Specifics of Geological Development of Caspian Block Structure*

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Abstract

Petroleum exploration in the Caspian began as long ago as the 19th century and resulted in the discoveries in the southern offshore area which was recently crowned with success in the Central and North Caspian. Large-scale seismic offshore operations starting in the 1980s made it possible to study the main features of geological structure and the presence of oil and gas in the Caspian Sea.

As a result of focused studies of geological structure of the Caspian offshore by all Caspian states, some new basic data was obtained from the zone of junction of the southern edge of the Pre-Caspian Basin and adjacent tectonic elements. The discovered large deposits such as Kashagan, Kairan, Aktoty, Khvalynskoye, Shirotnoye, Shakh-Deniz, Azeri-Chiraq-Guneshli and Zhemchuzhnoye and extensive exploration being carried out all over the Caspian call for revision of geological and tectonic setting of the region that unites the heterochronous East European Platform in the north, the Scythian-Turanian plate in the centre and Alpian orogenic belt in the south in order to define more exactly its petroleum potential.

At present the concepts of the Caspian Sea geology rely on, besides gravity, magnetic and seismic data, results of drilling of a relatively limited number of deep wells, most of which were drilled in the south, in the near-shore area and within the Apsheron Sill. Currently their number also increases in the northern and central parts of the sea, in the areas of already discovered fields. In addition, a comparison of structural setting in the western and eastern coasts was made. A distinct similarity in the Mesozoic and Cenozoic sequences of the Dagestan-Kalmyk territory and the South Mangyshlak trough provided the basis for their combining into a single oil and gas province. Based on interpretation of physical fields, the Agrakhan Guriev Fault was identified, crossing the greater part of the Central Caspian and North Caspian. However, subsequent seismic operations cast some doubts on its existence.

The North Caspian to the north of the line going from the mouth of the Volga River to the northern end of the Buzachi Peninsula is a part of the Pre-Caspian Basin. Among geologists there are two points of view on the age of the basement in the south of the Pre-Caspian Basin. V.A. Benenson, N.Y. Kunin (1978), O.G. Brazhnikov, B.S. Shenin and others believe it is Caledonian or Baikalian (V.S. Zhuravlev). Most researchers include the Pre-Caspian Basin in the ancient East-European (Russian) Platform (A.L. Yanshin, E.S. Votsalevsky, Y.A. Volozh, G.Zh. Zholtaev, L.G. Kirukhin, and others). The analysis of peculiarities of geological development of the territory throughout Devonian, Carboniferous and Permian periods (the interval of the pre-salt Paleozoic sequence explored by drilling) supports the second viewpoint on the structure and history of development of the region.

Paleozoic Geologic History

Middle Devonian, and presumably Lower Devonian, undisturbed mudstone and clayey carbonates were exposed by deep drilling in the Astrakhan Arch. The areas of distribution of Upper Devonian-Tournaisian and Upper Visean-Lower Bashkirian carbonates suggest that they spread to the south, to the area where they are absent now. Their development could have taken place only if there were no sourcelands of clastic products in the areas surrounding the Pre-Caspian Basin from the south.

In the middle of the Bashkirian age, the hinterland of the Pre-Caspian Basin subsided and tops of atoll-like carbonate massifs appeared to be below the level of shallow-water carbonate sedimentation. No sedimentation occurred on tops of these seamounts (their height was more than many hundreds of meters) during different times. Once the North Karakul trough, separating the Astrakhan carbonate massif from the Karakul-Smushkov zone, was filled with terrigene sediments, clastic deposits began to be supplied in abundance onto the surface of Lower Bashkirian carbonates. The thickness of this clastic sequence reached 1700 meters in the south of the Astrakhan Arch, it drastically reduced to hundreds of meters in the crest, then gradually decreased to 60 meters towards the northern edge and increased again up to 500 meters behind the carbonate scarp. Further east, in the North Caspian offshore area, a thick fan of Lower Permian clastics is traced south of the Zaburunye Field (near South Zhambai), however then the area of its distribution sharply reduces, it is traced as a narrow strip up to the northern end of the Buzachi Peninsula and stops at the Southern carbonate massif. East of the clastics fan, Artinskian terrigenous deposits are documented by drilling and seismic data only to the meridian of the Tortay structure (with inclusion of the last). Within the southeastern part of the edge zone (South Emba high, Yuzhnoye), carbonate sedimentation continued up to the Sakmarian age inclusive. Sedimentation of clastics that began in the Artinskian age was a result of the past tectonic events. Geodynamic processes by the end of Paleozoic culminated in collision of the East European-Turanian and Kazakh plates and formation of the Eurasian lithospheric plate. The overriding to the west Kazakh plate was raised and became an area of denudation. Thick clastics drifted from its surface and filled in troughs in the East European-Turanian plate in Late Permian and Early Triassic. At the end of the Sakmarian and beginning of the Artinskian ages, the Scythian-Turanian plate that was apparently monolithic at that time moved westward and blocked the main connection of the Pre-Caspian deep-water basin with the Tethys ocean. Mynsualmas, Buzachi and North Caspian micro-blocks located in the zone of junction with the East European platform shifted together with the Scythian-Turanian plate. Their movement led to crumpling of earlier deposited rocks and formation of high amplitude thick folds similar to orogenic structures in the zones adjacent to the East European platform (Karpinsky

Ridge, Mynsualmas, transverse East Donbass uplifts and Salsky Swell), that also advanced on the southern edge of the Pre-Caspian Basin by the system of tectonic faults. The faults were also a source of coarse detritus being supplied in abundance in the Pre-Caspian paleobasin. The appearance of tufaceous argillites on tops of atoll-like carbonate massifs Tengiz, Kashagan and others on the Zhylyoi high was a result of volcanic activity in the area south of the Pre-Caspian Basin.

In the Artinskian age the Pre-Caspian Basin, whose depth was more than 1500 meters, was initially connected with the world ocean only through the strait of the Western Pre-Ural region, however it was also closed in several places for the century by uplifts and molasses from the Ural Mountains. The isolation of the Pre-Caspian Basin from the Tethys paleoocean led to accumulation of thick evaporite deposits in the Kungurian age. These salt-bearing strata became an ideal seal for accumulation of hydrocarbons in the Paleozoic deposits.

Mesozoic Geologic History

At the end of Paleozoic and beginning of Mesozoic some events occurred that played a dominant role in the formation of the Caspian. Splitting of the Scythian-Turanian plate and shifting of its Turanian part by the Mangyshlak Fault in the southeastern direction resulted in the formation of a continental rift and creation of a new Caspian plate at the place of the present North Usturt and South Caspian. The territory of the present North Usturt and South Mangyshlak underwent intensive subsidence with accumulation of thick deposits. Graben-like troughs were formed in the Triassic that were filled mostly with continental sediments. In the Early Triassic (Neftekumskian time) only the East Manych trough remained undercompensated and reef build-ups of a barrier type were formed in its southern edge where clastics were not supplied. Y.P. Malovitsky, as far back as in 1962, noticed the absence of a clear continuation of the structures of the Mangyshlak Upland and the submerged Karpinsky Ridge in the Caspian offshore area. Attempts of some researchers to link together the structure of the Karpinsky Ridge and Mangyshlak Upland seem to be erroneous. The northern part of the Karpinsky Ridge was formed during shifting of the Scythian-Turanian plate before Artinskian time and it cannot even be compared with the structure of Big Donbass that came into existence at the end of the Carboniferous and beginning of the Permian periods providing conditions for formation of evaporites here in the Asselian and Sakmarian ages. Mangyshlak Upland and other uplifts developed at the end of the Triassic period due to inversion or compression in the zones of graben-like troughs.

In Late Permian and Early Triassic times due to the formation of a new Mezotethys ocean, geodynamic activity moved to the south and tension and plunging began here towards the South Caspian. One of the large tension structures was the Mangyshlak system. With short intervals, intracontinental rifting continued until the Middle Jurassic. In Middle and Late Jurassic all the southern part of the region subsided creating inland and over-rift sedimentary basins which were connected with Mezotethys through the Pre-Caucasian Mangyshlak and Amu-Darya straits. Moderate tectonic movements took place at the end of the Jurassic and beginning of the Cretaceous periods, in pre-Aptian and pre-Albian time.

Cenozoic Geologic History

Main events occurred at the beginning of Pliocene. Cardinal Mountain-building processes took place at that time in the Caucasus and the block of the Pre-Caspian Basin was raised together with the northern part of the Caspian plate. The sea abandoned this area and remained only within the South Caspian. The Paleo-Volga valley is traced approximately in the middle of the Central Caspian offshore area. The down-cutting of the valley is over 200 meters. Paleo-Volga had many distributaries that carried fragmentary material from the Miocene and more ancient formations, eroded by water.

The Caucasus Mountains were squeezed in between two plates. The movement of the Arabian plate northward led not only to the formation of the Greater and Lesser Caucasus orogens but also to a partial dislocation of some blocks in the East-European platform. A left-lateral shift occurred at that time in the north of the present Volgograd province which is well observed by the example of the Demyanov reef rupture. Dislocations of the Saratov Ring and Zhigulev swell are probably also associated with this process. In Late Pliocene the sea advanced again and almost all of the territory of the Pre-Caspian basin, the present Caspian Sea and adjacent lowlands appeared under water.

Conclusion

The above geodynamic events in the Caspian region had a different effect on the specifics of its petroleum potential and this should be taken into account in geological modeling of prospects and fields.

