Always moving forward!

"Domanik shale oil: unlocking potential"

London
10.03.2016

Aleksei Gabnasyrov

Presentation Agenda

Areas of Unconventional Resource potential within PJSC LUKOIL's leasehold/licenses in Volga-Ural and Timan-Pechora provinces

Results of Domanik Shale Studies by PJSC LUKOIL

Properties comparison of Domanik shale and other well-known shale basins in North America

Potential for implementation of the lessons learned during pilot studies of Domanik shale to successfully develop Domanik as an unconventional resource play

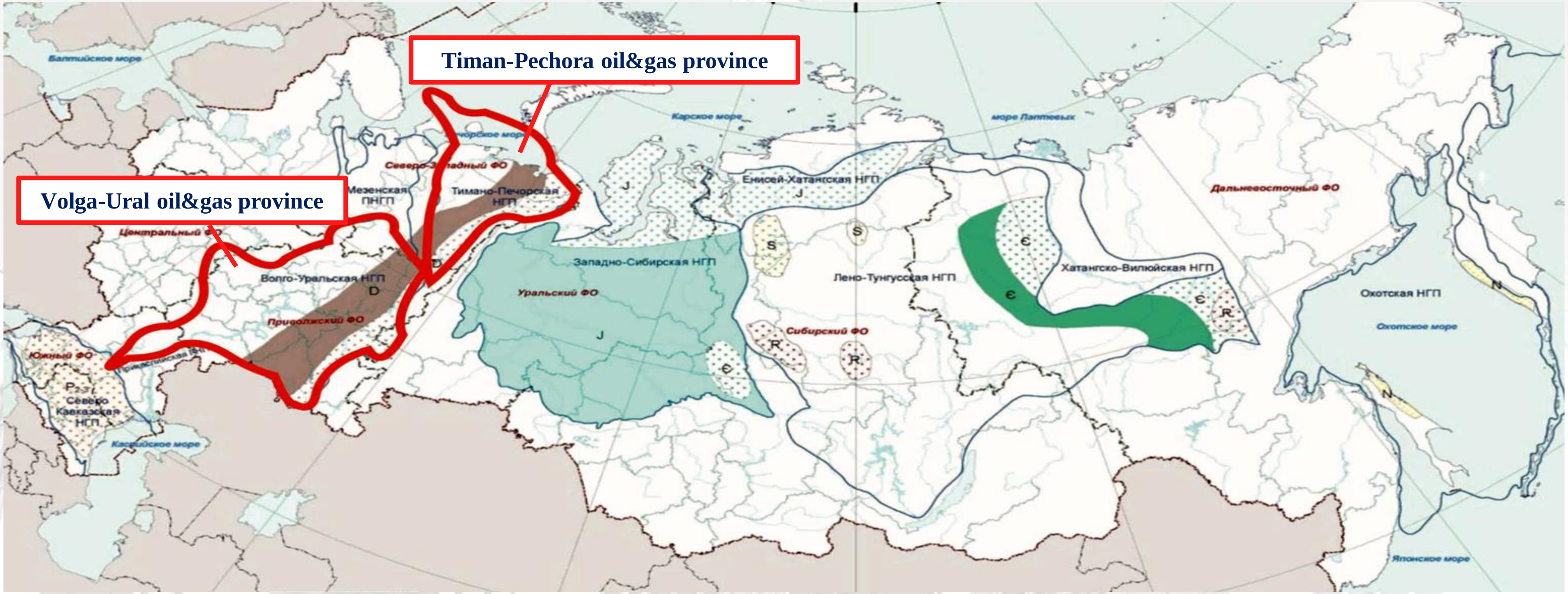
Future steps: program of additional studies of Domanik Shale at PJSC LUKOIL's license areas

Main results of Bazhenov Shale Studies by PJSC LUKOIL

Volga-Ural and Timan-Pechora provinces: Unconventional Potential

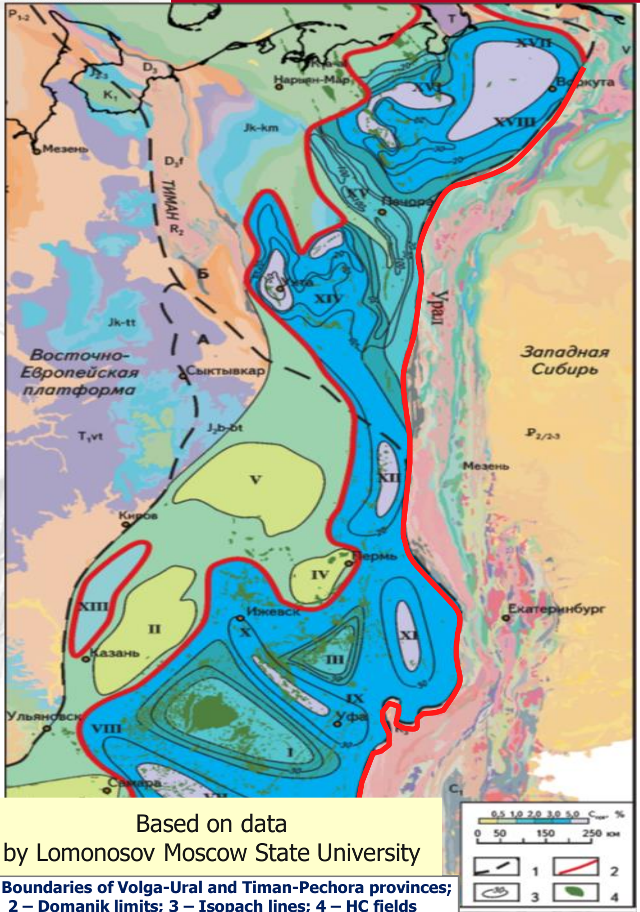
25 ЛЕТ ЛУКОЙЛ

Map of Domanik Shale Formation Within the Russian Federation Territory



Domanik deposits are the main oil source rocks for Timan-Pechora and Volga-Ural oil&gas provinces

Oil&Gas Potential of Domanik Deposits



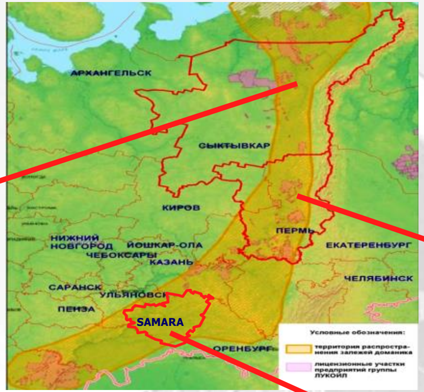
Based on data
by Lomonosov Moscow State University

1 – Boundaries of Volga-Ural and Timan-Pechora provinces; 2 – Domanik limits; 3 – Isopach lines; 4 – HC fields

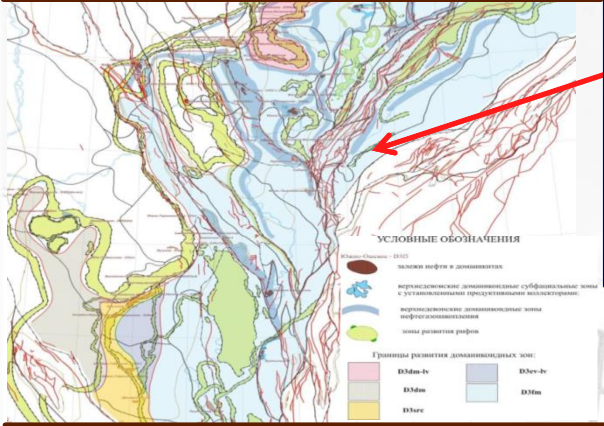
- **Republic of Tatarstan: over 330 targets have been tested with 44 cases of inflow**
- **Republic of Bashkortostan: over 100 t/day obtained within Belskaya depression areas**
- **Perm Oblast: 163 targets have been tested, with oil rate over 1 t/day obtained in 14 cases**
- **Republic of Udmurtia: most wells have been dry, 10 wells were wet, and 7 wells with oil inflow rate of 7 m^3/day**
- **Samara Oblast: 120 targets of which 34 targets have produced oil. The maximum oil and water inflow rate of 55 m^3/day has been obtained in the Domatovskaya area from the Buregsky horizon**
- **Orenburg Oblast: 34 targets of which 9 targets have produced oil. The maximum oil inflow rate over 100 m^3/day has been obtained in the Tverdilovskaya area**
- **Water inflows were found in 43 cases within Samarskaya and Orenburgskaya areas**
- **Timan-Pechora province: oil inflow in 48 wells, Qo of up to 88 t/day**

