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Vladislav N Melikhov, Marie-Françoise Brunet, Nikolay A Krylov, Igor V Shevchenko, Vladimir L Shuster. Eastern onshore side of the South Caspian Basin-prospects for oil and gas exploration (petroleum exploration) of carbonate deposits of the Upper Jurassic-Neocomian. [Intern report] VSEGEI. 2021. hal-03339885

HAL Id: hal-03339885

<https://hal.science/hal-03339885>

Submitted on 9 Sep 2021

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Eastern onshore side of the South Caspian Basin - prospects for oil and gas exploration (petroleum exploration) of carbonate deposits of the Upper Jurassic-Neocomian

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Abstract. For the South Caspian Oil and Gas Bearing Province, the conclusion is made that the Pliocene productivity is predominant in the western part of the province and that the oil and gas prospects in the Mesozoic for the eastern onshore part are a priority.

A retrospective analytical review of geological and geophysical data and published materials on the Mesozoic of South-West Turkmenistan has been accomplished, it revealed the low efficiency of the performed seismic and drilling works during exploration and evaluation of relatively complex Mesozoic targets. Massive resumption of seismic surveys and appraisal drilling of modern level in the priority areas and targets involving leading Russian companies is proposed. For some areas, a new improved estimation of potential gas resources is provided.

The example of modern, highly efficient supplementary exploration of a small Pliocene gas and oil field, West Cheleken, is presented which turned this field into a major one in term of reserves.

A first version of this review has been published in Russian (Melikhov et al., 2021).

The review is dedicated to the memory of the outstanding Turkmenistan petroleum geologist M.A. Ashirmamedov.

Melikhov V.N., Brunet M.-F., Krylov N.A., Shevchenko I.V., Shuster V.L., 2021. Eastern onshore side of the South Caspian Basin - prospects for oil and gas exploration (petroleum exploration) of carbonate deposits of the Upper Jurassic-Neocomian. VSEGEI report, St Petersburg, Russia.

Introduction

This review summarizes and analyzes the results and recommendations of long-term scientific and practical researches done by a group of authors in Turkmenistan (State Concern "Turkmenneft", "TurkmenNIPIneft", State Corporation "Turkmengeologiya" and its geophysical and drilling expeditions in West Turkmenistan; "Turkmen-NIGRI", Institute of Geology, RAS, etc.), the USSR and Russia (Institute of Geology and Development of Fossil Fuels/IGIRGI, Russian Research Geological Oil Institute/VNIGNI, etc.) referring Mesozoic issue of the South-West Turkmenistan (SW Turkmenistan) onshore part. The maximum number of reports and publications referring the Mesozoic deposits was recorded at the end of the Soviet period.

In modern Turkmenistan, the works were mainly published in scientific and technical journal "Oil and Gas of Turkmenistan". In 1980-2000, several regional exploration and appraisal programs for Mesozoic formations were developed, their implementation had an extremely reduced form.

Certainly, one of the strategically significant issues for SW Turkmenistan is the Mesozoic development (Godin, 1961; Kalugin, 1964; Kudelsky, Bartashevich, 1964; Mirzakhanov, Nazarov, 1964; Mirzakhanov et al., 1964; Kudelsky, Kalugin, 1968; Mirzakhanov, 1969; Nikolenko, 1969; Nikolenko, Skub, 1969; Odekov, Zakhidov, 1969; Zyubko et al., 1970; Zhukoborsky, 1971; Prozorovsky, Ilyin, 1972; Krylov et al., 1973a; Zhukoborsky et al., 1977; Alifan et al., 1979; Odekov, Valbe, 1979; Shein et al., 1986; Orel et al., 1987; Grachevsky, Kravchuk, 1989; Ashirmamedov, 1996; Kravchenko et al., 1998; Ashirmamedov et al., 1975a-b, 1978, 1999a-b-c-d; Gumarov, 2002; Melikhov, 2017). In almost all publications and reports, high degree of gas and oil prospects of carbonate Malm-Neocomian was declared, it is justified by a complex of positive geologic, geophysical, and geochemical prerequisites as well as gas and oil shows from the Upper Neocomian part of the Cretaceous. However, current negative condition of Mesozoic exploration in SW Turkmenistan is interpreted as an uncertain result of this direction in exploration and appraisal. For almost 20 years the Mesozoic direction of oil and gas exploration in SW Turkmenistan has been actually preserved. In this paper, an attempt to recommend the revival of the Mesozoic play at modern level of seismic exploration and drilling operations has been made.

South Caspian oil and gas province. Priority of gas and oil prospects of the eastern onshore side in the Mesozoic

Pessimism referring to the Mesozoic play in SW Turkmenistan is mainly defined by an abnormal complexity of geological conditions for well placing in lower Tertiary deposits in many areas of the region.

Pessimistic view on the Mesozoic was also contributed by lack of prompt discoveries and, indirectly, low assessment of oil and gas potential of Azerbaijan onshore Mesozoic (Alizade et al., 1972).

The overview map of regional structure of simplified oil and gas geological zoning and productivity of the South Caspian oil and gas province (NGP) (Melikhov, 2015) is presented in Fig. 1; it shows the Pliocene productive areas, zones, and fields of SW Turkmenistan, promising to some extent for the Mesozoic. Fig. 2 presents simplified oil and gas geological zoning of the province based on the thickness map of the main Middle Pliocene oil and gas complex (Glumov et al., 2004).

With a significant number of Mesozoic gas and oil shows on both Western Azerbaijan and Eastern Turkmen onshore sides of the South Caspian province, these sides are fundamentally different in their structure and, therefore, in gas and oil potential of the Mesozoic (Fig. 3).

The Mesozoic of the Azerbaijan onshore Kura-Shemakh-Gobustan region, excluding the Upper Cretaceous stage of carbonates and volcanic rocks interlayers up to 2 km thick, is mainly formed by volcanic rocks and effusive rocks to the depth of 8.3 km in the ultra-deep well Saatly (Fig. 4, 5). In this region, a small oilfield Muradkhanly was discovered in the volcanic rocks of the Upper Cretaceous. The same Mesozoic feature persists at great depths in Azerbaijan water area of the Caspian Sea, as is evidenced by the latitudinal regional seismic section through the South Caspian (see Fig. 3).

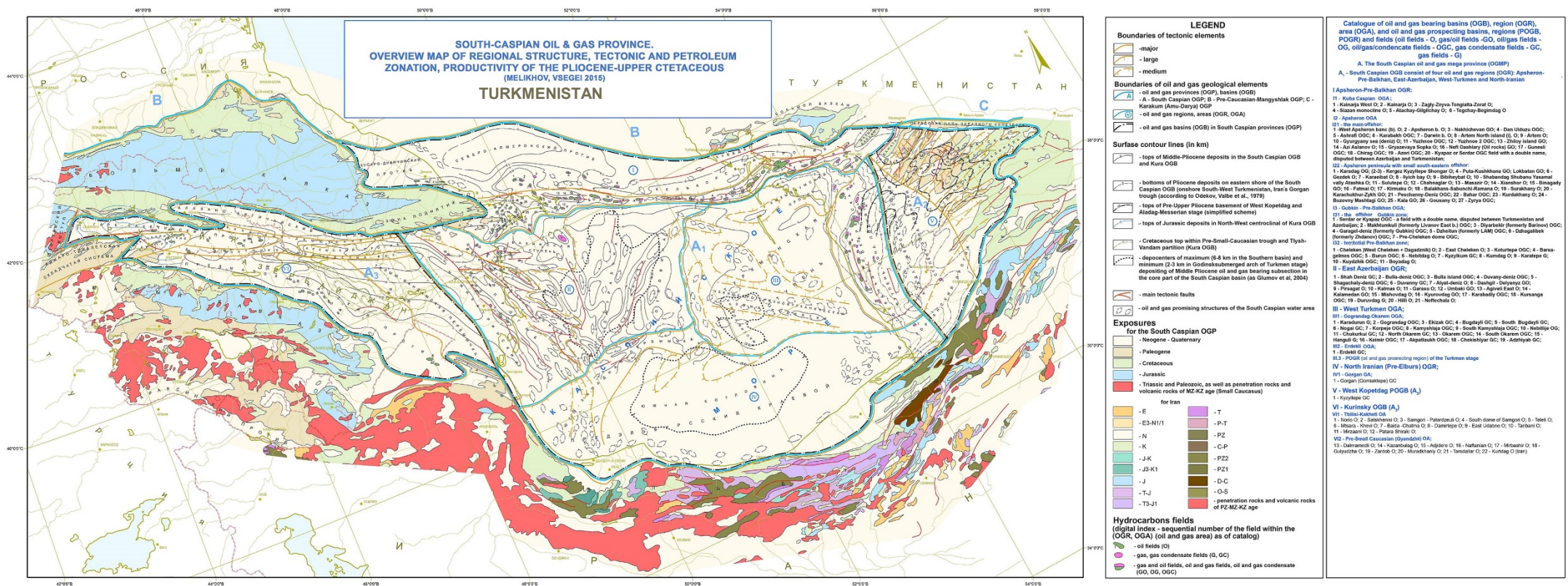
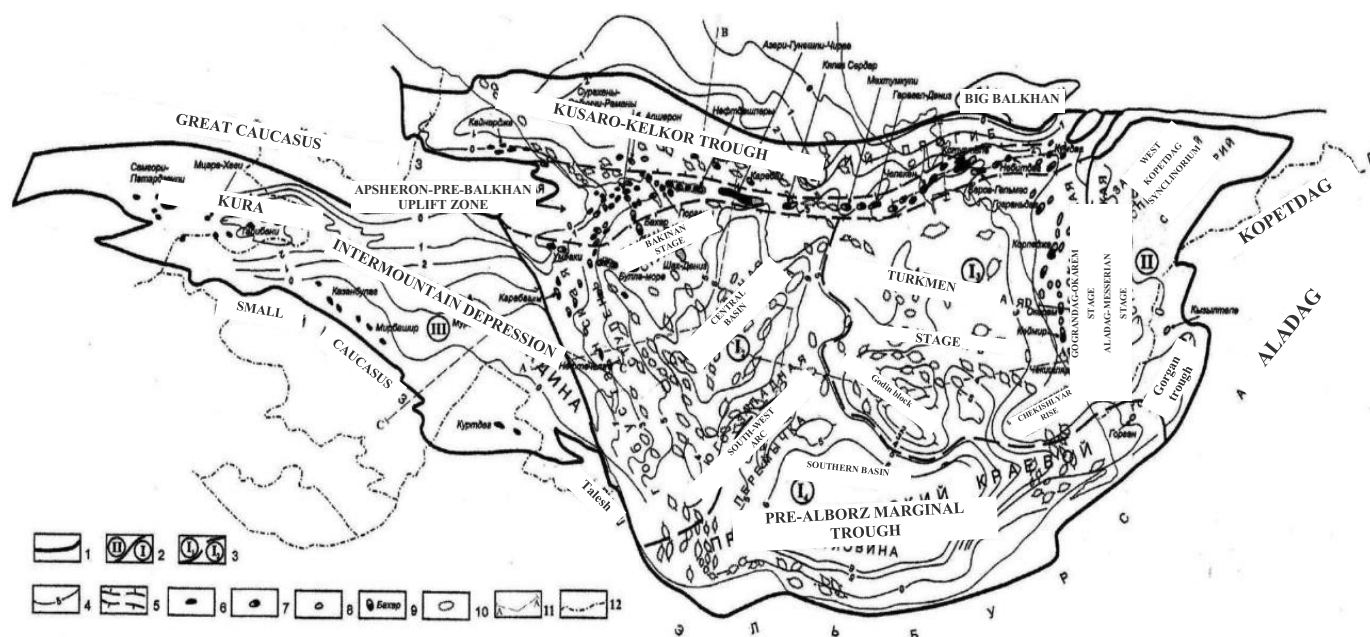
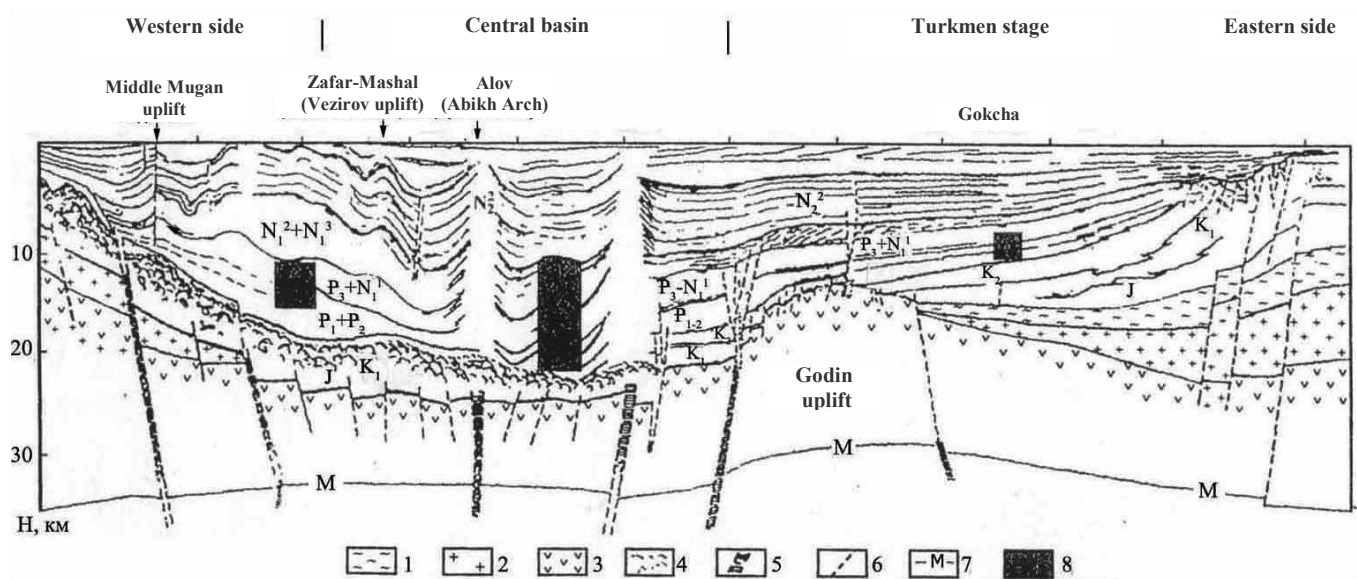


Fig.1. Map of tectonic, oil & gas and geological zonation, Pliocene-Upper Cretaceous productivity of the South Caspian oil and gas province (Melikhov, 2015)