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Specifics of geological development of Caspian block structures

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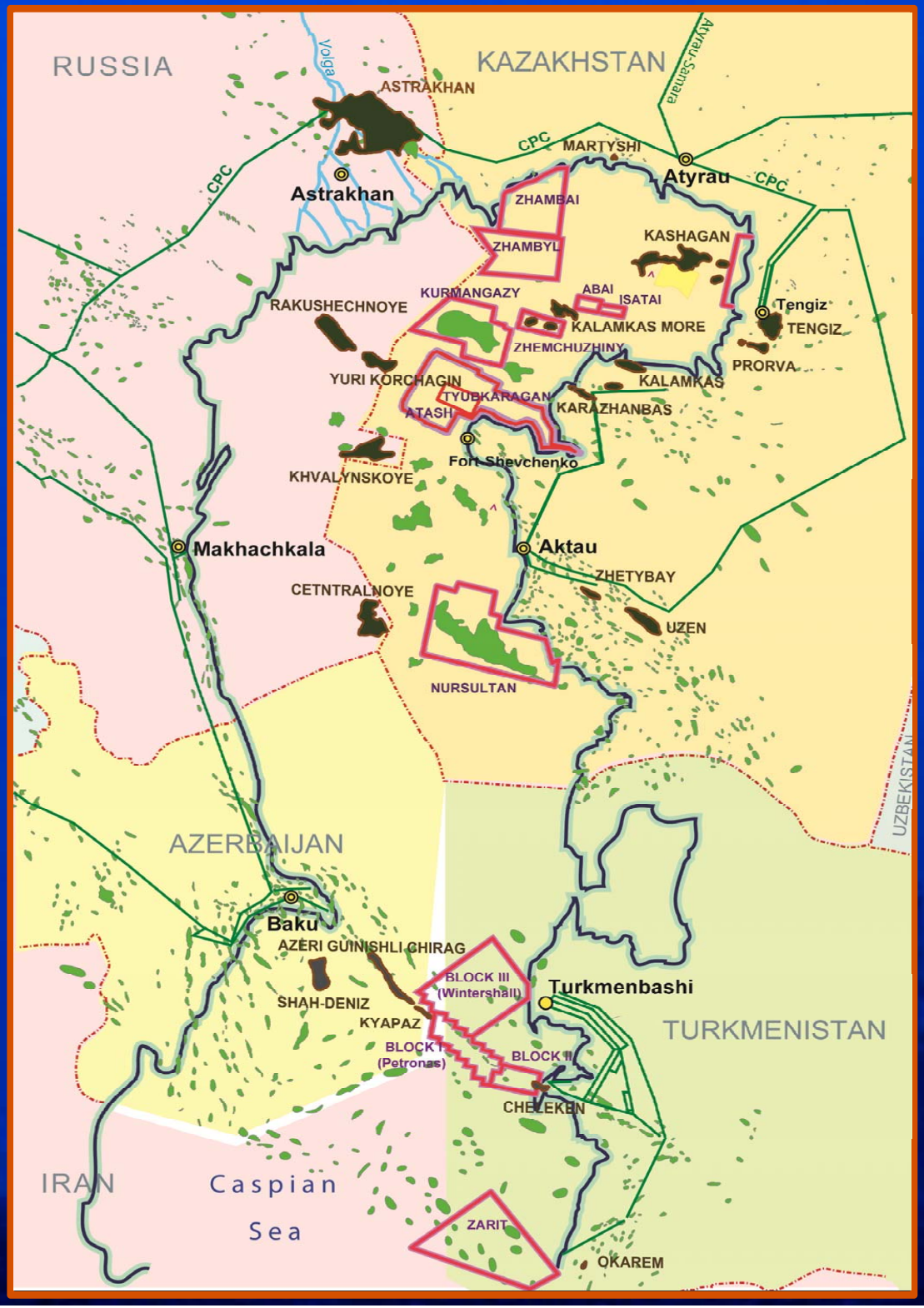
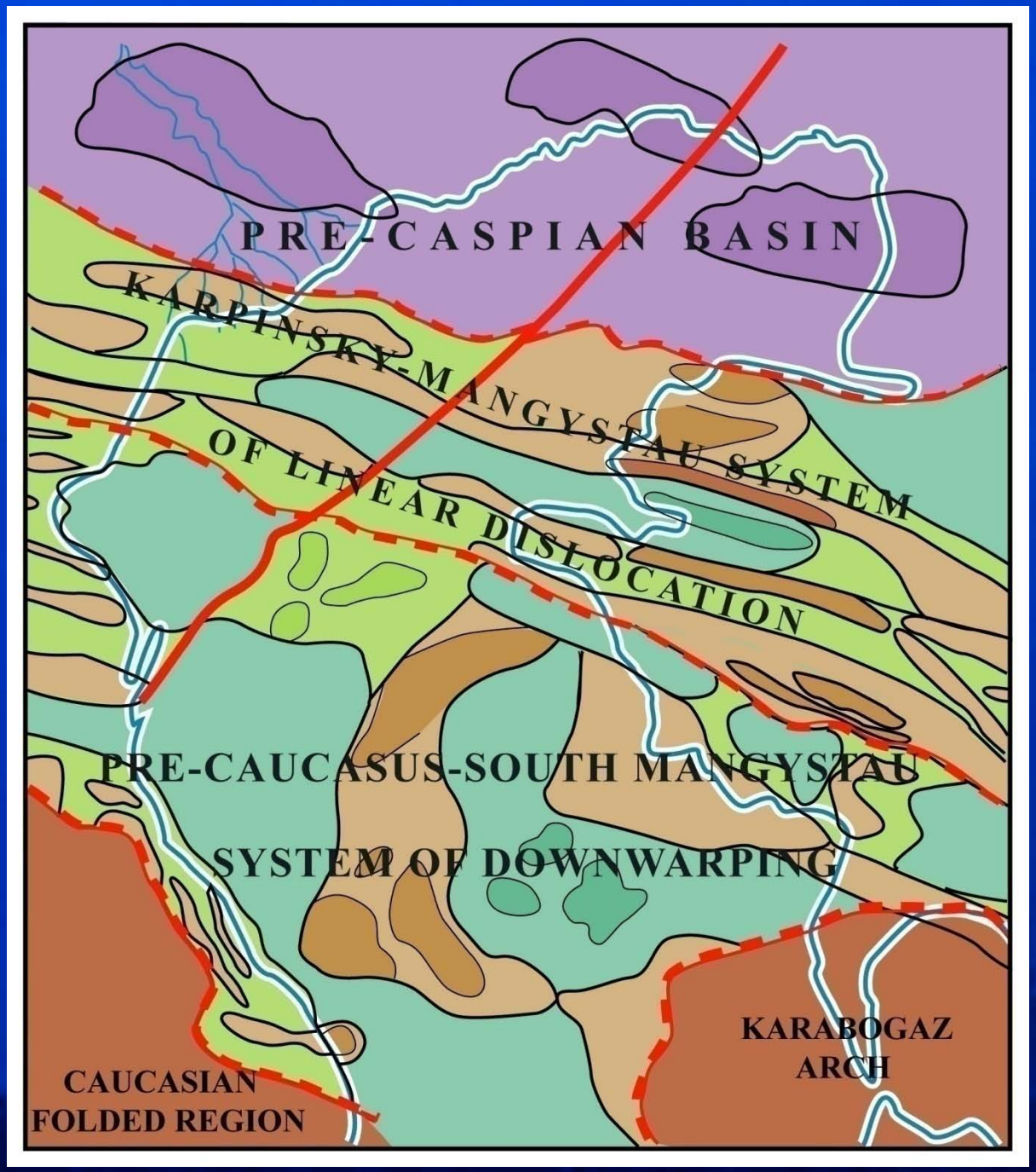
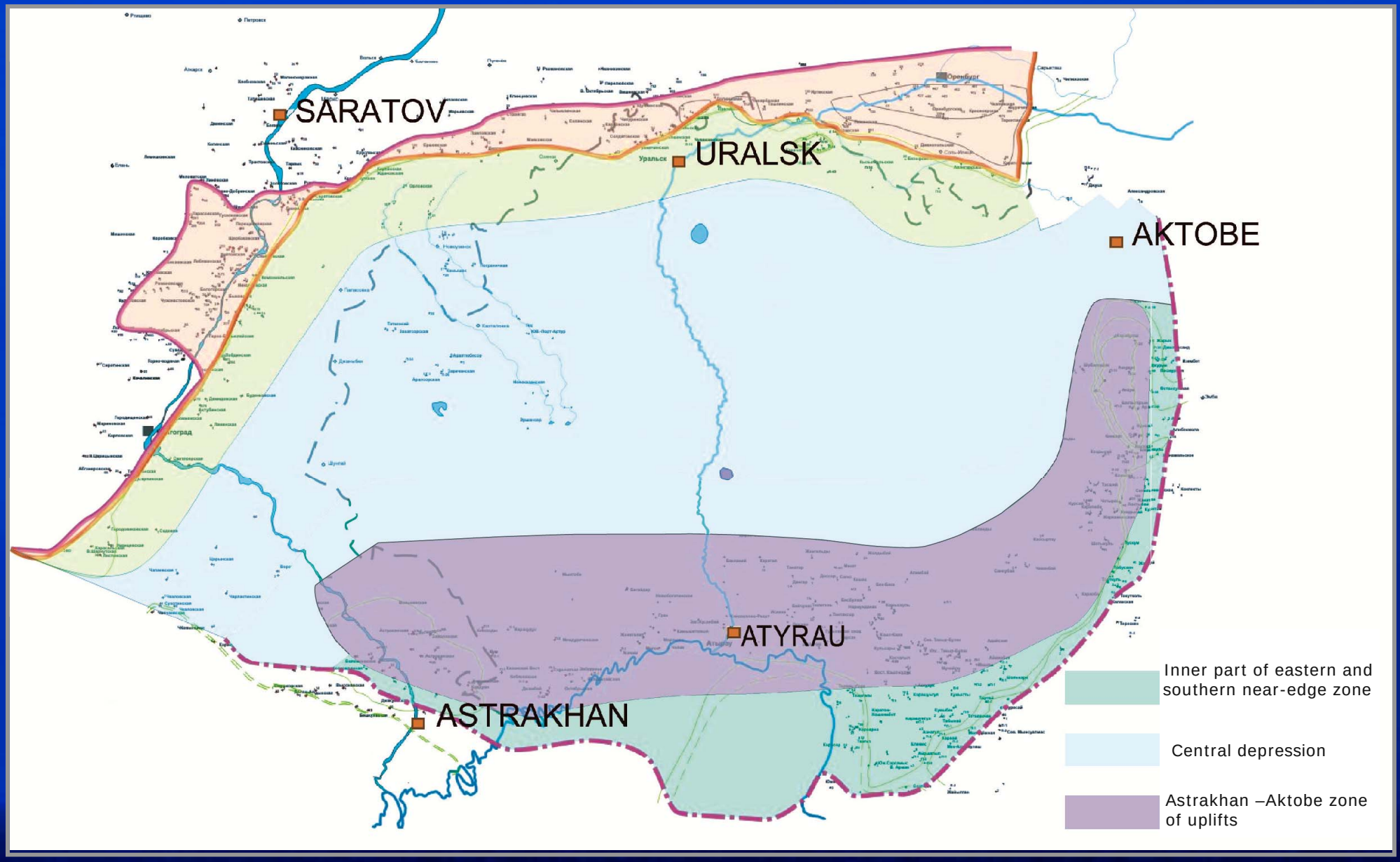
General map of Caspian region