Oil-gas saturation of Domanik deposits has been confirmed by number of well tests throughout the development area

Areas of Unconventional Hydrocarbon Resource Potential within PJSC LUKOIL's License Areas in Russia



Domanik limits within Komi Republic and Nenets Autonomous Okrug (Timan-Pechora province)



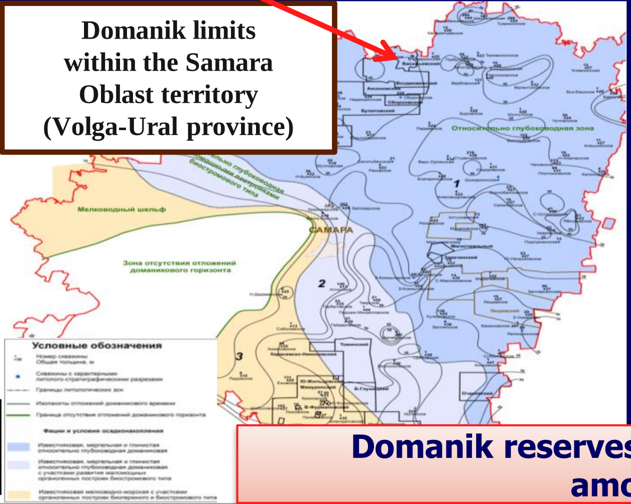
Domanik formation oil fields within the Timan-Pechora province

No.	Field	Formation	Reserves, thous. t
			C_1
			recov.
1	Severo-Vozeyskoye	Fr-T	785
2	Vozeyskoye	Fr-T	31
3	Suborskoye	Fr-T	198
Total:			1014
Additionally on the state register (8 fields)			3882

Domanik formation oil fields within the Samara Oblast territory

No.	Field	Formation	Formation parameters		Initial recoverable reserves, thous. t
			Kp	Ko	
1	Labitovskoye	D_3dm	0.13	0.827	181.4

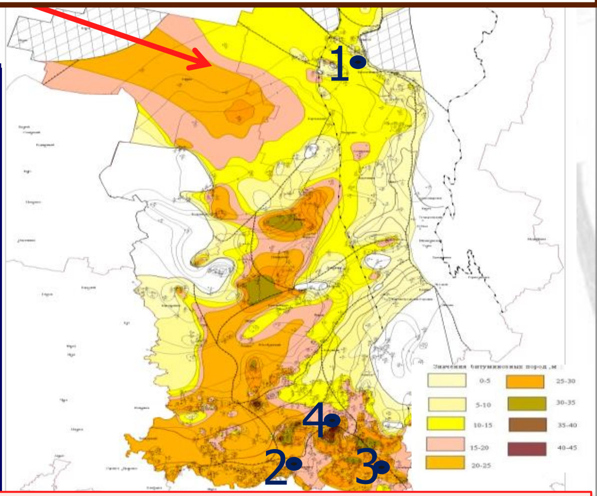
Domanik limits within the Samara Oblast territory (Volga-Ural province)



Domanik formation oil fields within the Perm Krai territory

No.	Field	Formation	Formation parameters			Reserves, thous. t
			Kp	Kos	Kperm, mD	A + B + C_1 recov.
1	Isanevskoye	Fr-T	0.1	0.8	178	112
2	Rakinskoye	Sarg	0.1	0.7	160	11
3	Tyushevskoye	Domanik	0.09	0.7	22	3
4	Stretenskoye	Mendym	0.12	0.7	98	31

Domanik limits within the the Perm Krai territory (Volga-Ural province)



Domanik reserves (A + B + C_1) of PJSC LUKOIL amount to 1.5 mln t

Results of Domanik Shale Studies by PJSC LUKOIL

Sedimentation Environment During the Domanik Age In Volga-Ural and Timan-Pechora Provinces

V Depression facies of uncompensated basins

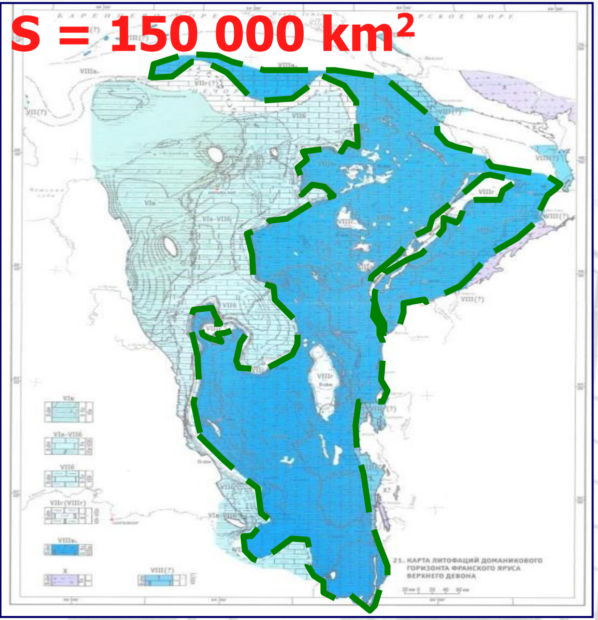
V Facies of shallow marine shelf

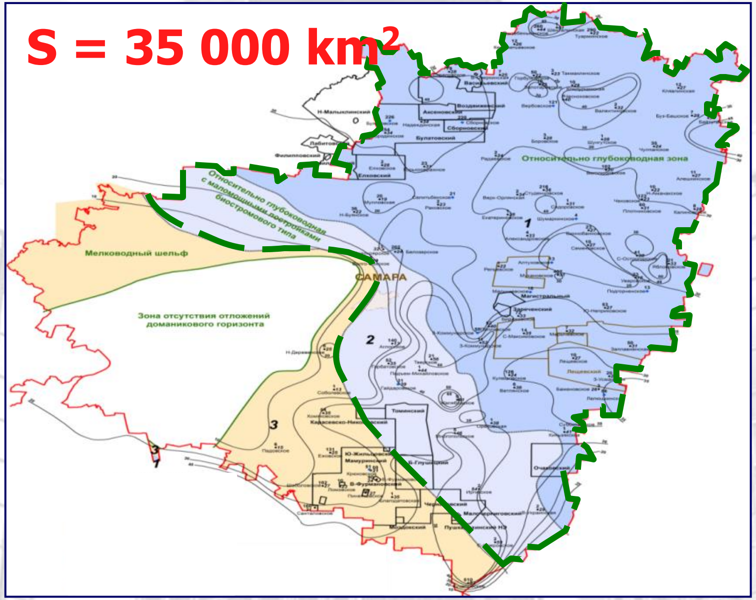
X Depression facies of compensated basins

