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Geomorphological Features Of Decrease Of Caspian Sea Level According To The Plume Mantia Model

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ABSTRACT
The evolution of the Caspian and Black Sea depressions was analyzed with reference to the "Plume Mantle" model. In the area of Paleo-Caspian the magma moved from the mantle layer to the earth's surface, changed the morphostructure near to the Earth's surface. It has been made clear that the area contoured by local anomalous areas in the gravity and magnetic fields corresponds to the morphology of the PaleoCaspian. The seismic activity zones corresponding to the circular shape of the Paleo-Caspian depression area and the observed circular regional faults, the current geodynamic stress conditions of the Caspian depression were assumed to be signs of the plume mantle process.
In the depth location of the hypocenters of earthquakes in the Caspian depression, it was determined that seismic activity, strong earthquakes with M≥6-8 are in the interval of 7-20 km. In this region, the formation of the morphostructure of the sedimentary layer with a depth of 40-53 km of Moho layer, Konrad 20-32 km and thickness of up to 25 km is reflected in the geophysical fields corresponding to this model. The process of sediment accumulation in the Caspian basin began before the Mesozoic and continued during the Jurassic period with intensive subsidence of the Earth's crust and the formation of the basin continued with approximately the same tendency.
Plume mantle processes are indicated in the article as the main reasons for the decrease in the level of the Caspian and Black seas. In order to accurately assess the decrease in the level of the Caspian Sea, it was recommended to improve the plume mantle model by use of modern geodetic GPS measurements and time-spatial changes in geophysical fields onshore and offshore. The main difficulties arise in relation to the oil industry, in oil platforms, oil-gas transportation systems, terminals, docks, etc. The importance of preparing engineering projects for the long-term operation of technical equipment in the coastal zones according to the rate of decrease of the level of the Caspian Sea has been shown.
KEY WORDS: *Caspian depression, geomorphological features, geodinamic-stress, vortical movement of magma, plume mantia model, horizontal and inclined movement, sea level, environmental contamination.*

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The area of the Caspian basin is 392,600 km², the volume of water in the basin is 78648 km^3, which makes up 44% of the lake water resources on Earth and covers the territories of Azerbaijan, Iran, Turkmenistan, Kazakhstan and Russia. Due to the abundance of water balance and its closure, the Caspian Sea is the largest lake on the planet Earth and an indicator of the climate of a large area. The level of the Caspian Sea is 27 meters below the ocean level.

The seabed relief is in three main forms: the shelf, the continental slope, and the deep depression areas of the seabed. The shelf zone in the Caspian Sea is 100 meters deep from the coast, and ends at 500-750 meters deep on the continental slope. The maximum depth in the Middle Caspian is 788 meters in the Darbend depression and 1025 meters in the Lankaran depression in the South Caspian. It is one of the most **urgent problems** to clarify the modern geographical conditions of the Caspian depression, geomorphological features, relief, the shape of basement of sedimentation basin, geological-tectonic structure, seismic activity and formation of this regional geostructure based on the "Plume Mantle" model.

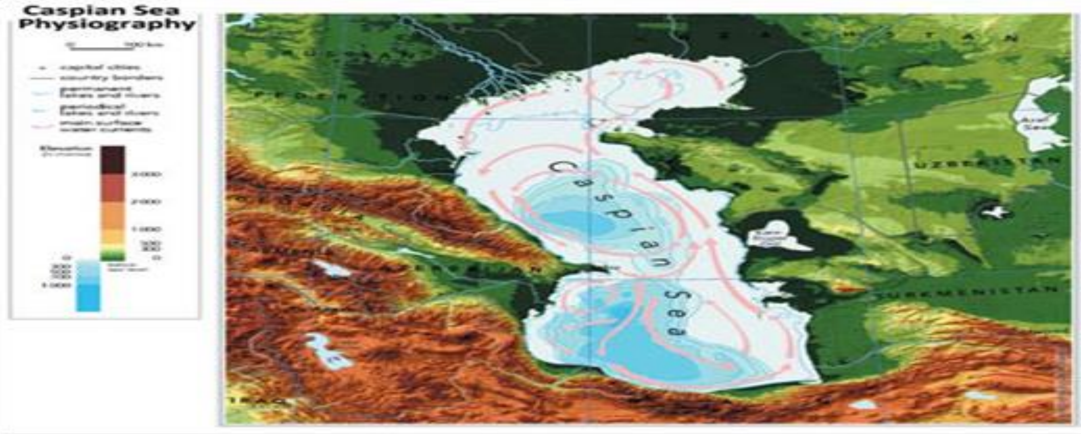
Purpose of work. The work aims to substantiate with scientific evidence that the Caspian Megabasin was developing according to the "Plume Mantle" model and to evaluate the role of this process in the future sea level change.

Research phases. The Caspian and Black Sea depressions evolution started before the Mesozoic era, and the Caspian Sea gradually separated from the Black Sea basin. During the Triassic, Jurassic and Cretaceous periods, the area of the Caspian Sea sometimes increased and sometimes decreased (Figure 1). Geodynamic processes played a key role in the formation of the Caspian basin, and although sharp changes in climate over millions of years caused changes in the sea level, the main reason was the deepening of the relief of the depression. In the following geological periods (approximately during 70-80 million years), the Tethys Ocean of the Ponto-Caspian Basin was isolated from the southern seas and gradually separated, and the water level underwent through various periods of transgression and regression phases. At the end of the Pontian, in the Middle Pliocene (10 million years ago), the huge and closed Sarmatian Sea, covering the area occupied by the modern Black Sea and the Caspian Sea (Fig. 1), was divided into different parts, and then the Caspian Sea emerged as a separate isolated basin (Fig. 2). The Caspian basin is divided into three parts according to its geomorphological features, physical-geographical conditions and geological-tectonic structure: North, Middle and South Caspian depressions (Fig. 2b).