Tectonic map of Caspian region



Sketch map of geotectonic zonation of Pre-Caspian basin (prepared by O.S. Obryadchikov)



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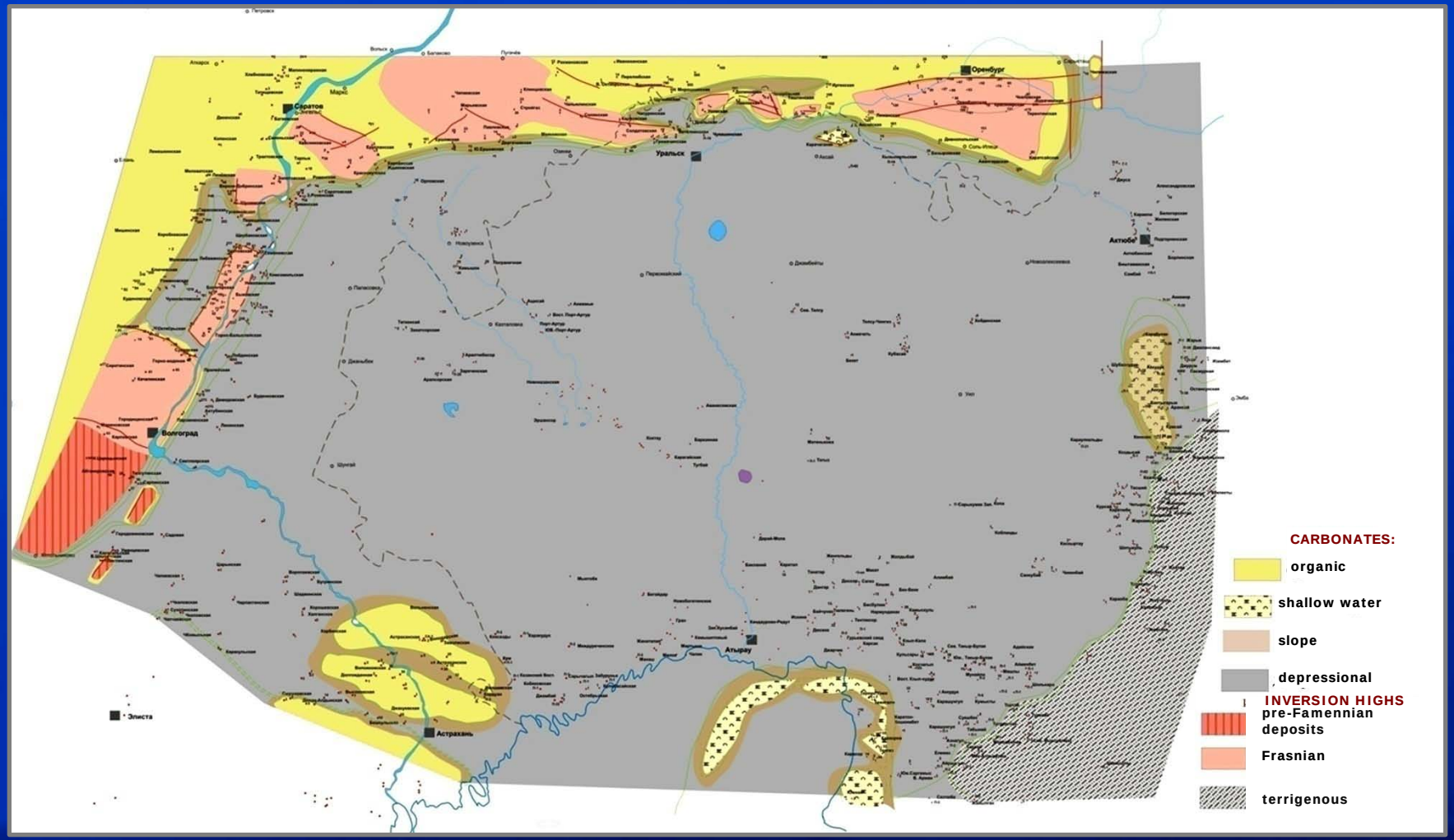
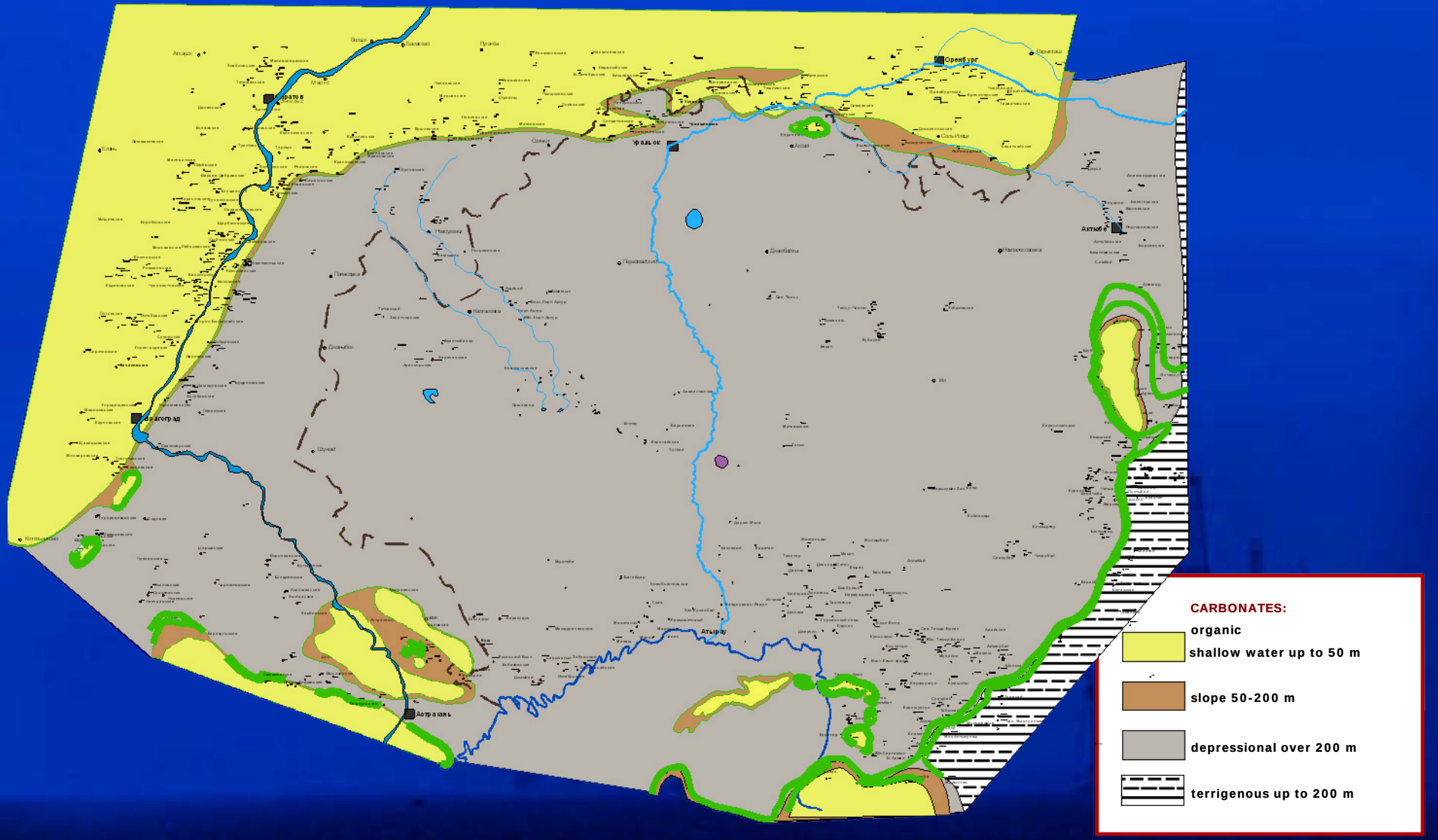
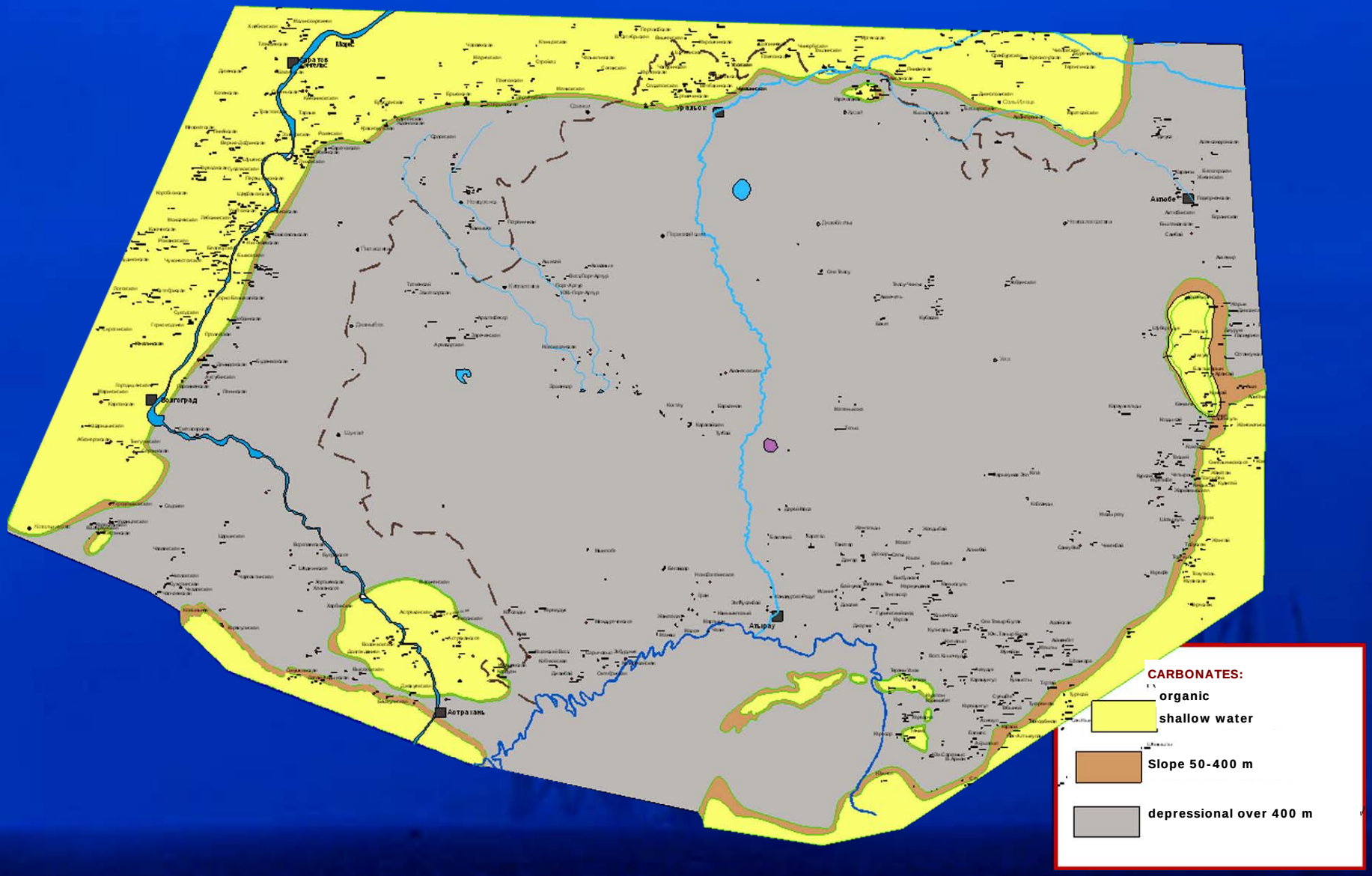