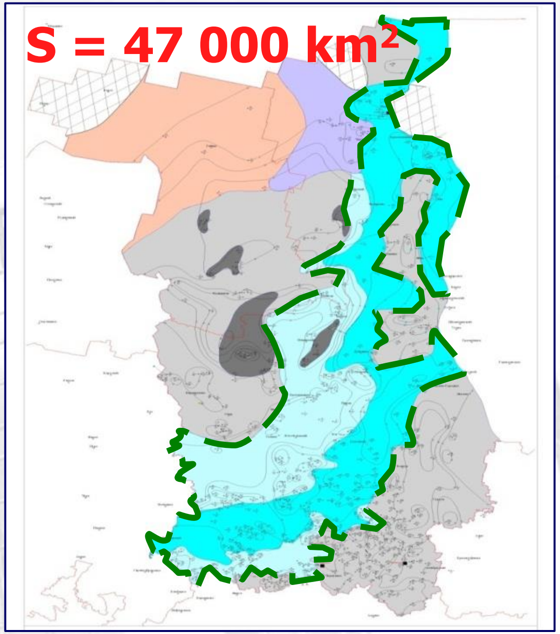
X Marginal-lagoon facies

X Platform-lagoon facies

X Reef-platform-lagoon facies



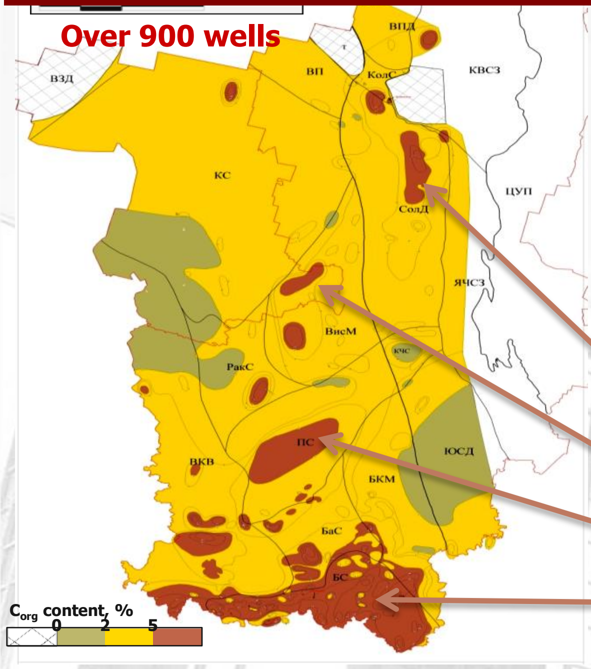


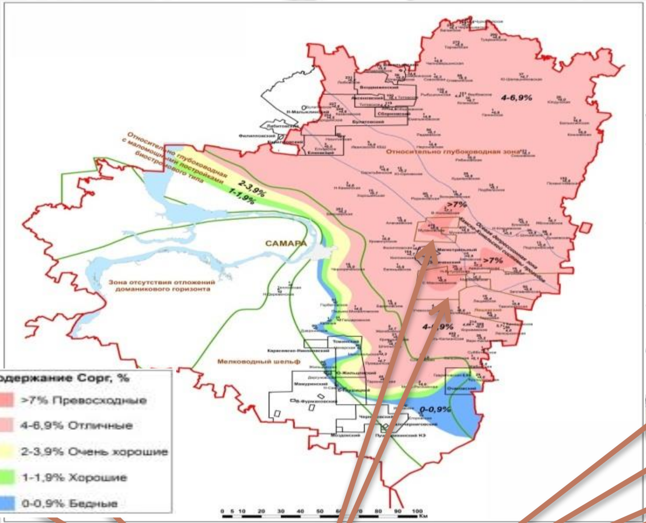


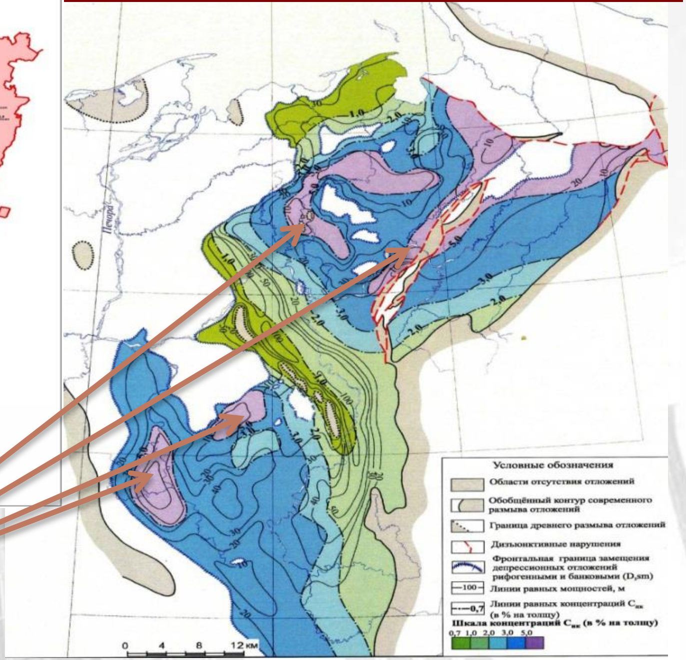
The Domanik formation within Volga-Ural and Timan-Pechora Provinces covers ~232 000 km²

Total Organic Carbon (TOC) Map of the Domanic Formation

within the Perm Krai territory (Volga-Ural province)	Samara Oblast (Volga-Ural province)	Komi Republic and Nenets Autonomous Okrug (Timan-Pechora province)





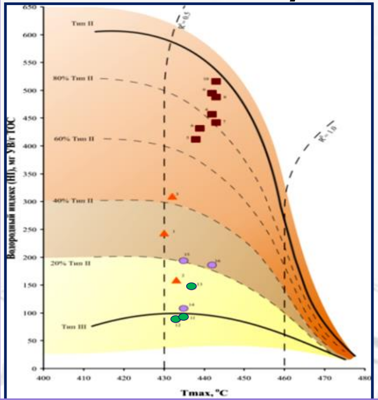


TOC > 5 %

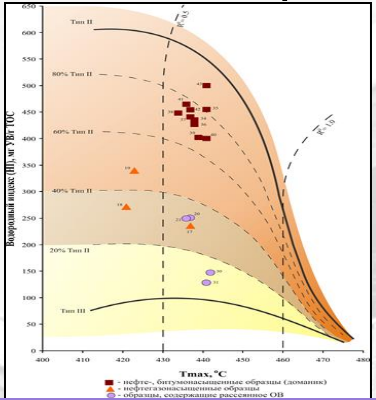
- ✓ Within Domanik formation there are large areas where TOC ranges from 2 to 5 % and occasionally up to 23 %
- ✓ TOC content was determined based on Geochemical data and core analysis in 4 wells
- ✓ Where no core analysis was available, TOC was determined based on TOC = f(GR), which could lead to major errors