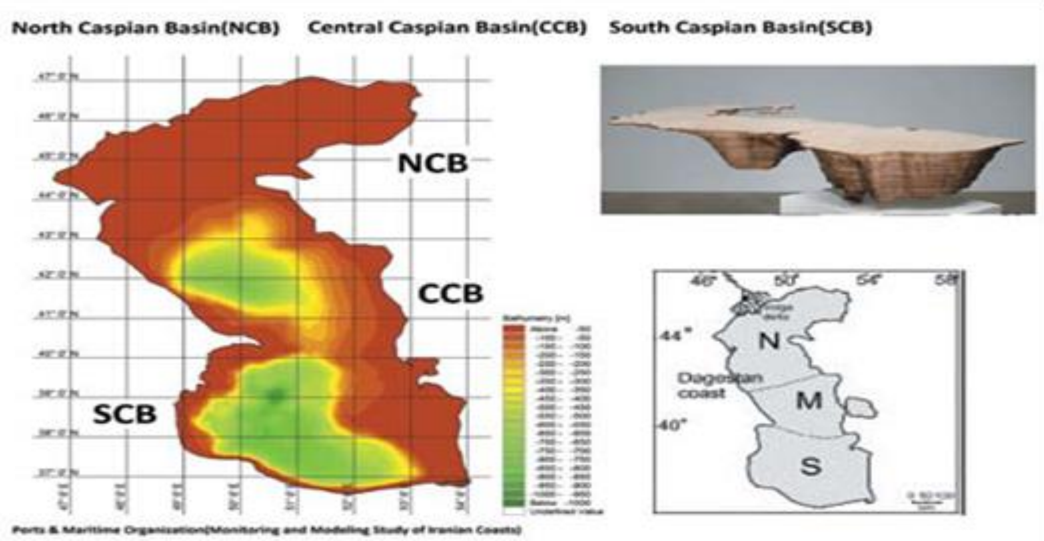
Figure 1. *Maps of formation of the Paleo-Caspian and the separation of the Tethys Ocean from the surrounding seas according to the plume mantle model (https://vk.com, https://vk.com).*

The thickness of sedimentary cover is 7-13 km in the North and Middle Caspian, and more than 18-25 km in the South Caspian [13, 15]. The geodynamically active processes occurring at the depth of the Mohorovicic discontinuity, which is at 40-53 km and Konrad is at 20-32 km depths constantly changed the morphostructure of the granite, basalt and sedimentary layers. The density of the rocks in the area is on average 2.65-2.85 g/cm^3, the thickness of the lithospheric layer is 45-55 km and 30-40 km in the central part of the South Caspian Sea. In the central part of the South Caspian, the thickness of the granite layer decreases sharply and it becomes difficult to trace [15].

About 130 large and small rivers flow into the Caspian Sea basin. Volga, Terek, Kur, Gusarchay, Gudyalchay, Valvalachay, Sumgayitchay, Lankaranchay, Astarachay, etc. are the rivers that bring the most water and sediment into the basin. (Fig. 3a). Northwest, north, and southeast winds blow over the Caspian Sea, and a circulation of water is constantly observed in the sea (Fig. 3b). Accordingly, waves moving from north and north-west, south and south-east or from south-east to north-west and north arise in the Caspian Sea. The north and north-west winds, which dominate most of the Caspian Sea, create more intense hurricanes, and these factors affect the formation of depositional layers in the basin.



a)



b)

Figure 2. *Geomorphological map of the Caspian megabasin a) modern coverage area of the Caspian basin, 3D depth model and distribution of the sedimentary cover; b) diagrams.*

a)

b)

Figure 3. *Maps of the reduction of the area of the Caspian Sea, the creation of new land areas and circulation of wind and sea water (https://pulse.mail.ru, https://yandex.ru/images/search?text).*

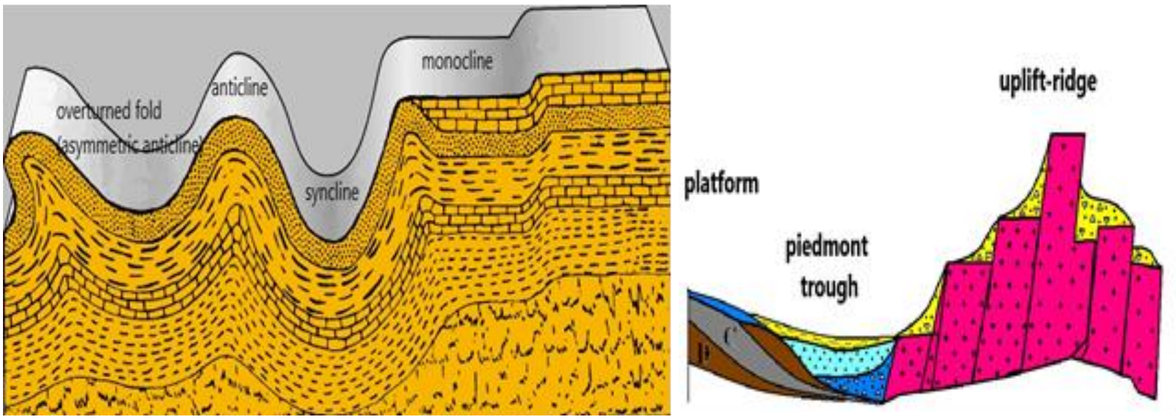
The average monthly air temperature of the Caspian Sea varies between 7-8 °C in the northeast of the sea, and 15-17 °C in the southern part. Since the Caspian Sea is a closed water basin, the river flow, climatic conditions, sea depth and bottom relief, as well as the physical and geographical features of the coast play an important role in the process of sediment accumulation. In the Caspian basin, mainly in the South Caspian, mud volcanoes are widespread in land and sea areas.

More than 2000 mud volcanoes have been recorded on Earth, and up to 500 of them are in the Caspian Sea and 344 are on the land of Azerbaijan. In the sea, mud volcanoes are observed in the form of islands, ridges and underwater heights. According to paleogeological, paleogeographical, archaeological and historical data, the level of the Caspian Sea has always decreased [18, 19, 20].