Sketch map of depositional environment in Turnaisian age (prepared by O.S. Obryadchikov)

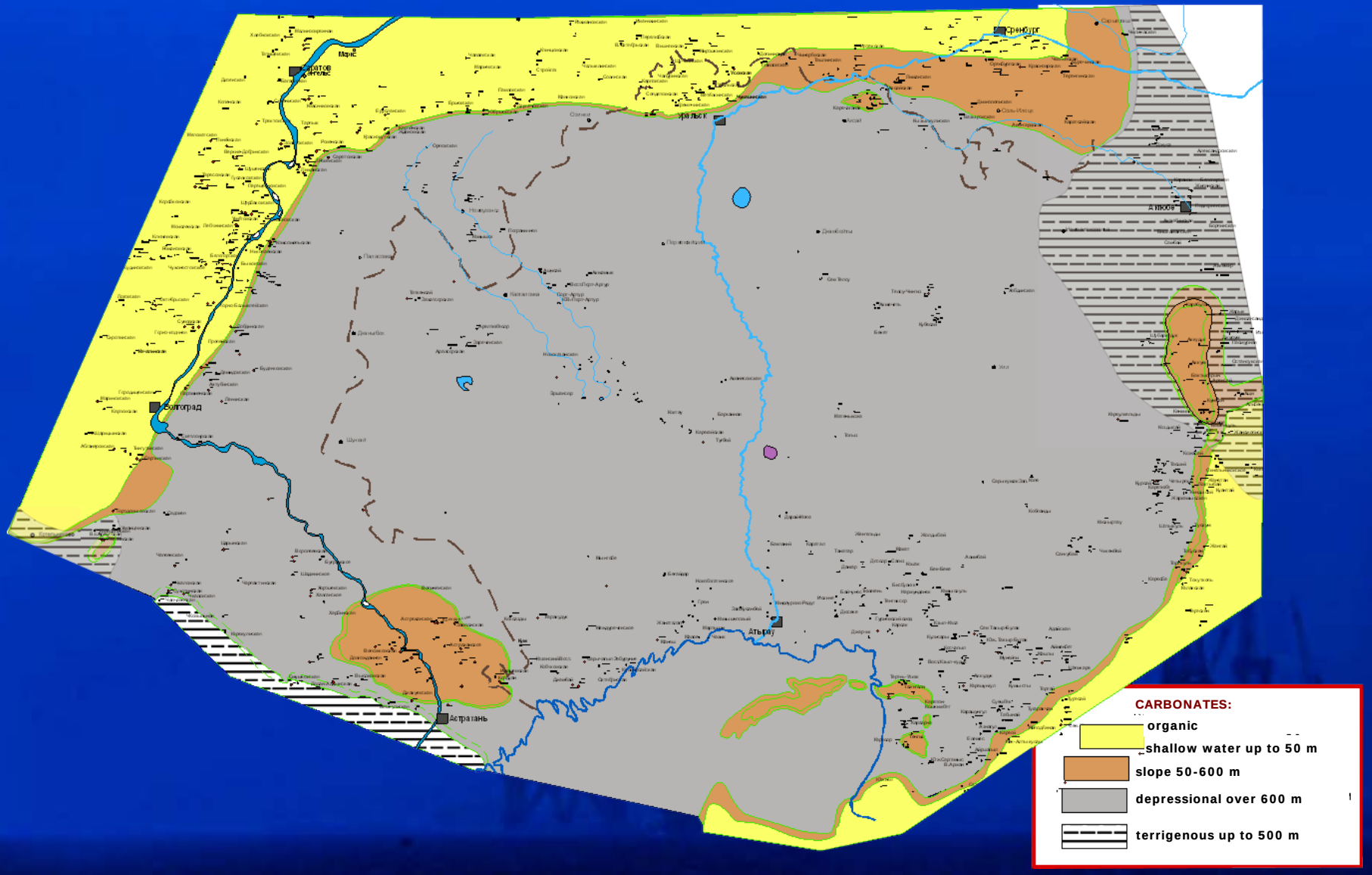


Sketch map of depositional environment in Early Bashkirian time (produced by O.S. Obryadchikov)



Sketch map of depositional environment in Late Carboniferous epoch

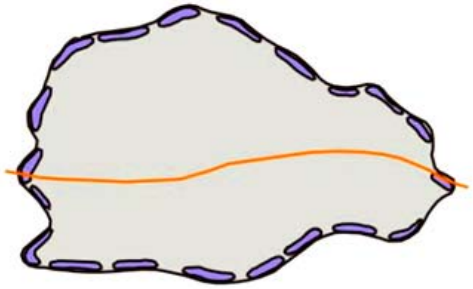
(prepared by O.S. Obryadchikov)



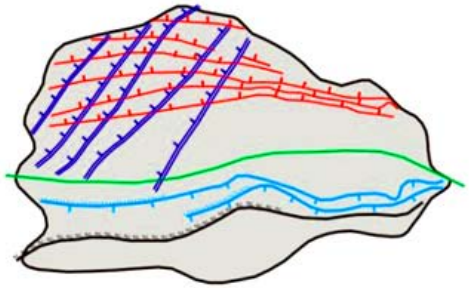
History progress of modern Astrakhan carbonate structure element

