 5.0 did not occur. The highest magnitude was 4.7 in 2018, 4.8 in 2019, 4.9 in 2020, and 4.5 in the first 6 months of 2021. Earthquakes in 2018–2021 covered a depth of up to 62 km. The main characteristic depth was determined ±60 km. So, earthquakes at this depth occurred more often. The analysis of the statistical data of M≥5.0 earthquakes in the Caspian Sea and nearby areas since 1953 showed that the maximum depth of the earthquakes was 80 km, and the minimum depth was 10 km. In addition, the maximum magnitude was 6.8, which was an earthquake that occurred on 25.11.2000 at a depth close to the characteristic depth I mentioned above, at a distance of 15.2 km from Baku.

Conclusion. If we try to predict earthquakes for the future, we can express our opinion using the help of the graph below (Fig. 11). So, if we mark the increase trajectory of earthquakes in the last 50 years with a red line, we can mark the trajectory with a yellow line in the next 50 years, considering the repetition of the same trajectory. Thus, the probability of an earthquake with a magnitude close to 7.0 is likely to be in 2050. This can be explained by the fact that in order for highest magnitude earthquake to occur, the process of higher energy discharge must take place. This means that the highest energy discharge occurred in the Caspian earthquake in 2000. After that, for the reoccurrence of such an earthquake, a lot of energy is necessary to be collected. The process of energy collection has been going on and on since 2000 till now. I hope our probability will not come true.

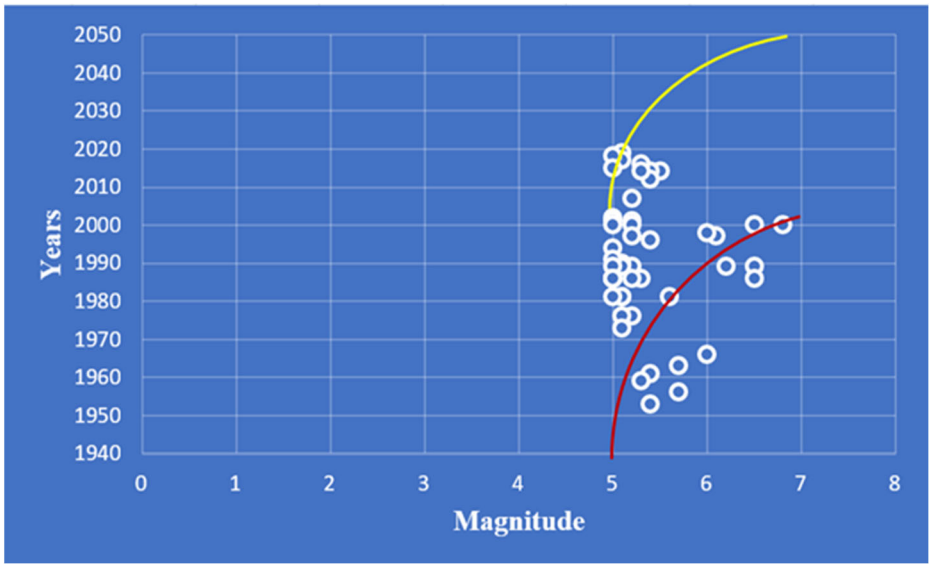

Fig. 11. Trajectory of earthquakes in the Caspian Sea (indicated by red line) and probable trajectory (indicated by yellow line)

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ПЕРІОДИЧНІСТЬ ЗЕМЛЕТРУСІВ У КАСПІЙСЬКОМУ МОРІ

Каспійське море є найбільшим закритим резервуаром у світі. Найсильнішим землетрусом у цьому районі був Красноводський землетрус 1895 магнітудою 7,9. Проаналізовано параметри землетрусів у Каспійському морі різної магнітуди за останні роки, на основі статистичних даних визначено характерну глибину. Спроби визначити їх періодичність та спрогнозувати їхню появу робилися на основі статистичних даних про землетруси, що сталися за останні 50 років у Каспійському морі та найближчих регіонах. У даних, узятих із каталогів землетрусів, використовувалися параметри землетрусів магнітудою вище 5,0. В останні роки в Каспійському морі зафіксовано землетруси магнітудою нижче 5,0. Характерна глибина землетрусів становить ±60 км. Імовірність повторення землетрусу магнітудою 6,8, що стався 2000 року, досить висока у 2050 році.

Ключові слова: Каспійське море, землетрус, магнітуда, глибина, сейсмічність.

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