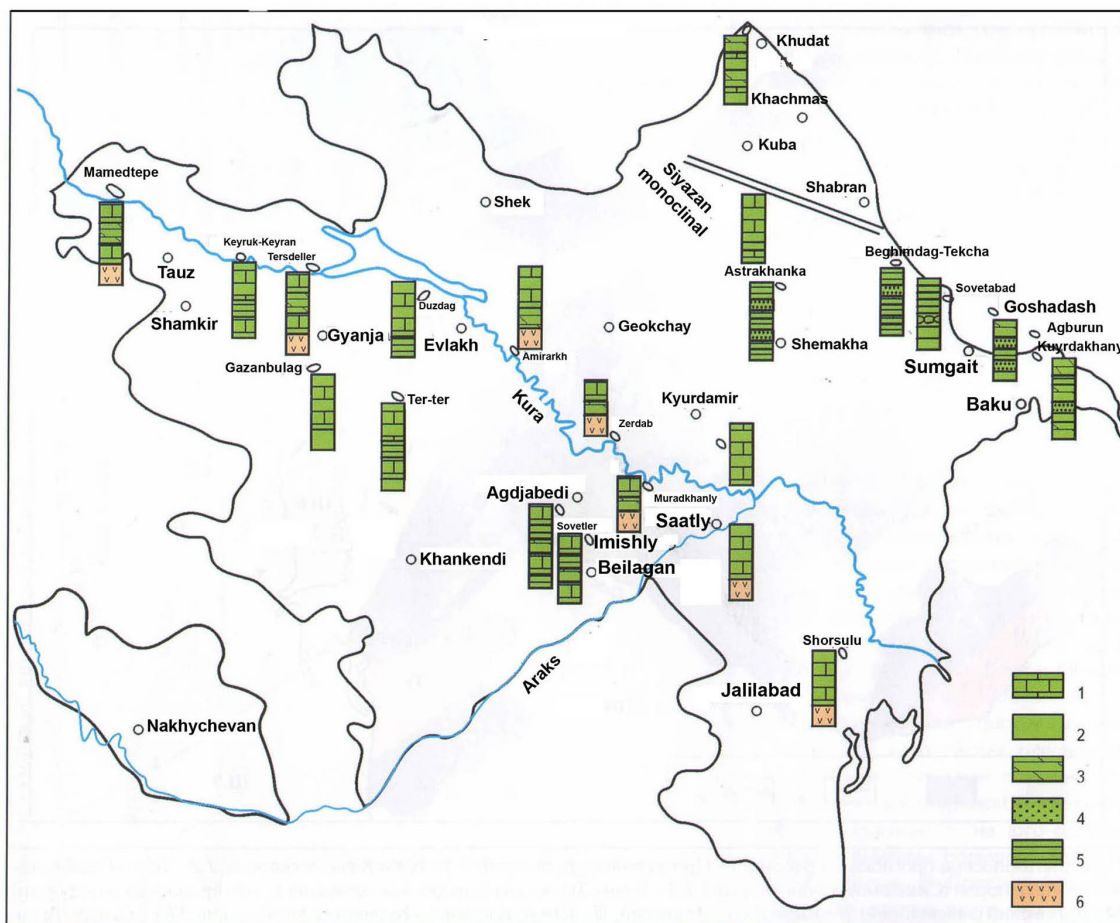
1 - external border of the South Caspian oil and gas basin (NGMB); 2 - boundaries and marking of oil and gas basins (NGB) included into the South Caspian NGMB: I - the South Caspian NGB, II - West-Kopetdag NGB, III - Kura NGB; 3 - boundaries and marking of oil and gas areas (NGO) included into the South Caspian NGMB: I₁ - Apsheron-Pre-Balkhan NGO, I₂ - East-Azerbaijan NGO, I₃ - West Turkmen NGO, I₄ - North Iran (Pre-Alborz) NGO; 4 - isopach lines of oil and gas Middle Pliocene complex in km (after Glumov et al, 2004 with changes on the eastern side of the oil and gas megabasin (NGMB)); 5 - Apsheron – Pre-Balkhan uplifts zone; 6 - 8 fields: oil fields (6); gas and oil fields, oil and gas condensate fields (7); gas condensate and gas fields (8); 9 - names of representative oil fields; 10 - oil promising structures of the South Caspian water area; 11 - lines of geologic and geophysical sections; 12 - state borders

Fig. 2. Version of simplified oil and gas zoning of the South Caspian NGB based on the thickness map of the main Middle Pliocene oil and gas complex (Melikhov, 2015)



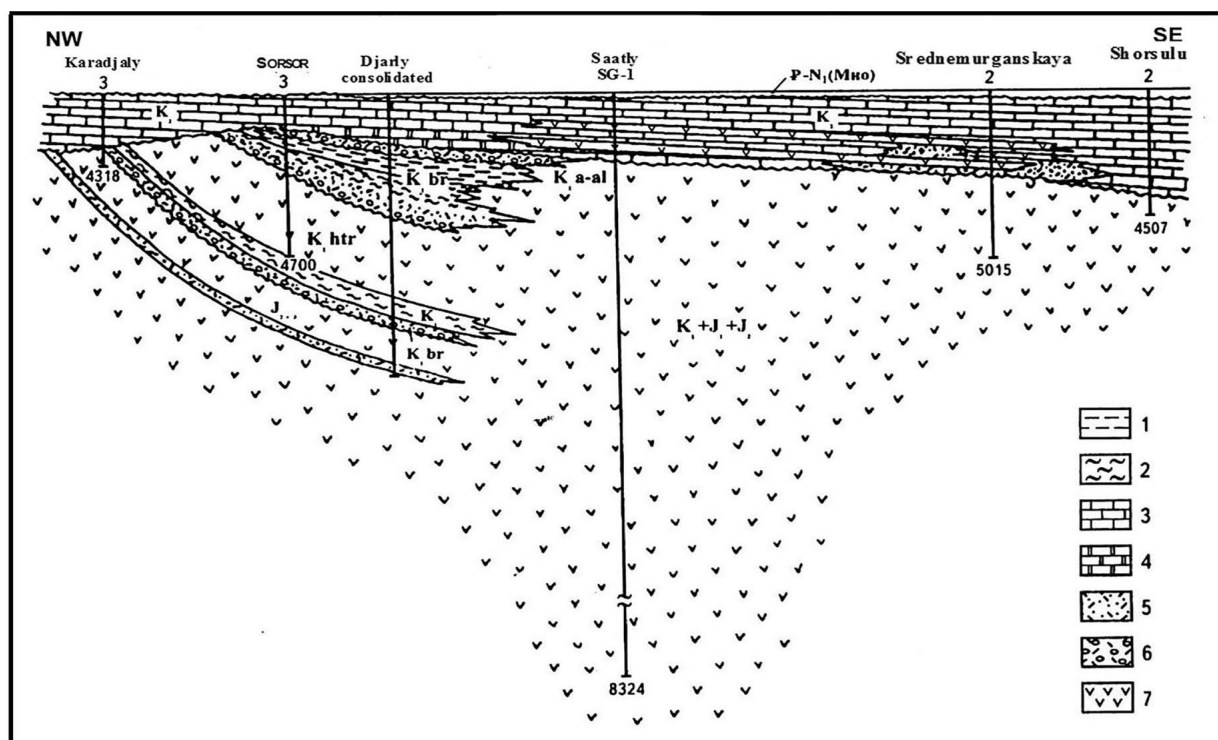
1 - Paleozoic basement; 2 - granite layer; 3 - basalt layer; 4 - Mesozoic igneous rocks; 5 - deep faults; 6 - faults; 7 - Moho surface; 8 - origins of hydrocarbons generation

Fig. 3. Sub-latitudinal seismic and geological section through the South Caspian depression with predicted location of hydrocarbons generation origins (Mamedov, 1992)



1 – limestones; 2 – dolomites; 3 – marlstones; 4 – sand and sandstones; 5 – clays; 6 – effusive rocks

Fig. 4. Upper Cretaceous lithology columns. Azerbaijan - onshore (Shikhaliev, Kocharly, 2015)



1 – clays; 2 – clay stones; 3 – limestones; 4 – dolomites; 5 – tuff stones; 6 – tuff conglomerates; 7 – effusive rocks

Fig. 5. Lithofacies profile of Mesozoic deposits through the ultra-deep well Saatly SG-1. Azerbaijan - onshore (Aliev et al., 2004)

In Turkmen offshore and onshore parts of the province, at substantially lower depths, a powerful (up to 5-7 km) Jurassic-Cretaceous sedimentary complex is registered, it is bedded with Permian-Triassic intermediate (from cover to crystalline basement) volcanogenic-sedimentary complex not less in capacity. Partial Mesozoic sedimentation and complete sedimentation of intermediate complex (IC) occurs at the largest and most defined Godin uplift in the South Caspian basin - the buried arch.

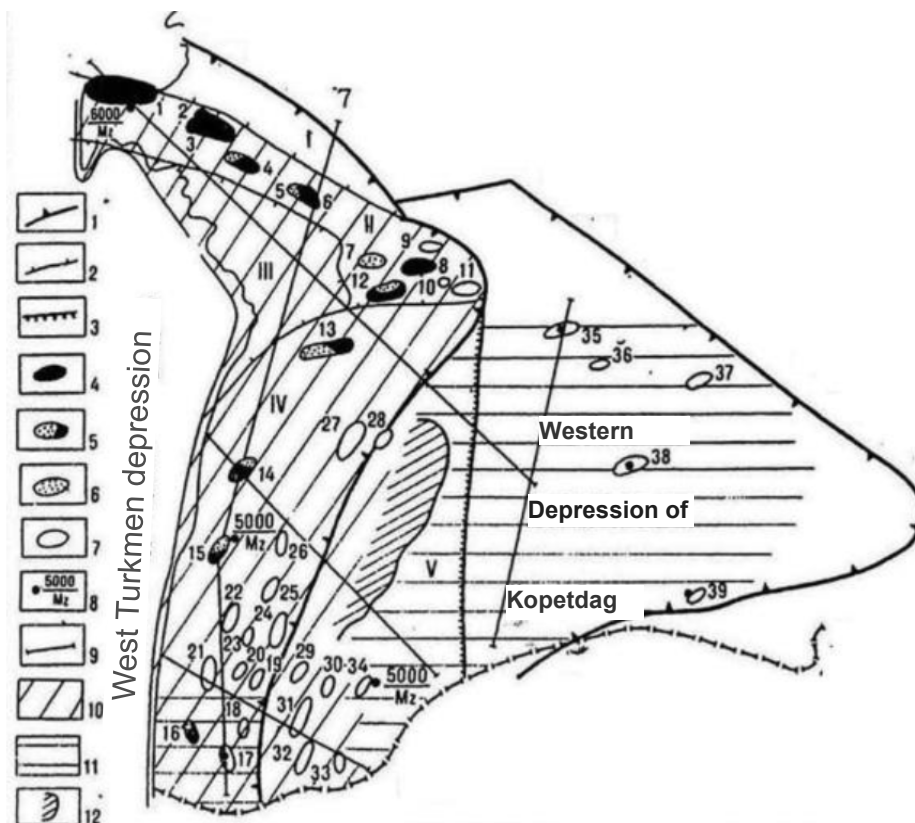
Based on the above, onshore Mesozoic of the eastern, Turkmen part of the South Caspian province, available for drilling to a depth of 3-6 km is promising referring to gas and oil capacity (with high potential in some zones, areas and section parts).

Exploration history of the region and the Mesozoic issue

SW Turkmenistan includes the West Turkmen depression - the eastern part of the South Caspian basin and the West-Kopetdag basin connected with it through the Aladag-Messierian bridge section - the Kopetdag synclinorium (Kalugin, 1964; Kudelsky, Bartashevich, 1964; Kudelsky, Kalugin, 1968; Zyubko et al., 1970; Krylov et al., 1973a; Zhukoborsky et al., 1977; Ashirmamedov et al., 1978; Kravchenko et al., 1998).

Development of exploration and appraisal and oil industry since the end of 19th century up to 70s of the 20th century is described in the book "Oil of Turkmenistan" (Alifan et al., 1979).

In the region, discussions of the Mesozoic issues began as early as in 1950s, number of reports and publications increased significantly in 1960-70s at the stage of gradual decline in reserves growth and oil production from the main Pliocene play and start of regional exploration studies of the Mesozoic with seismic transects and stratigraphic drilling (Fig. 6, 7).



Boundaries of structural elements: 1 - II order; 2 - III order; 3 - flexural fault zone;

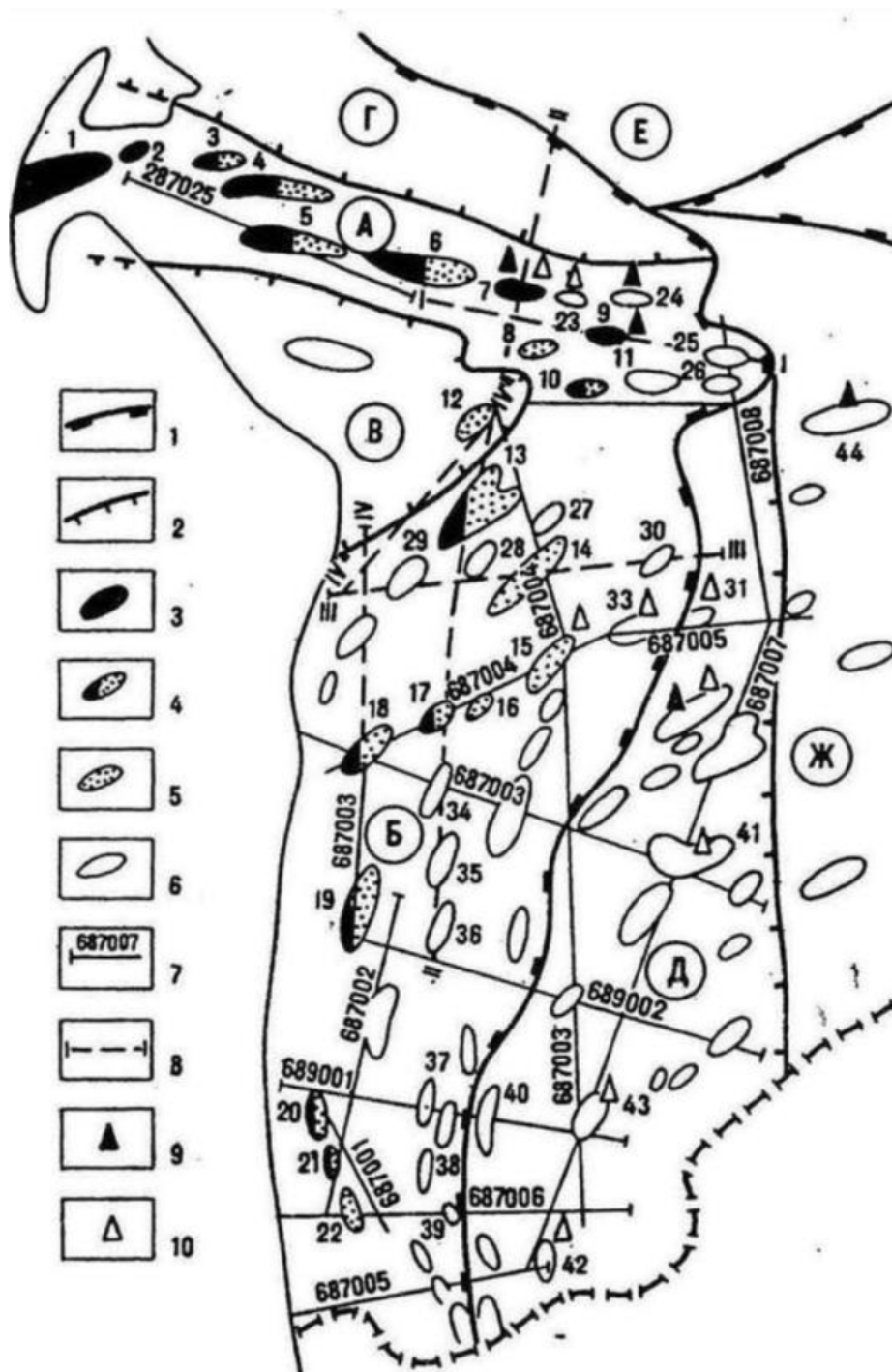
Field: 4 - oil; 5 - oil and gas; 6 - gas; 7 - prepared local structures; 8 - recommended reference and parametric wells; 9 - project regional seismic profiles with common midpoint method;

Areas of exploration works concentration: 10 - targeted at Neogene deposits; 11 - targeted at Mesozoic deposits; 12 - in the zone of Neogene deposits pinch-out;

Structures: I - Kelkor trough; II - Pre-Balkhan uplift zone; III - Kyzylkum trough; IV - Gograndag-Okarem uplift zone; V - Aladag-Messierian uplift zone;

Local structures: 1 - Cheleken, 2 - Komsomol, 3 - Koturtepe, 4 - Barsagelmes, 5 - Burun, 6 - Nebitdag, 7 - Kyzylkum, 8 - Kumdag, 9 - Karatepe, 10 - Kobek, 11 - Syrtlanli, 12 - Kuydzhi, 13 - Gograndag, 14 - Kamyshlaja, 15 - Okarem, 16 - Chikishlyar, 17 - Adjyab, 18 - Kavylskaya, 19 - Sartlali, 20 - South Chaynok, 21 - Akeser, 22 - Miasser, 23 - North-Chaynok, 24 - Inderlan, 25 - Khanguli, 26 - Chukurkui, 27 - Bugdali, 28 - Karmar, 29 - Nevchaytag, 30 - Bilyudzhin, 31 - Delali, 32 - Togolok, 33 - Karadjabatyr, 34 - Kyzylatrek, 35 - West Aladag, 36 - Chaaldji, 37 - Eishem, 38 - Kalaus, 39 - Isak