(prepared by O.S. Obryadchikov)

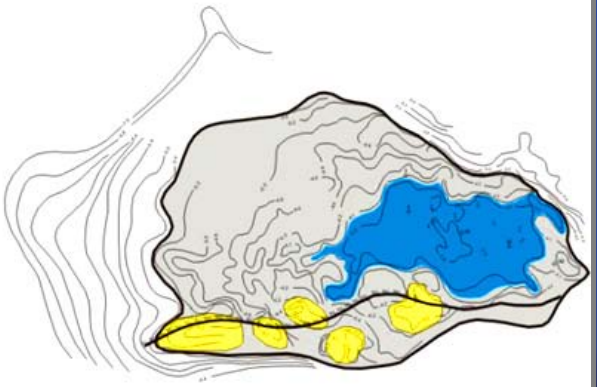
1. Astrakhan dome at the end of Early Bashkirian time

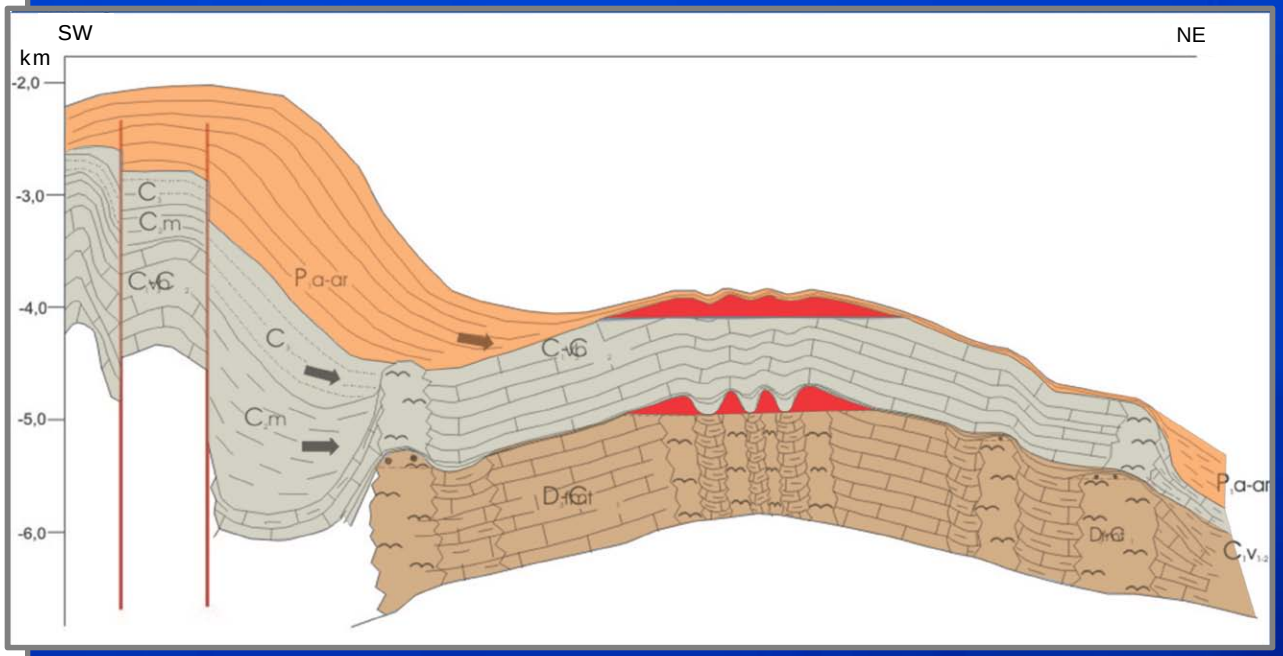


2. Scheme of Carboniferous regional dips in Astrakhan dome area



3. Carboniferous Lower Bashkirian modern structural plan



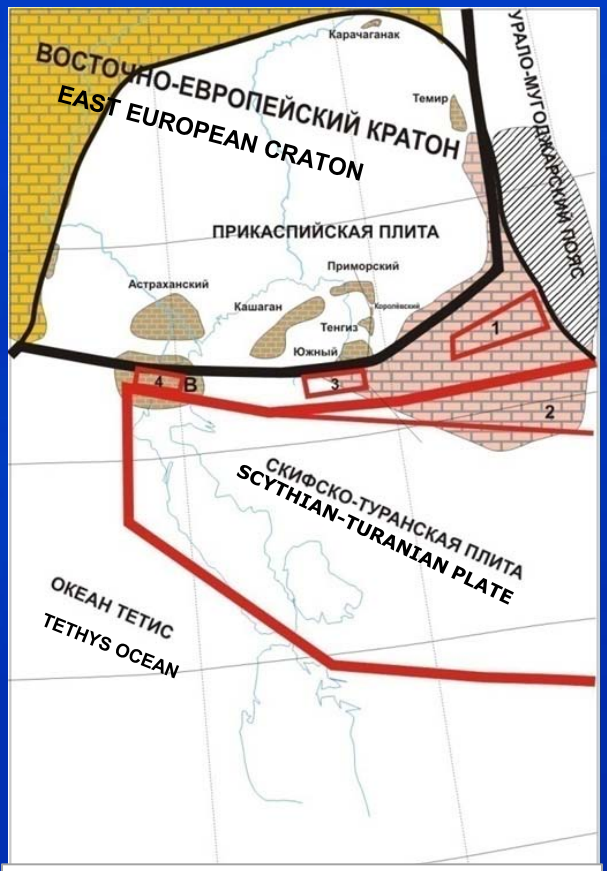


Astrakhan dome (AD) in Late Devonian – Early Bashkirian was a carbonate platform (bank) 1 km high.

By Artinskian age North Karakul trough was filled with sediments and Artinskian deposits created a thick clinoform: in the south of AD Artinskian deposits were 1700 m thick, in the centre about 100 m and in the north (Harabali) – 60 m.

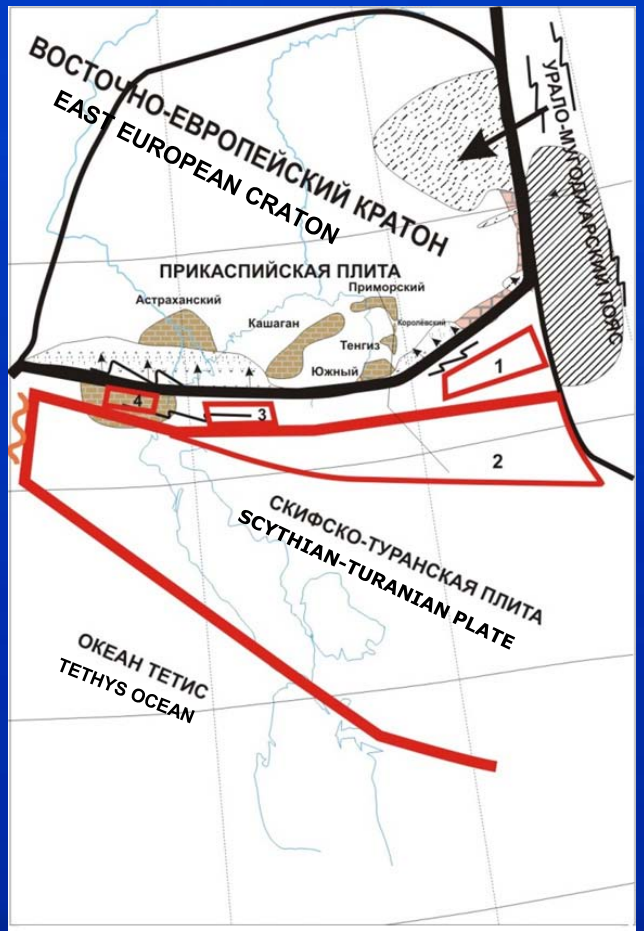
Evolution of Caspian region tectonics

End of Sakmarian age



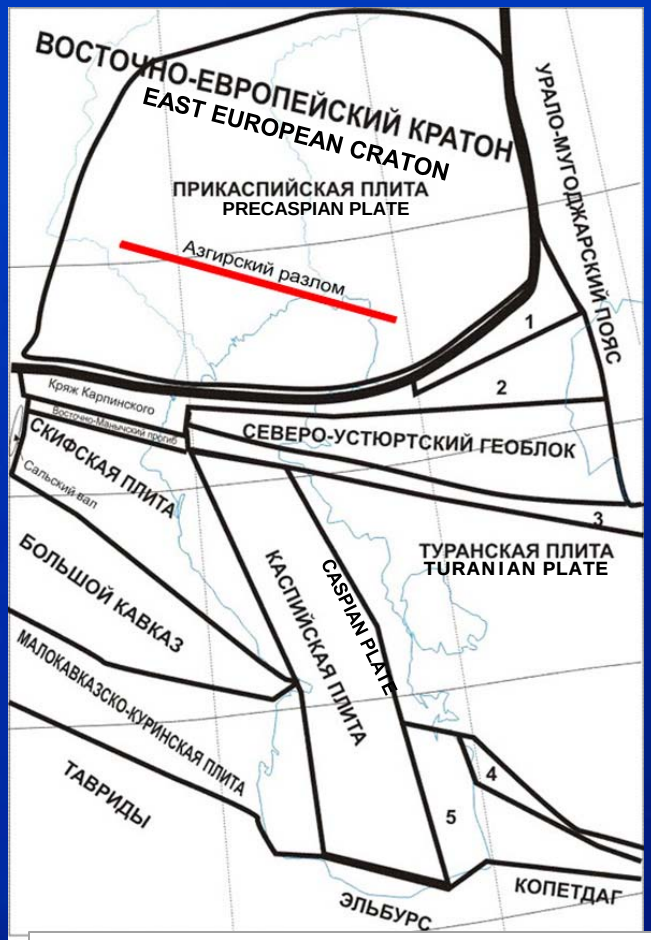
1 Boundaries of 1a Russian platform; 1b Pre-Caspian plate and western limit of Ural-Mugodzhary orogen, 2a Scythian-Turanian plate, 2b – blocks and microcontinents; 3 – Ural-Mugodzhary orogen, 4 – Volga-Ural carbonate platform , 5- Zhanazhol – Torkol – South Emba carbonate platform, 6-Atoll-like carbonate massifs and carbonate banks, 7- relatively deep-water part of the basin.

