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## GEOLOGICAL AND GEOPHYSICAL ASSESSMENT OF THE SOUTH CASPIAN OFFSHORE KAPAZ STRUCTURE

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Interpretation of seismic data shows that the Kapaz structure is located on the border of the sedimentary sources of the paleo Volga and paleo Amudarya. Regional seismic indicates that the paleo Volga probably continued to be the main source of terrigenous deposits. However, the Paleo-Amu Darya became a more important source of sediments during the Apsheron time. This is evidenced by the presence of clinoforms in seismic profiles direction, which is shown from the shelf margin in the dip direction to the west and southwest direction. It is shown that the Paleo-Amu Darya system eventually overlapped and pushed on the margin of the paleo-Volga shelf, effectively sealing the underlying terrigenous reservoir rocks. Growing diapir folds and compartmentation (southern and northern flank) were also observed in the feature of the structure. The reserves' calculation was carried out for each block of the Kapaz structure in scenarios P90, P50 and P10.

**Ключевые слова:** South Caspian, offshore, oil and gas, seismic interpretation, geology, forecast.

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**Keywords:** South Caspian, offshore, oil and gas, seismic interpretation, geology, forecast.

**R**egional Overview. Kapaz structure, located halfway between Cheleken & Apsheron Peninsula, approx. 110 km west of the harbor city of Turkmenbashi where water depth ranges from 80 to 150 m (decrease of depth occurs from the west eastwards). Geologically Kapaz is located in the central part of the Apsheron-Prebalkhanian threshold between Azeri and Livanova-west structures [1] (fig. 1).

**Exploration History.** Kapaz and Livanova-west structures were detected in 1959, which were earlier unknown. In 1965–1968 there were conducted detailed seismic studies, but the structure was determined in 1981 by CDP (central depth point) seismic survey. Kapaz structure was previously named Promeshutotshnaja, then Oktyabrskaya Revolyusiya. In Turkmenistan structure is named Serdar. During Soviet time between 1985–1988 years, the drilling took place at the Azeri structure (5 wells) which is located west side of the Kapaz structure. In 1988–1991, Kaspimorneft (an offshore division of the State oil company of Azerbaijan Republic) drilled at Kapaz 5 wells. In 1997 Azerbaijan assigned the rights of Kapaz to Lukoil, Rosneft & Socar; Subsequently annulled in response to Turkmen complaints. In 1998 Turkmenistan awarded negotiating rights to Mobil, but annulled rights in early 1999 on request of Mobil. In 2000 Azerbaijan offered 50:50 joint development which was declined by Turkmenistan. Exploration activity In the Kapaz structure is on hold due to a border dispute Between Azerbaijan and Turkmenistan [7].

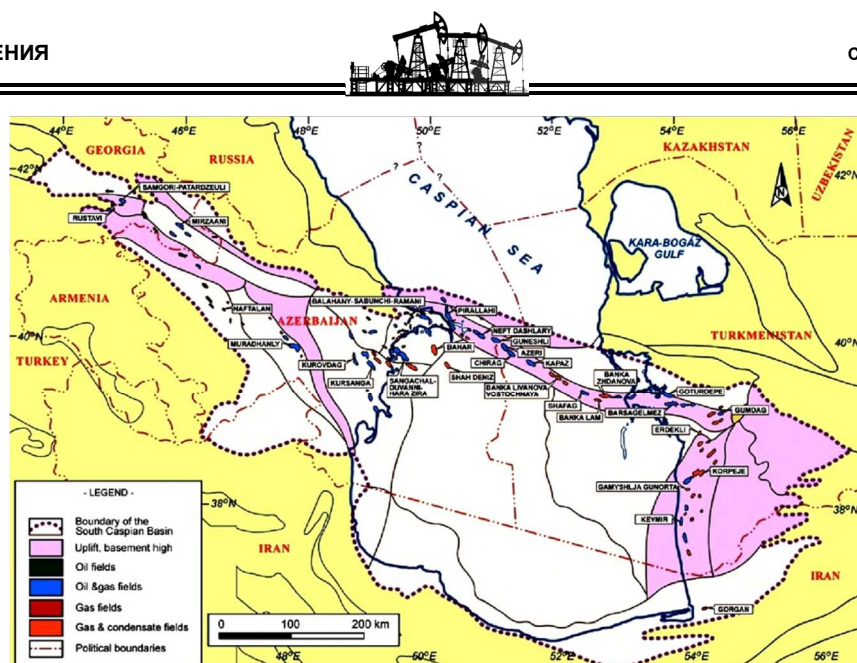


Figure 1 – South Caspian Basin – Location of Major Fields

Tectonics. This composite map in Figure 2 is based on the Russian geological map of Turkmenistan (1989). It displays the structural framework and incorporates the results of a tectonostratigraphic analysis. The northeastern part of the mapped area is dominated by the Turan Block which is part of the greater Siberian Platform. A prominent structure of this domain is the Garabogaz High and the adjacent Garabogaz Platform underlying the Garabogaz Gulf.

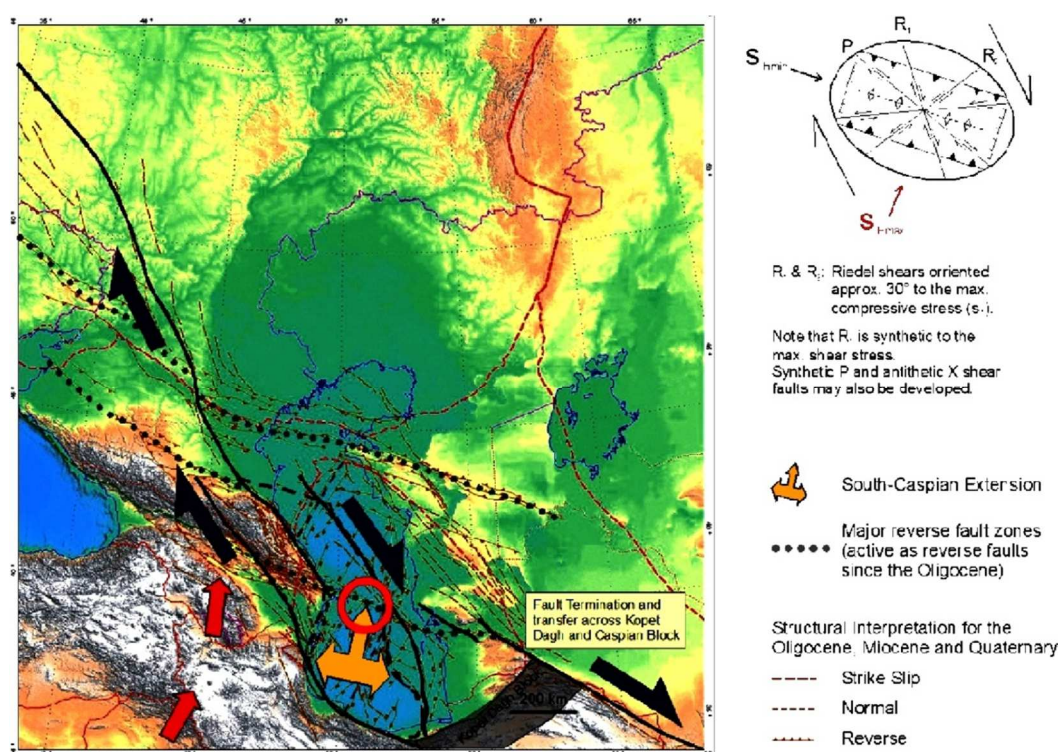


Figure 2 – Late Miocene to Recent Tectonic Development

These structural features are crystalline uplifts covered by thin Mesozoic and older Tertiary successions. Figures 3 and 4. The Turan Block is separated from the South Caspian Basin (i.e. Kelkor Trough) and Kopet Dag Fold Belt by a prominent fault system. This Ashgabad-Apsheron Ridge lineament represents the plate boundary between the Siberian platform (Turan Block) and the Paleo-Tethys and was transformed into a major dextral strike-slip system during the collision of the Arabian and Indian plates with the Siberian plate, respectively. Seismic activity in recent years (i.e., the Ashgabad earthquake in 1948) indicates that this fault system is still active.

