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Plume Mantle Model, Seısmogeodynamıc Sıtuatıon And Hydrocarbon Perspectıves Of Deep Layers In The Caspıan Basın

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ABSTRACT
Designing of detailed models of oil and gas basins discovered on the Earth makes it possible to correctly define the direction of exploration works. At present, with development of new technologies and equipment, we observe the increased importance of exploration for oil accumulations in the deep layers of hydrocarbon bearing basins. Currently one of the pivotal tasks consists in development of a modern geodynamic model taking into consideration the paleogeomorphological and seismo-tectonic features of Caspian basin and define future hydrocarbon exploration in deep layers.
KEY WORDS: *geodynamic stress, seismically active zones, horizontal movements, plate tectonics model, plume mantle model, buried intrusives, gravity field, deformation, circular-spiraled anticline structures, hydrocarbon perspectives.*

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Plume Mantle Model, Seısmogeodynamıc Sıtuatıon And
Hydrocarbon Perspectıves Of Deep Layers In The
Caspıan Basın: Review of Literature

To date several models of the Caspian basin (geosynclinal, mobilism, plate tectonics, plume mantle, etc.) have been designed on the basis of various notions and available geological, geophysical and seismological data [1, 2, 3, 4, 9]. These models enable us to derive knowledge on global tectonic processes, existed continents and oceans, display mechanisms of geodynamic stress accumulated in seismically active areas, mineral resources and oil and gas structures evolution and the genesis and migration of accumulated hydrocarbons.

In the past the evolution of mountain ridges, vast troughs, destructuve earthquakes, mud volcanoes and other natural phenomena were explained by mythical considerations and notions. Since the start of the last century the data acquired by geophysical equipment allowed to design more precise models explaining evolution history of oil and gas basins applying available scientific knowledge [1, 2, 3].

Up to the 60-ies of the XX century the basin evolution was explained according to fixism theory based majorly on the principle of isostasy and vertical movement of geostructures. Accordingly, the lithosphere was modelled as consisting of sedimentary, granite (continental) and basalt (oceanic) layer.

With the advent of GPS – Global Positioning System the plate tectonics model has been designed applying the latest available data [1, 11].

It has been substunsiated that the lithosphere with 250-90 km thickness is divided into continental and oceanic troughs by deep regional faults. Until now the horizontal motions, spatial positions, geodynamic stress and seismic activity of plates, tectonic blocks and large geological structures observed in various regions around the globe has been explained based on “Plate tectonics” theory. In Azerbaijan the acquired geophysical data is explained also according to this model.

For the last 20 years the geophysical and seismological stuides have been carried out across the whole area of Caspian basin applying the latest techniques and state-of the- art equipment. Results of geophysical studies performed in Azerbaijani section of Caspian sea allowed to design a different model of the Caspian on the basis of latest data. For the last years the Exploration Geophysics Branch of SOCAR GGD have performed

2D seismic survey by CDP technique on regional profiles across the southern slope of Great Caucasus and Middle Kur depression and acquired a large amount of data. Wide coverage of the Caspiian sea by 2D and 3D seismic survey allowed to study 8-10 km depth interval and resulted in drilling of wells deeper than 7000m, which make it possible to study in more detail trhe geological section. As a result of geophysical studies in Azerbaijan the areas of geodynamic stress were identified, areas with predicted intensification of activity in fault zones, areas with expected strong earthquakes have been defined [7, 9].

The Caspian basin is one of the largest geomorphological structures on the Earth (Fig.1). In evolutaion of the basin the plume mantle processes played more important role in comparison to the plate tectonics. The plaeocontour of the basin is characteristically displayed by abnormal effect in the gravity field across the area (Fig.2).

Figure 1. Paleomorphology of the Caspian basin.