Beginning of Kungurian age



1-4 Blocks and microcontinents : 1- Diyar –Teresken, 2 – Mynsualmas, 3- Bozashi, 4- Krasnohuduk.

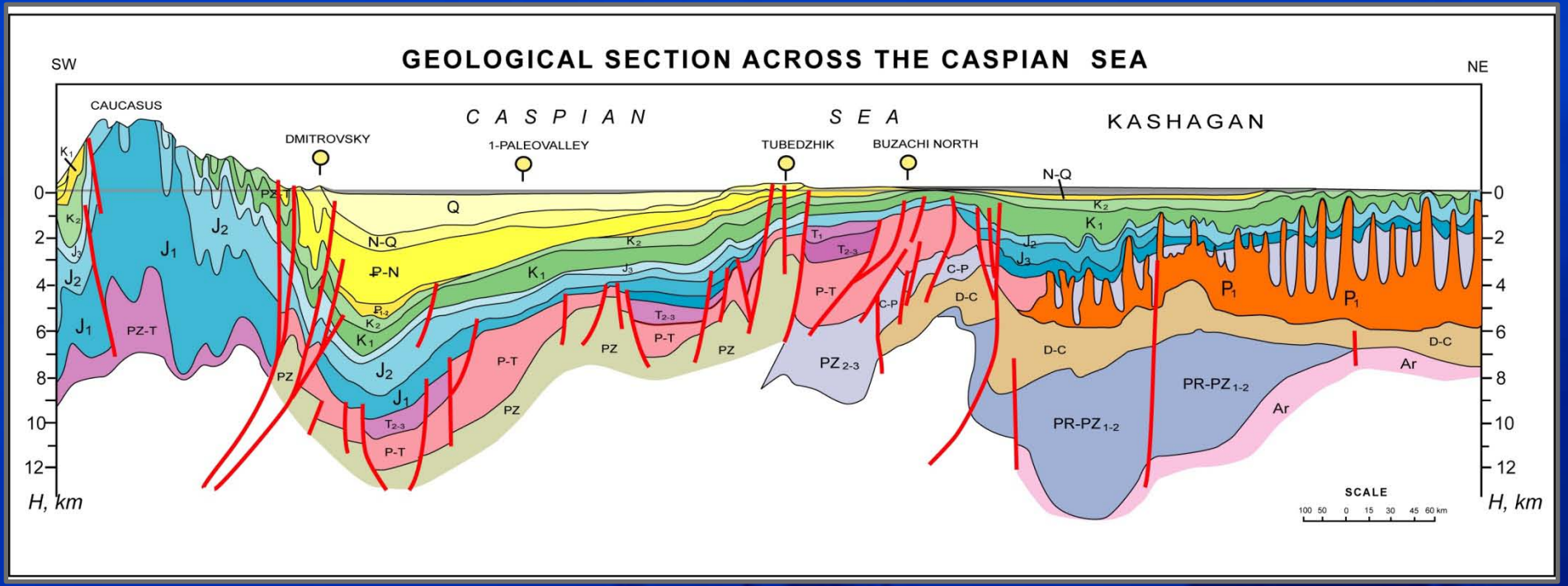
Mesozoic-Cenozoic



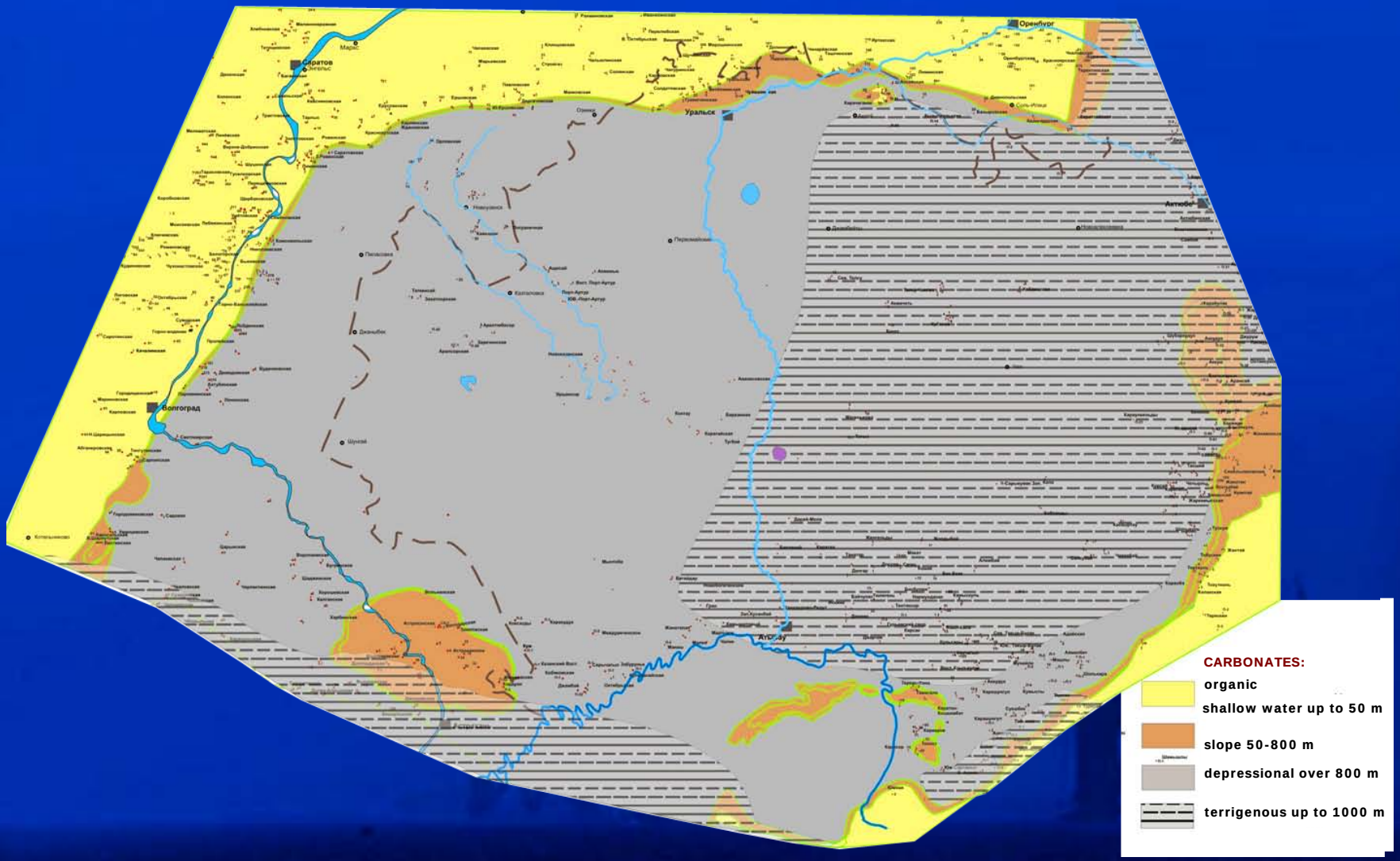
BLOCKS: 1. NORTH MYNSUALMAS –TERESKEN , 2 – KARPINSKY-BUZACHI-MYNSUALMAS, 3- MANGYSHLAK - CENTRAL USTURT, 4- BIG BALKHAN, 5 – WEST TURKMEN.