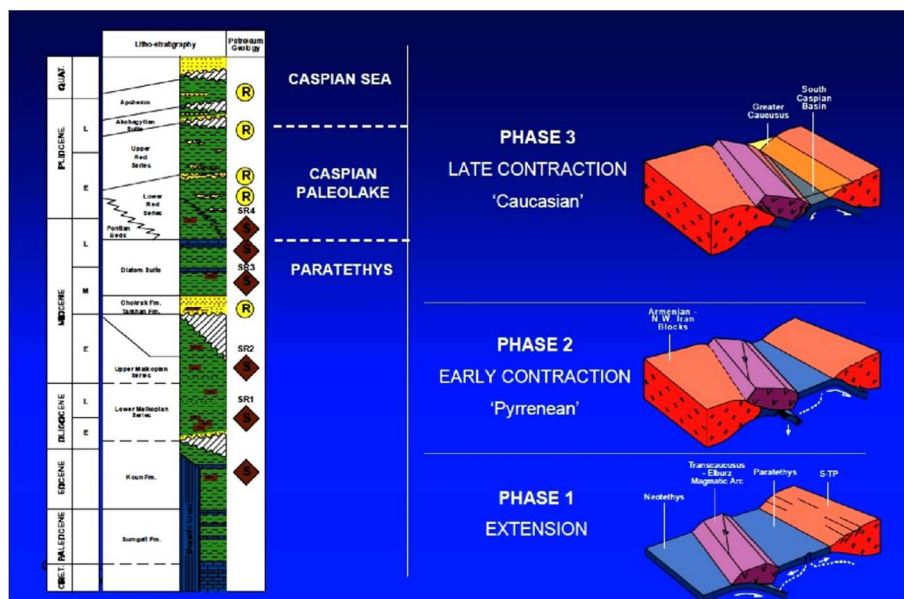


Figure 3 – Tectono Stratigraphy – South Caspian Basin

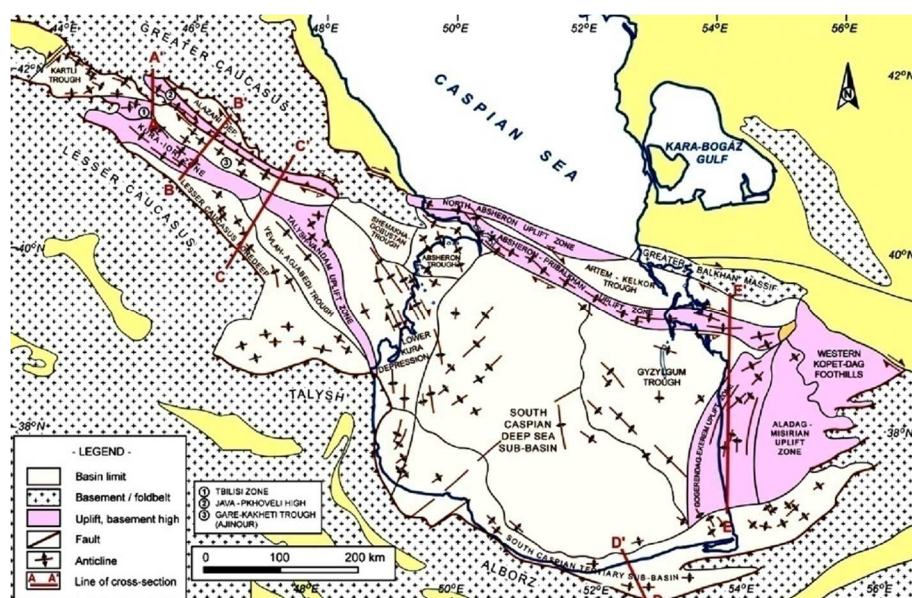


Figure 4 – South Caspian Basin – Structural Framework

South Caspian basin borders with prominent fold system of Major Caucasus & Copetdag on the north which are linked together across the basin via Apsheron-Pre Balkhan uplift belt which consists of 2 anticline lines: Apsheron-Turkmenbashi and Apsheron-Cheleken one.

The Apsheron trend where located Kapaz structure characterized by large, east to west striking folds and structures of the Pliocene section overlying and burying the underlying rifted margin structures and half-grabens of the Cretaceous, Jurassic, and possibly Triassic continental margin and shelf. The Tertiary structures display strike-slip influence, such as reversal of normal faults that bound the underlying half grabens; local back thrusting and flower-like structuring are common. The most significant volumetric potential lies offshore. Three elements are key to the extraordinary oil and gas potential of the South Caspian Basin. The high-quality reservoir sands are the Volga Pliocene delta and a lesser extent, The Kura and Amudarya deltas. The development of large anticlinal traps in response to structural compression was during the late Pliocene.

Stratigraphy. The Productive Sequence is the main petroleum play of the Absheron Province. In the North Absheron Uplift Zone, fields and prospects occur as a chain in the Absheron-Dan Ulduzu-Karabakh trend. The Productive Sequence is 1,200–3,800 m thick in the Absheron area, up to 6500 m, in the Baku Archipelago, and (from seismic evidence) more than 12 km thick in the deeper parts of the offshore basin. In Kapaz structure thickness of the Productive series reaches up to 4950 m. Kapaz structure is composed of



the deposits from the Sarmatian stage (based on seismic source), Productive series, Akchagyl, Apsheron stages, and of Quaternary deposits. The Productive Sequence is temporally equivalent to the Red bed Sequence in Turkmenistan. It is subdivided into the upper, middle, and lower parts and constituent suites as detailed in figure 5. The Lower parts of the Middle Miocene consist primarily of mudstone with thin persistent sandy units. The constituent Productive series Upper Kirmaku, Kirmaku, Lower Kirmaku, and Kala Suites are reservoir horizons in several fields. Oil and gas potential in the southwestern and north-eastern slope of the field is associated with the Pereiva suite and also with the underlying suites of the Productive series.