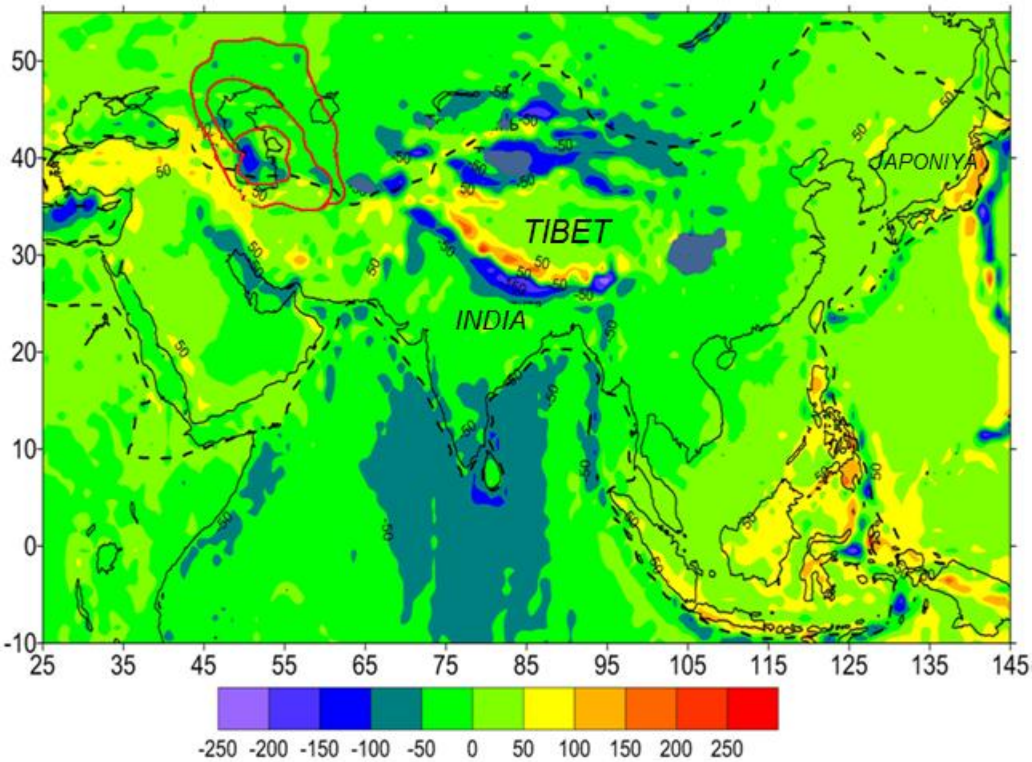
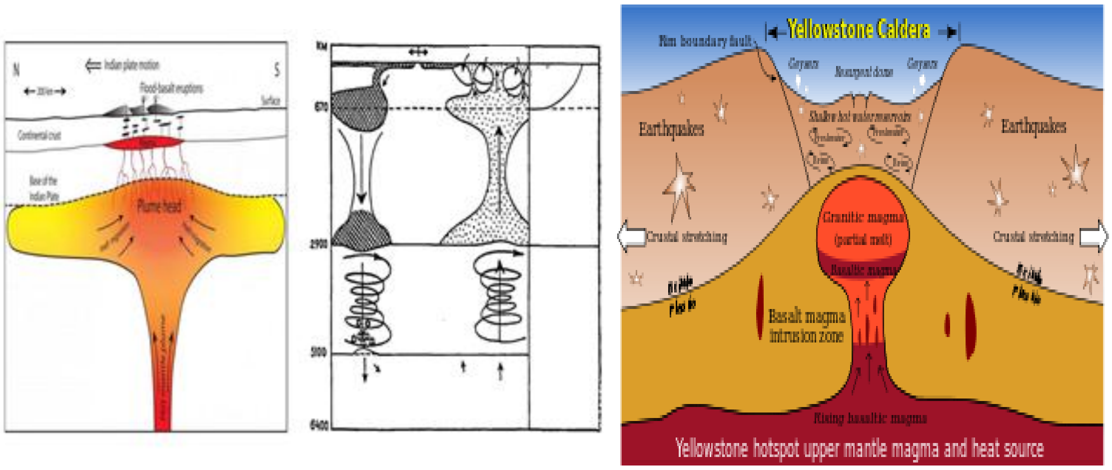


Figure 2. Paleocountour of the Caspian basin on the gravity map.