Types of Organic Matter

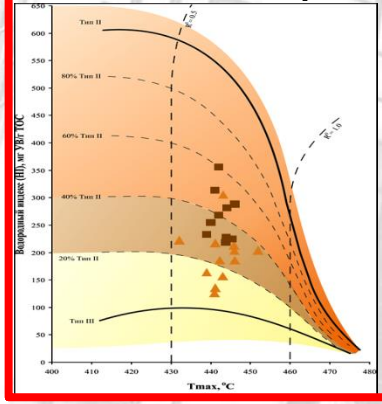
199 Andreevskaya



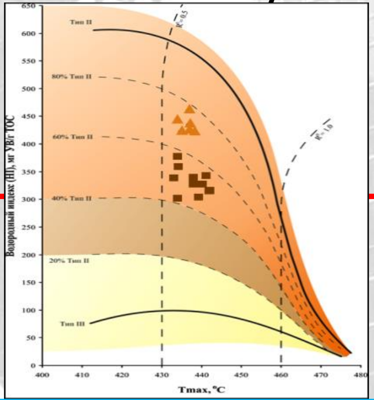
200 Andreevskaya

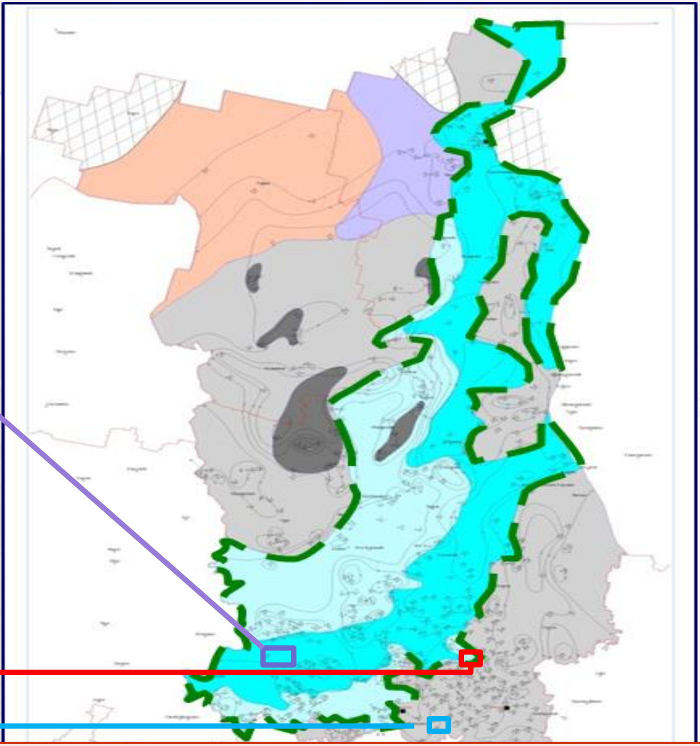


266 Zabrodovskaya



296 Pavlovskaya



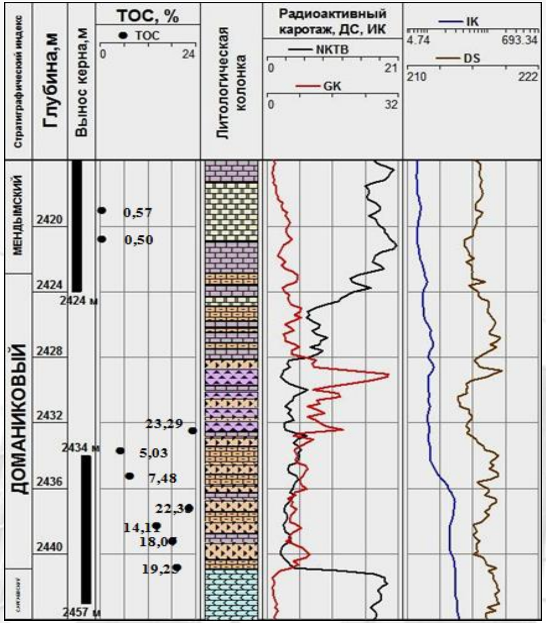


Domanik Mendymsky Sargayevsky Timansky

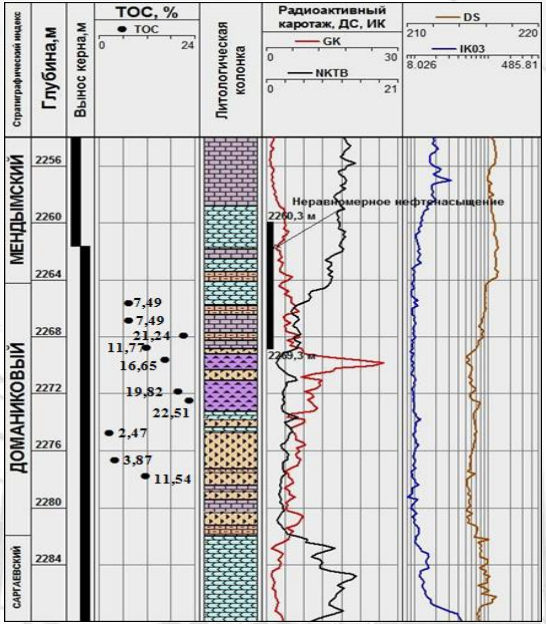
- Organic matter of Domanic formation is predominantly of type II kerogen.
- Upper and lower deposits contain organic matter of type II and II + III.

Results of Geochemical Core Analysis. Well #199 and #200 (Andreevskaya Area)

#199



#200

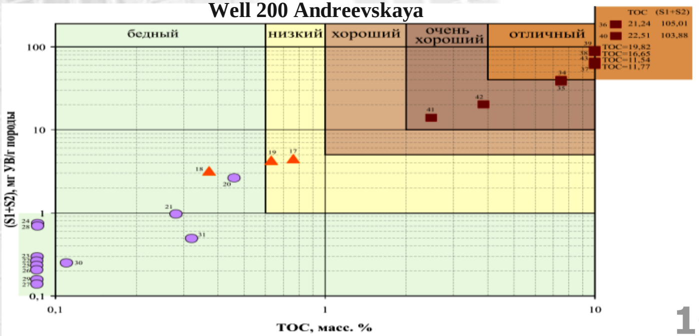


Pyrolysis results based on Rock Eval analysis

Parameter	Value
TOC	2.5–23.3 / 13.7
S1 + S2	14–119 / 70
PI	0.12–0.17 / 0.14
HI	400–516 / 450
Catagenesis stage	MK1

TOC – total organic carbon of rock, % wt.
HI – hydrogen index, mg HC/g TOC.
PI – productivity index, S1/(S1+S2)
S1+S2 – generic ponential of rock, mg HC/g rock

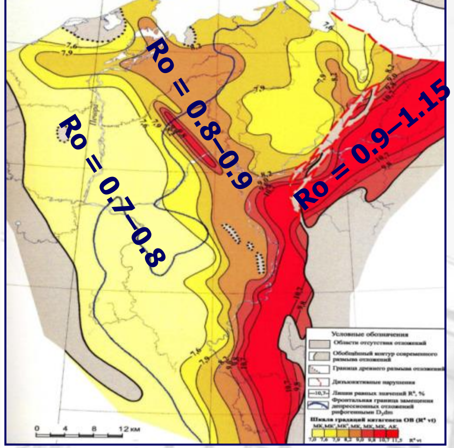
Generation potential of rocks based on Rock Eval analysis. Well 200 Andreevskaya

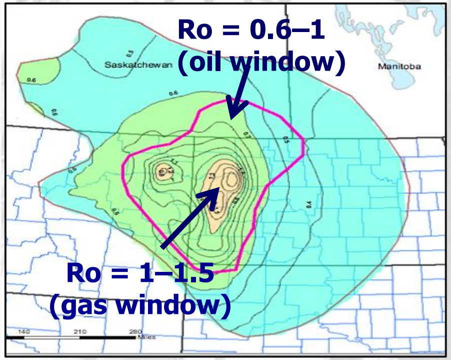


- **The estimated oil generation potential is good and very good;**
- **Geochemically, domanik deposits are promising as potential sources of shale oil and gas.**

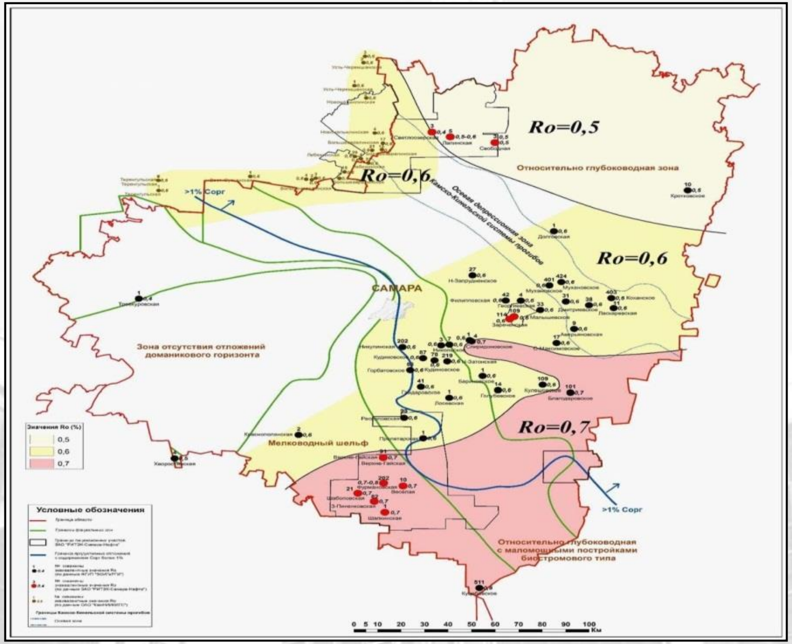
Thermal Maturity Maps of Domanik Shale (based on Vitrinite Reflectance)