Fig.6. Layout of exploration and appraisal directions for 1976-1980. SW Turkmenistan (Krylov, Silich et al., 1976)



Boundaries of tectonic elements: 1 - of first and 2 - second order;

Fields: 3 - oil fields, 4 - gas and oil fields, 5 - gas and gas condensate fields;

6 - regional structures;

Seismic profiles: 7 - surveyed, 8 - recommended;

Stratigraphic wells: 9 - drilled (penetrated Mesozoic) and being drilled with Mesozoic as a target; 10 - recommended;

Tectonic elements: A - Pre-Balkhan stage - uplift zone, Б - Gograndag-Okarem - uplift zone, В - Kyzylkum trough, Г - Kelkor trough; Д - Aladag-Messierian stage - uplift zone, Е - Kubadag-Big Balkhan horst anticline, Ж - Western Kopetdag;

Fields: 1 - Cheleken, 2 - East Cheleken, 3 - Komsomol, 4 - Koturtepe, 5 - Barsagelmes, 6 - Burun, 7 - Nebit-Dag, 8 - Kyzylkum, 9 - Kumdag, 10 - Kuijik, 11 - Boyadag, 12 - Erdekli, 13 - Gograndag, 14 - Ekiz-Ak, 15 - Bugdaili, 16 - South Bugdaili, 17 - Korpeje, 18 - Kamyshlaja, 19 - Okarem, 20 - Keimir, 21 - Akpatlukh, 22 - Chikishlar;

Structures: 23 - Monjukly, 24 - Karatepe, 25 - Tuzluchay, 26 - Syrtlanli, 27 - North Ekiz-Ak, 28 - South Karadurun, 29 - Karadashli, 30 - Kaimat, 31 - West Zirik, 32 - West Aladag, 33 - Karmar, 34 - Ak-Maya, 35 - Chukurkui, 36 - Hanguli, 37 - Inderlan, 38 - Sartlali, 39 - West Gokcha, 40 - Gourden, 41 - Izatkuli, 42 - Togolok, 43 - Bilyuji, 44 - Danata

Fig.7. Layout of regional exploration and appraisal and project for 1991-1995. SW Turkmenistan (Mamiesenov, Silich et al., 1992)

Regional oil and gas exploration and appraisal works in onshore SW Turkmenistan were performed in small volumes and with different tasks since 1970s (Ashirmamedov et al., 1975a, 1978; Krylov et al., 1973a; Mamiesenov et al., 1992). Since 1985, they were principally focused on the Mesozoic and the Miocene (see Fig. 7).

Due to high level of Pliocene hydrocarbon resources development (87% of oil and 65% of gas in 1990), in 1986-90s a maximum volume of designed regional seismic surveys was observed – 1100 linear km for 13 profiles (the project was completed by less than a half), which showed only short, dynamically weak reflections with uncertain stratigraphic identification in the Mesozoic (Mamiesenov et al., 1992). Instead of 20 parametric wells planned for 1986-1990s, six wells were drilled, of which only 4 wells penetrated the Mesozoic and provided some information on it.

For 1991-1995s, it was planned to drill 10 stratigraphic wells with total meterage of 54 thousand meters and acquisition of 600 linear km of seismic profiles including 500 -with common mid-point method, 100 – with correlation refraction seismic method, which was also only partially completed. Since 1996 until now, no seismic transects have been performed on the Mesozoic. Till 2000, small area surveys with common mid-point method were performed so far and individual wells targeted at the Mesozoic were drilled. In 2002 in Turkmenistan, a drilling program for 6 stratigraphic wells targeting the Mesozoic was approved; of these wells only one was drilled in Cheleken and it was shut down at TD 6030 m due to technical reasons.

Negative condition of Mesozoic exploration and ways to overcome it

Almost all seismic survey data on the Mesozoic of SW Turkmenistan due to poor quality, do not match requirements for survey and preparation of assets to exploration drilling.

Structural mapping was not performed for promising deposits of the Malm-Neocomian and Upper Neocomian part of the Cretaceous. Usually, diagrams for overlying phantom seismic horizons were presented and their structure does not reflect geometric shapes of promising assets that occur thousand meters below them. Besides, geophysical data contained no information on the Mesozoic geological record forecast (Mamiesenov et al., 1992).

There is no alternative to seismic study of the Mesozoic, except massive implementation of new high-tech seismic surveys of regional exploration and area surveys in the region. The authors recommend these works to be performed by Russian service geophysical survey company e.g., "Saratovneftegeophysika" with broad positive work experience in the Central Asian region of the Commonwealth of Independent States (CIS), which demonstrated high-quality mapping of the Mesozoic and the Paleozoic and structures development in the Ustyurt region of Uzbekistan (Gafarov et al., 2010), as well as survey of very complex sub-thrust assets in Tajikistan. It is feasible to engage Russian major oil and gas company for exploration of the Mesozoic structures of SW Turkmenistan.

In the 1996-2000s, on the initiative of Demina Z.K., all significant seismic profiles and resultant maps from the reports of Western Geophysical Expedition, and of its previous and subsequent reincarnations, were summarized and analyzed in the system of Geology Management of the TSSR (Turkmen Soviet Socialist Republic) - State Corporation "Turkmengeologiya".

As a result, consolidated fragmentary seismic structure maps of the Neocomian and Cenomanian phantom seismic horizons (Fig. 8) were compiled on a scale of 1:100 000; that is a great achievement allowing to design more confidently future regional exploration and areal high-resolution seismic surveys in the Mesozoic of SW Turkmenistan.



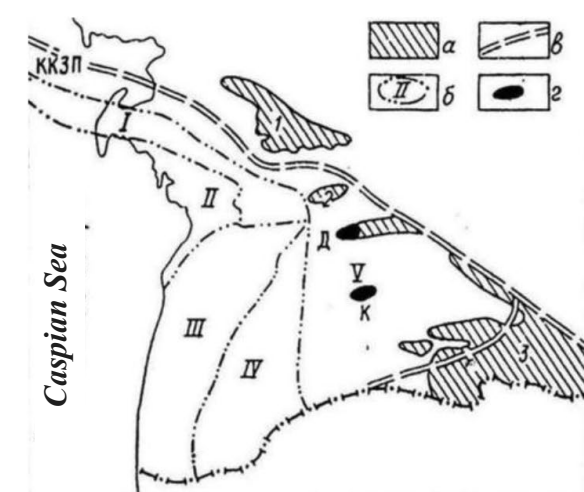
1 - common mid-point method profiles; 2 - contour lines of phantom seismic horizon mapped close to Neocomian bottom; 3 - contour lines of phantom seismic horizon mapped close to Neocomian top; 4 - contour lines of phantom seismic horizon mapped inside Lower Cretaceous deposits; 5 - tectonic faults from seismic survey data; 6 - deep drilling wells; 7 - the most accessible due to their depth anticline and anticline-block Malm-Neocomian objects recommended for preparation and exploration

Fig. 8. Consolidated fragmentary structure map of phantom seismic horizon of the Neocomian and Cenomanian on-shore of SW Turkmenistan (Demina et al., 2000)

Regional geologic features and Mesozoic oil and gas prospects of SW Turkmenistan

Mesozoic deposits were surveyed with stratigraphic and structural wells at 22 areas in South-West Turkmenistan. At most of the above mentioned areas, wells penetrated only the Upper Neocomian part of the Cretaceous section with mainly shaly composition. Gas and oil shows from Mesozoic deposits are observed in wells and natural sources. Gas shows predominate (about 50), oil shows are no more than 5. The largest number of gas shows is observed while wells drilling and this was mainly due to Cenomanian, Albion and Senonian deposits. Regional predominance of gas over oil shows may reflect the actual ratio of gaseous and liquid hydrocarbons amounts in subsurface deposits.

The main promising complex of the region — the Malm-Neocomian carbonate rocks — were penetrated only in stratigraphic wells in Karatepe area (top of the Early Barremian) and Danata area. The last well is a stratotype for the whole region (Fig. 9) (Ashirmamedov et al., 1978; Ashirmamedov, 1996; Ashirmamedov et al., 1999d) since it completely penetrated the Malm-Neocomian, Middle to Lower Jurassic and for the first time penetrated carbonates of the Late Triassic at 800 m that are not known anywhere else in Turkmenistan. Well #1 Kuilar is certainly a stratotype for the Upper Neocomian carbonate section about 3 km thick (see Fig. 9, Fig. 10).



LEGEND

a - mountain structures:

1 - Big Balkhan,

2 - Small Balkhan,

3 - Kopetdag;

b - boundaries of structural and sedimentary areas:

I - Pre-Balkhan,

II - Kyzylkum,

III - Gograndag-Okarem,

IV - Aladag-Messarian,

V - West-Kopetdag;

c - tectonic faults;

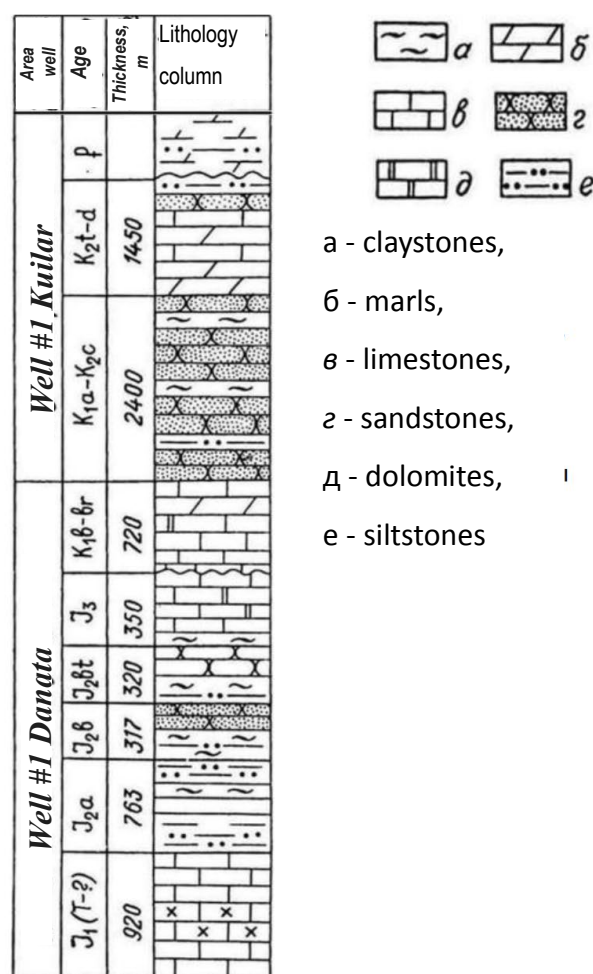
d - anticline structures:

d - Danata,

k - Kuilar

KK3П - Kusaro-Kelkor trough area

a



6

Fig. 9. Overview map of South-West Turkmenistan

(a) Consolidated litho-stratigraphic section of West Kopetdag

(b) drilling data of Danata and Kuilar wells (Ashirmamedov et al., 1978)

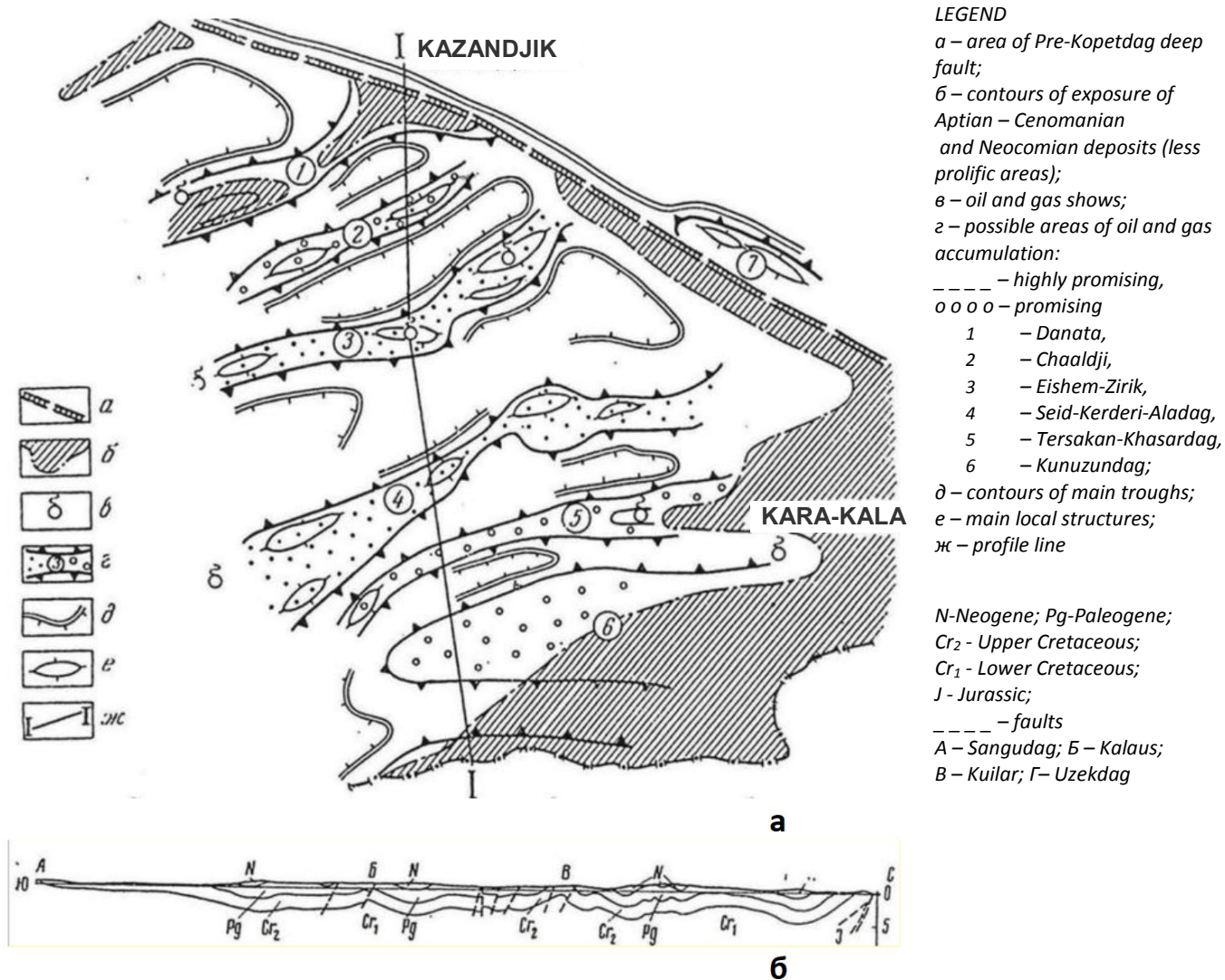
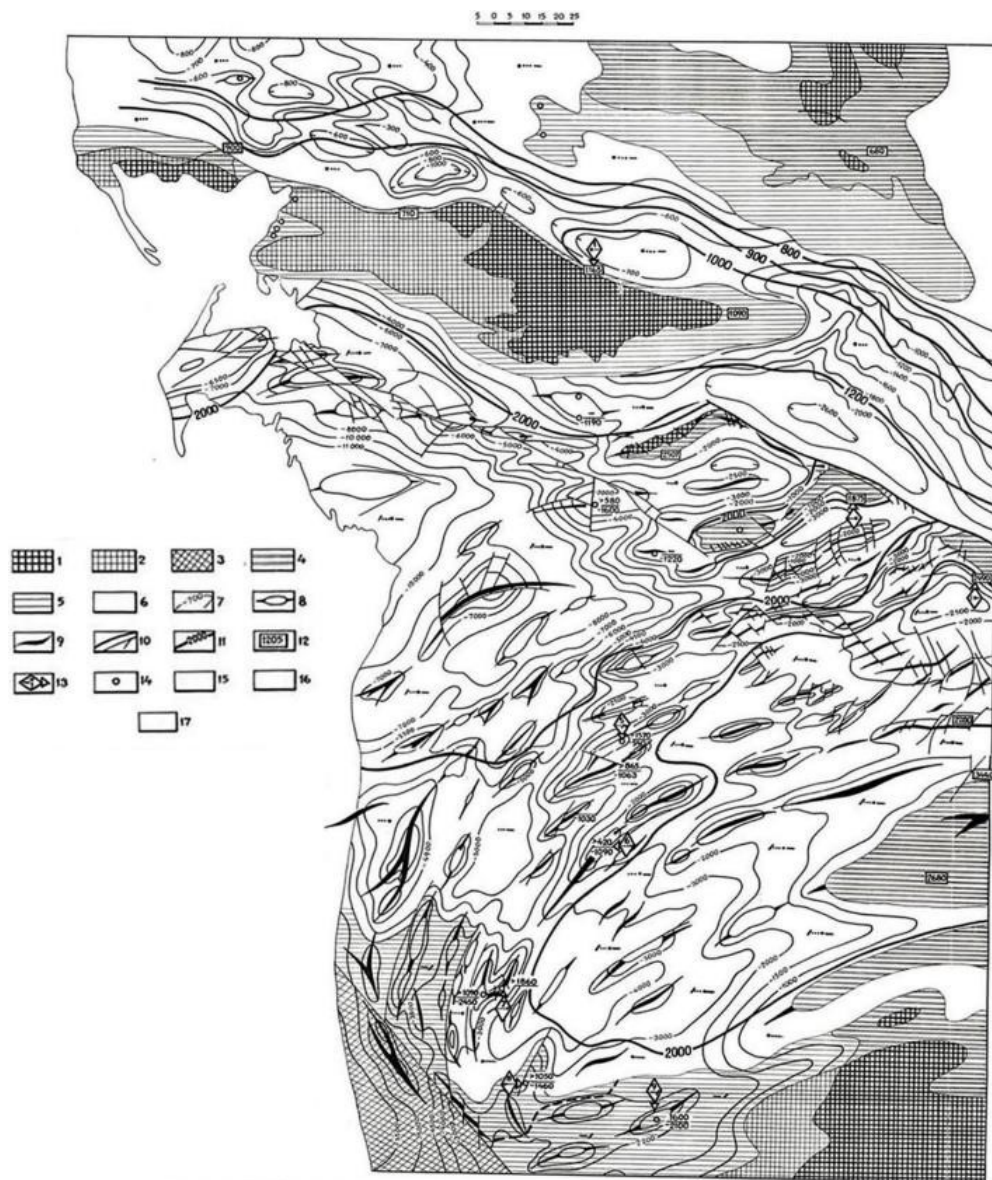