Geological thoughts. People's geological way of thinking is developing rapidly, their scientific knowledge is widening, and new ideas are emerging. The science of geology has been formed and developed since the 19th century and it is a science about evolution of the Earth in the Universe, the occurrence of volcanoes, earthquakes, the formation of mountains, depressions, their development history, depth structure, lithological composition of rocks, the origin of minerals, the formation of deposits, their location patterns and exploration methods. People determined the direction by inventing a compass, made maps by measuring distances, used angle measurements in construction works, used for exploration of oil and gas, iron, gold, copper, etc. in search of deposits, changes in the level of water basins, increasing the height of mountains, etc. and new theories have begun to emerge based on measurement habits. In the development of geological science, geometric-geodetic measurement works, the evolution of modern GPS measurements have led to the creation of new models.

Geosyncline theory. In the first stage of development of geological science, starting from the second half of the 19th century, James Hall (1857), James Dana (1873) and others wrote his ideas about the formation of geosynclinal and geoanticlinal structures due to the effect of dislocations on the ground, and starting from 1920, Emil Ogom formulated this theory. Geological data, geodetic-leveling measurements, elevation of geostructures, mountain massifs, elevation of depressions, in general, observation of the vertical movements lead the scientists (R.V. Bemmelen, E. Khaarman, R. Willis, V.V. Belausov, etc.) to develop the "geosynclinal theory" (Figure 4).

Dislocation of earth layers, intensive subsidence process, formation of uplifts, occurrence of tectonic fractures, metamorphism of rocks, etc. was explained on the basis of geosynclinal theory, currently there are supporters of this theory. Through the period of 1930 - 1960, as the application of geophysical methods expanded and the geological data base increased, the explanation of many regional processes on the basis of the Geosynclinal theory was not sufficient.



a) b)

Figure 4. The model of formation of depressions and mountain massives b) under the influence of regional dislocations a).

The theory of plate tectonics is a very widespread theory in geological science that clarifies the geodynamic processes occurring inside the earth based on the horizontal movements of the lithospheric plates relative to each other. Causes of ocean depressions, mountain ranges, volcanic eruptions, earthquakes, etc. it is explained as signs of geodynamic tension caused by horizontal displacements of plates-pans, tectonic blocks in different directions.

In 1920, the idea of the movement of tectonic blocks was proposed by Alfred Wegener, and from the 1960s this idea was developed as the theory of "plate tectonics". With reference to the horizontal movement of the plates that make up the solid layer of the earth, the formation of geomorphological structures, volcanism and earthquake processes began to be explained according to the "Plate tectonics" model (Figure 5).

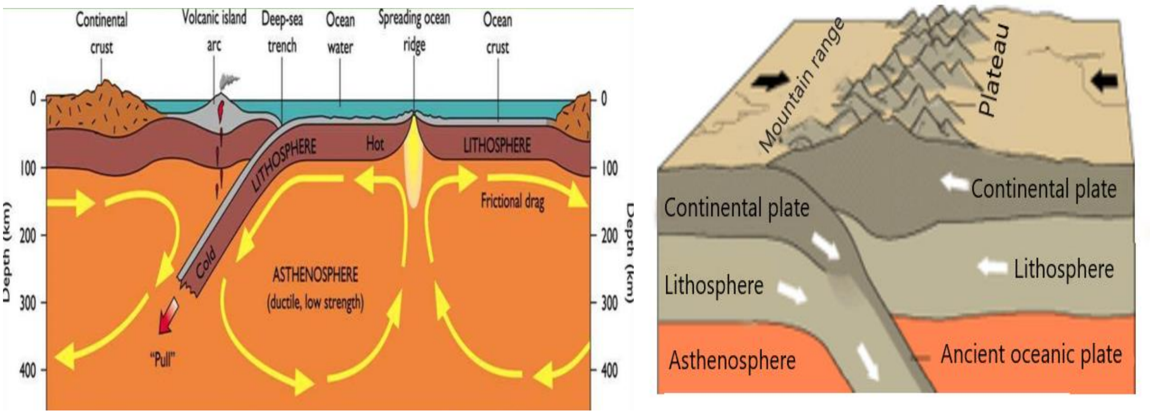


Figure 5. *Models of the horizontal movement of the plates that make up the Earth's solid layer and the formation of geomorphological structures according to the "plate tectonics" model*

Plume mantle theory. Modern geological science tries to explain the emergence of geostructural units, volcanic processes, and earthquake occurrence models on the basis of vertical, horizontal and recently circular-vortical movements, referring to scientific methods based on modern geophysical measurement data. The model of the earth based on seismotography, gravity, magnetic, electric and other geophysical fields data is divided on core, mantle, lithosphere, hydrosphere, atmosphere and magnetosphere layers. As the Earth's mantle layer moves, circular-vortex-shaped movements occur in the plume, and as a result of these movements, large geostructures are created, earthquakes occur, and magmatic volcanoes activate and erupt (Figure 6). Until the 60s of the 20th century, the formation of large structures was explained with reference to the vertical movements of geostructures, based on the principle of isostasy, according to the fixism theory. Later, since it was possible to measure horizontal movements (GPS-Global Positioning System), a plate tectonics model was created based on the new data (Allen, M, J, Jackson, and R. Walker. 2004). It was found that the lithospheric layer with a thickness of 250-90 km is divided into continental-ocean type pans by deep regional tectonic fracture and moves horizontally in different directions. The "Plate Tectonics" model is more often referred to clarify time-spatial horizontal movements, spatial positions, geodynamic-stress conditions and observed seismic activity of plates, tectonic blocks, and large geological structures.