Ro map of Komi Republic domaniks

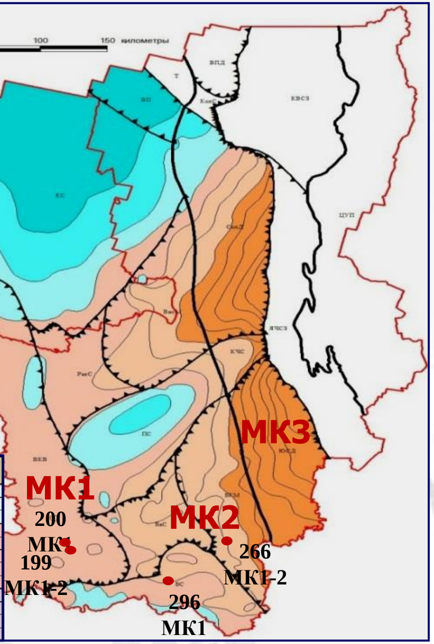




Ro map of the Bakken field



Ro map of Samara Oblast domaniks

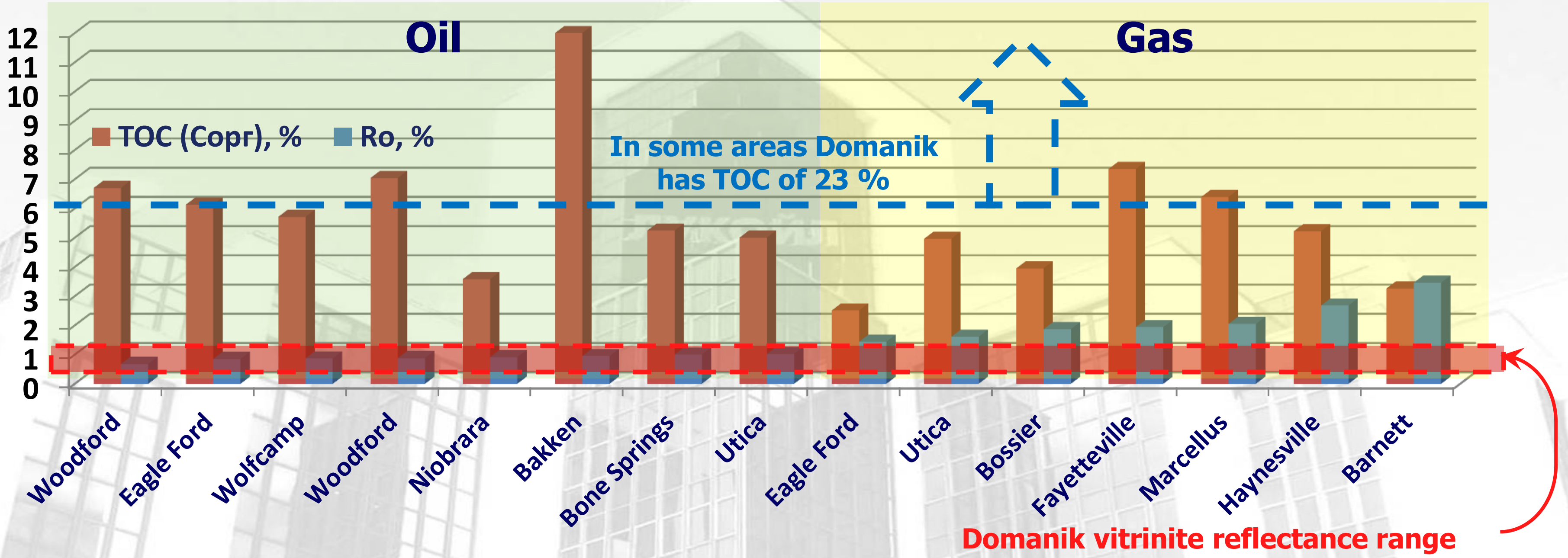


Градация	Ro,%
ПК1	0.25-0.3
ПК2	0.3-0.4
ПК3	0.4-0.53
МК1	0.53-0.65
МК2	0.65-0.85
МК3	0.85-1.2
МК4	1.2-1.55
МК5	1.55-2.05
АК1	2.05-2.5
АК2	2.5-3.5
АК3	3.5-6.0
АК4	6.0-11.0

Ro map of Perm Krai domaniks

Domanik horizon catagenetic zoning maps based on geochemical studies of wells show promising areas (Ro ≥ 0.6) in all the three regions

TOC and R_0 Comparison of Domanik Shale of Perm Krai and US Shale Formations



TOC and Thermal Maturity of Domanik Shale is comparable and as good as commercial shale deposits in the USA

25 ЛЕТ ЛУКОЙЛ

Luminescent – Bituminological Analysis

199 Andreevskaya

Глубина отбора образца, м	Глубина отбора образца увязанная, м	Номер образца	Литология	Люминесцентное свечение хлороформенной капиллярной вытяжки (Длина капиллярной вытяжки, мм: 0–200)	Номер эталона ХБА	Длина капиллярной вытяжки, мм	Тип ХБА
2417,00	2415,30	1			11	40	МС
2420,72	2419,02	2		D3mn	10	61	МС
2422,48	2420,78	3			11	41	МС
2434,15	2432,45	4			13	163	МС и СА
2435,40	2433,70	5			13,5	145	МС и СА
2436,90	2435,20	6			13,5	105	МС и СА
2438,85	2437,15	7		D3dm	13,5	149	МС и СА
2439,95	2438,25	8			14	140	МС и СА
2440,90	2439,20	9			14	146	МС и СА
2442,45	2440,75	10			14	141	МС и СА
2448,70	2447,20	11			9	33	МС
2449,28	2447,78	12		D3sr	8	21	МС
2453,00	2451,50	13			8	26	МС
2453,90	2452,40	14			7	15	МС
2454,28	2452,78	15		D3tm	6	14	МС
2455,60	2454,10	16			6	37	МС

200 Andreevskaya

Глубина отбора образца, м	Глубина отбора образца увязанная, м	Номер образца	Литология	Люминесцентное свечение хлороформенной капиллярной вытяжки (Длина капиллярной вытяжки, мм: 0–200)	Номер эталона ХБА	Длина капиллярной вытяжки, мм	Тип ХБА
2266,89	2265,59	34			13	109	МС и СА
2268,11	2266,81	35			13	125	МС и СА
2269,13	2267,83	36			14	148	МС и СА
2270,01	2268,71	37			14	137	МС и СА
2270,87	2269,57	38		D3dm	14	147	МС и СА
2273,13	2271,83	39			14	140	МС и СА
2273,73	2272,43	40			14	165	МС и СА
2276,05	2274,75	41			12	68	МС и СА
2277,95	2276,65	42			13	125	МС и СА
2279,06	2277,76	43			13,5	145	МС и СА
				41,04 м			
2320,00	2318,80	17			9	112	ЛМ
2320,98	2319,78	18		D3tm	12,5	167	МС
2322,85	2321,65	19			12,5	164	МС
2323,15	2322,15	20			5	17	Л
2323,78	2322,78	21			5	15	Л
2323,95	2322,95	22			5	15	Л
2324,76	2323,76	23			4,5	13	Л
2325,80	2324,80	24			4	10	Л
2326,25	2325,25	25		D3ps	4	7	Л
2327,05	2326,05	26			4	5	Л
2327,56	2326,56	27			4	5	Л
2327,95	2326,95	28			4	6	Л
2328,50	2327,50	29			4	4	Л
2328,85	2327,85	30			5	27	Л и С
2331,65	2330,65	31			5	31	Л и С

296 Pavlovskaya

Исходная привязка образца, м: От	Исходная привязка образца, м: До	Привязка по результатам гамма-сканирования, м: От	Привязка по результатам гамма-сканирования, м: До	Номер образца	Люминесцентное свечение хлороформенной капиллярной вытяжки (Длина капиллярной вытяжки, мм: 0–200)	Номер эталона ХБА	Длина капиллярной вытяжки, мм	Тип ХБА
2075,48	2075,55	2074,48	2074,55	1		11,5	31	СА
2077,37	2077,50	2076,37	2076,50	2		11,5	40	СА
2079,45	2079,53	2078,55	2078,63	3		11,5	45	МС
2081,19	2081,33	2080,29	2080,43	4	D3mn	12	63	СА
2083,62	2083,72	2082,72	2082,82	5		11,5	53	МС
2084,77	2084,84	2083,87	2083,94	6		12	39	СА
2088,02	2088,14	2087,12	2087,24	7		14	149	СА
2089,84	2089,91	2088,94	2089,01	8		14	144	СА
2091,48	2091,56	2090,58	2090,66	9		14	146	СА
2093,25	2093,35	2092,35	2092,45	10	D3dm	14	150	СА
2095,54	2095,62	2094,64	2094,72	11		14	149	СА
2097,11	2097,18	2096,31	2096,38	12		14	142	СА
2099,22	2099,31	2098,42	2098,51	13		14	141	СА
2101,07	2101,13	2100,27	2100,33	14		14	149	СА
2103,62	2103,70	2102,82	2102,90	15		14	140	СА
2105,27	2105,37	2104,57	2104,67	16		14	135	СА