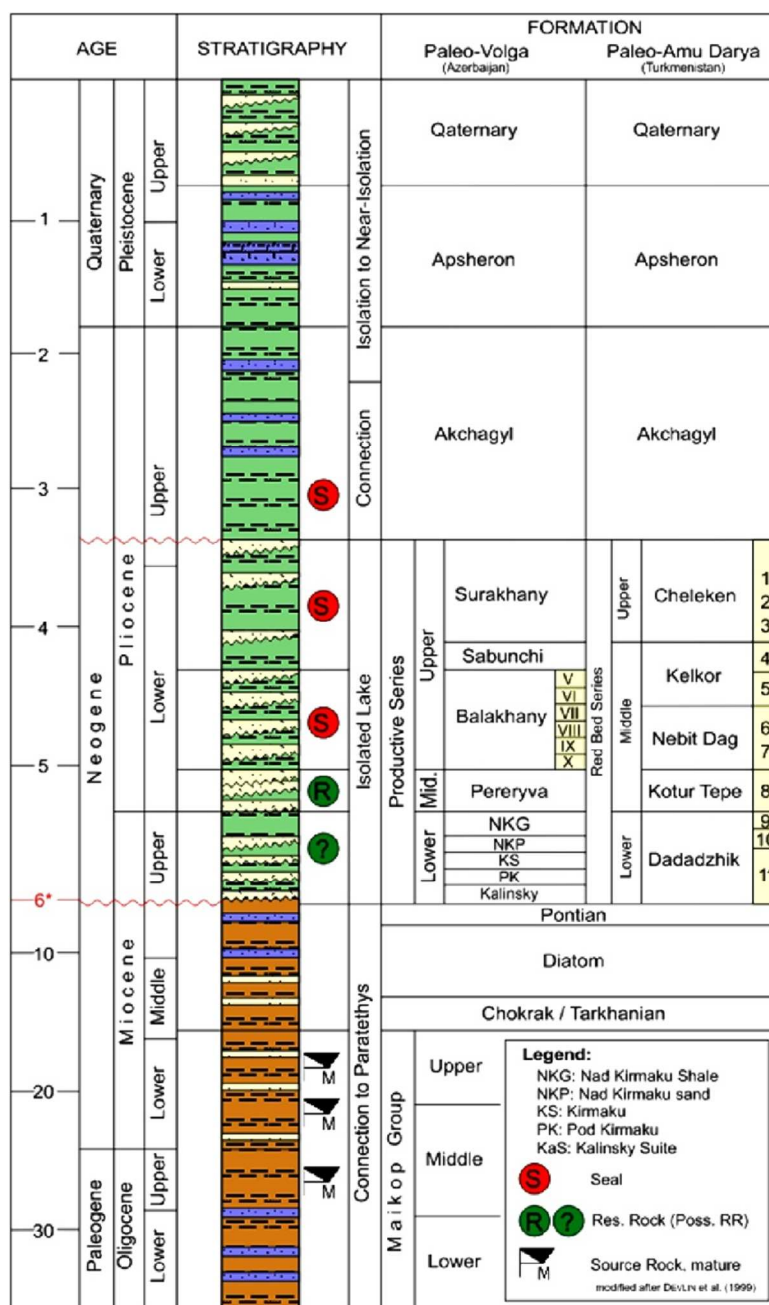


Figure 5 – Stratigraphy & HC System

Reservoir Facies, Facies Development. Kapaz structure is located in South Caspian structural play. In Turkmenistan waters, this play covers the field trend on the Apsheron Ridge.

There was the fluvial-deltaic environment, where paleo Volga River sediments dominated (fig. 6). Delta front and shoreface sands, prograding Paleo-Volga complex. The overlying Balakhany Suite has characteristics of a river-dominated delta environment. Paleo Volga facies domain diminishes at the end of Pliocene due to exclusive sedimentary input from the Paleo-Amu Darya River (fig. 6).

Regional information (logs) shows a deterioration of reservoir quality (Pereryva) from West (Azeri-Chirag-Guneshli) to East (well Kapaz-5) (fig. 7).