Geological section across the Caspian Sea

(Drawn up by O.S. Obryadchikov)



Sketch map of depositional environment in Artinskian age



Location of tectonic plates of Caspian region

BLOCKS:

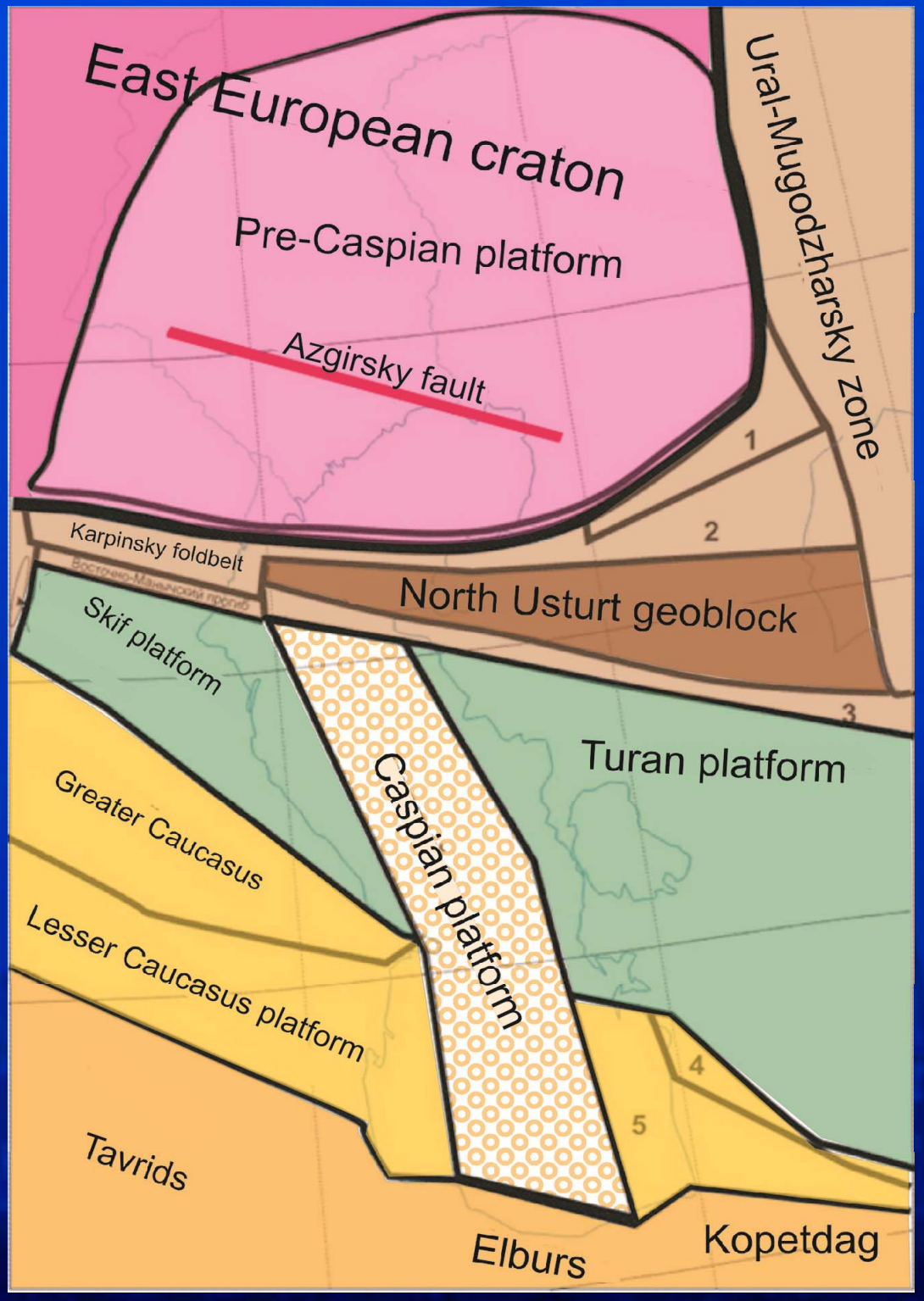
1 – NORTH MYNSUALMAS-TERESKEN

2 – KARPINSKY-BUZACHI-MYNSUALMAS

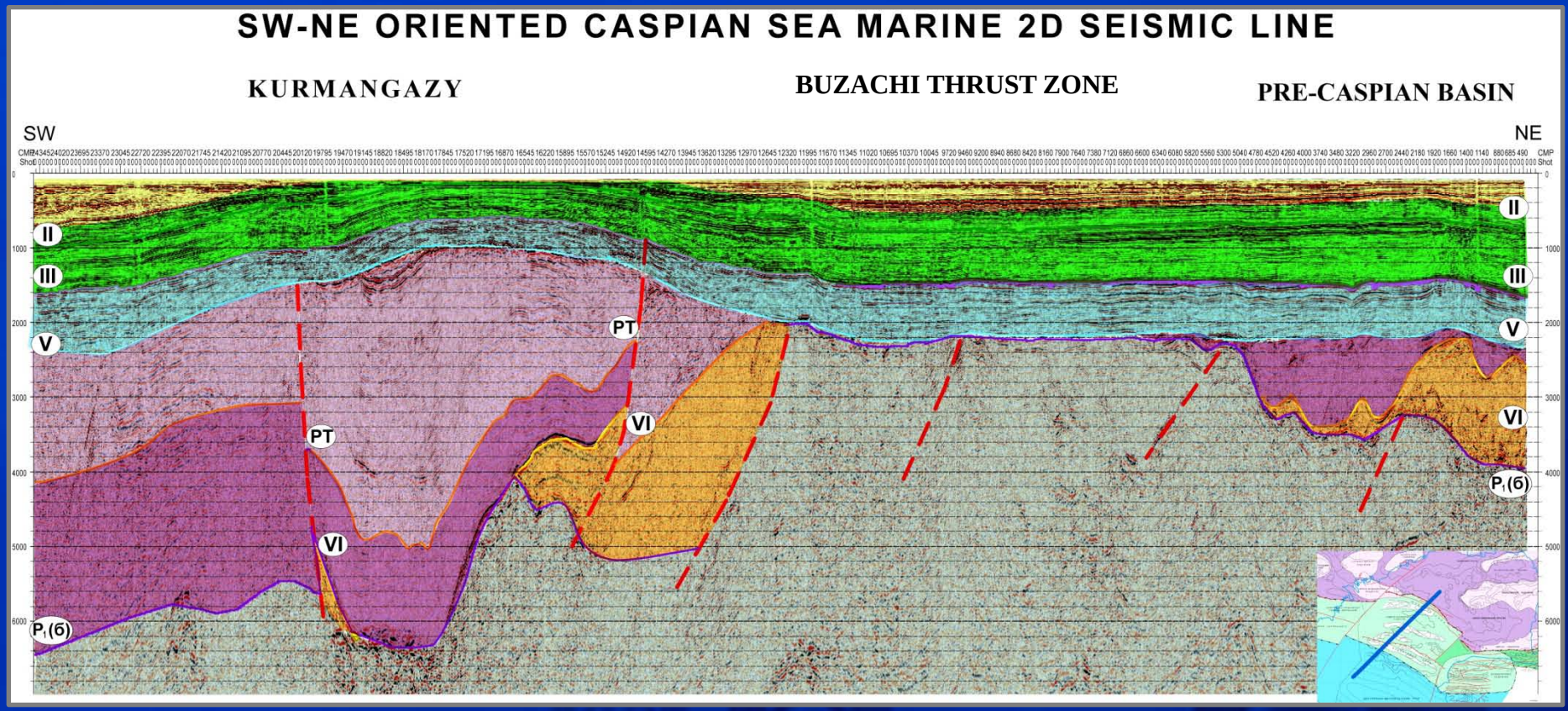
3 –MANGYSHLAK –CENTRAL USTURT

4 – BIG BALKHAN

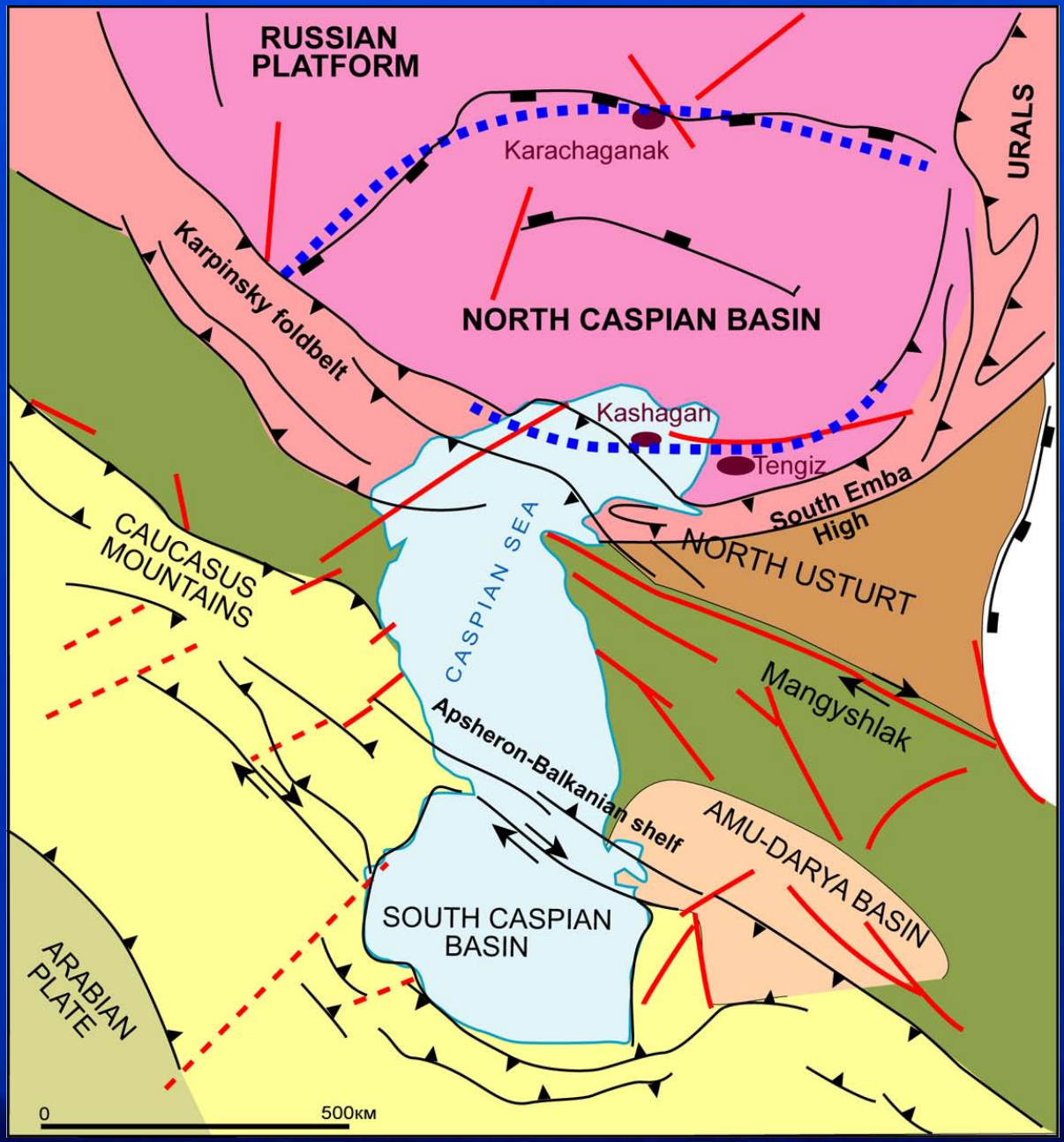
5 – WEST TURKMEN



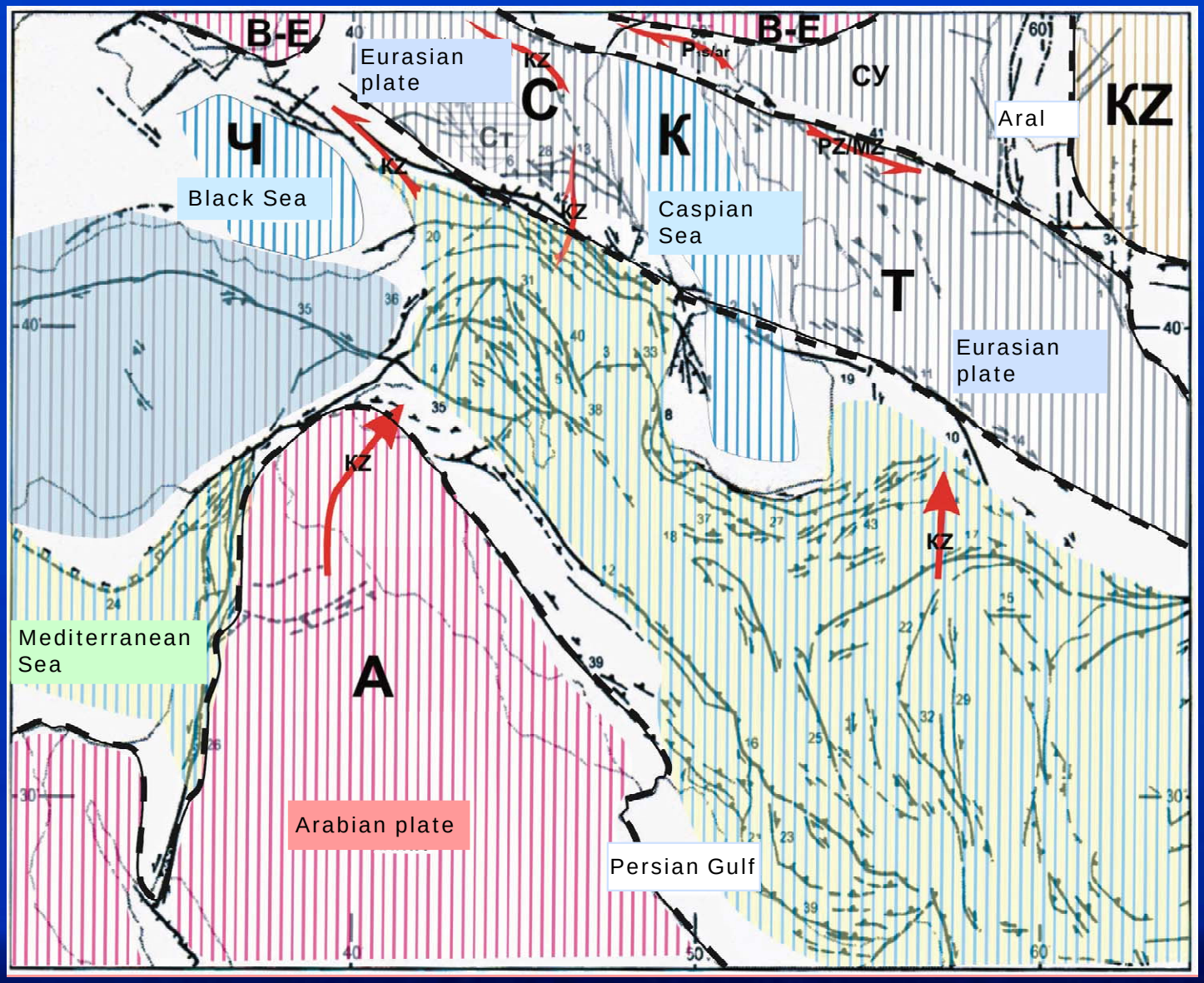
Seismic line across Makhambet zone of thrusts