266 Zabrodovskaya

Исходная привязка образца, м: От	Исходная привязка образца, м: До	Привязка по результатам гамма-сканирования, м: От	Привязка по результатам гамма-сканирования, м: До	Номер образца	Люминесцентное свечение хлороформенной капиллярной вытяжки (Длина капиллярной вытяжки, мм: 0–200)	Номер эталона ХБА	Длина капиллярной вытяжки, мм	Тип ХБА
2241,34	2241,42	2242,74	2242,82	1		11,5	28	С, МС
2244,30	2244,39	2245,70	2245,79	2		11	30	МС
2246,00	2246,09	2247,40	2247,49	3		11	27	МС
2250,10	2250,20	2251,50	2251,60	4		11	25	МС
2252,30	2252,38	2253,70	2253,78	5		11	21	МС
2254,28	2254,39	2255,68	2255,79	6		11,5	58	МС
2256,78	2256,85	2258,18	2258,25	7		11	23	МС
2258,70	2258,79	2260,70	2260,79	8		11	22	МС
2260,35	2260,44	2262,35	2262,44	9	D3mn	11	23	МС
2262,73	2262,81	2264,73	2264,81	10		11	24	МС
2264,80	2264,89	2266,80	2266,89	11		11,5	21	С, МС
2266,00	2266,09	2268,00	2268,09	12		11,5	28	МС
2269,82	2269,90	2272,22	2272,30	13		11	24	МС
2271,93	2272,03	2274,33	2274,43	14		11	29	МС
2276,50	2276,59	2279,20	2279,29	15		11	25	МС
2277,50	2277,61	2280,20	2280,31	16		11	34	МС
2282,89	2283,01	2285,59	2285,71	17		12,5	42	МС, СА
2284,15	2284,22	2286,85	2286,92	18		12,5	24	МС, СА
2286,94	2287,01	2289,64	2289,71	19	D3dm	14	138	СА
2288,82	2288,89	2291,52	2291,59	20		14	142	МС, СА
2289,45	2289,53	2292,15	2292,23	21		14	143	СА
2292,48	2292,59	2295,18	2295,29	22		14	154	МС, СА
2294,86	2294,94	2298,06	2298,14	23		14	146	СА
2296,71	2296,79	2299,91	2299,99	24		14	141	СА
2298,70	2298,78	2301,90	2301,98	25		12,5	43	СА

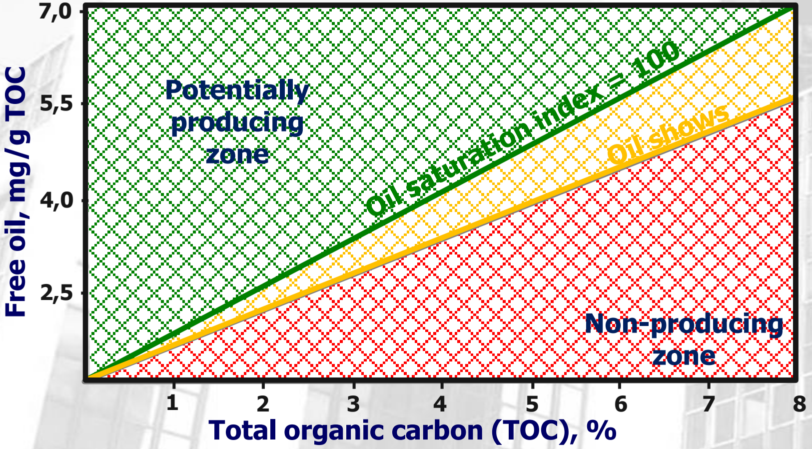
Domanik formation rocks feature high saturation

Jarvie Oil Saturation Index

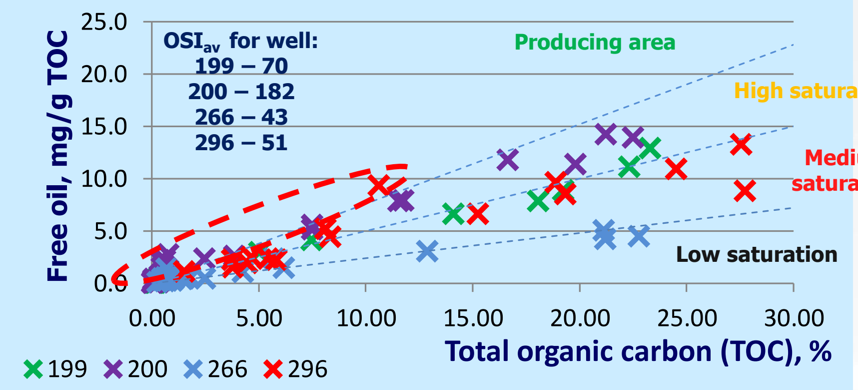
Oil saturation of shale formations should be calculated taking into account oil fraction adsorbed by organic matter

$$OSI = S1 \div TOC \bullet 100$$

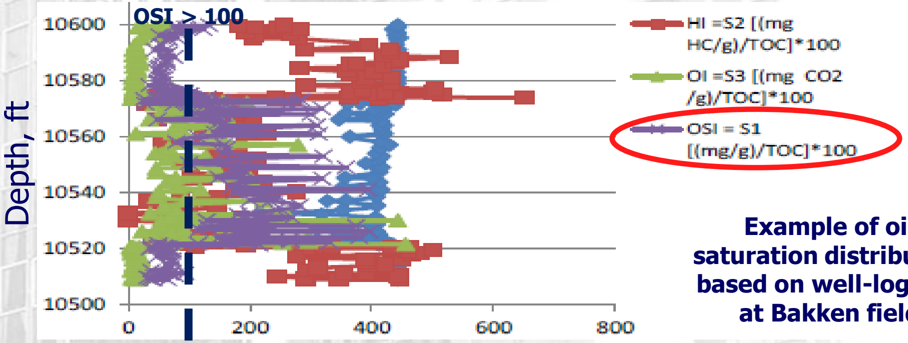
OSI – oil saturation index, mg/g TOC; S1 – mobile oil, mg/g; TOC – total organic carbon, %



Oil saturation distribution of Eagle Ford wells



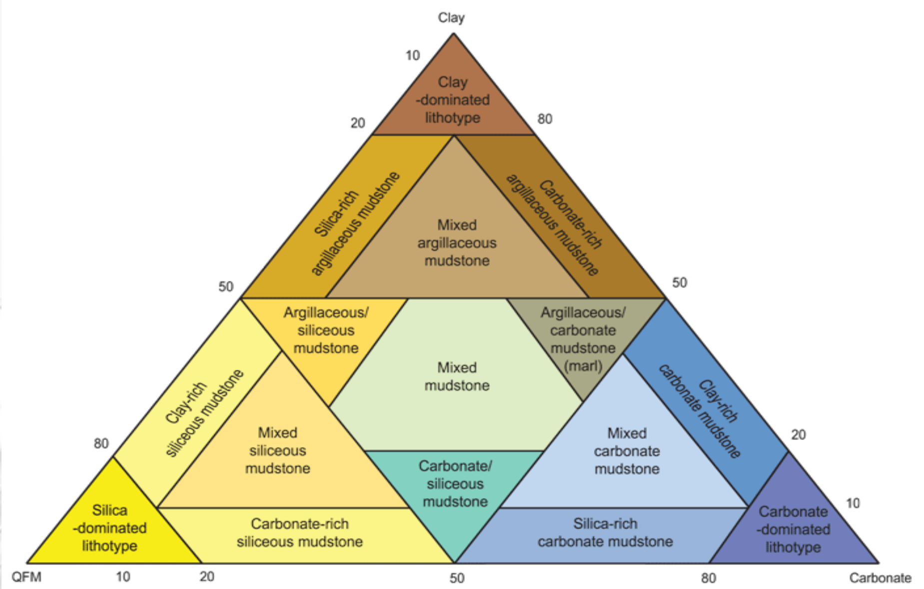
Oil saturation distribution of Frasnian and Givetian core samples of wells 199, 200 of Andreevskoye, 266 Zabrodovskoye, 296 Pavlovskoye fields