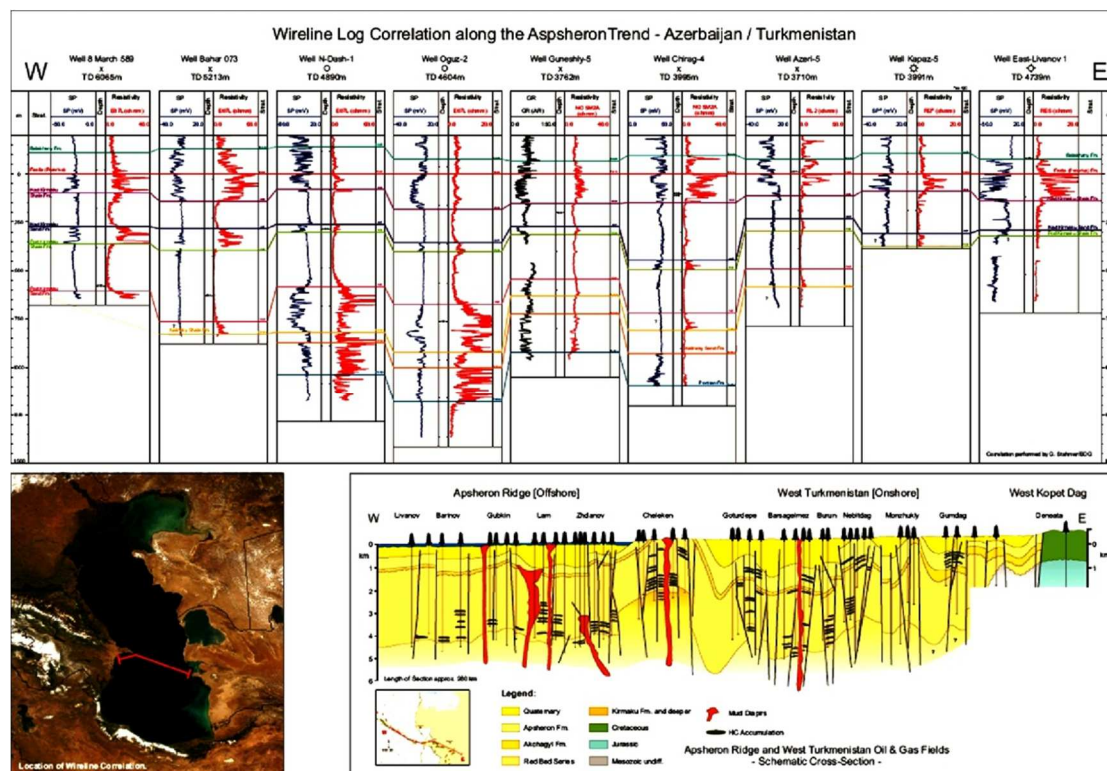


Figure 6 – Pliocene Paleogeography and Facies

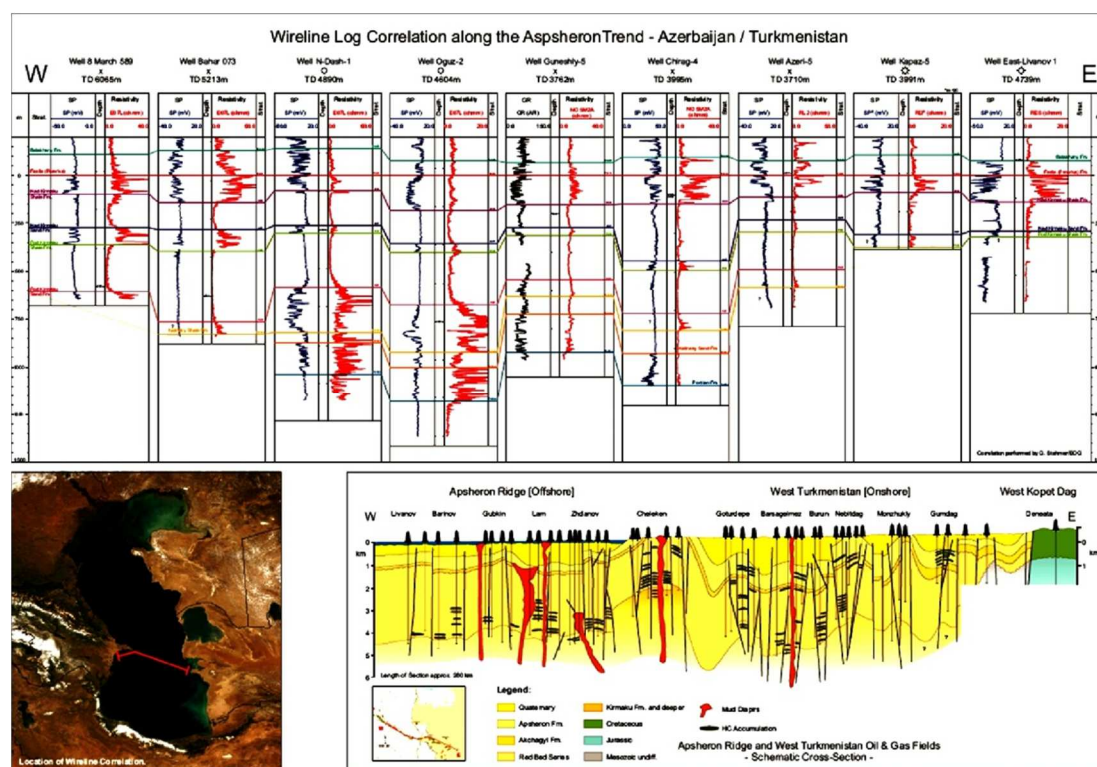


Figure 7 – Log Correlation along the Apsheron Trend

Source Rock: Oligocene to Miocene Maykop Formation. is the main source rock in the South Caspian basin. Hydrocarbon systems and production from surrounding fields show that the north-eastern flanks of the structures are predominantly oil-bearing indicating migration from the oil-prone Kelkor Trough. Southern flanks (towards gas-producing central parts of the South Caspian basin are either dry (gas pressure has exceeded lithostatic formation pressure) or contain some gas. In the prolific South Caspian basin, the Maykopian is buried >6 km and has not been drilled up to now (fig. 8).



Reservoir Rock: Sandstones of the Productive/Red Bed Series (Pliocene, Kalinsky to Surakhany Formations), Paleo Volga and Garabogaz facies domains possible, mainly fluvial-deltaic-shallow marine deposits.

Trap defined by 4-way dip closures partly faulted and intruded by shale diapirs.

The seal is intra-formational clays and regional (Akchagyl) transgression

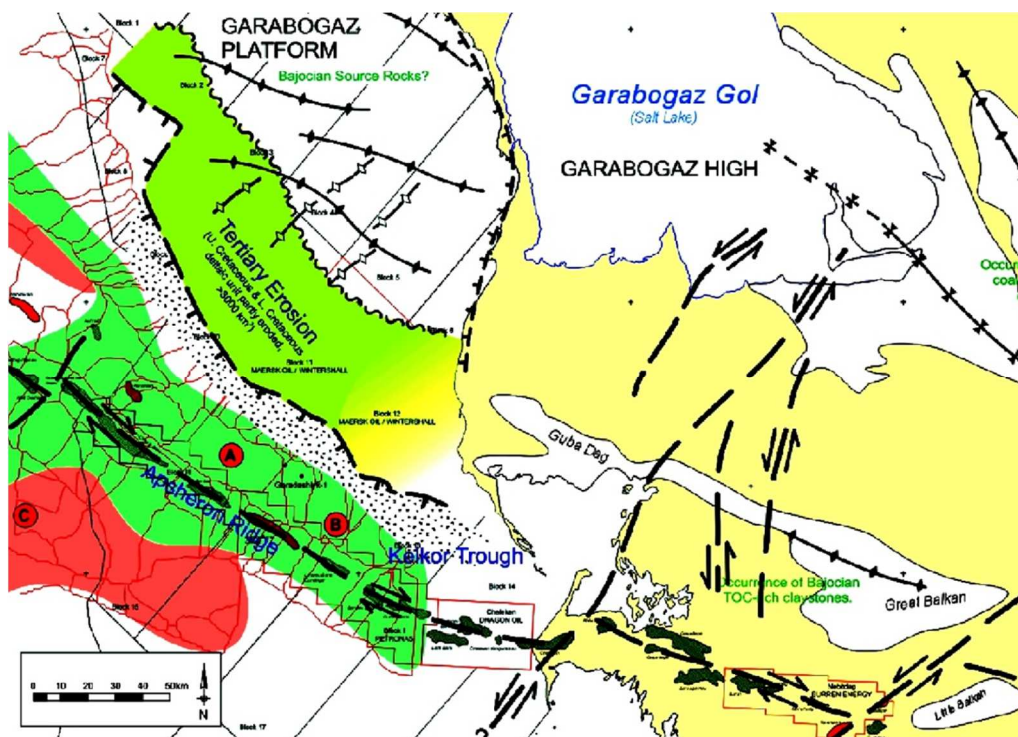


Figure 8 – Source Rock Maturity Map

In the Kelkor Trough, the bulk of the source interval is within the oil window. This coincides with the observation that most of the fields on the Apsheron ridge where located Kapaz structure are predominantly oil-bearing. Free gas, for example, the gas-cap of the Livanov Field, which is located east side of Kapaz could:

- have been migrated from the South (deeper parts of the South Caspian basin where the source interval should have reached the gas window),
- be of biogenic origin, or
- be the result of de-solution during structural leakage and related pressure depletion.

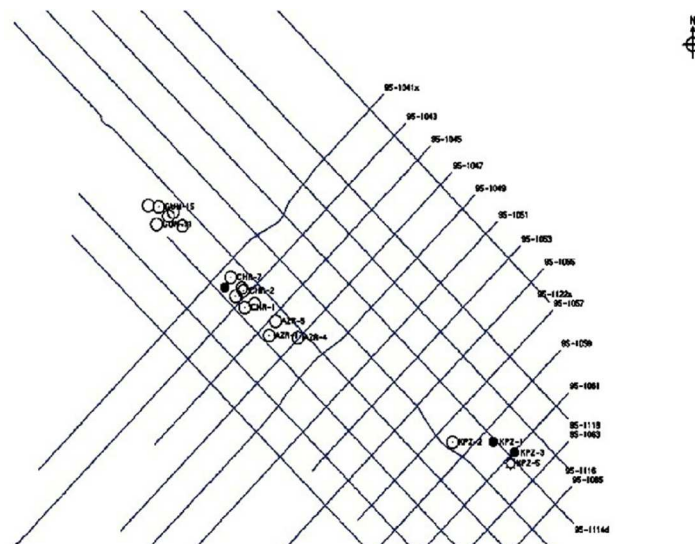
In the central parts of the South Caspian basin depocenter the Maykop Formation is buried >10 km and therefore assumed to have reached the gas window.

The different Pliocene fluvial-deltaic facies units were subsequently overprinted by clockwise directed paleo-currents in the Pliocene South Caspian basin water body, similar to the processes which can be observed in the South Caspian today. The cause for the current is, besides temperature and density differences of the water body, the Coriolis force. There are clear seismic indications for longitudinal bar sands developed by these reworking processes in Kapaz. These bar sands are known from many deltaic-shallow marine complexes and often form excellent reservoirs.

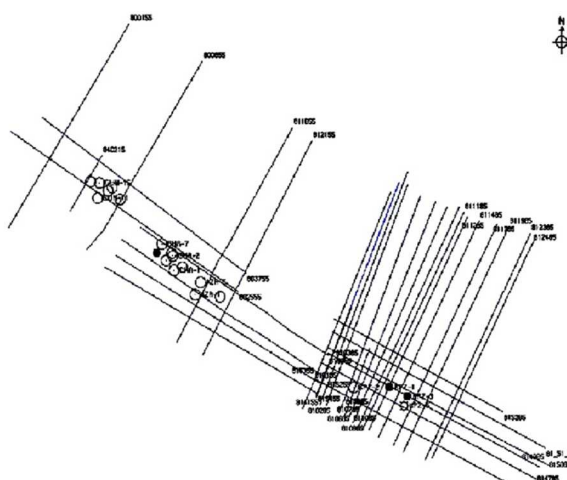
**Maturation and Migration History.** The South Caspian Basin is one of the fastest subsiding areas known in the world. Subsidence rates exceed 2 km/my since at least Pliocene. This results in a low geothermal gradient (approx. 1,6 °C / 100 m, figure taken from literature). The deeper parts of the Oligocene-Miocene Maykopian source rock have currently reached the gas window in the central parts of the South Caspian basin. Gas might have partly replaced oil in high conductive reservoirs.

