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Research Article

Complex Analysis of the Geodynamic Conditions of the Absheron-Balkhan Oil and Gas Zone

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Abstract:

The Absheron-Balkhan oil and gas area is located in the contact zone of the Scythian-Turanian platform with the South Caspian basin (SCB).
The purpose of the work is to study the features of geodynamics of the zone of the junction of the South Caspian basin and the Scythian-Turanian epi-Hercynian platform. The research methodology combines a complex analysis of geological, seismological, geomorphological, and geodetic data on the studied area. Geological and geophysical data in particular on regional profiles were used to link earthquakes to specific geological structures. The high seismic activity of the study area, the observation of crustal deformations at the edges of the basin (based on GPS data), and the development of mud volcanism indicate that the geodynamic conditions of the basin are active. Analysis of the focal mechanisms and depths of earthquakes proves that they are not specific to collision structures. Analysis of the seismic events data shows that the subduction of the oceanic crust of the SCB in the zone of the Absheron threshold under the continental crust of the Scythian- Turanian is the main geological event that caused seismic activity in modern times.
New data obtained on the basis of a detailed analysis of seismic conditions in the study area can be used to accurately assess the geodynamic development of the region.

1. Introduction

The northern flank of the South Caspian Basin is more interesting according to its complex tectonic structure and seismicity. This zone is the junction point of the Scythian-Turanian epi-Hercynian platform and the Alpine structures of Caucasus-Kopeh Dagh, as well as the Absheron-Balkhan threshold, which separates the southern and northern Caspian. Anomalies of gravity, magnetic, thermal, and other geophysical fields, and high seismic activity are observed here. The Apsheron–Balkhan zone of uplifts accommodates the main hydrocarbon resources of the SCB is another important feature of this territory.
Until the 2000s, the origin of the very large negative gravity anomalies and deep-focused strong earthquakes observed here was controversial due to the lack of accurate and reliable seismic data on the depth structure of the northern flank of the basin. However, both features were a direct and reliable source of information about the collision of two consolidated crusts of different origins in the transition zone to the platform and the subduction event that occurred here. In order to determine the origin of earthquakes, it was necessary to determine the structure of the earth's crust in the transition zone on the basis of seismic data. However, until the 1990s, seismic surveys in the Caspian Sea provided information to a depth of 12-16 km.
A wide range of seismic, gravimetric, geothermal, seismotomographic, etc. studies were carried out to determine the structure of the sedimentary cover of SCB, the structure of the crystalline base, the history

of development, and the characteristics of sedimentary rocks during the last years [1, 3, 5, 7, 10,13, 14, 17]. These new pieces of information and evolutional progress in the tectonics of the depression require a new scientific approach to the structure of the lithosphere of the basin and the study of the origin of earthquakes in the region.

The purpose of the work is to study the features of the geodynamics of the zone of the junction of the South Caspian Basin and the Scythian-Turanian epi-Hercynian platform.

The research methodology combines a complex analysis of geological, seismological, geomorphological, and geodetic data on the studied area. Geological and geophysical data in particular on regional profiles were used to link earthquakes to specific geological structures.

2. Material and Methods

2.1 Geology of studied area and deep stucture

In the earth's crustal structure, the South Caspian Basin differs significantly from both the northern part of the Caspian Sea depression and also the surrounding mountain systems. The deep seismic soundings carried out in the South and, partly, Middle Caspian basin and on the adjacent land revealed principal features of the deep structure in the region under consideration, which includes different zones [8].

The Middle Caspian depression was formed on the foundation of the Hercynian fold and involved only the Mesozoic and Cenozoic eras. However, the lithosphere of the South Caspian has a completely different structure, and there are two layers (sedimentary and basalt layer) in the structure of its crust. The South Caspian mega-depression corresponds to a gravity minimum complicated by positive anomalies in its southeastern and southern parts. On the northeast, and west gravity gradients related to deep-seated faults border the depression [8].

The existence of an oceanic type thin crust (8-10 km) at the base of the South Caspian Basin is confirmed by seismic methods (Deep Seismic Sounding, Ultra-Deep seismometry by the method of Common Depth Point), seismotography method, and also according to the results of functional analysis of seismic waves [2, 5, 13]. The fact that the foundation of the basin has a thin oceanic crust, and the subduction of the consolidated crust under the Scythian-Turanian epi-Hercynian platform in the Absheron threshold zone is reflected in Ultra-Deep seismometry by the method of Common Depth Point (UD-CDP) time sections (Fig.1) and other seismic models [3, 10, 13].