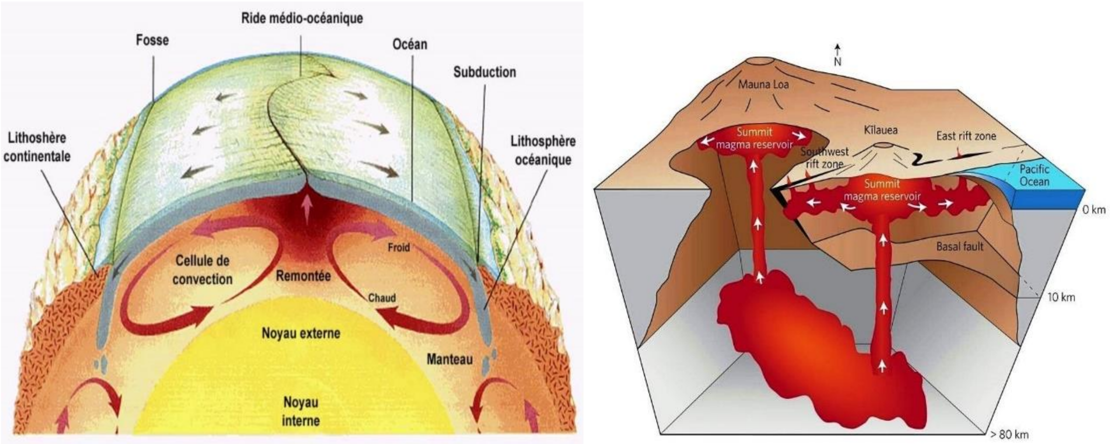
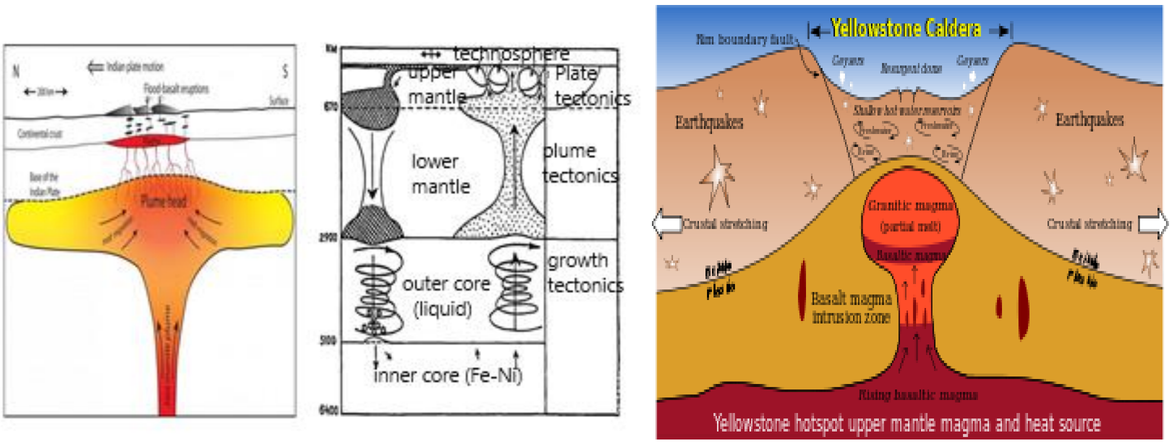


Figure 6. *Models of circular-eddy motions in the dynamic mantle layer based on the plume mantle model*

The model designed on the basis of "plume mantle" theory is known as Sh.Maruyama model (Maruyama Sh., 1994; Grachev A.Ф., 1996) based on Tucho Wilson's "plume mantle" theoretical ideas expressed in 1965. The excitation in the core-mantle transition zone was formed based on the circular-vortex movement of the magma-like plume towards the earth's surface (Fig. 7). In this model: a) The plume moves towards the earth's crust and creates vertical and horizontal displacements in the lithospheric layer; b) During the movement of the plume directed towards the earth's crust, the geodynamic conditions of the environment change with spiral and various movements; c) The plume begins to cool in the lithospheric layer and large-sized morphostructures are formed (Fig. 7).



a) b) c)

Figure 7. Schematic models of the supposed formation of the Plume in the area corresponding to the Caspian Basin

Theory of "tilting plates". This is the first time this theory is offered. Just as vertical movements in the geosynclinal theory, horizontal movements in the theory of plate tectonics, circular-vortical movements in the plume mantle theory play the main pole, in the theory of "plate tilting" along with these movements, the radial-inclined movements of the plate plane at a certain angle play the main role. The same plate or block undergoes a radial displacement at a certain angle over the time. In the descending parts of the plate plane, the vertical compression takes place, while in the ascending opposite part of the plate plane, the processes of expansion occur. In order to observe the mentioned radial-inclination movements, long-term observations should be carried out at the permanently operating stations by use of tiltmeter devices.

Plume Mantle model of the Caspian and Black Sea depressions evolution. Taking into account the geophysical data gathered up to now, according to the plume-mantle model we have analyzed the models in which the excitation generated in the core-mantle transition zone in the deep layers of the Paleo-Caspian area and caused the movement of the magma-like plume [6, 10, 11] to the earth's surface (Figure 8). It can be seen from the schematic models of the supposed formation of the plume in the area corresponding to the Caspian depression: a) The plume moved towards the earth's crust and created vertical and horizontal displacements in the lithospheric layer; b) During the movement of the plume directed towards the earth's crust, the geodynamic conditions of the environment changed with spiral and various movements, and regional tectonic faults were created; v) seismic activity in the area was evaluated as increasing and circular; d) an anomalous gravity field created by a plume corresponding to the shape of the depression is observed currently. The appropriate morphostructure of the Caspian basin was formed according to this model and these processes are still ongoing. The plume that moved from the appropriate mantle layer of the area covered by the Paleo-Caspian to the earth's surface was the basis for the formation of the basin.