The aim of this study is the research on Caspian basin evolution on the basis of Sh.Maryama model [4, 5] and "plyum mantle" theory developed in 1965 by Tuco Wilson. In our point of view, in geological past the excitation emerged in the core-mantle transition zone caused the movement of the magma-like plume [5] to the

earth surface. (Fig. 3). In the area corresponding to the paleogeomorphological setting of the Caspian basin it can be seen from the schematic models for the plume that: a) Plume was moving to the earth crust and caused vertical and horizontal displacements in the lithosphere; b) Plume movements to the earth crust influenced the geodynamic situation in the area by its spiral-shaped and other motions; v) Plume was cooling in the lithosphere creating morphostructure attributed to the Caspian basin. These geodynamic processes continue currently. As a result, the earthquakes take place in areas surrounding the plume.
According to the PaleoCaspian (Fig.3a) territory the plume moving from the mantle to the earth surface created the base for basin evolution. These consisted of buried intrusives with changed morphostructure, activization of magmatism at various geological ages and volcano eruptions in some places. At later stages the plume activity became weaker and entered into the cooling-hardening stage with later development of Caspian basin in this area (Figure 1).



a) b) v)

Figure 3. Supposed schematic models of the Plume in the area of Caspian basin:

a) The movement of the plume to the earth surface generating vertical and horizontal displacements in the lithosphere;
b) Spiraled and diverse shaped movements of the plume in earth crust direction; v) Cooling phase of plume in the lithosphere and evolution phase of morphostructure of Caspian basin.

The area of plume mass outlined by characteristic local minimum in gravity field [6] corresponds to the morphology of PaleoCaspian (figure 3b). Temperature variation on temperature map shows configuration corresponding to circular form of the Caspian basin [7].

Seismic activity areas of circular form across the territory of Caspian basin and observed circular regional faults reflect geodynamic stress in the current Caspian basin area [9].

At present, researchers make attempts to explain time-spatial motions of plates, tectonic blocks and large geological structures, their spatial position, geodynamic stress and current seismic activity on the basis of observed horizontal movements [10, 11]. Observations by use of GPS stations are done across the territory of Caucasus since 1991 and across the territory of Azerbaijan since 1998 in 26 locations by Institute of Geology and Geophysics and since 2012 in 24 locations by Republican Seismological Service Center of Azerbaijan Academy of Sciences. As a result, in each observation point the vectoral direction and displacement value of current horizontal movement is calculated and drawn in maps. Studies carried out in Azerbaijan allowed to outline zones of geodynamic stress, areas of supposed increase of activity in fault zones and possible instant events and strong earthquakes. According to the data acquired until now the movement is more active in the south-eastern part of Small Caucasus with 9-12 mm/year value while in the Great Caucasus the movement is in the north-north-eastern direction with 12 mm/year rate [11, 12](Figure 4).