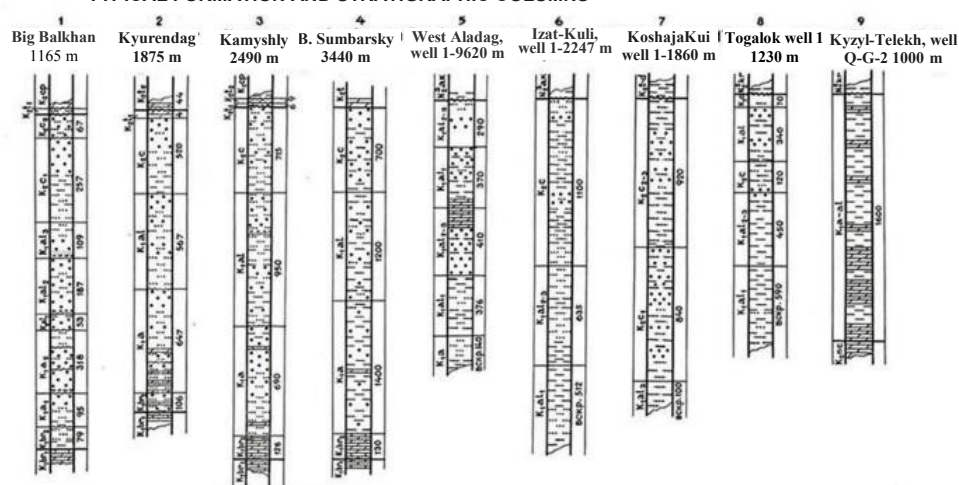
Fig. 10. Contour map of oil and gas prospects of West Kopetdag (a)
 Regional geologic section of line I-I (Kazandjik-Sangudag) (б) (Nikolenko, 1969)

Weighted average capacity of lithologic and stratigraphic complexes of West Kopetdag and Aladag-Messierian zone are as follows: Early - Middle Jurassic terrigenous deposits (1–2.4 km), Upper Jurassic-Neocomian carbonate deposits (1–1.5 km), Aptian-Cenomanian terrigenous rocks (1–1.5 km) and Upper Cretaceous-Paleogene shale-carbonate complex (up to 2 km).

Concept on stratigraphy and lithology of the Upper Neocomian part of the Cretaceous and Paleogene is provided by typical formation well logs for specific areas, submitted with series of maps for structural and formational features of the Paleogene, Turonian-Maastrichtian, and Upper Barremian-Cenomanian (Fig. 11) of SW Turkmenistan (Melnik, Valbe et al., 1980). Region tectonics and distribution of Mesozoic-Cenozoic sections besides mentioned map series, were presented in a generalized form in "Geologic and tectonic map of South-West Turkmenistan" (Odekov, Valbe, 1979).



TYPICAL FORMATION AND STRATIGRAPHIC COLUMNS



1 - exposures of more ancient deposits; 2 - absence of Upper Barremian - Cenomanian from the section; 3 - undifferentiated Mesozoic deposits under Pliocene - Quaternary period cover; 4 - exposures of Upper Barremian - Cenomanian; 5 - partially eroded deposits of Upper Barremian - Cenomanian covered by younger deposits separated by major unconformity; 6 - Upper Barremian - Cenomanian covered by younger deposits if there is no significant unconformity (fields with no black hatching); 7 - contour lines close to Cenomanian top; 8 - contour lines of anticline uplifts (intermittent and intermediary folding type); 9 - hinge lines of anticline uplifts (linear folding type); 10 - faults; 11 - lines of equal thickness of Upper Barremian - Cenomanian; 12 - thickness of Upper Barremian - Cenomanian in natural exposures; 13 - legend key of typical section: at the top - section number, beneath - its symbol; 14 - drilling wells not passed through Upper Barremian - Cenomanian; 15 - promising areas with possibility to discover medium lithologic sealed deposits and small anticline deposits; 16 - little potential and promising areas with anticline and presumably tectonic type of traps; 17 - areas for which oil and gas potential evaluation is not provided

Fig. 11 Map of structural and formation features and oil/gas potential, typical sections of Upper Barremian - Cenomanian of West-Turkmen depression - onshore (Melnik, Valbe et al., 1980).

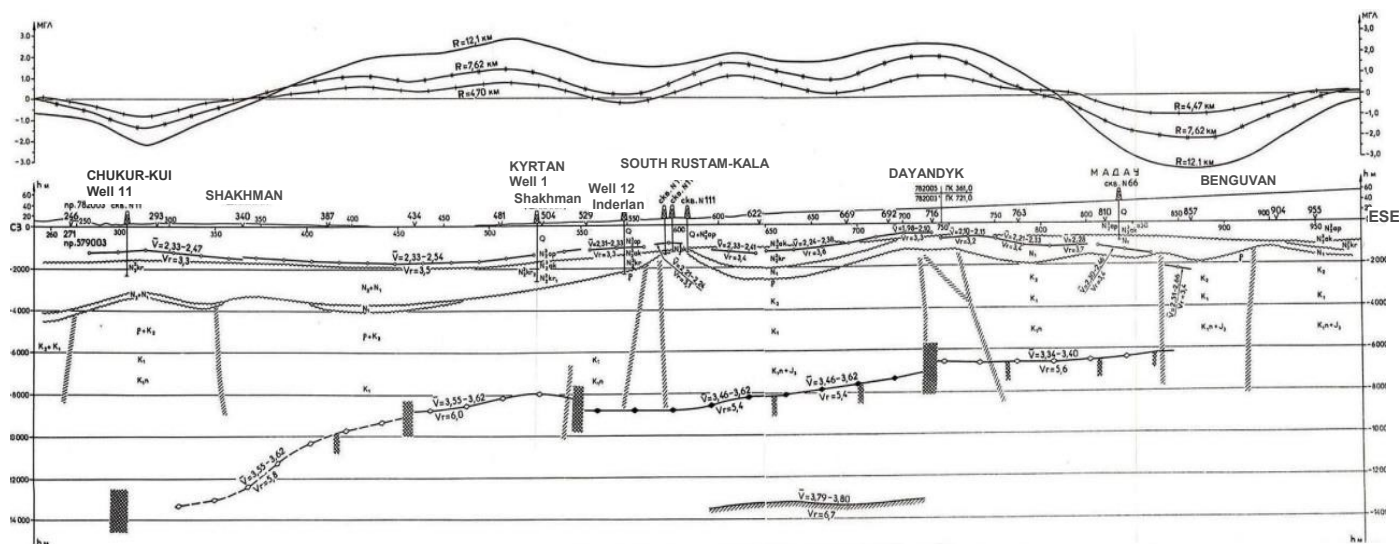


Fig. 13. Geologic and geophysical section through the Aladag-Messierian stage from regional profile 782003 (Shakhnazarov, 1988)

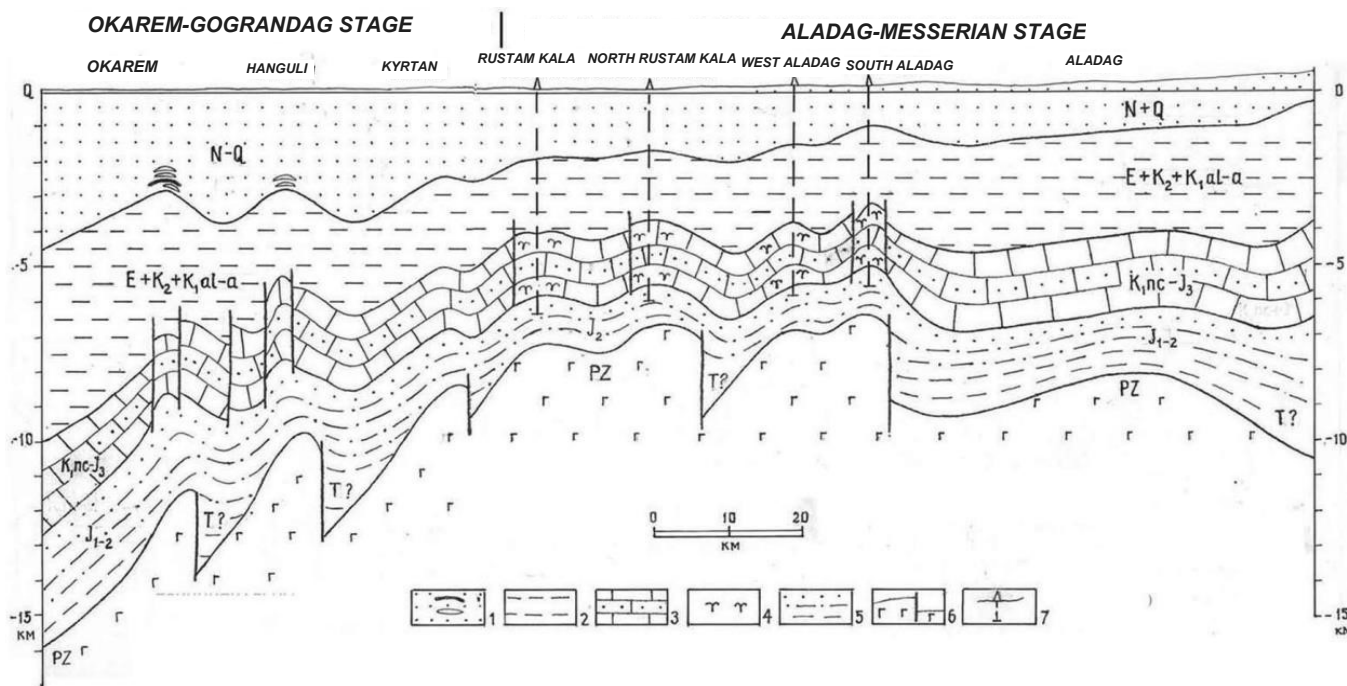


Fig. 14. Principal geologic section through the Gograndag-Okarem and Aladag-Messierian stages of the line Okarem-Aladag (Melikhov, 2007)

In the Iran's Gorgan region, adjacent to the Aladag-Messierian zone from the South (Ibragimov et al., 1974), while testing well Kyzyltepe #2, gas inflow was observed from 4370 m with 170 thousand m^3/d flow rate from the limestones of the Tirgan suite (Barremian). When testing limestones of the Mozduran suite (Oxfordian-Upper Jurassic), gas with 0.5 million m^3/d flow rate was observed from about 4800 m, wellhead pressure was 50 MPa. During penetration of carbonate-terrigenous Jurassic formations to 5700 m, several gas deposits were observed with abnormal high pressure.

In the aspect of gas and oil capacity of Mesozoic deposits in SW Turkmenistan, the most important part belongs to the Malm-Neocomian carbonate complex, which is a thick (1–1.5 km) natural reservoir that can preserve

its reservoir properties at a great depth (4 – 6 km) in contrast to its overlying and underlying terrigenous complexes. Based on drilling results in the Kyzyltepe area in Iran, considered carbonate complex has internal impermeable beds, allowing to reckon on discovery of multi-pay oil and gas fields in it.

The most prolific section of the Malm-Neocomian was located in the southwest region periphery, in the Iran's Kyzyltepe region. According to the forecast (Kravchenko et al., 1998) in the Iranian field Kyzyltepe and the adjacent Priatrek and Aladag-Messierian regions in SW Turkmenistan and, presumably, in the Kuilar region of the West Kopetdag, a multi-pay natural reservoir developed, with a combination of certain reservoir and impermeable bed formations, both in the Upper Jurassic and the Neocomian parts of the section. In these areas, the Malm-Neocomian carbonates are the most accessible for drilling.

In the cores of anticlines of the Gograndag-Okarem district and the greater part of the West Pre-Balkhan district, the Malm-Neocomian complex is embedded in hard-to-reach depths of 6-7 km, though in the anticlines of the Aladag-Messierian district it is expected at depths of 3.5-4.5 km and in the Kuilar region – at 1.5-3.5 km. The eastern part of the Pre-Balkhan zone is more accessible as per Malm-Neocomian depth compared to western part, but the possibility that there might be large traps in the Mesozoic is problematic. The largest, moderately deep (6 km) anticline traps in the Neocomian deposits are assumed at Cheleken field – the highest in Pre-Balkhan area (Ashirmamedov et al., 1999d) and at Okarem field – in the Gograndag-Okarem area.

The most promising Mesozoic assets in all areas of southwestern Turkmenistan, with other equal criteria, shall include large less disturbed traps in which, under optimal regional and local conditions for accumulation and conservation of hydrocarbons, the main Malm-Neocomian carbonate complex of the region is located.

Further, the analysis of structure features and evaluation of estimated gas and oil capacity of the Mesozoic and its main Malm-Neocomian carbonate play from differently mapped promising districts of SW Turkmenistan are provided.

Mesozoic gas and oil promising districts of SW Turkmenistan

Promising Kuilar district

According to the data (Kalugin, 1964; Kudelsky, Bartashevich, 1964; Kudelsky, Kalugin, 1968; Nikolenko, 1969; Zyubko et al., 1970; Ashirmamedov et al., 1978; Kravchenko et al., 1998), in the West Kopetdag in the Jurassic-Paleogene, there was a mio-geosyncline characterized by a sharp predominance of sedimentary formations, their significant thickness, differentiated submersion, lack of magmatic shows and metamorphism, very moderate folding and prominent linearity of structural and formation zones distribution.