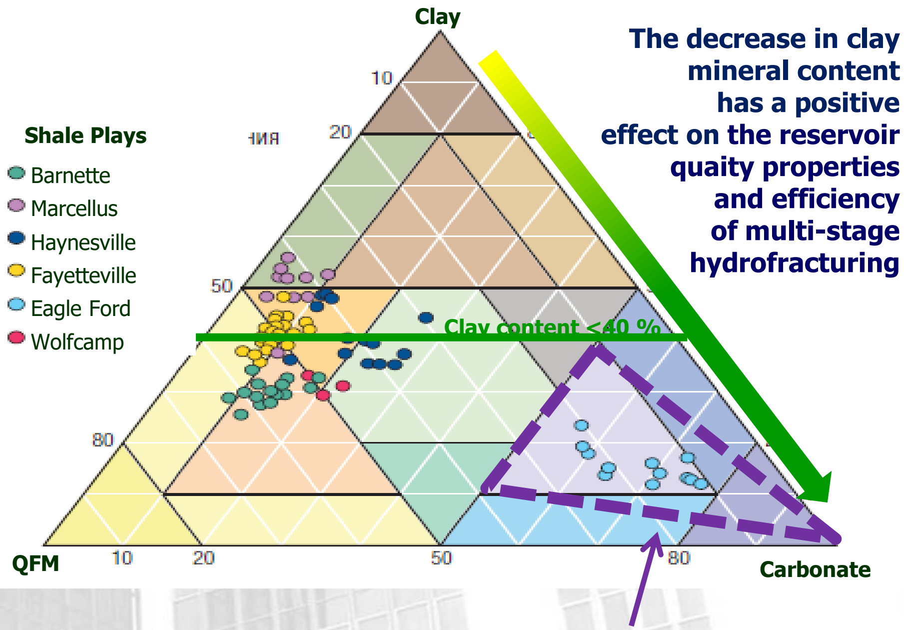


Example of oil saturation distribution based on well-logging at Bakken field

Core analysis of LUKOIL PERM LLC wells shows that unconventional reservoirs has potential for production

Domanic Mineralogy





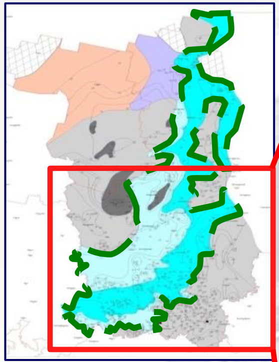
The decrease in clay mineral content has a positive effect on the reservoir quaity properties and efficiency of multi-stage hydrofracturing

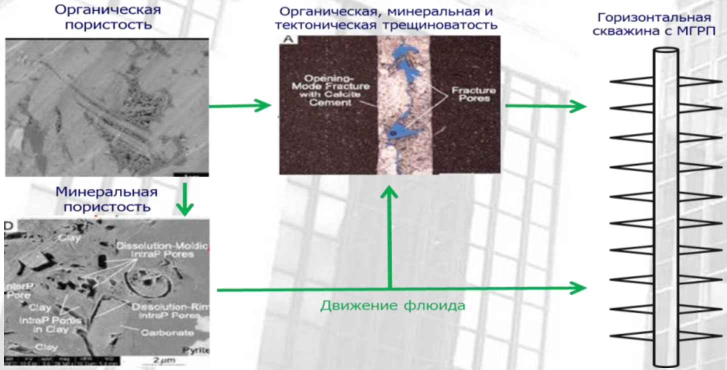
Mineral composition of domaniks within Volga-Ural and Timan-Pechora oil and gas provinces

The prevailing mineral composition of domanik shale is similar to one of the U.S. largest Eagle Ford shale deposits and is promising for good reservoir quality properties and efficient multi-stage hydrofracturing

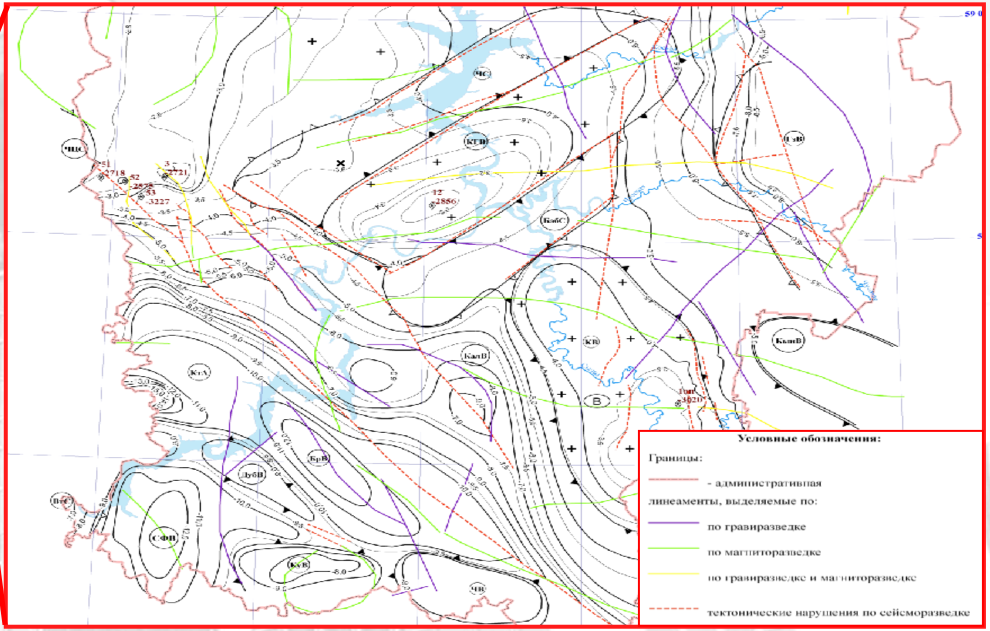
Fracturing

Due to extremely low permeability it is required to maximize the contact area between the matrix and highly permeable filtration channels by detecting natural fracturing areas and creating artificial fracturing areas





Shale reservoir fluid movement



Fragment of Perm Krai basement tectonic map

Many faults result in favorable conditions for domanik development

Comparison of Domanik shale and other well-known shale basins in North America

Domanik Shale vs. Major US and Canadian Unconventional Basins (Kimmeridge Energy, 2014)

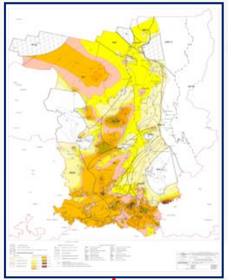
Basin	New Albany (US)	Bakken (US)	Exshaw (US/Canada)	Duvernay (Canada)	Domanik (Russia)	Domanik (Russia)	Eagle Ford	Woodford	Wolfcamp	Kaliningrad
	Illinois Basin	Williston Basin	WCSB	WCSB	Timan-Pechora	Volga-Ural	Maverick Basin	Anadarko Basin	Delaware Basin	Baltic
Age	Upper Devonian	U. Devonian-Miss	Upper Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Upper Cretaceous	Upper Devonian	U. Penn- L. Permian	Lower Silurian
Area of mature source mass (mln. acres)	6	14	65	49	50	47	11.7	9.6	8.6	1.7
Thickness (ft)	100–300	10–75	10–65	40–240	50–650	80–130	50–600	120–280	200–1800+	390–490
Kerogene type	II	II	II	II	II & I	II & I	II	II/III	I/II/III	II
Sedimentation environment	Marine, anoxic	Marine, anoxic	Marine, anoxic	Marine, anoxic	Marine, anoxic	Marine, anoxic				
Corg content (%)	2.5–12.7	15–25+	1–16+	1–20	1–30*	1–20+				
Average content. Corg (%)	6	19	10	6	6	8/7*	4.7	6	5.4	7
Hydrogen index (mg/g TOC)	450	625	500	500	600	500/450*	650	375	450	400
Maturity (Ro %)	0.85	0.80	0.90	1.25	0.80	0.75*	0.74	1.50	0.90	1.00
S1 (mg HC/g rock)	4.7	12.0	4.3	1.6		–/4.22*	4.8	4.8		
HC potential (S1 + S2)	45	162	57	40	35		32	30		
Generation potential of basin (MMbbl. eq)	143,469	415,613	658,023	1,242,670	2,491,571	1,911,639	>800	280	580	240
Specific generation potential (bbl./acre)	25,243	29,592	10,049	25,145	50,150	40,717				
Drilling depth (ft)	3400–4600	8850–11500	5000–9000	>8000	6500–11500+	6550–13000	4000–10000	6500–10000	5500–11000	4600–7500+
Quartz content (%)	31–49 %	20–68 %	7–82 %	3–54 %	35–95 %	10–15 %	2–40 %	41–75 %	20–50 %	
Carbonate content (%)	12–36 %	20–60 % (in Middle Bakken)	20–60 %	18–90 %	0–40 %	70 %*	10–90 %	2–14 %	10–60 %	
Porosity (%)	12 %	2–10 %	4–8 %	6–10 %	13	9–12 %*	4–15 %	3–9 %	2–10 %	5.9–15.9 %
Permeability (mD)		0.005–0.01 mD					400–1000 nD	1–1000 nD	10–30000 nD	
Pressure	Normal	Abnormally high formation pressure		Abnormally high formation pressure			Abnormally high formation pressure	Below normal	Abnormally high formation pressure	