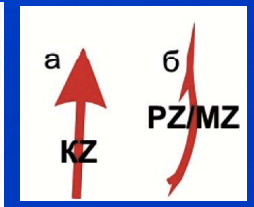


Structural-tectonic map of Caspian region



Plates of Arabian-Caucasian region and directions of their movement





Movement:
a – plates
b – direction of shifts

B-E – East European

A - Arabian

KZ – Kazakh massif of caledonides

C – Scythian

K – Caspian

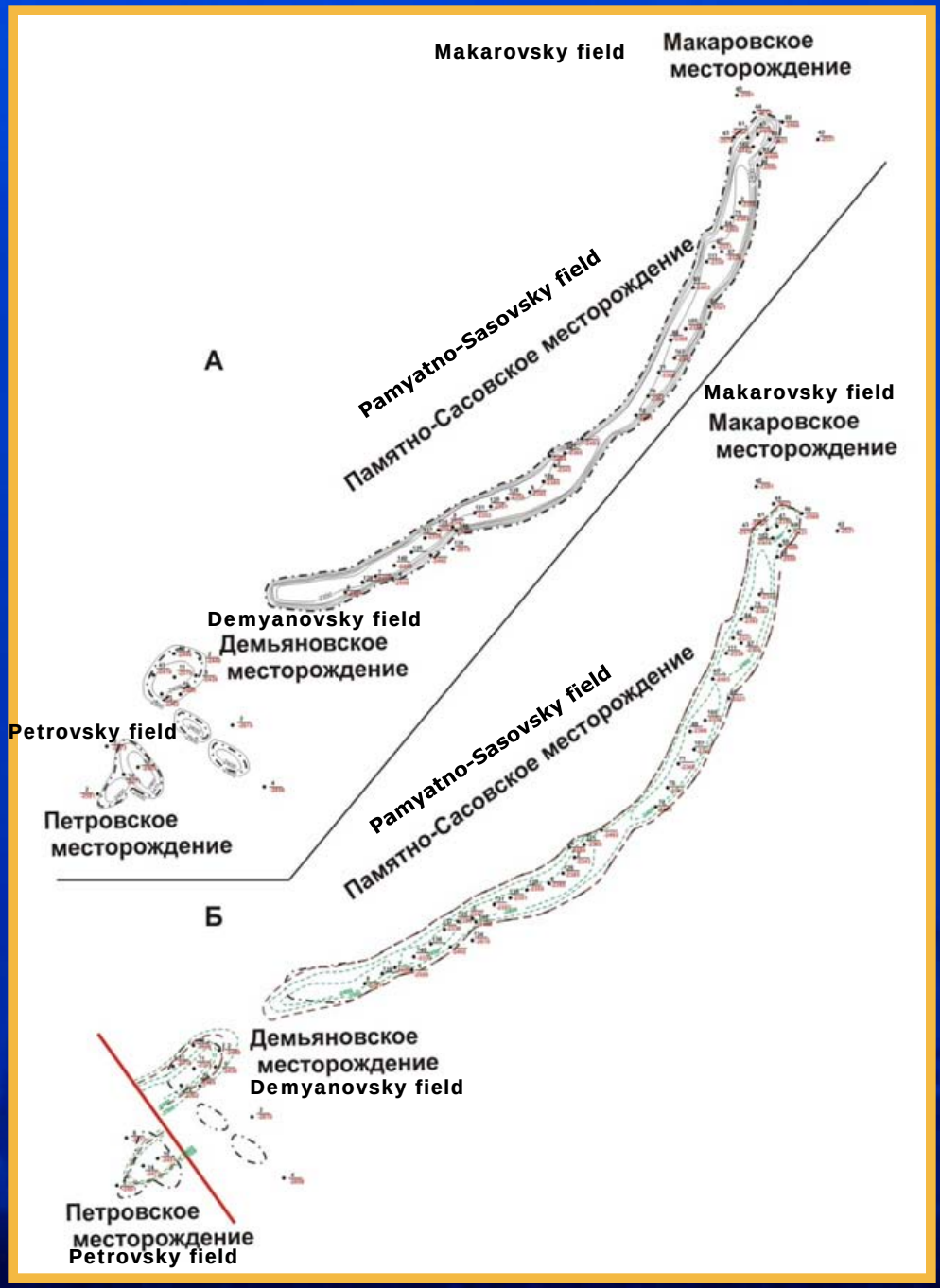
Ч – Black Sea

T – Turanian

СУ – North Usturt

Versions of different interpretation of reef structure by an example of Demyanovsky field

(Russia, Volgograd province)



Thank you for your attention