In the shallower Kelkor Trough the Maykopian is in the oil window today. This trough, located north of the Apsheron ridge, is the kitchen area for the northern flanks of the Apsheron ridge structures.

**Database:** The data set for this study consist of a regional 2D seismic shot by Kasmorneft and Caspian Geophysical in Azerbaijan and Turkmenistan offshore. Seismic interpretation has been made by using Opentech software. As the dataset is proprietary, the coordinates/location of the line could not be shown. Part of the presented seismic interpretation was used during the preparation of the presentation published in the international Earth Sciences Colloquium of the Aegean Regions, in Izmir, Turkey in 2005 [4]. Figures 9 and 10 For the HC forecast were used REP program table 1 and 2.

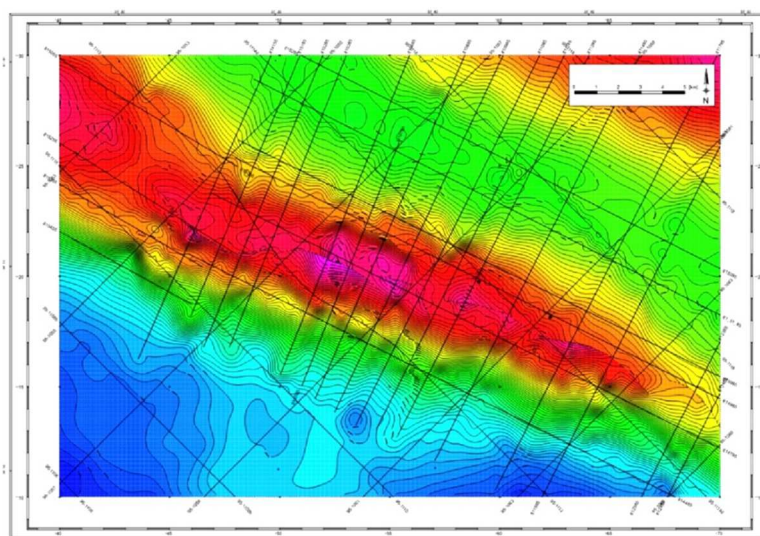


**Figure 9** – Seismic Database – from the '80s

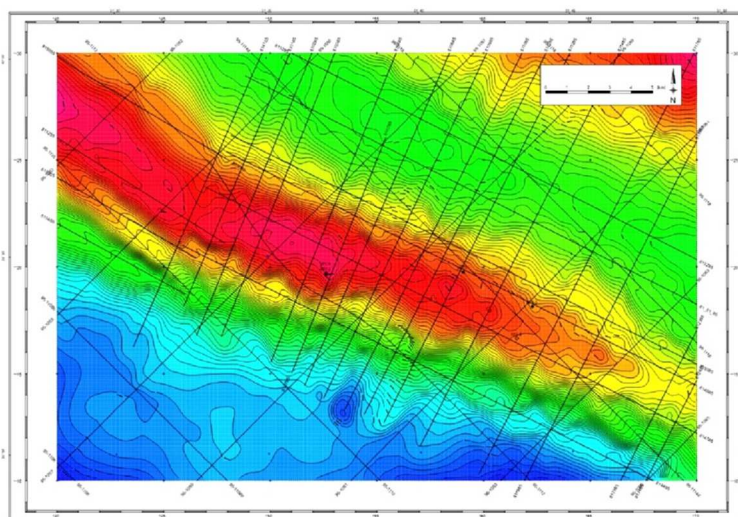


**Figure 10** – Seismic Database from 1995 and 1996 (South Caspian Regional Survey)

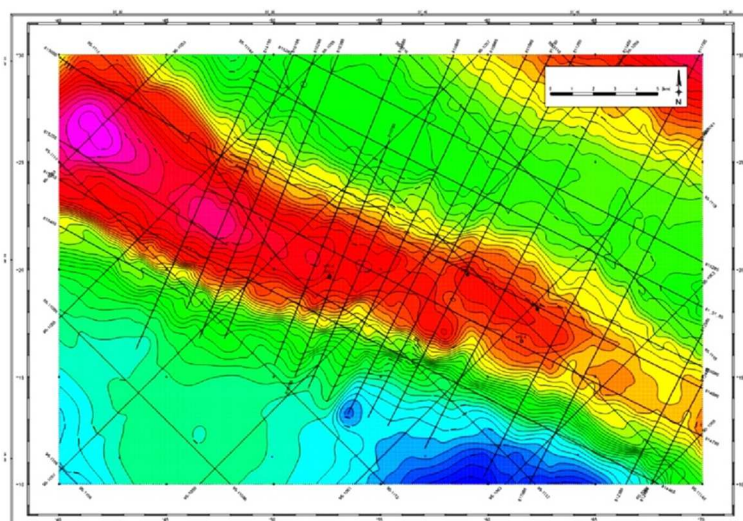
Four seismic horizons were mapped to delaminate an anticline shale diapir structure in the Kapaz structure (top Pereriva, top Balakhany, top Surakhany, and top Akchagyl horizons). The upper horizons show no or only negligible compartmentation within a longitudinal structure (fig. 11, 12, 13, 14).



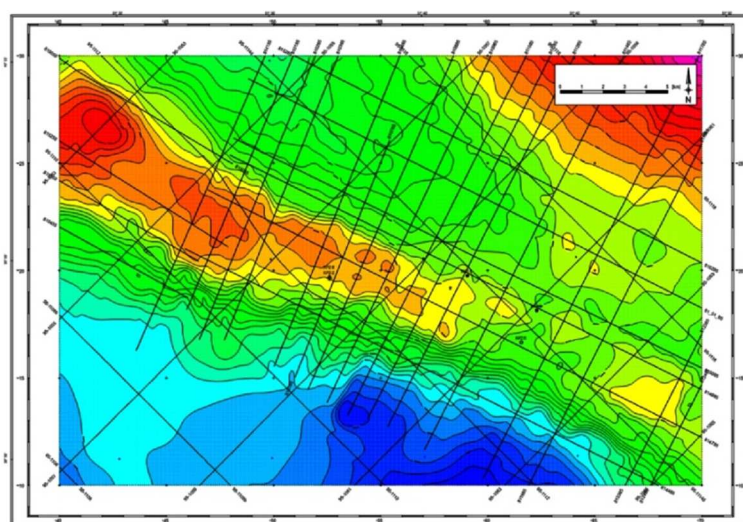
**Figure 11** – Kapaz. Depth Contour Map Top Pereriva Fm



**Figure 12** – Kapaz. Depth Contour Map Top Balakhany Fm



**Figure 13** – Kapaz. Depth Contour Map Top Surakhany Fm



**Figure 14** – Kapaz Depth Contour Map Top Akchagyl Fm

In the seismic top Pereriva pick represents the top of the most critical producing reservoirs. Its facies can be characterized by a fluvial to the fluvial-deltaic environment. The Pereriva suite is overlying an ero-



sional unconformity and represents the most widespread distribution of the Apsheron sandy facies over the South Caspian basin including the Kapaz structure. The fold bend in the upper Pliocene undulates twice and in the middle Pliocene, it undulates thrice. Faults cut the Kapaz structure into several blocks. As a result, the central arch part of the structure that is situated between them along the strike of the uplift becomes dissected. The Lower Productive series pick can be thought of as defining the base of the Productive series, and the transition from Pliocene into Miocene deposits. In between top Pereriva and top Pontian lie several potential reservoir layers like the Upper Kirmaki sandy (UKS), Lower Kirmaki (LK) & Kalin (KaS) suites.