Promising Kuilar region (see Fig. 9, 10) is identified with the West-Kopetdag synclinorium – an independent basin with average volume of sedimentary filling of approximately 250 thousand km³. The largest number of known gas shows is associated with this basin.

There are known gas shows coming from the Cenomanian and Senonian deposits in structural wells in the Tersakan and Seitkarderi anticlines. Combustion gas natural seeps were recorded in the areas of Danata, Kazandzik, Oboy and Chaaldji structures (Zyubko et al., 1970; Zakhidov, 1974; Ashirmamedov et al., 1999a-c). In well # 5 of Sumbar river valley, oil films in drilling mud were observed while drilling in the interval 450 – 650 m (Early Cenomanian) and 1080 m (Albian).

As a result of exploration well #1 drilling in Danata area in the Middle Jurassic interval 1940 - 2085 m, an increased hydrocarbons content was observed, based on mud log and prolific dissolved hydrocarbon gas during well log while drilling (Grachevsky, Kravchuk, 1989). During drilling of minor water wells of Geology Department of the TSSR at Kuilar structure, gas and oil shows were observed from the Upper Cretaceous (Ashirmamedov et al., 1999c).

Deposits of terrigenous and carbonate Jurassic, carbonate-terrigenous Neocomian, terrigenous Aptian-Albian are considered to be the main stratigraphic complexes of rocks that are promising for gas and oil in Kuilar region. Major Kuilar, Eishem and Kalaus anticlines that were prepared for deep drilling by geologic and structure surveys (Ashirmamedov et al., 1999a-c) are considered as priority assets for oil and gas exploration surveys. It shall be noted that previously drilled stratigraphic well at Kuilar did not penetrate the Malm-Neocomian carbonate complex dominant for oil and gas.

Perspective Aladag-Messerian district

The Aladag-Messerian uplift zone is considered as a direct continuation of the Kuilar region anticline lines (Mirzakhonov, 1969; Zyubko et al., 1970; Odekov, Valbe, 1979; Kravchenko et al., 1998; Odekov, Zakhidov, 2002)(see Fig. 13, 14; Fig. 15). Here, gas shows were observed during structural exploration drilling in West Aladag and Izatkuli areas from the Albian deposits.

The Aladag-Messerian uplift zone is separated from the Gograndag-Okarem zone by a large fault with an amplitude of 5 km. Considered region is characterized by the highest position of folds in relation to adjacent structural elements. Seismic surveys and structural drilling detected significant number of local structures developed from the Pliocene deposits (see Fig. 15).

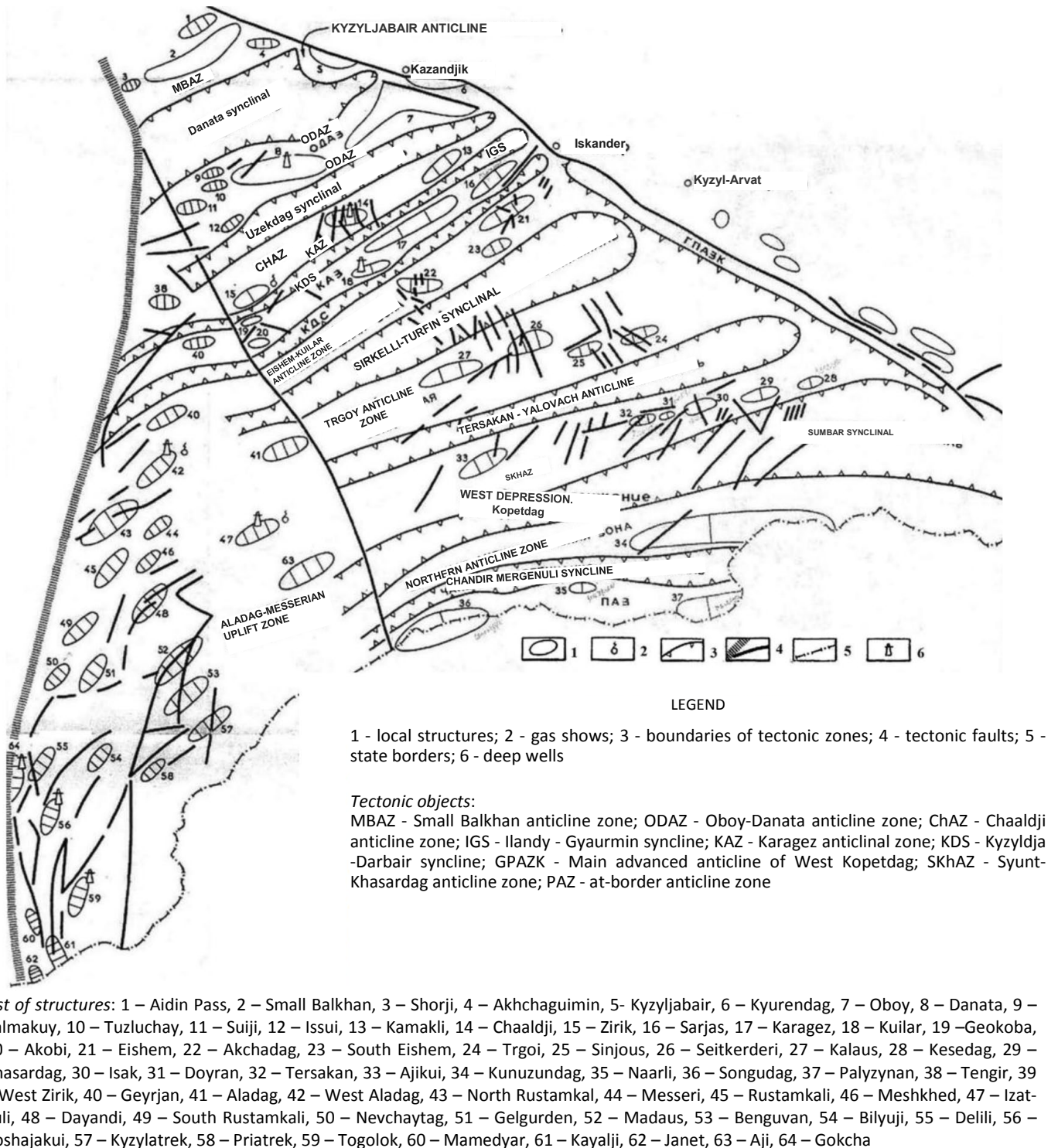


Fig. 15. Layout of tectonic zonation and oil and gas prospects of West Kopetdag and Aladag-Messerian stage (Krylov et al., 1978)

Mesozoic structural plans fundamentally differ from the Pliocene ones due to complex deep structure of the Mesozoic structural stage which is difficult for satisfactory interpretation based on low-quality seismic records in Mesozoic intervals and, especially, in the targeted Malm-Neocomian complex. In the Aladag-Messierian zone, the Upper Neocomian-Cretaceous deposits shale out comparatively to West Kopetdag exposures and together with the thick (up to 1-2 km) Paleogene-Miocene clays create a reliable regional cover for hydrocarbon accumulations in the Upper Jurassic and Neocomian deposits.

Carbonate Malm-Neocomian lies here at the accessible, optimal depth (3.5-5 km), in numerous traps that are favorable for accumulation and conservation of hydrocarbon deposits, their structure and productivity can be studied successfully and cost-efficiently. For example, on the Caspian shelf of Turkmenistan, it is required to drill many times more expensive wells 5-7 km deep, targeted at lower red beds and the Miocene.

In the Aladag-Messierian region of SW Turkmenistan it is now feasible to concentrate main volume of regional exploration and site high-tech seismic exploration and drilling operations for the Malm - Neocomian. Utmost importance here shall be paid to the creation of modern exploration seismic network partly duplicating low-quality Mesozoic regional and exploration profiles of common mid-point method, performed before 2000. Additional areal seismic surveys shall be performed at all uplifts with no exception, that were previously considered to be prepared. Actually, they shall be pre-prepared for drilling wildcat wells.

The largest representative structures of the considered district that are subject to priority seismic surveys and drilling (from North to South) are West Zirik, West Aladag, Izatkuli, Kyzylatrek, Delili (Kravchenko et al., 1998).

West Aladag group of structures

The West Aladag uplift was surveyed by structural drilling (Mirzakhonov et al., 1964) and prepared by seismic exploration with common mid-point method for common depth in the lower red bed, its structural plan for the Mesozoic is completely unknown. Approximate dimensions of the West Aladag uplift is 18×7 km, amplitude – up to 1000 m.

The stratigraphic well West Aladag #2 with reached depth of 4719 m, was suspended in the Early Aptian. No signs of oil and gas bearing were observed while drilling. This is probably due to limb position of the well, which is indicated by inclination of the Mesozoic deposit layers registered in core samples that make up 45-50 degrees or more. Previously, significant gas show was observed with an estimated rate of 10-15 thousand m³/d from Albian lenticular sandstones in the near-crestal (?) structural well #3.

The structure of the sections adjacent to the West Aladag structure, which is the largest in size, remains unclear from the East and South. In the adjacent areas, South Aladag and Kemendere, the existence of local structures was assumed, probably even raised in relation to West Aladag (Kravchenko et al., 1998). Further drilling in the latter well shall be performed taking into account the structure of the Kemendere and South Aladag areas, which are important independent objects for subsequent exploration.

A prerequisite for the construction of a new parametric well in the West Aladag group of structures is to conduct site seismic exploration with the common mid-point method of the current level and prepare the Malm-Neocomian conditioned objects here.

Izatkuli group of structures

The Izatkuli anticline is the central fold of one of the largest groups of uplifts in the area under consideration. Getting information in the center of the large Izatkuli group of uplifts, which is associated with a protrusion of the basement surface according to the correlation refraction method data, is particularly important (Kravchenko et al., 1998).

Therefore, it is feasible to locate one of stratigraphic wells of top priority 5 km deep in the Izatkuli structure. The bottom hole of the nearby well Izatkuli #1 is located in the middle part of the Aptian deposits at 2652 m. Taking into account total thickness of Aptian deposits of 600-800 m if there is no repetition of the section due to low-angle overthrust, the top of Neocomian deposits can be expected at a depth of 3-3.5 km. In this case, the full section of the Malm-Neocomian carbonate complex will be covered up to 5 km. If the arch part of Izatkuli structure is complicated by overthrust, the Upper Jurassic-Neocomian deposits in the sub-thrust part of the structure will be deposited at uncertain but greater depth. In this case, the lower part of carbonate formation can be not penetrated by drilling (Ashirmamedov et al., 1978; Krylov et al., 1973c).

Rustamkala structure, which was drilled in the late 1980s, is most likely a periclinal complication of large risen West Aladag chain of structures. The earlier reinterpretation of seismic profiles assumes significant dipping of Neocomian carbonates surface in the Rustamkala area (4.8 km). Thus, the Rustamkala arch is lowered by 1.4 km versus the Izatkuli structure arch, where Neocomian carbonates top is expected to be at 3.4 km.

Forecast gas deposits calculated by TurkmenNIPIneft based on Mesozoic deposits of Kuilar and Aladag-Messerian districts amount to 704 billion m³ as a total (Ashirmamedov et al., 1975b). Actual gas resources of the latter highly prolific district only can amount to 2–3 trillion m³ according to modern evaluation. It is premature to speak about oil deposits of Aladag-Messerian district before obtaining exploration results for 1-2 key objects. Oil resources of the district can be preliminary estimated at 20% of gas deposits.

Promising Pre-Balkhan district

All known oil and gas fields in the Pre-Balkhan uplift zone are connected with terrigenous Pliocene strata. Most of them are largely developed and are at a late stage of development. There are no new promising structures for oil and gas. Stabilization and further increase of oil and gas production rate are accomplishable here only with increased exploration and appraisal for the Mesozoic terrigenous-carbonate stage up to 5–7 km thick (Ashirmamedov et al., 1975b; Ashirmamedov, 1996; Ashirmamedov et al., 1999d). Tectonic diagram of the Pre-Balkhan uplift zone is provided in Fig. 16.

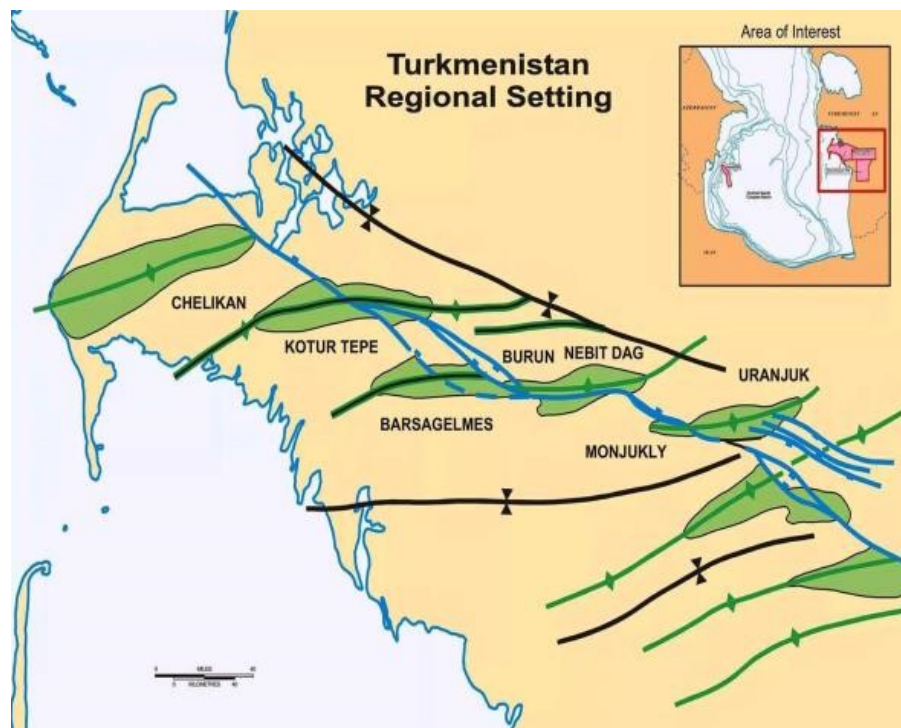


Fig. 16. Tectonic diagram of Pre-Balkhan uplift zone

The largest Cheleken fold within the Apsheron-Pre-Balkhan threshold on the eroded surface of the Mesozoic is a pronounced asymmetric brachyanticlinal 35x15 km in size and with an amplitude of up to 2 km. In the pre-Neogene period, it was an elevated land area that was subjected to intense erosion (Ashirmamedov et al., 1999d).

Besides highly expressed Cheleken, the key structures of the Pre-Balkhan region for the Mesozoic are the largest oil and gas condensate field Koturtepe in SW Turkmenistan and the largest and the oldest gas and oil field Nebitdag.

For the first time for the Pre-Balkhan zone, medium-scale structural mapping was performed for the Mesozoic, it was done by Ashirmamedov et al., based on the results of seismic survey analysis (Ashirmamedov et al., 1999d) (Fig. 17, 18).