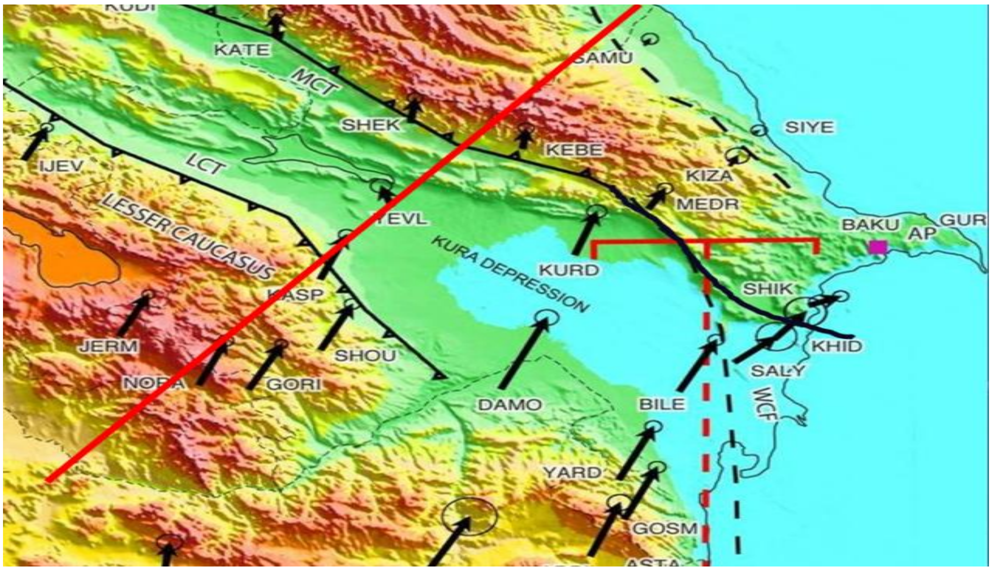


Figure 4. Map of horizontal movements on the territory of Azerbaijan [11, 12].

The question is whether horizontal motions observed on the earth surface are traced by characteristic features of deformations of layers in geologic section, change of fault directions and generation of stress areas? The other question is whether the horizontal movement of troughs, blocks and geomorphological structures is fully reflected?

Deformations and displacements are actively observed in the upper part of section in 2D profiles acquired by CDP method across the southern slope of the Great Caucasus in two depth intervals from 50-100 m to 3500-4000 m. Faults are gradually gaining the inclined form. Deeper at 3500-9000 m interval the number of faults are lesser and keep their previous vertical direction with relatively less deformation features in layers (Figure 5).

The layered form of horizontal displacement is observed within the sedimentary sequence along with geodynamic stress and blocks motion (figure 5). In our point of view, it is quite complicated to trace different horizontal movements by GPS surveys.

In the map of epicenters and depths of hypocenters of earthquakes for the territory of Azerbaijan the changes of seismic activity in the above indicated intervals is observed in the circular form (Figure 6). Despite the large number of earthquakes occurred in the upper 3-5 km portion of the earth crust their magnitude is not higher than M≥4. Deformations in this interval are intensive and despite the high rate of horizontal movements the tectonic displocations and large number of faults decrease the stress energy. Relatively strong earthquakes with M≥6-8 occur within 7-20 km interval leading to large destructions. It can be seen from seismic sections that within 7-20 km interval the deformation is not characteristic. Due to large number of instant events-earthquakes the huge amount of energy is released leading to drop of geodynamic stress. Earthquake focuses is observed in areas attributed to the contact zones and tectonic dislocations within blocks.