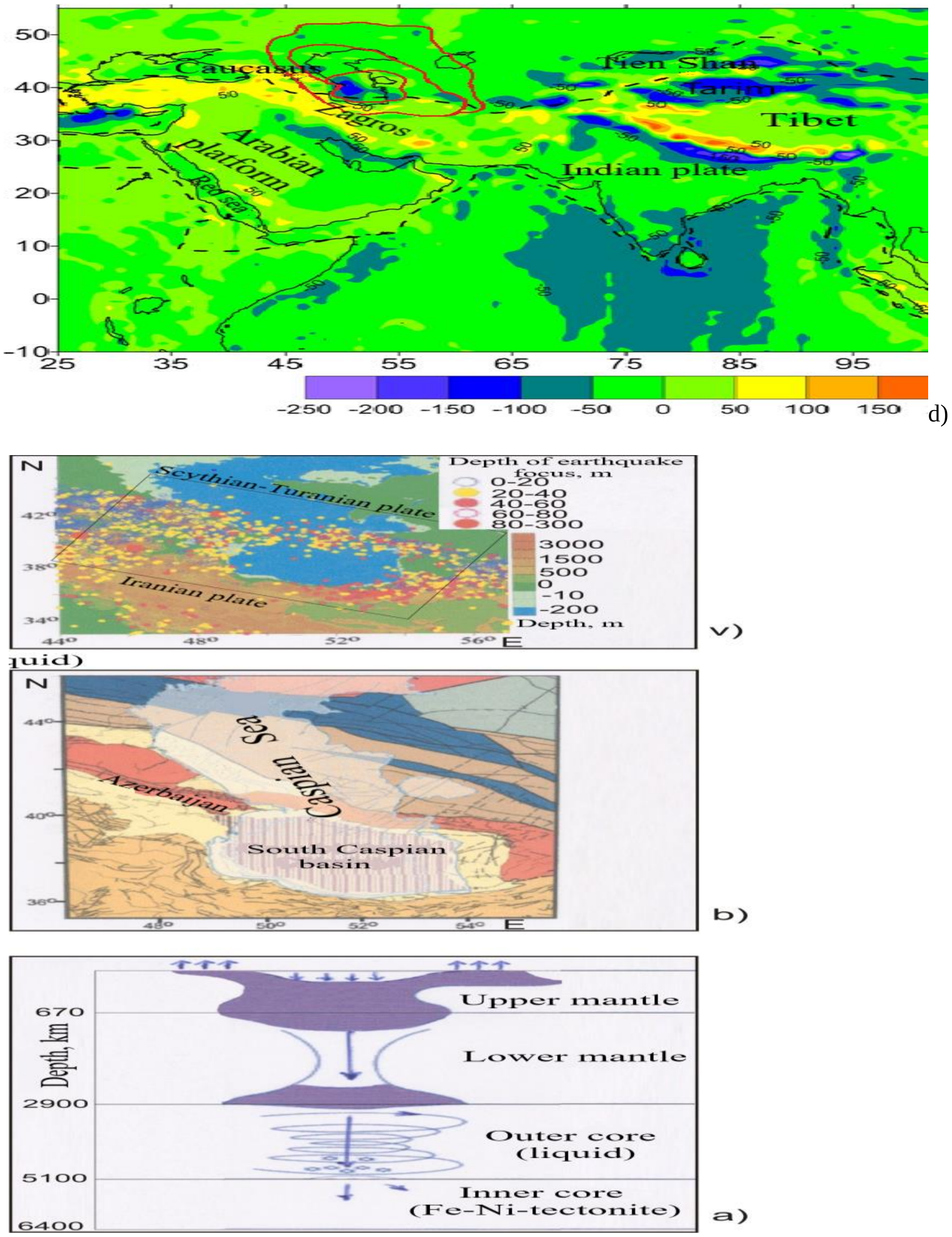


Figure 8. *Model of the Caspian depression according to the Plume mantle model: a) movement of the plume; b) regional tectonic faults; v) epicenters of seismic activity-earthquakes in its territory; q) patterns of anomalous gravity field generated by the plume corresponding to the shape of depression.*

The morphostructure of the depression created by the plume mass and its area contoured by the characteristic local minimum in the gravimagnetic fields correspond to the morphology of the Paleo-Caspian [12, 19]. The circular seismic activity zones of the Caspian depression area and the observed circular regional faults reflect the current geodynamic stress conditions of the Caspian basin [15, 16]. In the map of epicenters of earthquakes in the area of the Caspian depression and the location of hypocenters by depth, corresponding changes in seismic activity are observed in a circular form, although the number of earthquakes occurring in the upper 3-5 km interval is large, the magnitude does not exceed M≥4. Here, strong earthquakes with M≥6-8 occur at intervals of 7-20 km. Since the activity of the plume remains in the basalt layer in the northern arc of the South Caspian Sea in the interval of 55-65 km, the signs of deformation in this interval are observed according to the characteristic earthquake foci. In our opinion, as a result of changes in the circular-eddy movement of the plume, the further deepening of the Caspian depression and the rise of the surrounding mountainous areas have a characteristic effect on the modern state of the basin. In the relief of the separating boundaries of the lithospheric layer and the upper layers, mainly in the sedimentary cover, the circular configurations created by the plume are formed and reflected in the appropriate geophysical fields [14]. Due to complex geological structure, rich hydrocarbon resources and geodynamic activity, the Caspian depression occupies an exceptional place among similar basins in the world. It must be noted also that the thickness of sedimentary cover reaches 24-26 kilometers in the Caspian Sea as in no other basin on our planet. According to the hydrocarbon potential per square kilometer, it is comparable to the oil and gas regions of the Gulf of Mexico.

The reasons for the change in the level of the Caspian Sea. It is observed that the sea level changed sharply in the past geological periods (Figure 9) [18, 19, 20]. Since the formation of the Caspian depression according to the plume mantle model, the process of deepening has constantly continued, and the active dynamics of this process can be clearly observed now.