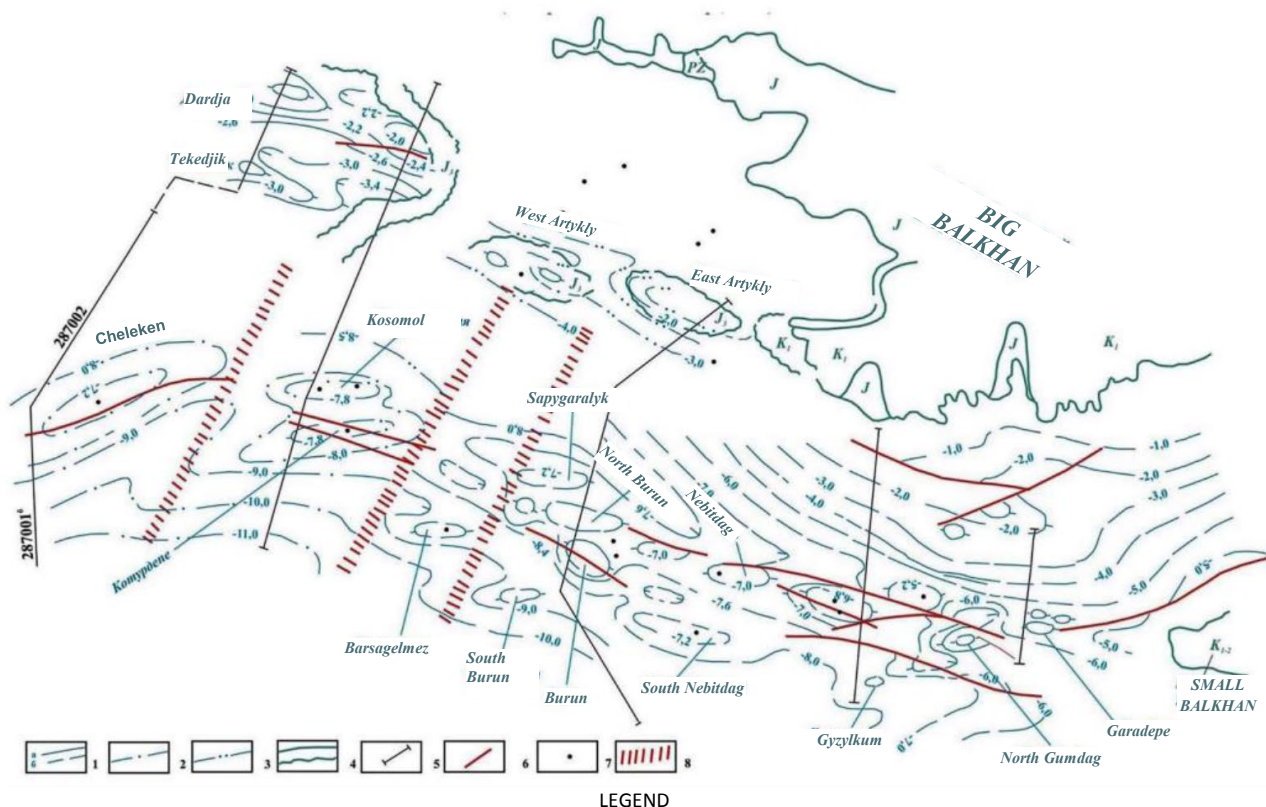


Fig. 17. Structural maps of phantom seismic horizons mapped close to the Pre-Balkhan uplift zone and Kelkor trough for the Mesozoic deposits (Ashirmamedov et al., 1999d)

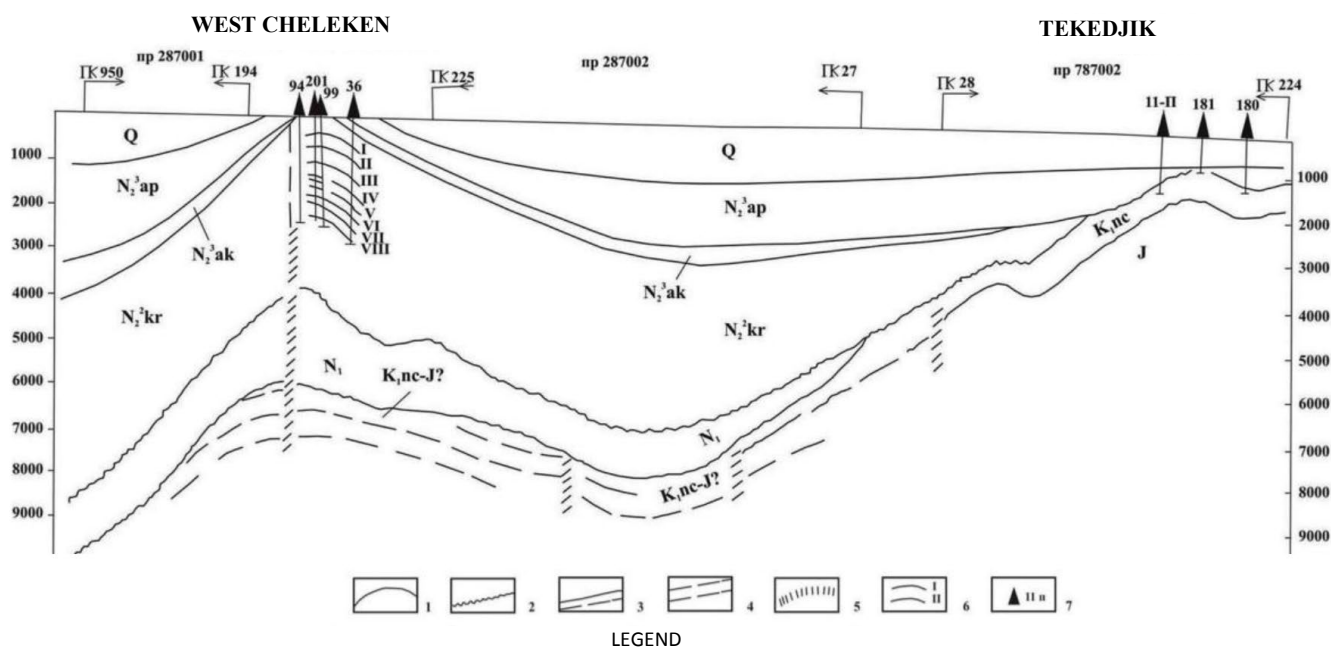


Fig. 18. Transverse seismic and geologic section through the Pre-Balkhan uplift zone. Kelkor trough from the line West Cheleken - Tekedjik (Ashirmamedov et al., 1999d)

Structural plan of Mesozoic formations of the Pre-Balkhan zone mainly corresponds to the Pliocene. New folds that were not developed in the Pliocene were also found in the Mesozoic complex. Judging by the completed constructions, one of the features of tectonic structure of the folds of the Pre-Balkhan uplift zone is their sharper dislocation in Pliocene deposits than in the layers of the Mesozoic complex. Their number and amplitudes decrease dramatically with depth. However, even in the Mesozoic, the role of main discontinuous faults that form the Pre-Balkhan uplift zone remains crucial.

Wide development of regional faults of various amplitudes - from 100-200 to 1000 meters or more is registered. Discontinuous faults of long-term development had a great influence on the formation of oil and gas accumulation zones.

Mud volcanoes with oil and gas shows rooted in the Mesozoic deposits, are also associated with the faults (Kravchenko et al., 1998).

Deep geological structure of Mesozoic deposits of the Pre-Balkhan zone is poorly studied. Prospects for oil and gas fields discovery in Mesozoic complex are based on oil and gas shows both natural and observed while drilling, on the information referring content of organic matters and bitumen in Mesozoic rocks. Natural oil and gas seeps are observed in the vents of mud volcanoes in Cheleken and in a form of hardened oil and bitumen covers at Nebitdag field. Gas and oil show was observed at Karatepe area during penetration of limestone top of the Early Barremian.

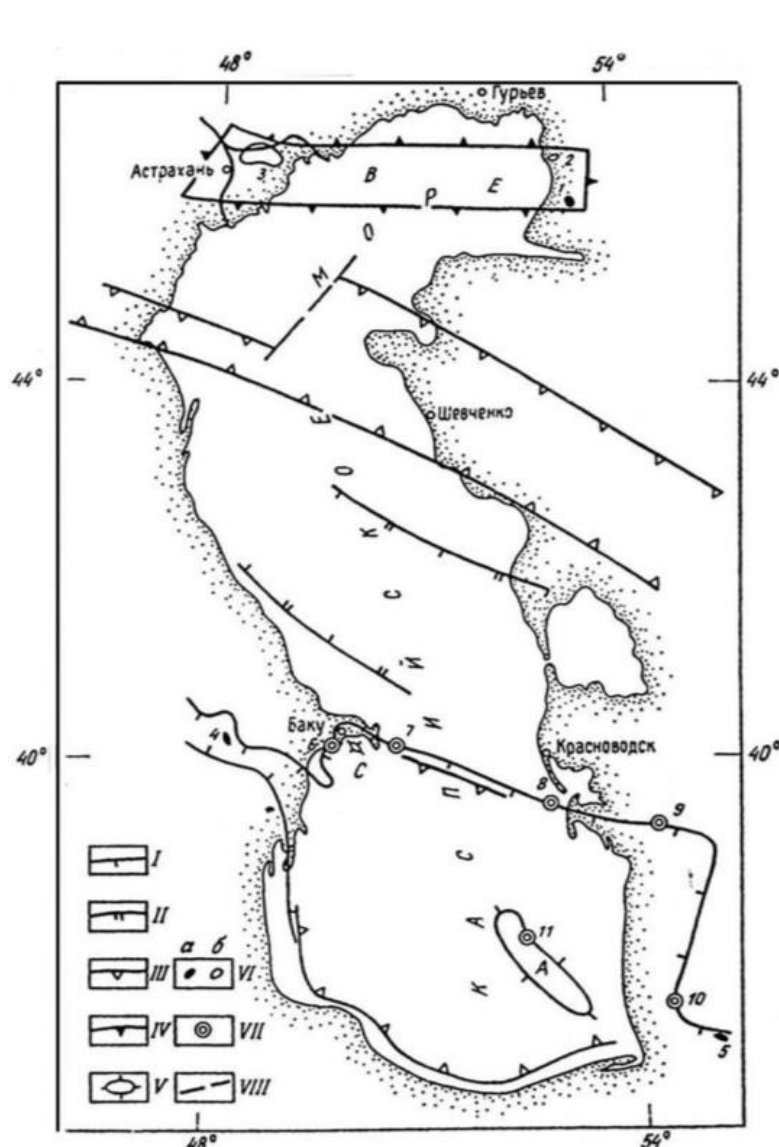
Mesozoic deposits at the Pre-Balkhan uplift zone were penetrated at 6 areas. Location and introduction into development of major oil and gas fields, that are estimated in the Mesozoic deposits of the Pre-Balkhan region, is one of the most important conditions to improve oil and gas exploration efficiency.

Within the Pre-Balkhan zone, it is feasible to continue studying Mesozoic structure with modern seismic exploration in the relatively accessible depth of the eastern part of the zone (further study of Karatepe Mesozoic uplift - Neocomian reef?), as well as at major fields - the key uplifts of West Pre-Balkhan – Cheleken, Koturtepe and Nebitdag.

Karatepe uplift

According to M. Ashirmamedov et al., hydrocarbon gas show was observed at 4875 m in stratigraphic well #23 in the top of Barremian limestone at Karatepe area of the Pre-Balkhan zone. Oil film of 0.865 g/cm^3 was observed from the interval 4875-4895 m. Unfortunately, due to technical incident the well #23 was not drilled deeper and no surveys were done. Subsequent wells did not penetrate the Mesozoic underlying Miocene clay diapir masking forecast reef. Thus, for the first time in the Balkhan uplift zone on the Karatepe area, a direct sign of Neocomian oil and gas potential was established. Further investigation of the mentioned structure for the Mesozoic was stopped. We will briefly discuss the rationale for the exploration of the Mesozoic and the projected reef in the Karatepe area.

According to Grachevsky M.M. and Kravchuk A.S. (1989) behind specified problem of exploration and survey of barrier reef fringe and internal mega-atoll of the South Caspian oil and gas basin is a paleogeomorphic analogy of similarly-named depression with the depressions of the Gulf of Mexico and the Caspian Depression. By analogy with the highly productive Mexican barrier reef Reforma, it is predicted that there are oil deposits at 4000-6000 m concentrated in a narrow line of the Mesozoic carbonate clinoform morphological scarp with the Apsheron threshold as a surface reflection in the water area (Fig. 19).



LEGEND

I-IV — basin slope of barrier reefs respectively for the Cretaceous, Jurassic, Triassic, Devonian - Carboniferous age

V - reefs inside the basin
(A, B — South Caspian and North Caspian mega-atolls, C — single reef Bakhar);

VI - fields in Mesozoic deposits:
a - oil fields
(1 - Tengiz, 4 - Murandakhly, 5 - Kyzyl-Tepek),
б - gas fields
(2 - Tadjigali, 3 - Shyriaev (Astrakhan));

VII — recommended deep drilling wells for Mesozoic reef ledge
(6 - Shakhovo-sea, 7 — 2 South, 8 - LAM Bank, 9 - Monjukly, 10 - Gokcha, 11 - Mud Volcano);

VIII - transform fault.

Fig. 19. Forecast for potential oil and gas reefs of the Caspian Sea (Grachevsky, 1999)

In SW Turkmenistan, according to geophysical data, a Neocomian barrier-reef ledge with a length of 400 km, coinciding with the Shorja-Gokcha fault and Pre-Balkhan structural zone was mapped and described (Grachevsky, Kravchuk, 1989) (see Fig. 19). The validity of identifying and tracing the barrier-reef ledge is confirmed by the presence of reef debris with oil traces in the emissions of the Aligul volcano (Cheleken).

Cheleken uplift

On seismic profiles done with common mid-point method within Cheleken, red beds are marked with extended seismic events. Below is a zone with poorly marked seismic record interpreted as predominantly shaly Pontian - Miocene. This complex is characterized by increased capacity as it approaches pre-arch part of the fold.

Therefore, rocks dip angles of red beds bottom are much steeper compared to those observed in the Mesozoic. It is assumed that the Pontian-Miocene at Cheleken area with erosion occurs on the Jurassic-Lower Cretaceous, possibly on the Neocomian (Ashirmamedov et al., 1999d) (see Fig. 17, 18).

Among the carbonate rocks selected from the eruptive products of the mud volcano Aligul by Professor Amanniyazov K. N. and chief geologist of the Cheleken Oil and Gas Production Division Tuvakov A., organogenic, clastic, algal, bryozoan and coral limestones were discovered according to data of the Central Laboratory of the Department of Geology of the TSSR. According to micro-faunal studies, their age is dated as Upper Callovian. Based on recommendations of Ashirmamedov M.A. et al., the well #20 with project TD 6500 m was drilled in 2002–2004 with the Mesozoic as a target interval and was located in the eastern periclinal of the major rise.

Due to technical reasons, the well was shut down at 6030 m (factor of abnormally high reservoir pressure 2.2-2.3, mud weight 2.45 g/cm³); the well penetrated the Early Eocene. Intense inflow of reservoir water with gas and small amount of oil has been observed in the Miocene (Shevchenko, 2007a-b, 2008).

At the East-Cheleken gas and oil field, defined characteristics of known and newly located paying intervals of lower red beds (Fig. 20) were determined in the cased holes of exploration wells using advanced logging methods.