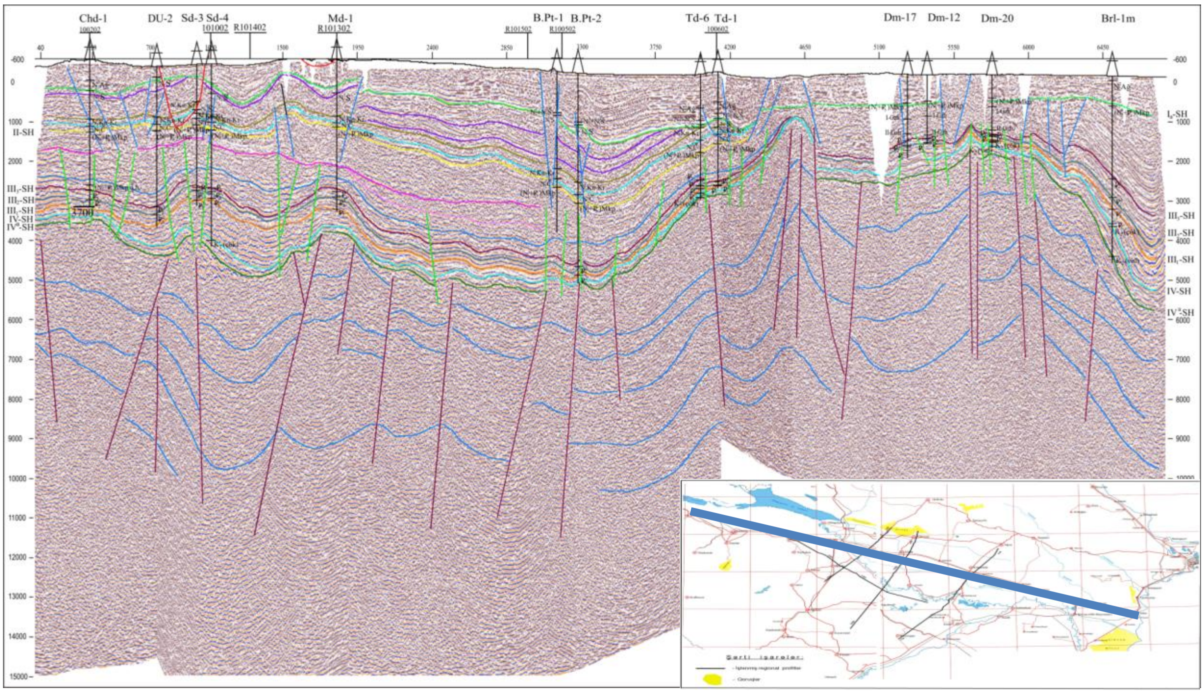


Figure 5. Poylu-Dalimammadli regional line on the territory of Azerbaijan.

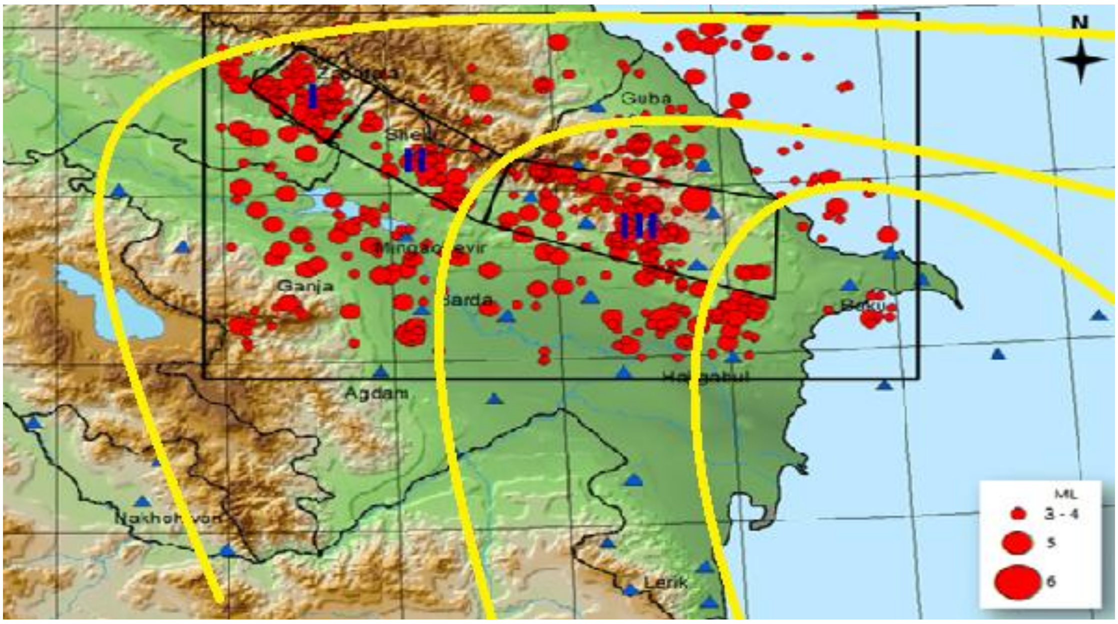


Figure 6. Seismic activity is observed with characteristic sequence in circular zones of Caspian basin area (applied seismological data are available at the web-page of Republican Seismological Service Center).