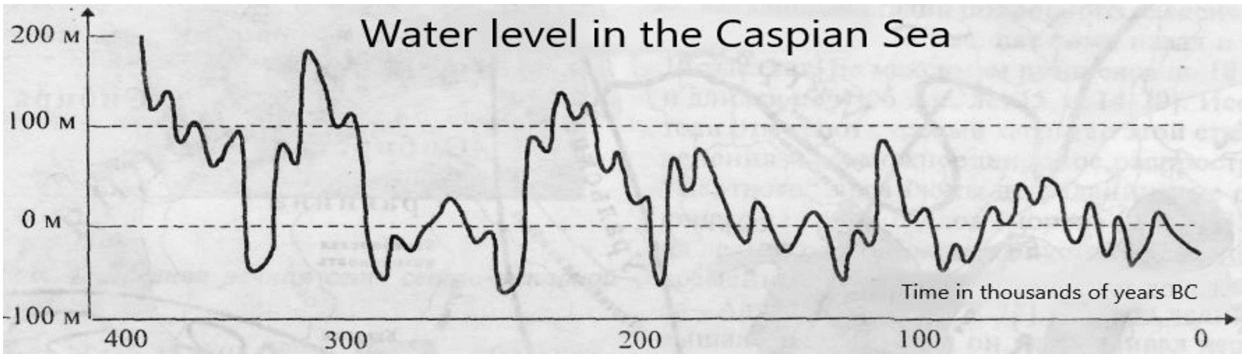


Figure 9. The graph of sea water level changes in the Caspian Sea for 400 thousand years period starting before our era (https://rudocs.exdat.com).

The maximum level of the Caspian Sea is -29.04 m, and the level has decreased by 16-18 cm/year in the last 20 years [24, 25]. Analysis of sea level for the time period of 1840-2010 shows that the sea level has dropped by 4-2.5 m and the amplitude change of the level is 2-3 m. Currently, the level of the Caspian Sea is 27 m below the ocean level (Figure 10). Deepening of the depression and drop of the sea level started from the time of the Caspian Sea and the Black Sea separation. The deepening of the bottom of the Black Sea is also continuing according to the plume mantle model, but as the Black sea is connected to the ocean, the change in the sea level is not observed sharply [18, 19, 20].

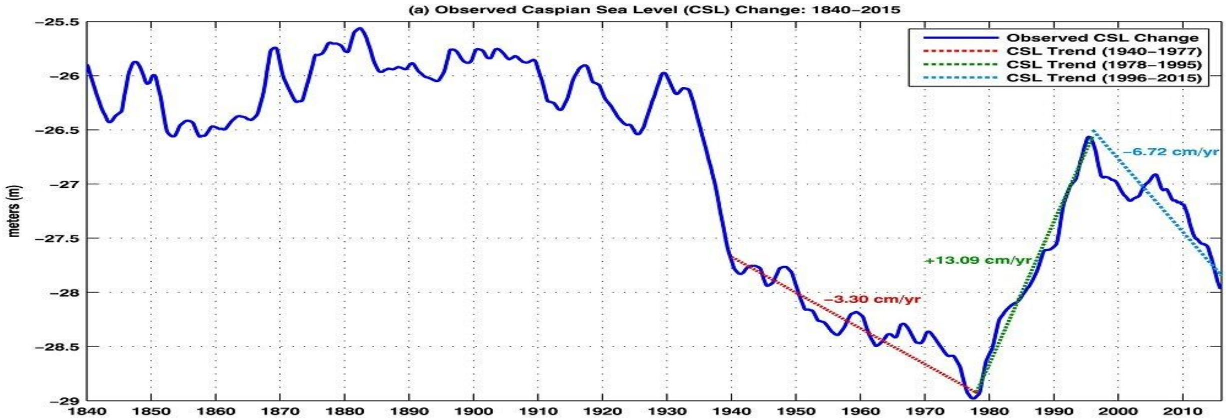


Figure 10. The graph of Caspian Sea water level change (https://yandex.ru/images).

The sea level change according to the plume mantle model is just a visual indicator of the deepening of the Caspian depression. The circular and mostly inclined movement of the plume is more intense than the rapid lowering of the relief of the regional depression [11]. An example of this is the submergence of cities located on the shores of the Caspian and Black Seas in different historical periods (from the period of ancient civilization to the present) and the discovery of their remains at the depths of 5-300 m (Fig. 11). As a result of the relief deepening on land, the discovery of cities and ancient buildings at 5-10 meters and sometimes 100 meters below the surface displays that the main factor is not the rise and fall of the water level, but the rise and fall of the relief.

a)

b)

Figure 11*. The ancient city of Sabayel under the waters of the Caspian Sea and the buildings of the ancient city in the Black Sea.*

By monitoring the level of the Caspian Sea, researchers have so far attempted to explain the changes of sea level in Caspian sea by climate change, global warming, a decrease in the water balance, an increase in agricultural irrigation systems, inefficient use of water, etc. [16, 17, 18, 19, 20]. They associate the process of sediment accumulation with sea level change (Figure 12).

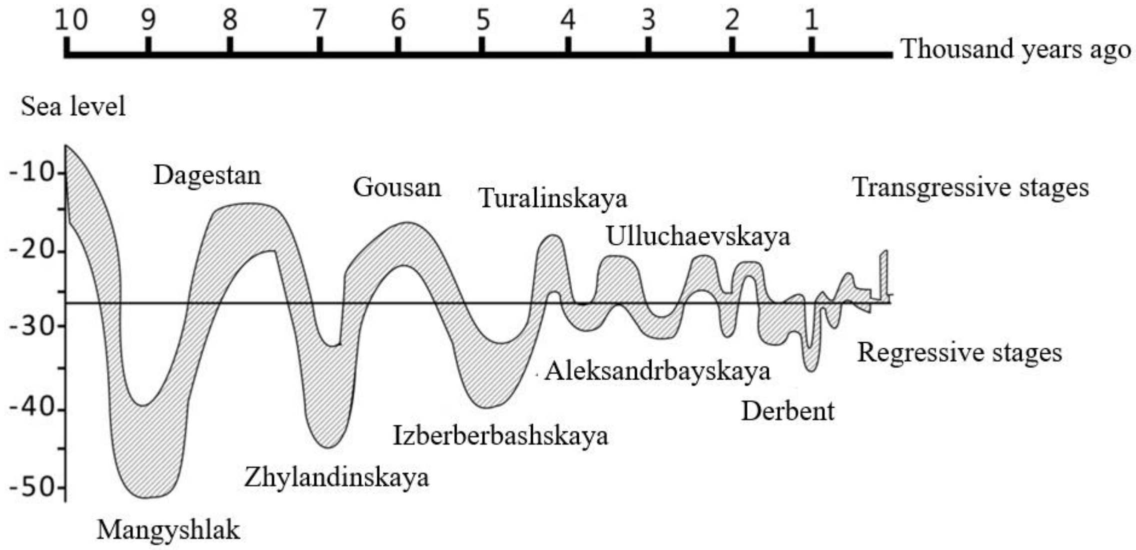
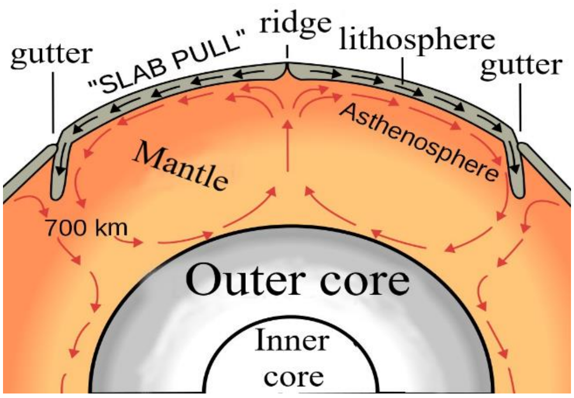