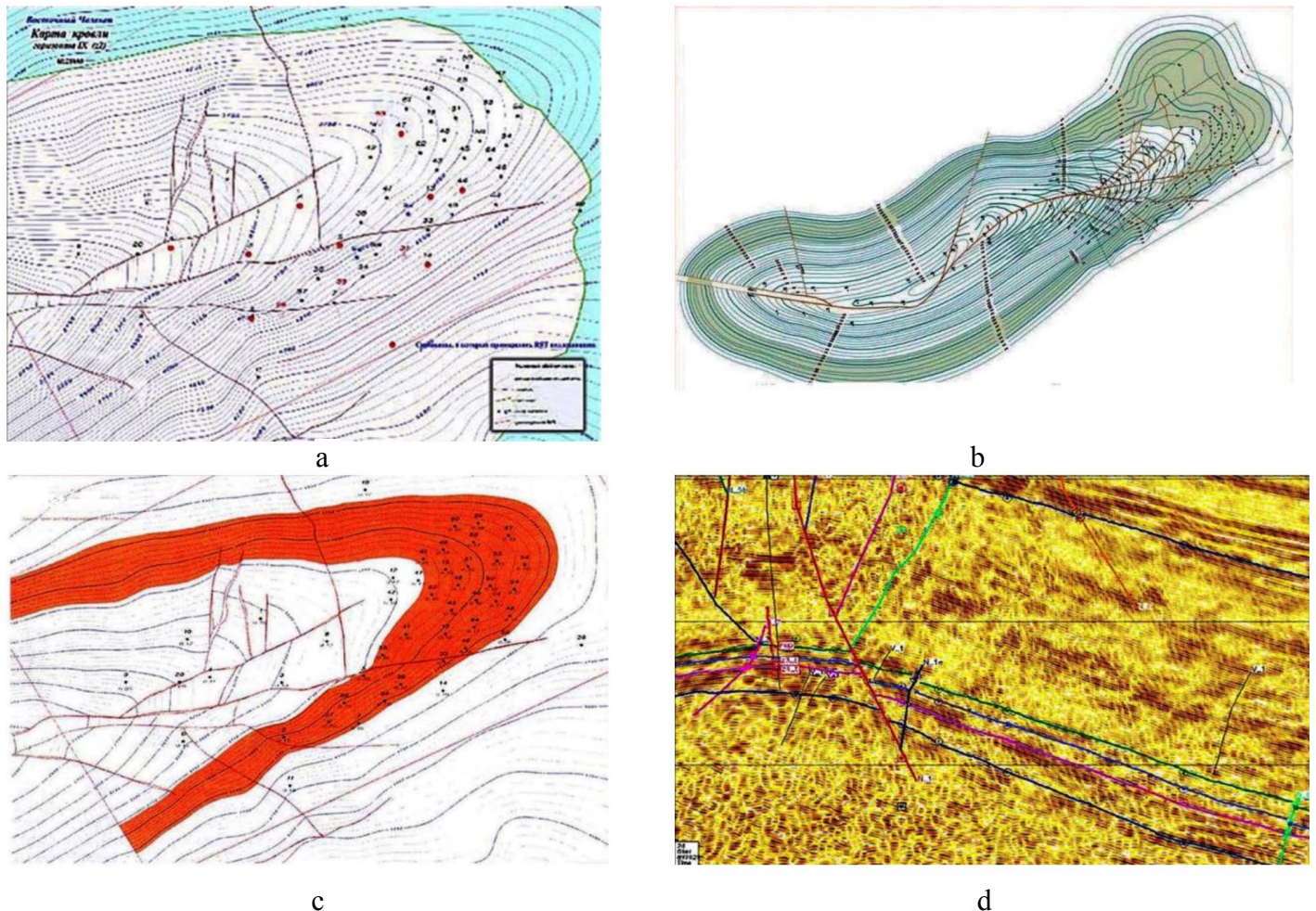


Fig. 20. Geological and geophysical data of East-Cheleken gas and oil field (Shevchenko, Grigoriev, 2007)

- 20.a** – structural map for the top of main paying block Z2–Z3 with marked "old" (in red) and "new" (in black) wells;
- 20.b** – generated map of Z2-Z3 formation top for the Major Cheleken structure, including the area of East Cheleken field (rectangular box in the north-eastern part of the map);
- 20.c** – distribution of average porosity of Z2-Z3 block reservoirs in the most favorable hypsometric range of their development (3800–4300 m);
- 20.d** – a fragment of time section of profile 897029 – re-interpretation of 2D seismic survey data (fault type disturbance crossing the entire red bed strata with series of secondary branch faults is marked in red bold line)

In 2007, a program of additional 3D/2D seismic surveys was accomplished in combination with VSP in new wells, and a 3D field model was developed. The data obtained in connection with the available seismic data allowed to create a new geological model of the object, to drill new exploration wells, and to ensure a steep increase of reserves (to the level of a major field) and oil production (Shevchenko, 2007a-b, 2008).

The pattern of hypsometric location of highly productive reservoirs was revealed for the lower red bed deposits of East Cheleken located in the form of line in the peripheral part of the structure in the interval of 3800–4300 m, amid low productivity of the Central part of the structure due to tectonic break, erosion, and degradation of reservoir properties (see Fig. 20c) (Shevchenko, 2007a-b, 2008).

This experience of highly efficient additional exploration of the East Cheleken field using new geophysical and drilling technologies with extended options, can be replicated for old fields and underexplored structures of the Pre-Balkhan and Gograndag - Okarem regions.

Promising Gograndag - Okarem region

The uplift zone with the same name is located in the near-Caspian strip of SW Turkmenistan and is gas and oil zone in the lower red bed deposits. Separate hydrocarbon deposits were discovered in the Miocene and Upper Pliocene (Ashirmamedov et al., 1975b; Alizade et al., 1985; Ibragimov, 1985; Ashirmamedov et al., 1999a; Gumarov, 2002).

At certain fields (Okarem, Keimir, Akpatlauk, etc.) an increase of abnormally high reservoir pressure factor in the lower red bed up to 1.7-2 was observed, thus causing underexploration for oil and gas content up to 500 m of the section of lower red bed and the Miocene, not mentioning the penetration of the Mesozoic (Ibragimov, 1985).

To overcome this barrier of abnormally high reservoir pressure, it is required to search for certain "gaps" with acceptable level of abnormally high reservoir pressure at these fields. Similar barrier of abnormally high reservoir pressure and other complications "stopped" deepening of Mesozoic well at key Okarem uplift with project TD 6000m. This well for the Mesozoic shall be duplicated, selecting the "gap" for barrier of abnormally high reservoir pressure based on new up to date geophysics surveys.

The size of the Okarem uplift at the red bed top is 48x10 km, with an amplitude - more than 500 m. Arch of the uplift matches well defined gravity minimum with intensity 5 mgl due to the availability of uplift with uncompacted strata 5 km below the arch (Kireev B.I.). Gumarov K.S. associates this uncompacted rocks with a huge gas accumulation with estimated volume of 1-5 trillion m³ under the screen of abnormally high reservoir pressure in red bed bottom (Kudelsky, Bartashevich, 1964). The probability of such a cluster is indirectly indicated by the huge volume of hill breccia 5-10 km³, erupted by the South Okarem buried mud volcano (Kravchenko et al., 1998).

If the hypothesis of a huge gas accumulation under the Pliocene Okarem structure is confirmed, the Okarem field will be one of the largest gas deposits in the South Caspian province. Naturally, forecast gas deposits of Gograndag-Okarem district will increase dramatically (up to several trillion m³).

Using the examples of Okarem and other oil and gas containing uplifts in the considered area, Gumarov K.S. puts forward a hypothesis regarding participation of hydrocarbon fluids in the formation of uplifts (Kudelsky, Bartashevich, 1964).

At Keimir field, industrial hydrocarbon inflows were obtained for the first time from thin-layered sand reservoirs of the lower red bed that practically are not displayed on the SP curves (Kudelsky, Kalugin, 1968). This particular part of the section became extremely difficult for well placing due to dramatic abnormally high reservoir pressure issues.

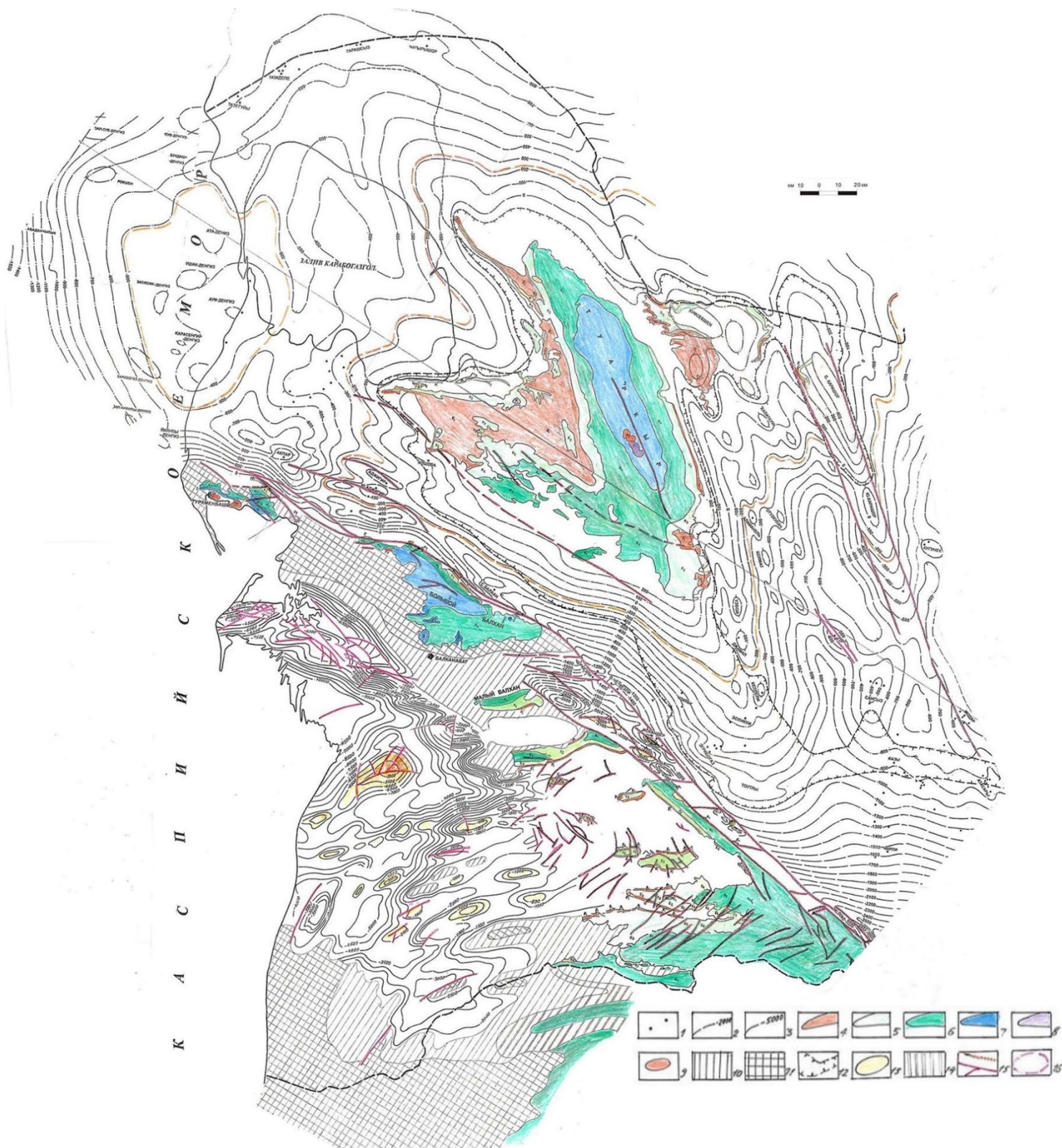
Testing of certain wells at Keimir, Akpatlaukh and Chekishlyar fields proved availability of high-rate oil and gas deposits in the lower red bed sediments associated with low-resistant formations that were not identified as productive. Consequently, logging complex of these objects was re-evaluated to identify productive reservoirs in low-resistant sections (Ibragimov, 1985).

Field Kerpedzhe is the largest within the Gograndag-Okarem zone. Multilayer gas and oil reservoir of the field is concentrated in the lower red bed. Below it, in the Miocene, a "bright spot" is clearly located - anomaly zone of seismic recording in the interval of 4500-5000 m. This reservoir type seismic anomaly appeared to be identical to the new thick Miocene oil deposit (Ibragimov, 1985; Ashirmamedov et al., 1999a). It is required to make further study of this field to the depth (up to the Mesozoic?) with seismic survey and drilling of modern type.

Promising Priatrek district

This region, distinguished for the first time, is not shown in the overview oil and gas geology map of SW Turkmenistan (see Fig. 2); it comprises southern parts of the Gograndag-Okarem and Aladag-Messarian uplift zones.

In the South of the Gograndag-Okarem zone, starting from Chikishlyar and up to the Iran's border, intense pre-Pliocene erosion cuts off the Pontian-Miocene and Paleogene deposits, and the red bed lays on different formations of the Upper Cretaceous - this can be clearly seen in structural and formational maps for features of deposit complexes of the Paleogene - Cretaceous and typical well sections (Cenomanian - Upper Barremian in Fig. 11) and in structural and geological maps of the Paleocene and Cretaceous surfaces of West Turkmenistan (Fig. 21).



1 – wells penetrating Paleogene and Cretaceous deposits; 2 – structure of the Paleocene surface in North-West (NW) Turkmenistan; 3 – structure of the Cretaceous surface in South West (SW) Turkmenistan; 4 – 9 – exposures of the Paleocene (4), Upper (5) and Lower (6) Cretaceous, Jurassic (7), Triassic (8) and Paleozoic (9); 10 – 11 – areas of partial (10) and full (11) absence from the section of Turonian – Maastrichtian deposits in South West Turkmenistan due to cut off by Pre-Middle Pliocene, Pre-Cretaceous and other erosions; 12 – stratigraphic section and drainage of the Paleocene and different volumes of Cretaceous deposits by Pre-Middle Pliocene erosion in the area of erosion cut of pre-Amu Darya and at a group of uplifts in NW Turkmenistan; 13 – promising objects for hydrocarbons: anticlinal and anticlinal-block Paleocene – Cretaceous deposits of SW Turkmenistan; 14 – prospective areas for lithostratigraphic hydrocarbons accumulation in the Paleocene – Upper Cretaceous deposits in SW Turkmenistan; 15 – faults; 16 – major uplifts in NW Turkmenistan

Fig. 21. Structural map of the Paleocene surface in the North-West Turkmenistan and the Cretaceous surface in the South-West Turkmenistan
(Melikhov, 2007, using data of Ashirmamedov, Zakhidov, Kudelsky, Melnik, Mirzakhanov, Odekov, etc.)

The depth of the erosion surface in Chikishlyar, Adzhiyab and other structures varies in the range of 3700-4000 m. From East to West and from North to South, the rise of deep-lying formations is observed due to pre-Pliocene erosion (Ashirmamedov et al., 1975b). Approximately the same depth of erosion is observed in the South of the Aladag-Messarian uplift zone (Geokcha, Koshaja-Kui, Togolok, Kyzyl-Atrek), where a significant part of the Upper Cretaceous system is also eroded. Promising for oil and gas capacity, the Malm-Neocomian carbonate in the Priatrek region, becomes accessible for penetration in the arches of uplifts at moderate depths of 4-5 km. The criteria for the prospects of oil and gas capacity of the Priatrek region are not entirely clear; a negative factor is the loss of a thick regional clay cap of the Pontian-Miocene-Paleogene from the section.

The Mesozoic deposits of the Priatrek region are characterized by intense rocks diversity and disjunctive dislocation, this complicates mapping of these deposits using seismic exploration. Separate representative structures of the Priatrek region, that were considered to be prepared for Neocomian phantom seismic horizons and based on which wells, that were suspended in the Aptian-Albian, were drilled (Togolok, Kisylatrek), they shall be re-prepared for the Malm-Neocomian using high-tech seismic surveys to locate new wells 5000 m deep.

The most important object for stratigraphic drilling in the Priatrek region is the Togolok anticline, one of the few comparatively surveyed by seismic exploration. It is located in close proximity to the Iran's Kyzyltepe field, in an area with potential prolific section of the Malm-Neocomian carbonate reservoir. Due to its structural intensity, height, volume of closed trap and expected depth of the Neocomian, the Togolok structure appears to be more preferable compared to surrounding structures (Kravchenko et al., 1998).

According to the available and insufficiently conditioned data of seismic survey by common mid-point method, the Togolok anticline is a large two-dome structure, its size is 18x4 km and height (of the main southern dome) is 300-400 m. The fault passes through the axial part of the fold and does not significantly reduce reservoir properties of the trap. Previously drilled well at the Togolok structure, which opened up Albian deposits at a depth of 3.1 km, allows us to confidently design and place a new parametric well with a depth of 5 km.