Accumulated geodynamic stress and earhtquakes resulted from horizontal, vertical and diverse motions constantly impact active dynamics of Moharovichich of 40-53 km, Konrad 20-32 km and sedimentary cover of up to 25 km thickness. Thus, the morphostructure and activity dynamics of granite, basalt layers and sedimentary cover constantly vary. In our point of view the current state of the basin is mainly the result of plume mantle processes. In borders of these layers the circular configuration created by a plume is observed and they are reflected in appropriate geophysical fields.

The deposition process in the Caspian basin started before the Mesozoic and the earth crust subsidence is continued with the same rate during Jurassic. In the central portion of the current South Caspian area the sedimentation objects deposited as a result of spiraled motion generated by plume and marine circular motions developing a vast sedimentary cover with over 25 km thickness. All these led to evolution of circular-spiral anticline structures (Bahar, Shahdeniz, Absheron, Shafag, Mashal, Babek, Umid, Bulla deniz, Asiman, Zafar, etc.) with accumulation of huge hydrocarbon potential (Figure 7).

We have attempted to study in more detail the structural setting and geodynamic stress in geological sections of Shahdeniz, Umid and Babek in order to explain the vast hydrocarbon potential in deep layers (at 6-12 km interval and deeper). These structures have been discovered in the 50-ies of the last century, however, their oil and gas reserves have been proved after 1999.

To study the Pliocene in Umid and Babek structures in total 103 km of seismic lines have been processed and interpreted along 16 lines through the period of 2008-2012. Total 1300 sq.km of 3D seismic survey has been done across Babek-Umid in 2012. In this structure the well drilled down to 6006 m depth recovered VII horizon of Productive Series (Fasila suite). Well logging allowed to identify gas saturation of the V and VII horizons of Productive Series. Intensive gas flow was observed from the VII horizon of Productive Series.

To evaluate hydrocarbon potential along the burial direction of layers of the VII horizon of Productive Series, to study in detail the tectonics and lithological-stratigraphic section the exploration well N 10 has been drilled with project depth of 6500 m in 2011. Geological and geophysical data acquired in Shahdeniz, Nakhchivan, Alyat-deniz, Zafar-Mashal, Bahar and Bulla-deniz areas have been analyzed and high gas and gas-condensate accumulation perspectives have been predicted.

In deeply buried layers of Umid area, in surroundings of mud volcanoes and the structure the complications are lesser in comparison to upper layers creating favourable environment for hydrocarbon migration (Figure 8). Due to the impact of geodynamic stress observed in Umid structure despite the wide area of mud volcano in upper portions, the form of the structure in deeper layers is unchaged keeping its antcline features.