***Figure 12**. Schematic linking of the process of sediment accumulation with changes in the level of the Caspian Sea in geological periods (http://casp-geo.ru/chto-skryvayut).*

Although these processes play a certain role in drop of the sea level, the main reason is related to the deepening of the sea bottom under the influence of the plume mantle processes. The deepening of depression took place during a very long geological period (Fig. 13). In the first periods, the circular-vortical circulation of plume-magma began in the deep layers of the Earth, in the mantle (Fig. 13a), then its signs were observed on the Earth's surface, seismic activity intensified, volcanic activity occurred (Fig. 13b).

At the next stage, the Caspian and Black Sea depressions began to deepen (Figure 13c) and the evolution of both basins were continued as Carpathians, Caucasus, Anatolia, Iran and other mountains were rising around them (Figure 13d). The deepening of the depression occurred more intensively than the elevation of the mountains (Fig. 13e), and as a result, the Caspian depression deepened and the sea level decreased (Fig. 13f). In recent times, due to the influence of plume processes in the South Caspian depression, the relief of the seabed has been intensively lowered, and as a result, it is observed that the sea level has decreased on the coasts of the Nothern and Middle Caspian and land areas have spread over very large areas.



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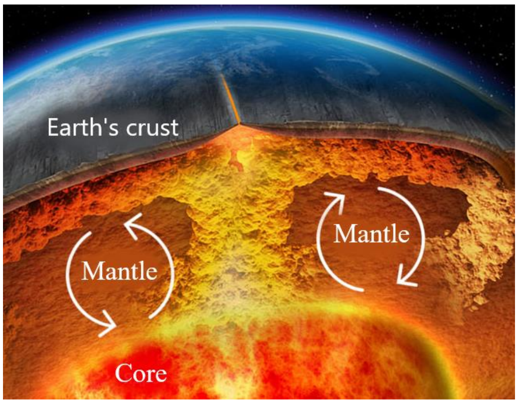

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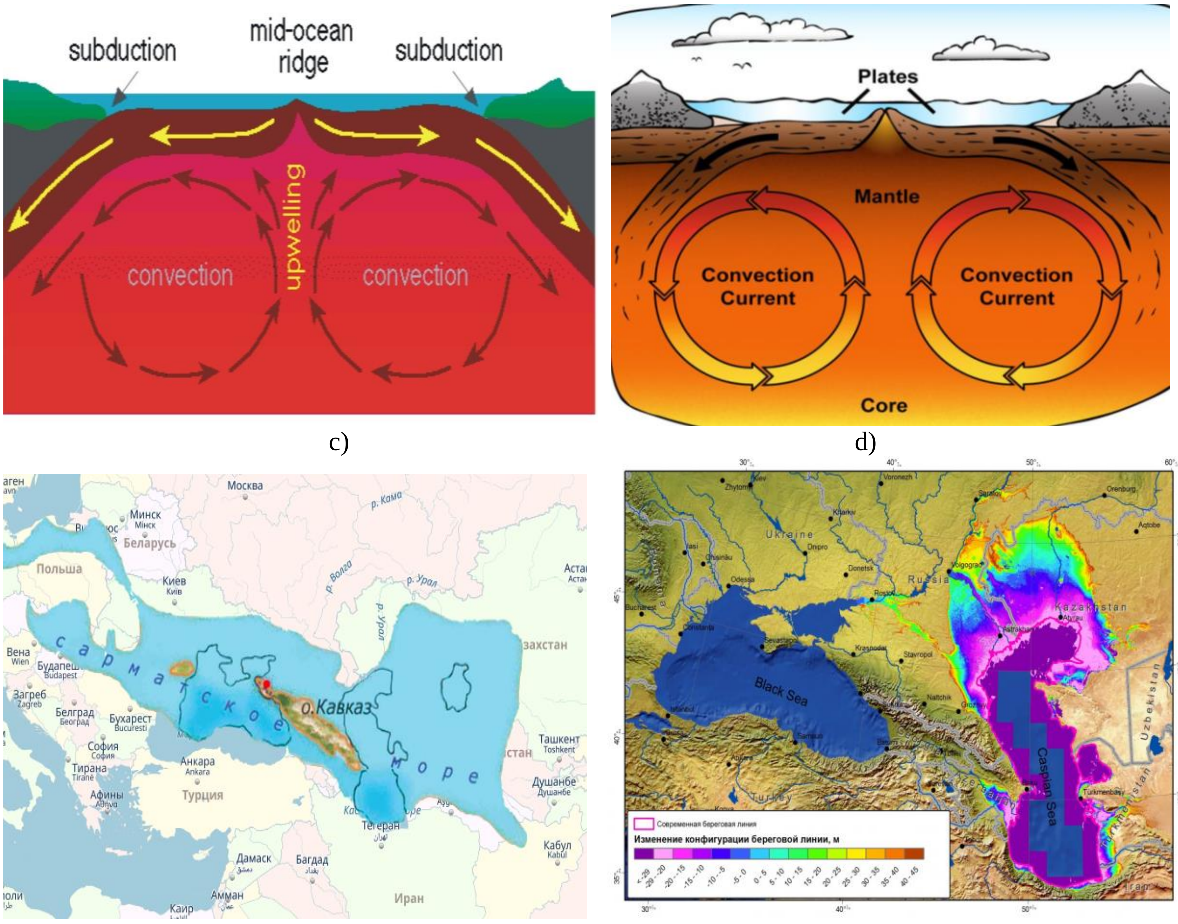

c) d)

e) f)

Figure 13. Models of evolution of Caspian sea and Black Sea depressions as a result of Plume mantle processes (https://www.the-dialogue.com).