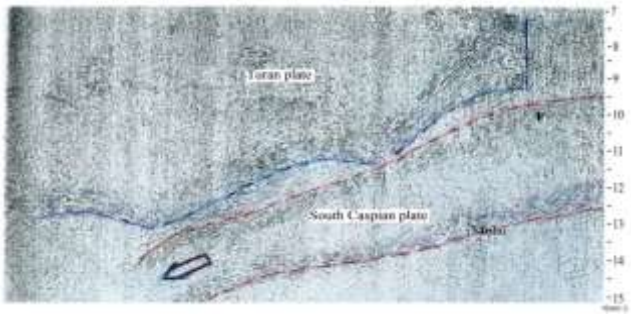

Figure 1. *Subduction model of the South Caspian lithosphere (NW-SE) beneath the Scythian- Turanian epi-Hercynian platform at the Absheron Ridge (Interpretation of Mammadov P.Z.)*

The depth models of the Caspian lithosphere compiled on modern gravimetric data, show that the very large negative gravity anomaly (~130 mGal), which is observed at the junction area of the South Caspian basin with the Scythian-Turanian epi-Hercynian platform, is explained by the low of compressed mass due to subduction [7].

All subduction zones are the zone of plate collision, high geodynamic stress, and degassing of the earth. Here, active seismic processes related to the formation of fractures and deformations occur more intensively than in other areas of the depression.

Coming from this position, it became necessary to study the relationship of the seismic activity with deep layers of the lithosphere of SCB and the accretionary prism that has formed over subducting crust from scraping from its surface Mesozoic-Paleogene formations.

2.2 Features of relief of the studied area

As expressed in the Caspian seafloor topography, the Middle Caspian Basin is separated from the South Caspian Basin by the Apsheron–Balkhan zone of uplifts, which bridge the fold systems of the Greater Caucasus and Kopeh Dagh. It consists of two chains of brachyanticlines, the western of which is located immediately north of the Apsheron Peninsula. They are the Central Caspian Basin to the north of this ridge and the SCB to the south of it. An oceanic type of crust is believed to exist within the South Caspian Basin. The northern boundary of the SCB is a submerged line of structural highs that forms the so-called Absheron–Balkhan Ridge [8].

2.3 Seismicity of the studied region

Historically, it is known that strong earthquakes with magnitude (M) > 7.0 occur on the southern, western,

and eastern coasts of the Caspian basin (M=8.1 in 856; M=8.0 in 959; M=7.8 in 1668; M=7.9 in 1895; M=7.4 in 1990). Earthquakes occurred at greater depths (D=92 km, M=3.5 in 1982; D=80 km, M=5.0 in 1976; D=75 km, M=3.5 in 1986; D=74, M=5.2 in 1986) in the central water area of the Caspian Sea, as well as strong earthquakes related to this zone occurred in different years (M=6.4 in 1911; M=6.0 in 1961; M=6.2 in 1963; M=6.2 in 1986; M=6.3 in 1989). It belongs to the crust of the majority of the earthquake focuses that occurred in the eastern part of Kopeh Dagh and the Greater Caucasus. The distribution of deep earthquake focuses (more than 70 km) is related to the upper parts of the mantle in the Middle Caspian, as well as in the North Caucasus [9, 18]. According to the researchers, the strong earthquakes that occurred on the western side of the Caspian Sea (East Caucasus), on the Absheron Peninsula, in the Turkmenbashi and Greater Balkhan regions correspond to deep faults in the places where two continental-type lithospheric blocks collided The oceanic crust has already subducted in these areas, and the microcontinental plates pushing it from the south to the north collided with the Scythian-Turanian platform. Analysis of the current seismic condition of the SCB shows that its central part is characterized by a relatively weak seismic activity, while the northern edge zone (together with adjacent areas of the Middle Caspian) was always and still characterized by higher seismic activity (Fig.2).

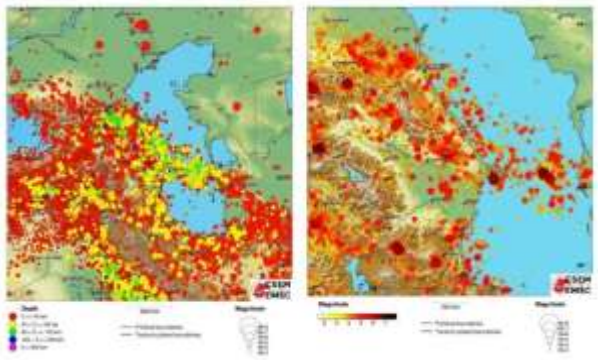

Figure 2. *Distribution of earthquakes in the Caspian region (Earthquake reported by RSSC of Azerbaijan National Academy of Sciences. This seismicity maps have been generated by concatenating the ISC catalogue since 1964), the EMSC Euro-Med Bulletin catalogue and the EMSC Real Time catalogue.https://www.emsc-csem.org/Earthquake/earthquake.php?id=743130#*

Here, very strong crust-mantle originated earthquakes had taken place along with crustal earthquakes. Occurrence of the majority of the earthquake focuses at depths greater than 30 km along the northern flank of the SCB indicating that they are not peculiar to a collisional structure. A lot of earthquakes occurred in the Absheron sill and in the pre-platform zone within the accretionary prism [11].