Seismic lines well define mud diapirs of Kapaz structure as well. Mud diapirism is a widespread feature both offshore and onshore of the South Caspian basin. Within the Caspian Province of Azerbaijan and Turkmenistan, the diapirism is well documented by exploration seismic data and is manifested as mud volcanoes at the surface, locally associated with sand intrusions [6]. Mud diapirism in the South Caspian basin began in Early Miocene times. Mud diapirs may originate from as deep as 14 km [2], as testified by fragments of Mesozoic and Paleogene rocks contained in the mud breccia generated in larger mud volcanoes during catastrophic events [5]. Most of the erupted mud, however, is derived from the pelitic parts of the Oligocene–Miocene Maykop Series, the major petroleum source rock in the South Caspian basin [3]. Mud diapirism has induced doming of the Plio–Pleistocene Akchagyl and Apsheron Formations in the Kapaz structure (fig. 15, 16, 17, 18, 19).

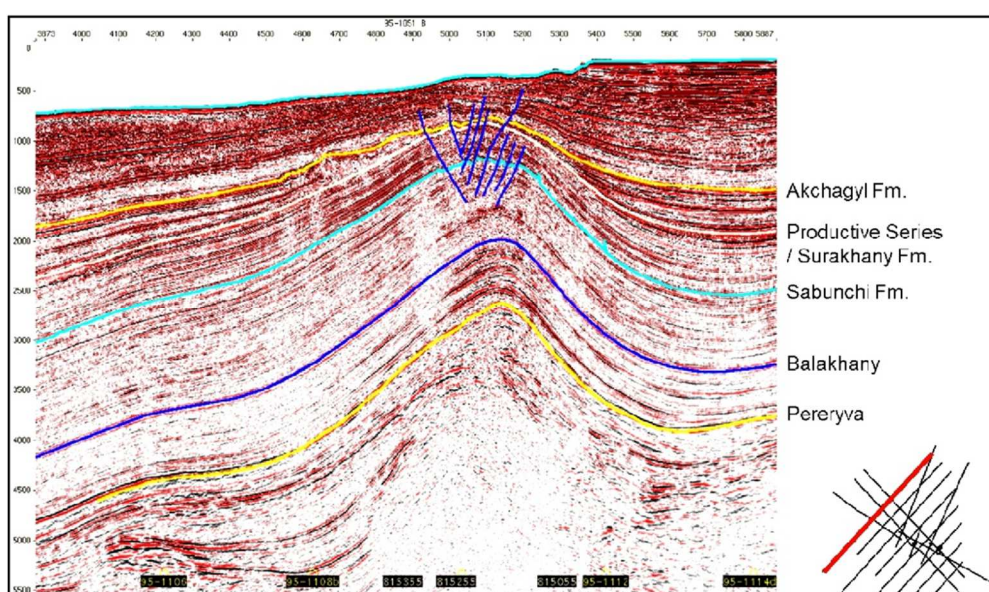


Figure 15 – Kapaz. Seismic Line 1 SW-NE direction

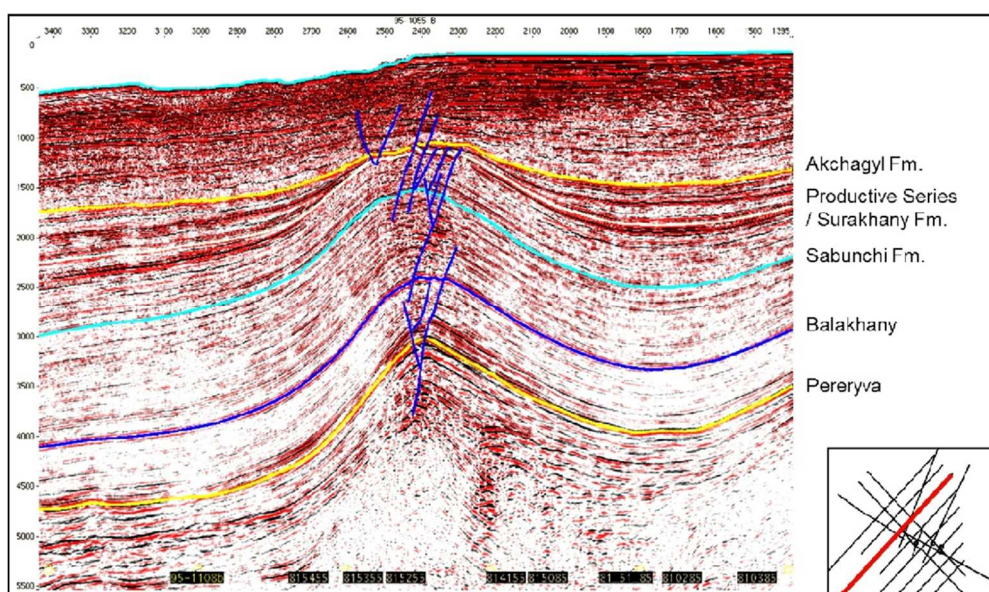


Figure 16 – Kapaz. Seismic Line 2 SW-NE direction

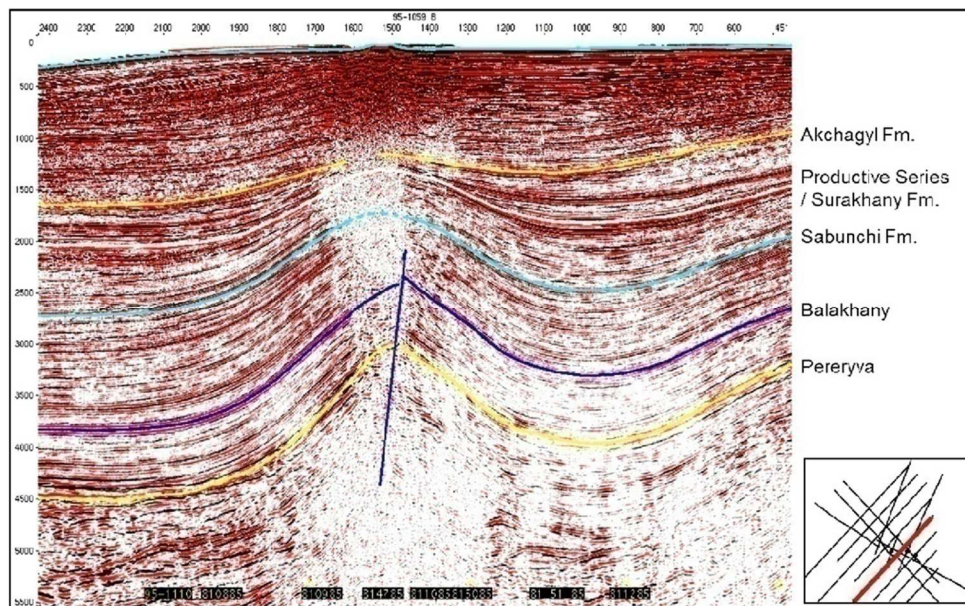


Figure 17 – Kapaz. Seismic Line 3 SW-NE direction

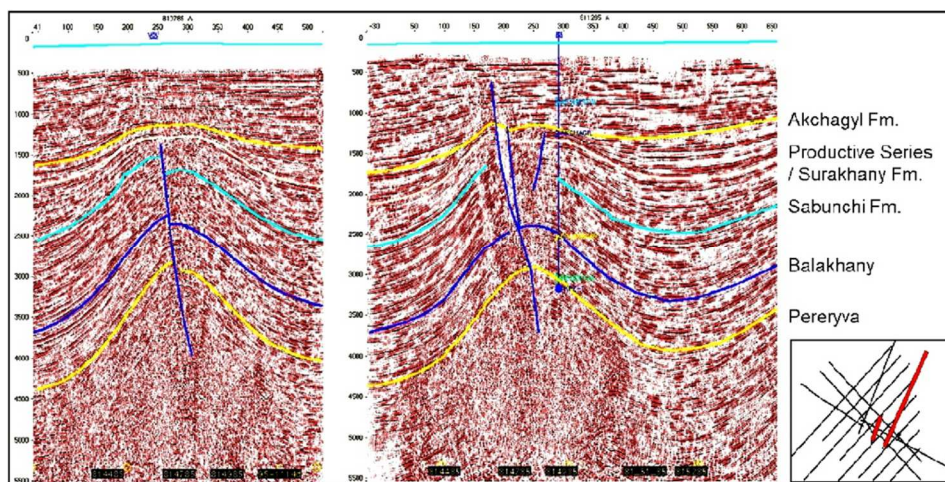


Figure 18 – Kapaz. Seismic Lines 4 (SSW-NNE) and 5 (SSW-NNE)

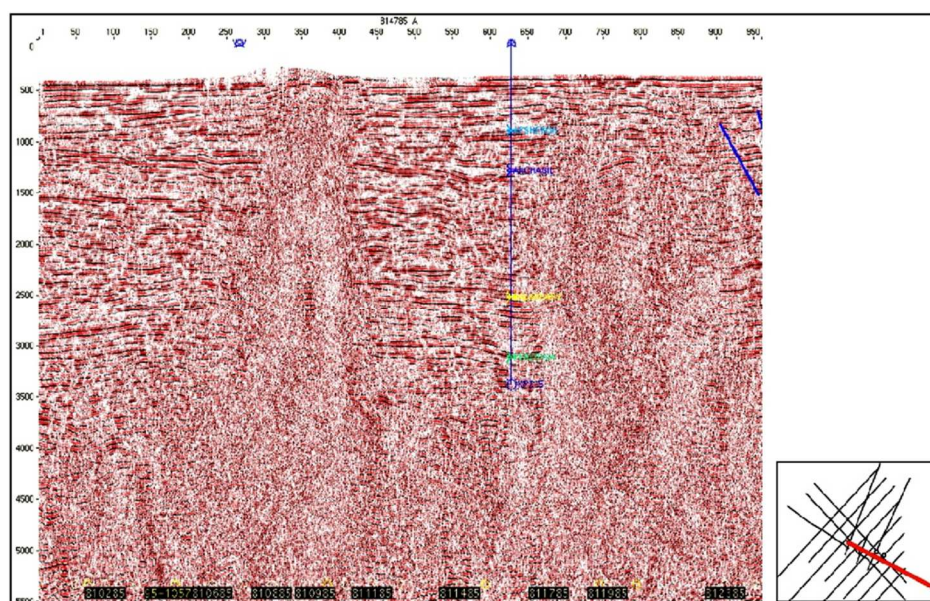


Figure 19 – Kapaz. Seismic Line 6 (WNW-ESE)



From a sedimentology point of view, the Kapaz structure is located on the border of the Paleo Volga and Paleo Amudarya depositional system. Regional seismic points out that the Paleo Volga system probably continued to stay the main source of terrigenous sediments. However, Paleo Amu Darya probably became a more important source of sediments in the Apsheron time. And the presence of clinofolds on the borderland of the shelf was observed as dipping to the west and SW. It is shown that the Paleo Amudarya system at last overlapped and overthrust on the borderland of Paleo Volga shelf effectively sealed underlying terrigenous rocks-reservoirs.

It has not yet been established if the entire area of the structure forms a single hydrodynamic system or not. The fact that the Kapaz-5 appraisal well tested only gas suggests that one of these blocks (i.e. at least the block in which the well number 5 is located) is hydrodynamically separated. The Pereryva reservoir in the block where the well № 5 was drilled maybe only gas-bearing or the well may have tested only a gas cap. The correlation of Kapaz well logs well defines the distribution of regional reservoirs (fig. 20, 21).

Exploration well N1 drilled in the crest part of the north-eastern slope of the Kapaz structure, Drilling stopped at a depth of 3730 m., and testing of the «Pereriva» suite obtained, a commercial inflow of oil ( $Q = 285$  tons/day) and gas ( $Q_g = 20$  thousand  $m^3$ /day). Later, well N3 was drilled to the southeast of well N1 in the crest part of the north-eastern slope, which was stopped at a depth of 3848 m due to complications in the wellbore. Testing of the objects obtained inflow of oil ( $Q = 327$  tons/day) and gas ( $Q_g = 26$  thousand  $m^3$ /day). Figures 20, 21, 22, and 23 show a reservoir formation evaluation of drilled three Kapaz wells.