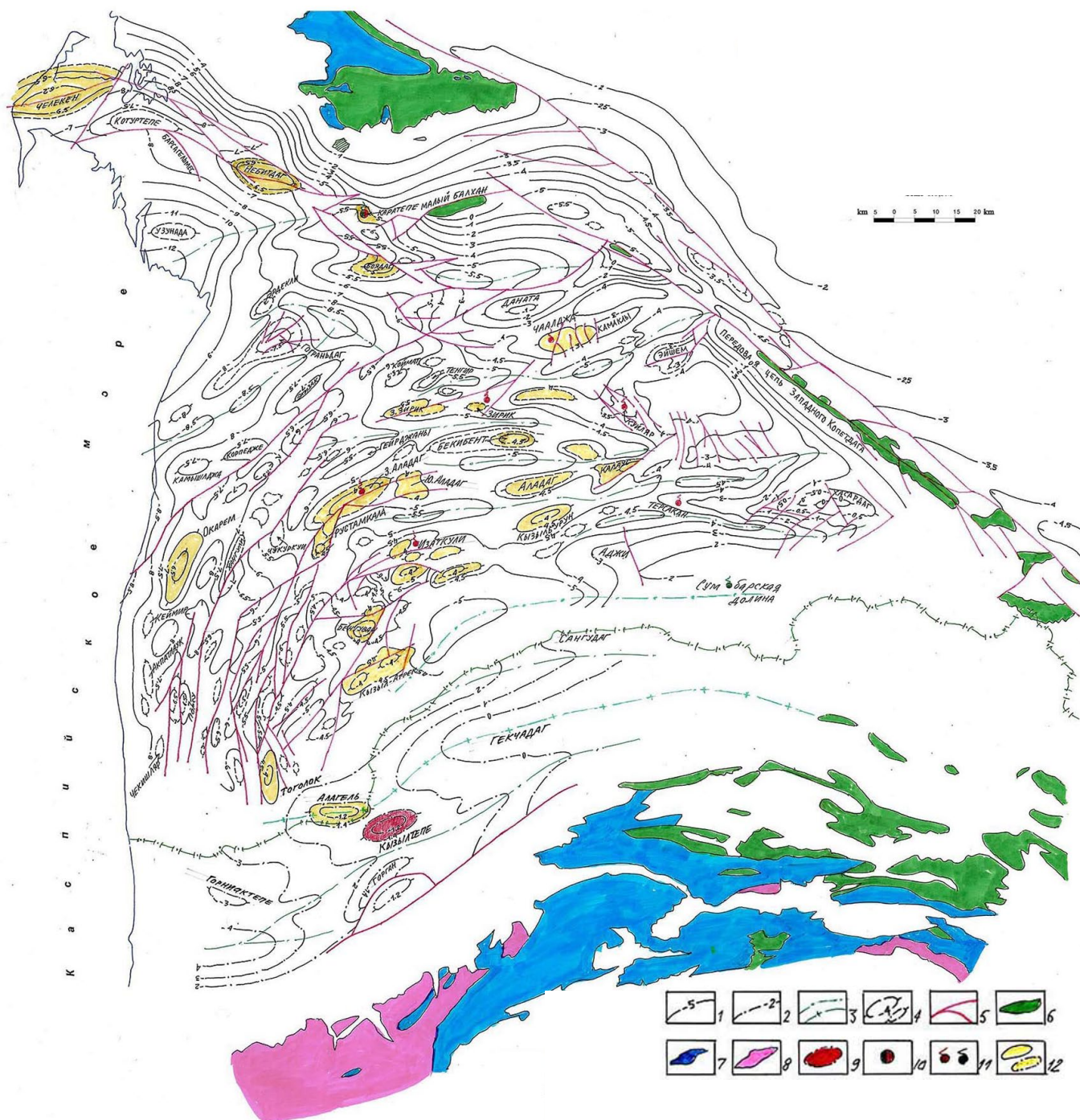
According to the forecasts of "TurkmenNIPIneft" natural gas resources of the Mesozoic deposits of the territory which is now identified with the Priatrek region, in the category D₂, amount to 300 billion m³ (Ashirmamedov et al., 1975b).

This evaluation appears to be underestimated. Authors believe that forecast Mesozoic gas deposits, mainly in the Malm-Neocomian carbonate in the Priatrek region, can be estimated at not less than 1 trillion m³.

Location of top priority objects for preparation and exploration of the Malm - Neocomian carbonate complex of SW Turkmenistan

Resulting structural and geological map of SW Turkmenistan (Fig. 22) shows simplified Neocomian surface structure.

This structure enables approximate localization of main anticlinal and anticlinal-block objects of the Malm - Neocomian including the most defined and accessible by depth potential gas and oil traps. Some parts of these traps are recommended for top priority preparation and exploration using modern seismic surveys and drilling operations. Corresponding recommendations are provided in the sections referring Mesozoic prolific areas and zones of the region.



1 – forecast contour lines close to Upper Barremian top in SW Turkmenistan; 2 – contour lines of Albian surface in Iran's Gorgan district; 3 – talwegs and structural ridges of Lower Barremian and Albian surfaces; 4 – local uplifts; 5 – faults; 6–8 – exposures of the deposits of: 6 – the Neocomian; 7 – the Jurassic; 8 – pre-Jurassic deposits; 9 – gas condensate field Kyzyltepe (Iran) – deposits in Barremian limestones (Tirgan suite, depth 4730 m) and Oxfordian-Upper Jurassic (Mozduran suite, depth about 5000 m), a few more potential deposits up to the depth of 5800 m; 10 – Karatepe area, well #23 - oil and gas show at 4875–4895 m from the top of Lower Barremian limestones; 11 – gas shows in Kuilar and in Sumrar valley of West Kopetdag; 12 - the most accessible by depth anticlinal and anticlinal-block objects of the Malm - Neocomian recommended for preparation and exploration

Fig. 22. Simplified structural surface model of Neocomian deposits with allocation of the most accessible by depth objects for preparation and exploration of Malm - Neocomian carbonate complex of South-West Turkmenistan (Melikhov, 2007, using data of Ashirmamedov, Demina, Zhukoborsky, Kravchenko, Krylov, Kudelsky, Mamiessenov, Melnik, Odekov, etc.)

Conclusion

Finalizing the overview of the promising Mesozoic direction for gas and oil exploration and appraisal in onshore SW Turkmenistan, it can be claimed that its implementation will revive the past glory of the oldest oil region (Fig. 23), that has almost depleted potential of the main Pliocene play onshore (remaining Pliocene deposits are estimated up to 100 mln t of oil and first hundreds of billion m³ of gas). Naturally, the huge gas and oil potential of the region belongs to the lower Pliocene and Miocene of the almost undrilled Caspian shelf. There is no sense to compare operations for the onshore part which has been explored since the end of 19th century and for the unexplored shelf.

It can be recalled how the glory of the main gas region of the South-East Turkmenistan - Murgab basin - was revived. With huge prospects of gas bearing subsalt carbonate deposits, their potential was poorly explored until the end of the Soviet period due to technical and technological imperfections of wells drilling to the depth of 5 km under real (bittern salt shows, etc.) and imaginary geological complications of the section (technically failure wells were massively suspended due to geological reasons).

Gas deposits in subsalt carbonates were often penetrated using heavy-weight drilling mud, which was used to reduce bittern shows in salt intervals and was not changed to light mud in due time.

Definitely, after such operations, gas shows were observed during well testing in best cases but not commercial gas inflows. With the establishment of drilling technology and discipline in 1990s, since the start of 21st century in the Murgab basin, the amazing discoveries of the unique group of Galkynysh fields of gas deposits (its current estimate is 21 trillion m³) and other fields have begun.

According to the authors, a similar renaissance can be expected for the onshore part of SW Turkmenistan, if massive implementation of the Mesozoic play in the conditions of dramatic improvement of geophysical and drilling technologies with the involvement of leading Russian companies and modernization of their own enterprises begins. The primary, highly promising Mesozoic exploration area in SW Turkmenistan is undoubtedly the Aladag-Messerian region with the most accessible depth of the target Malm-Neocomian carbonate complex. In the submersed area of the region, the largest Mesozoic objects are Cheleken and Okarem. Forecast resources of Mesozoic gas in SW Turkmenistan are estimated at 3–5 trillion m³.

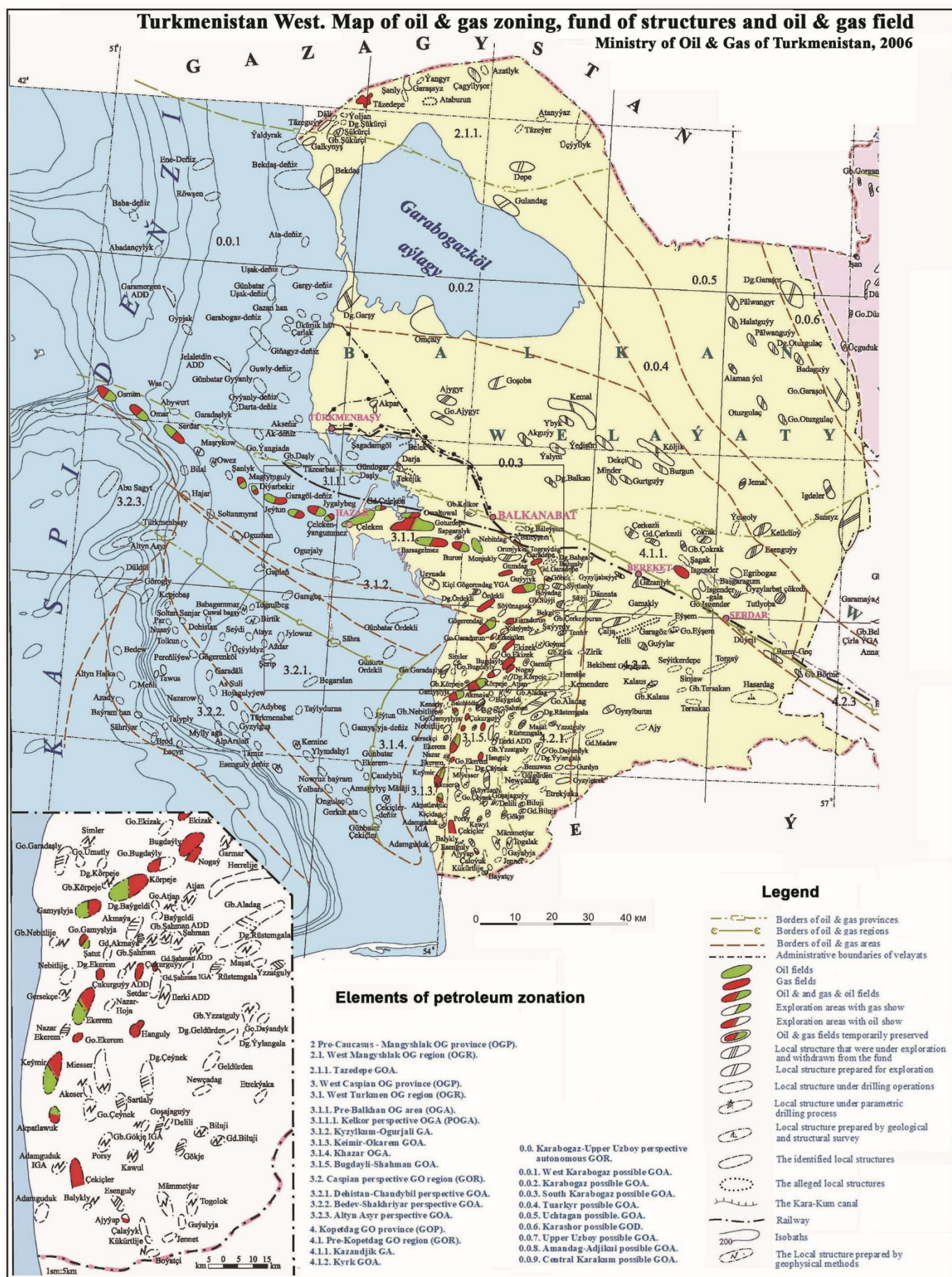


Fig. 23. Map of oil and gas zoning, Western Turkmenistan.

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**In memory of Mars Ashirmamedov –
outstanding petroleum geologist of Turkmenistan**

Mars Ashirmamedov departed this life. He was born in 1938 in Kyzylarvat (now Serdar) in a well-respected family of teachers. His father, Ashir Mamedov, a participant of the Finnish and Great Patriotic Wars, passed away early, not fully recovered from his wounds.

In 1957 Ashirmamedov M.A. graduated from work school and was qualified as a geologist. He started his career as driller's assistant in the Okarem Department of exploration drilling. From 1959 to 1971 he worked as a geologist engineer, deputy head and head of Geology Department of the Production Association "Turkmenneft" in the capital of the Turkmen "oil region" town Nebitdag (literally "oil mountain" - now Balkanabat).

In off-work hours he graduated from Moscow Institute of Oil and Gas Industry (now Russian State University of Oil and Gas) named after Gubkin I.M. In 1966, he defended his candidate dissertation on "Geology and oil-and-gas bearing of the Pliocene of the West-Turkmen depression" under the guidance of professor Uspensky N.Yu.

From 1971 to 1992 Ashirmamedov M.A. was the head of the geologic service in "Turkmenneft" as Deputy General Director - Chief geologist of the association. Extensive works regarding exploration and development of oil and gas fields in Western, Central and Eastern Turkmenistan were fulfilled under his management. Together with a team of authors, he was awarded the USSR State award in science and technology sphere (1974) for the giant Shatlyk gas field.

Later, as the Director of industry-specific Research Institute and an informal adviser on strategic issues of the development of oil and gas industry in the South-West "oil region" of Turkmenistan, he actually continued supervision of matters regarding subsurface exploration and ensuring resources potential of this hydrocarbon region.

In 1996, according to the report in the Academy of Sciences of Turkmenistan, summarizing all his works on geology and oil-and-gas bearing of the South-Western Turkmenistan, Ashirmamedov M.A. was awarded a degree of Doctor of Geological and Mineralogical Sciences. Subsequently, he became a full member of the Eastern Petroleum Academy.

In 1997 Ashirmamedov M.A., as a Director of industry-specific research institute, was awarded the International award "Gold Star" in Madrid. In 2009 he received the award at the X summit of the Economic Cooperation Organization in Tehran.

In Turkmenistan, Ashirmamedov M.A. was awarded with the Order of III degree "Altyn Asyr", the medals "Gayrat" and "For love of the Country", the State title "Honored people's elder" and the title "Honored worker of Turkmenistan industry".

Both in Soviet times and in modern Turkmenistan, Mars was well regarded and had indisputable authority of management members and specialists of "Turkmenneft", "Turkmengeologiya", "Turkmengaz", their divisions and research institutes, and was highly respected in the Ministry of oil industry and in the main oil and gas institutes of the USSR. His well-deserved authority, talent as a geologist, researcher, production specialist, and, at the same time, great responsibility for the directions and results of oil and gas exploration and production in such a very complex "oldest" region by world standards (oil production in South-Western Turkmenistan was carried out from the end of the XIX century, first from wells and small Nobel wells and other industrialists, currently oil and gas are extracted here from depths up to 4000-5500 m), allowed him to solve many fundamental problems that seemed not always manageable taking into account low technical and technological level of seismic exploration and drilling at that time.

It should be noted that Ashirmamedov M.A. became the head of geological service of "Turkmenneft" not during the period of increase and peak of oil production in the region (21 million tons in the 1960s), but during more difficult period of decline in oil production and "depletion" of new fields.

A number of new areas and objects of exploration and appraisal, the development of which was constrained due to poor infrastructure of certain areas in the region and real geologic challenges in the penetrated formations, were introduced into exploration thanks largely to persistence and unique diplomacy of Ashirmamedov M.A. with technical management of "Turkmenneft"; it led to new discovered fields and oil and gas deposits.

Mars was a decent man, ready to provide help and all possible assistance to people in difficult situations, he was an excellent mentor for young specialists. He had a good sense of humor, including about himself. One of his figurative humorous expressions, which has a certain basis, sounds like this: "We have a head in the XXI century, and a tail in the XIV."

On behalf of his friends and colleagues, who are already few in this world, numerous followers and students, we express our deep condolences to the family and friends of Mars.

We believe that implementation of his ideas in the context of geology and oil and gas exploration will be successfully continued by the next generation of Turkmen citizens.

As they say in the Muslim tradition: **"May Allah reward you for your patience, inspire you with peace and comfort and let Him forgive possible sins."**

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