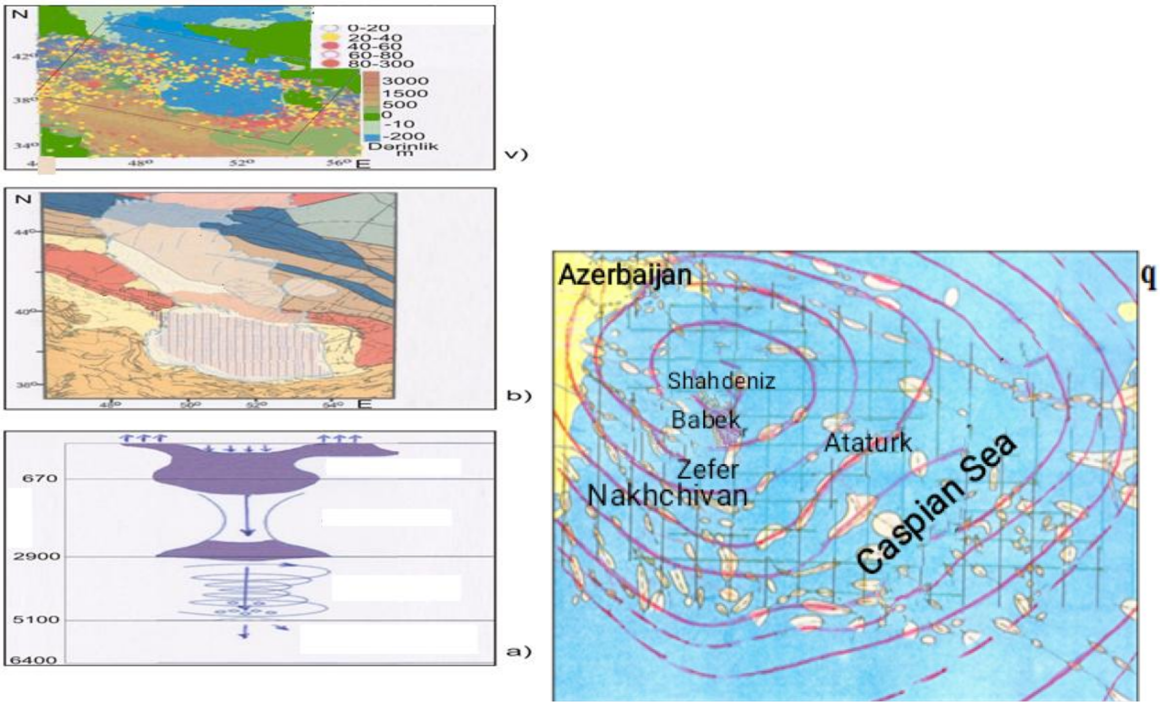


Figure 7. The Caspian basin model compatible with plume mantle model: a) plume moovement; b) regional faults; v) seismic activity-earthquake epicenters; q) oil and gas accumulation areas in circular-shaped zones.

The Umid structure is in the form of asymmetric anticline of the north-west-south-east extension outlined by 7000-7900 m isohypses. The width of structure is 3.5-4.0 km and traced at 19 km distance. In the north-east flank it is outlined by 7000-8700 m isohypses with 16-24^{o} dip burial. The south-west flank outlined by 7000-8500 m isohypses is buried under steeper angle (26-45^{o}). The deepest part of the syncline is outlined by 9600 m isohypse.

The north-eastern flank of Umid structure transits into Kichikdagh-Umid syncline separating it from Bulla-deniz structure. In 2017 SOCAR AQS company drilled production well N14 with total depth of 6352m from stationary platform "Umid-1" which resulted in discovery of vast gas field in the south-eastern pericline of the structure.

Babek structure is outlined by 7750 m isohyspe. According to this isohypse the extensions of closed part of structure is 15.5 x 2.7 km. The structure is complicated by faullts of various amplitude. As a result of disjunctive dislocation the crest of the structure is divided into the blocks which fall towards the south. The north-eastern flank with relatively uncomplicated setting falls down to 9250 m depth and conjugates with Kichikdagh-Umid syncline. The deepest part of the syncline is outlined by 10000m isohypse.