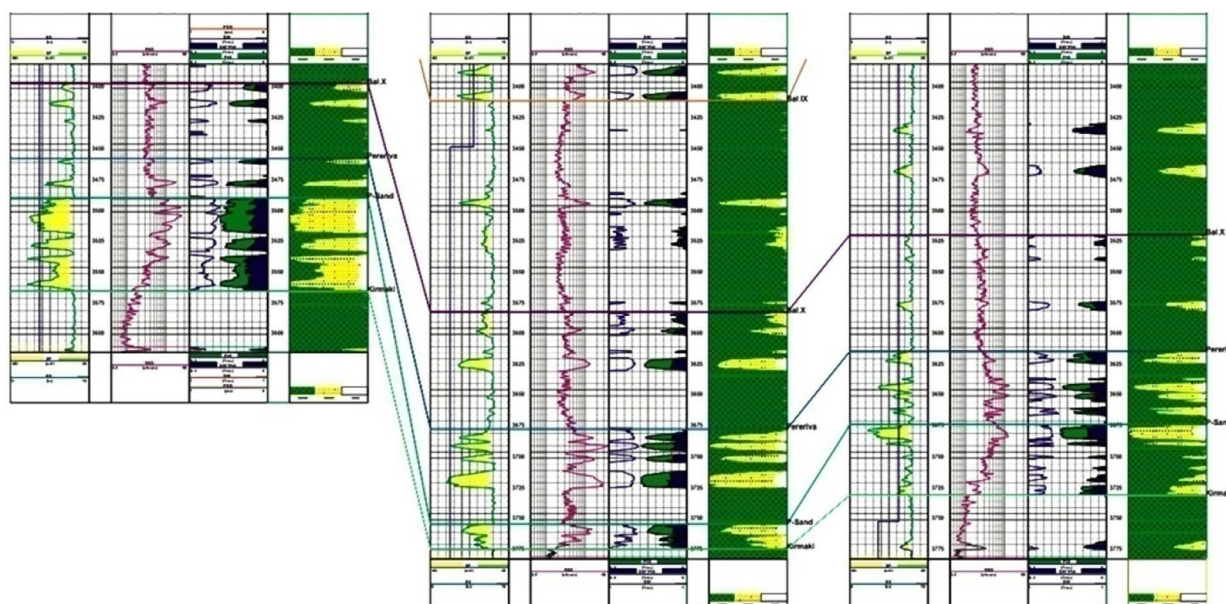


Figure 20 – Formation Evaluation Wells Kapaz-1, -3, -5

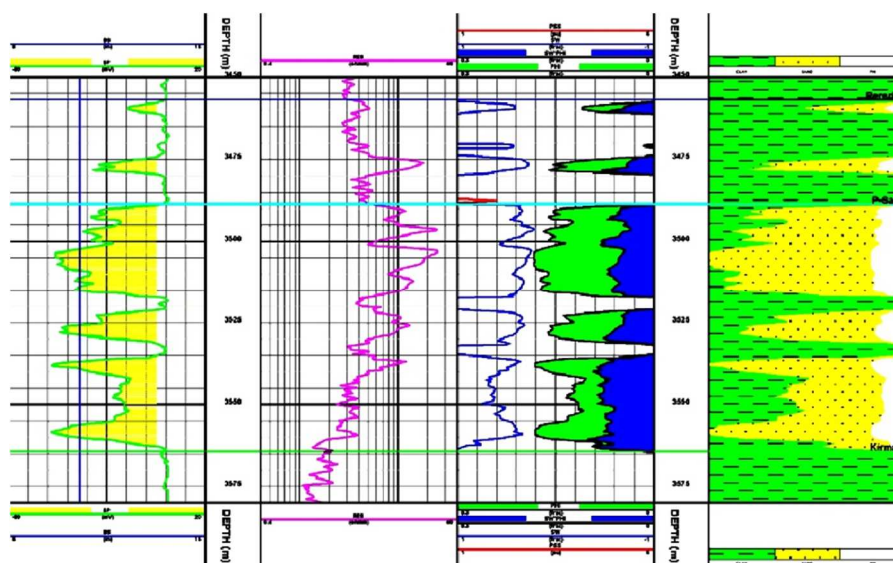


Figure 21 – Formation Evaluation of Well Kapaz-1



Well	Kapaz-1	Average
Top of the reservoir (m)	3456	—
Bottom of the reservoir (m)	3565	—
Res.Thickn.(m)	108	107
Net Thickn.(m)	71	50
Net/Gross (%)	66	47
Phl aver (%)	14,4	13,9
Sw aver (%)	44	44
Vsh aver (%)	29	27
Phl*h (m)	10,20	6,91
Ph*h*So (m)	5,71	4,1
Well	Kapaz-5	Average
Top of the reservoir (m)	3614	—
Bottom of the reservoir (m)	3730	—
Res.Thickn.(m)	116	107
Net Thickn.(m)	40	50
Net/Gross (%)	34	47
Phl aver (%)	13	14
Sw aver (%)	49	44
Vsh aver (%)	23	27
Phl*h (m)	5,02	6,91
Ph*h*So (m)	2,57	3,85
Well	Kapaz-3	Average
Top of the reservoir (m)	3677	—
Bottom of the reservoir (m)	3774	—
Res.Thickn.(m)	97	107
Net Thickn.(m)	39,2	50,1
Net/Gross (%)	40,4	47
Phl aver (%)	14	14
Sw aver (%)	41	44
Vsh aver (%)	28	27
Phl*h (m)	5,51	6,91
Ph*h*So (m)	3,25	4,1

Figure 22 – Kapaz wells result of Formation evaluation

Net pay calculation: Cut off PHI =>8 %; Vcl-none; Sw-none.

Well	X-longitude	Y-latitude	Balakh. VIII	Balakh. IX	Balakh.X	Pereriva	UKS	Kirmaky
Kapaz-1	559039,16	4417776,91	–3085,95	–3209,25	–3396,09	–3456,59	–3488,59	–3564,18
Kapaz-3	562264,09	4416459,43	–3287,58	–3409,96	–3581,25	–3676,66	–3753,31	–3773,58
Kapaz-5	561540,83	4414966,17	–3185,01	–3298,86	–3518,62	–3613,87	–3673,15	–3730,00

Figure 23 – Kapaz. Formation tops. All depths in m

Valid and separate closure exist throughout Upper Kirmaku and Pereryva Formation up to the Early Balakhany formation. Upper Balakhany and younger no separate closure -Kapaz is the eastern extension of the Azeri mega-structure. ODT/OWT at neighboring Azeri & Chirag structures some 900 m shallower in Pereryva. Initial pressure >1000 psi lower in Azeri structure. Reservoir pressure in Well Kapaz-1 & -3 is similar, about 1000 psi higher in Well Kapaz-5 (fig. 24).

**Conclusion.** From this geological and geophysical study the following conclusions are drawn:

1. Interpretation of seismic data (Seismics from 1980s and 1995–1996 years).
2. Construction of structural maps. (top Pereriva, top Balakhany, top Surakhany, top Akchagyl).
3. Formation evaluation of three drilled wells (Kapaz, 1: 3 and 5).
4. Correlation well logs with other oil and gas fields (8 March well-589 (TD 6065 m); Bahar well-073 (TD 5213 m); Neft Dashlari Well-1 (TD 4890 m); Oguz well-2 (TD 4604 m); Guneshly well-5 (TD 3762 m); Chirag well-4 (TD 3995 m); Azeri well -5 (3710 m); Kapaz well-5 (TD 3991 m); East Livanov well-1 (TD 4739 m)
5. Estimation of reserves (tab. 1, 2).

Table 1 – Kapaz HC volumes. Northern flank. Oil prone 100 %

Probability	OIP [MMBBL]	Reserves [MMBBL]	Solution Gas [BCM]
P90	259	79	1,6
P50	875	276	6
P10	2368	777	18,2
MSV	1150	371	8,5
Top Trap	3075 m		
Spill	3650 m		
POS:	72 %		



### Капaz 1

■ Date	: 1988	
■ Perforation Interval	: 3491 – 3527 m	
■ Test Rates	● Oil : 331 m <sup>3</sup> / d (286 t / d)	- 2088 bopd
	● Ass. Gas : 20 000 Nm <sup>3</sup> / d	- 0.746 MM scf/d
■ GOR	: 60.3 Nm <sup>3</sup> / m <sup>3</sup>	- 358 scf / bbl
■ Reservoir Pressure @ 3510 m	: 419 bar	- 6075 psi

### Капaz 3

■ Perforation Interval	: 3682 – 3725 m	
■ Test Rates	● Oil : 435 m <sup>3</sup> / d (375 t / d)	- 2738 bopd
	● Ass. Gas : 35 000 Nm <sup>3</sup> / d	- 1.306 MM scf/d
■ GOR	: 80.4 Nm <sup>3</sup> / m <sup>3</sup>	- 477 scf / bbl
■ Oil Density	: 0.8573 g / cm <sup>3</sup>	- 33.6°API
■ Reservoir Pressure @ 3704 m	: 427 bar	- 6191 psi

### Капaz 5

■ Perforation Interval	: 3640 – 3684 m	
■ Test Rates	● Free Gas : 100 000 Nm <sup>3</sup> / d	- 3.73 MM scf/d
■ Reservoir Pressure @ 3650 m	: 492 bar	- 7136 psi (IHS)

Figure 24 – Test results of Kapaz wells

Table 2 – Kapaz HC volume. Southern flank. Gas prone 100 %

Probability	GIP [BCM]	Reserves [BCM]	Reserves BOE [MMBBL]	NGL [MMBBL]
P90	5,5	3,1	24	6,1
P50	34,1	19,3	148	38
P10	115	67	519	135
MSV	50,4	29	224	59
Top Trap	2871 m			
Base Trap	3650 m			
POS	72 %			

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