Focal mechanisms of most deep (D>30 km) and strong (M≥5.0) earthquakes on the top level of the consolidated crust, mainly characterized by extension stresses which are likely associated with the bending with degrees more than 22-25^0 and with subduction of the South Caspian plate, whereas in the pre-platform zone with ruptures and by fragmentations of the platform edges and with the displacement of its blocks (Fig.3).

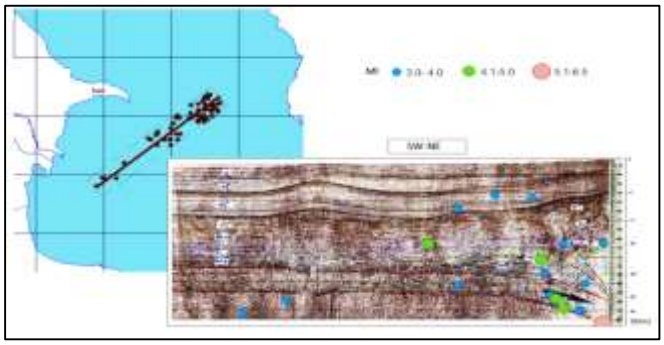

Figure 3. *The location of the earthquake focuses on the UD-CDP time section*

Analysis of the focal mechanisms has shown that earthquakes at depths of 15-25 km within the accretionary prism are mainly associated with compression stress condition and formation of thrusting-nappe structures [11].

The recording of weak but deeper earthquakes in the studied area in recent years suggests that the subduction process continues today (Fig.4).

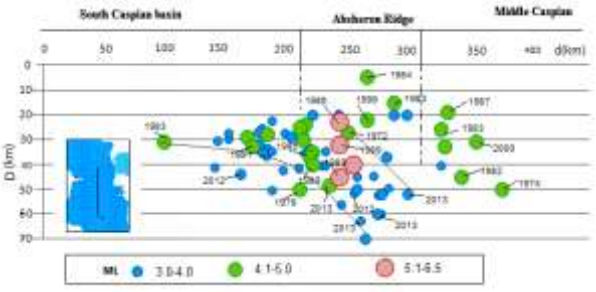

Figure 4*. The date (year) of the occurrence of earthquakes is indicated on the seismological section (during the years 1970-2013)*

2.4 Geodetic data

The measurements of the Global Positioning System (GPS) of space geodesy used in the Caucasus-Caspian region made it possible to study horizontal displacements in the upper layers of the earth's crust, the movement of plates and other geophysical issues

[6, 15, 19].

It was revealed that as a result of the movement of the Arabian plate in the north direction, the South Caspian microplate is subjected to compression pressure from the Alborz side at the current stage. Right-sided sliding movements with the speed of 11±1 mm/year were observed along the Western Caspian fault on the western side of the South Caspian Basin and horizontal displacements with the speed of 6.9-7.9 mm/year on the southeastern side of the depression [4, 12]. It is mentioned in some studies that the speed of horizontal movements in the northwest direction in the SCB is 6.5 ± 2 mm/year and greater (7-10 mm/year) [5, 16].

3. Results and Discussions

The South Caspian Basin is surrounded by active mountain zones on all sides. The Kopeh Dagh, Alborz, and Talysh mountains, which connect the eastern, southern, and western sides of the basin, are observed with earthquakes not deeper than 30 km. In contrast, earthquakes were observed in the Absheron-Balkhan threshold, which covers the northern part of the basin, at depths greater than 30 km. Tectonically, the Absheron-Balkhan threshold is located at the junction of the South Caspian oceanic crust and the epi-Hercynian Scythian-Turanian continental crust.

Seismic events, mainly in the northern part of the South Caspian Basin are necessary to study the geodynamic conditions of this area, and to determine the causes of earthquakes. It was observed that the strongest and deepest earthquakes, as well as tectonic processes, occurred in the northern flank of the South Caspian Basin, in the Absheron-Balkhan fold zone, and in the pre-platform area. Analysis of the focal mechanisms and depths of earthquakes proves that they are not specific to collision structures. The high seismic activity of the study area, the observation of crustal deformations at the edges of the basin (based on GPS data), and the development of mud volcanism indicate that the geodynamic conditions of the basin are active. Analysis of the seismic events data shows that the subduction of the oceanic crust of the SCB in the zone of the Absheron threshold under the continental crust of the Scythian- Turanian is the main geological event that caused seismic activity in modern times.

Practical-scientific significance of the work: New data obtained on the basis of a detailed analysis of seismic conditions in the study area can be used to accurately assess the geodynamic development of the region.

4. Conclusion

Due to the powerful geodynamic pressure from the south to the Anatolian-Iranian block of microcontinents in front of the Arabian plate studied area of earthquakes is remaining as a mobile zone and is characterized by periodic "revivals" of subduction and deformations within sedimentary cover (compression, folding, bulging, mud volcanism, etc.). Thus, based on the analysis of existing seismic data and seismological dataset, it is proved that activation of seismicity on the northern edge of the South Caspian Basin is related not to the hypothetical and unconfirmed existing data about sub-vertical faults, but to subduction of South Caspian Basin and tectonic deformations within the accretionary prism.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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