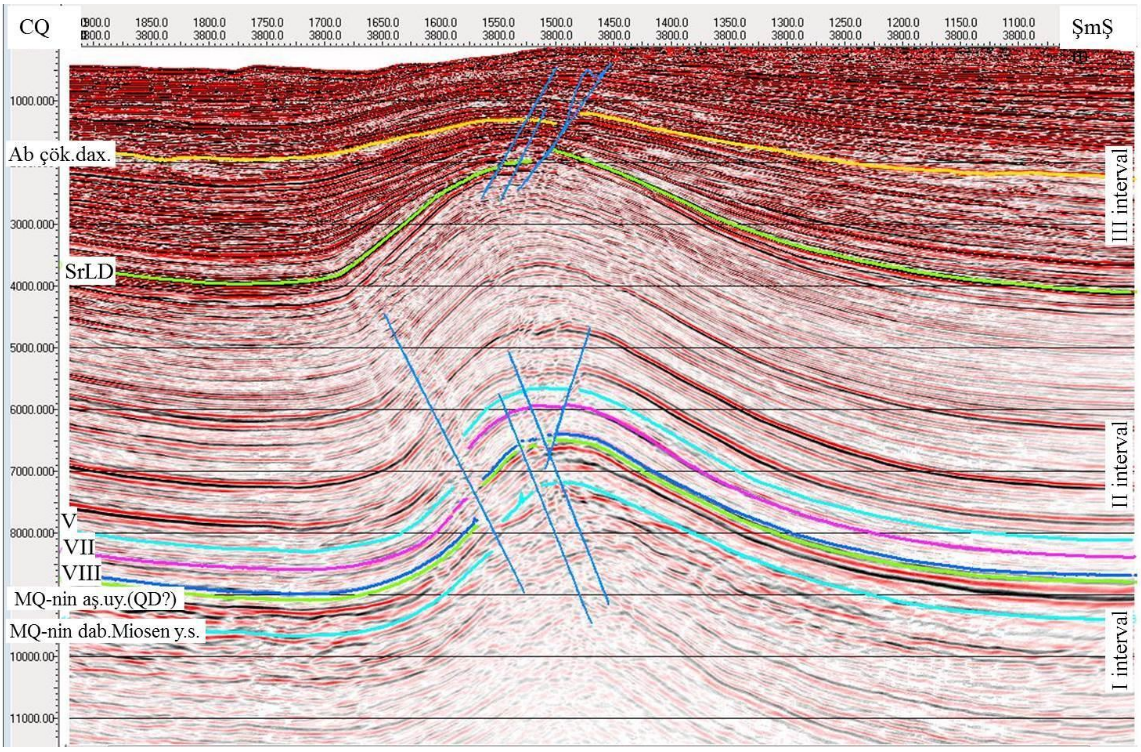


Figure 8. Deep section of Umid structure.

Seismic survey data evidence deep tectonic setting of these structures favorable for hydrocarbon fields development.

I. CONCLUSION

Caspian basin evolution has been analyzed on the basis of acquired geophysical data according to “plume mantle” theory and it was supposed that circular geodynamic processes in the mantle play a major role in development of Caspian basin morphostructure.

Geodynamic stress accumulated as a result of horizontal, vertical and other movements, eqarthquakes influence activity dynamics of Moho 40-53 km, Conrad 20-32 km and sedimentary cover of up to 25 km thickness leading to chnages in morphostructure of granite, basalt and sedimentary cover. In the surface relief of these layers the circular configuration created by plume is traced and this is observed in appropiate geophysical fields and occurred earthquakes.

In the sedimentary cover the geodynamic stress, blocks movements are accompanied also by horizontal movements of layers and in our point of view it is quite difficult to trace deep horizontal movements by GPS survey.

On map of epicenters of earthquakes occurred in Azerbaijan and hypocenters allocation through the deep layers the seismic activity in the above indicated intervals are observed in circular form and despite the large number of earthquakes occurred in the upper 3-5 km their magnitude does not exceed M≥4. In this area the earthquakes with M≥6-8 occur in the 7-20 km interval and in this interval the deformation features are not characteristic. The earthquake epicenters are according to the inter-block faults.

It is recommended to design more detailed geodynamic model taking into account paleogeomorphological setting and seismo-tectonic features in order to fulfill exploration for deep hydrocarbon accumulations according to this model.

It has been shown that similar to Umid, Babek, Shahdeniz and other structures of the South Caspian in the deep layers below the Productive Series the situation is favorable for hydrocarbon accumulation.

In the Umid structure the surface of layers below Productive Series, the tectonic setting, stratigraphic-lithological features and seismo-geodynamic situation is favorable for oil and gas accumulation.

Petrophysical and lithological features in the deep layers of Umid structure is similar to that observed in wells across Shahdeniz, Bulla-deniz and Alyat-deniz areas.

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