Environmental impact of the sea level decrease in the Caspian sea. The decrease in the level of the Caspian Sea leads to the expansion of land, large-scaled environmental changes in transition zones. The landscape of transition zones is changing, fauna and flora is disturbed, new sources of contamination are emerged (Fig. 14), it becomes more difficult for ships to dock at the ports, technical facilities lose their functions, etc.

Figure 14. Environmental contamination caused by the lowering of the level of the Caspian Sea

As the deepening of the relief is more intense in the Caspian basin, mainly in the South Caspian basin, which is the center of the Plume process and as there no connection between the sea and the ocean, the water balance is accumulated in this basin. On the North Caspian and Middle Caspian coasts, the dry areas are enlargening more intensively, leading to rapid increase of environmental problems. In the next 100 years, the sea level is likely to drop by 9-18 m, and there is a high probability that land areas will be even larger in the future (Figure 15).

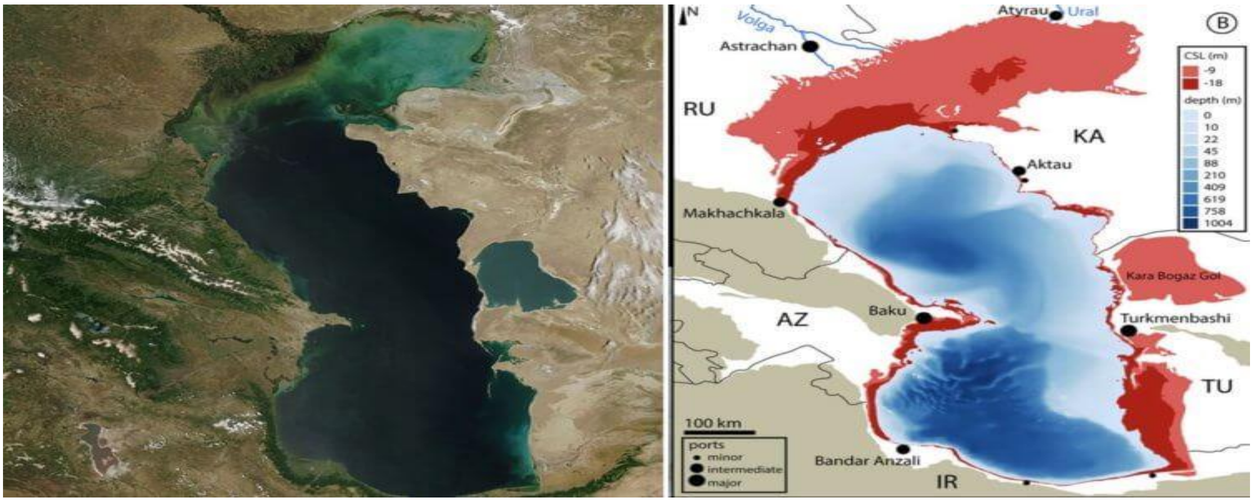

Figure 15. *Maps of forecasting of Caspian Sea level changes (https://hi-news.ru/research-development*

The difficulties are mainly arise in connection with the oil industry, especially in oil platforms, oil-gas transportation systems, terminals, docks, etc. There is a need to develop engineering projects suitable for the long-term operation of technical equipment in the coastal zones according to the rate of decrease of the level in the Caspian Sea. The special devices should be designed in a way that they can be lowered and raised by pistons or repositioned by rollers according to the sea level change. For this, it is important that the relevant engineering design specialists should be aware in the problems of sea level change in the Caspian Sea.

SUMMARY

1. The evolution of the Caspian depression was analyzed in the light of "plume mantle" model, taking into account the vailable geophysical data. It has been supported by scientific evidences that the role of circular geodynamic processes in the mantle play the crucial role in the current morphostructure of the basin.

2. The geodynamic stress accumulated as a result of the vertical, horizontal-vortical-circular and inclined movements created by the plume in the mantle affected the activity dynamics of the sedimentary layer, which is 40-53 km in the Moho layer, 20-32 km in the Konrad layer and has a thickness of up to 25 km, as well as constantly changed the morthostructure of granite, basalt and sedimentary cover. The horizontal movement of each of these layers has been different and the earthquakes have occurred according to their movement dynamics, and high activity is observed currently.

3. In the map of epicenters of earthquakes in the Caspian depression, corresponding changes in seismic activity are observed in a circular form, although the number of earthquakes occurring in the upper 3-5 km interval is large, the magnitude does not exceed M≥4. Here, strong earthquakes with M≥6-8 occur at intervals of 7-20 km.

4. **The main reason for the decrease in the level of the Caspian and Black seas is the lowering of the bottom of depression due to the influence of plume mantle processes. Due to the connection of the Black Sea with the ocean waters, the water level is restored there, while in the Caspian Sea, the decrease of the area of the basin, enlargening of dry areas, the decrease in the amount of evaporation and, as a result, the decrease in the amount of precipitation reduce the balance of water entering the basin, and consequently drops the sea level.**

5. In order to accurately assess the paleogeomorphological conditions in the Caspian basin, its seismotectonic features, the deepening of the basin, it is recommended to improve the plume mantle model by studying modern geodetic GPS measurements offshore and onshore and time-spatial changes of geophysical fields.

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