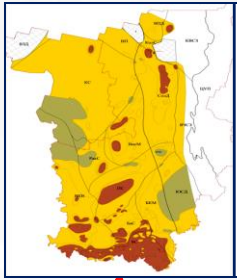
* Consistent with survey results of wells 199, 200 of Andreevsky, 266 Zabrodovsky and 296 Pavlovsky fields

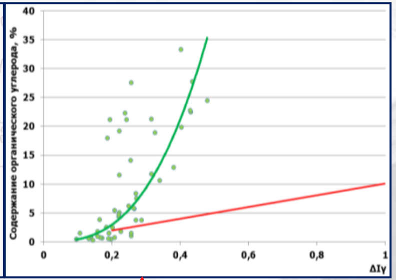
* Consistent with survey results of wells in Timan-Pechora province

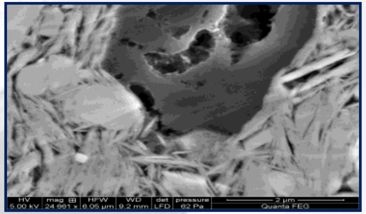
Average parameters of Domanik Shale are similar to the shale deposits in the US and Canada that are currently being successfully developed, confirming the promising potential as an unconventional resource play

HC Potential Estimation of Domanik Formation by "Volumetric-Geochemical" Method





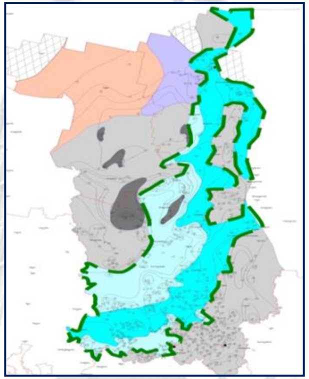


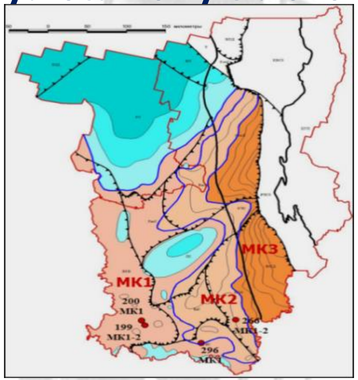


$\rho_{om} = 1.3\ g/cm^3$

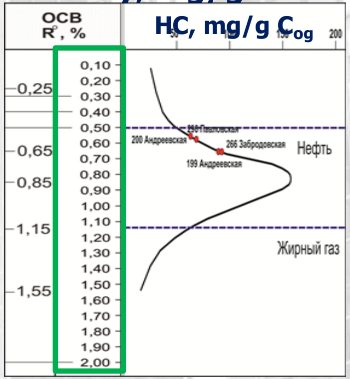
$$S\ h\ C_{орг}\ \rho\ \lambda = HCP$$

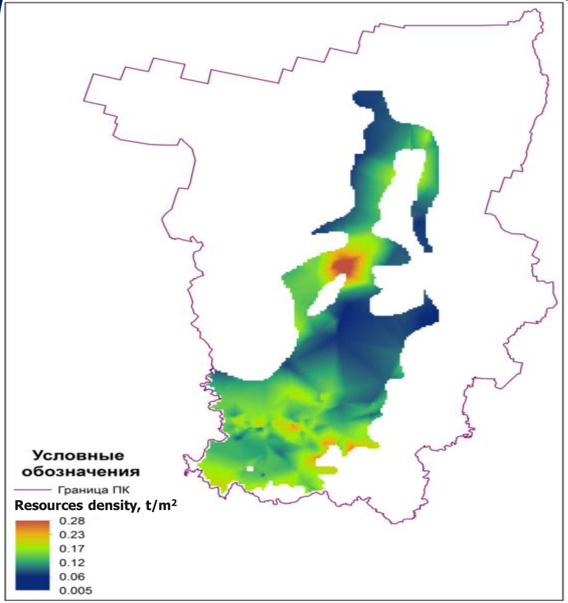
Hydrocarbon yield of organic matter vs. maturity, mg/g





Градация	Ro,%
ПК1	0.25-0.3
ПК2	0.3-0.4
ПК3	0.4-0.53
МК1	0.53-0.65
МК2	0.65-0.85
МК3	0.85-1.2
МК4	1.2-1.55
МК5	1.55-2.05
АК1	2.05-2.5
АК2	2.5-3.5
АК3	3.5-6.0
АК4	6.0-11.0





Density map of Domanik Formation

When evaluating Unconventional Resources, TOC and Thermal Maturity should be taken into account

Probabilistic Assessment of Domanik Formation Resources within the Perm Krai Territory

	P 90	P 50	P 10
Thickness	$D3_{dm}$	$D3_{dm+mn}$	$D3_{dm+mn}$
Area	Extent area of shallow marine shelf (SMS) facies and uncompensated basins (UCB)		
TOC Organic matter content, %	Based on GR dependence, $C_{org} = f(GR)$	According to experts, based on one-time geochemical surveys	According to experts, based on one-time geochemical surveys
HC generation, mg/g organic matter	Based on general dependence	Based on dependence for domanik organic matter	Based on dependence for domanik organic matter
Amount of expelled HC	Based on one-time geochemical surveys (70 %)	Based on one-time geochemical surveys (70 %)	Based on common value (50 %)
Resources, bln t	**0.78**	**3.57**	**5.95**

**Even by pessimistic assessment, Domanik contains huge amounts of hydrocarbons.
It is reasonable to plan and conduct additional pilot studies to calibrate the methods of high grading the areas and evaluation of recoverable reserves per well**

Potential for implementation of the lessons learned during pilot studies of Domanik shale to successfully develop Domanik as an unconventional resource play

Methodology to Develop Successful Well Program

core analysis

Geochemical survey

HC classification, identification of oil-gas accumulation zone and paleographic environment, organic matter distribution over rocks under study, obtaining the main information on organic matter (generation potential, kerogen type, maturation), revision of domanik resource potential considering vertical migration

Lithological character of the section

Opening, dip and strike azimuth, fracture intensity, mineral composition, analysis of facies, study of pores and their interior structure, composition, presence of kerogen, presence of microporosity, study of fluid influence (water, acids, fluids for oil recovery increase) on mineral aggregates

Petrophysical survey

Determination of ultra-low permeability of unconventional reservoirs, pore distribution up to nanosize, study of reservoir quality properties, residual water and oil by nuclear magnetic resonance

Geomechanical survey

Determination of rock stress-strain properties for hydrofracturing design and horizontal well drilling. Determination of Young's modulus, Poisson ratio, pore compressibility, tensile and compression strength under formation conditions

TOC > 2 %

Organic matter maturity, presence of mobile HC

Well-developed fracturing

Favorable geomechanical conditions

well logging

Induced spectral gamma-ray logging (LithoScaner/ Wide range induced spectral gamma-ray logging)

Saturn 3D radial probe

Nuclear magnetic logging (MR Scanner/Nuclear magnetic logging)

Spectral gamma-ray logging (NHGS/spectral gamma-ray logging)

Gamma-gamma lithodensity logging

Cross-dipole sonic logging (SonicScanner/dipole full waveform sonic logging)

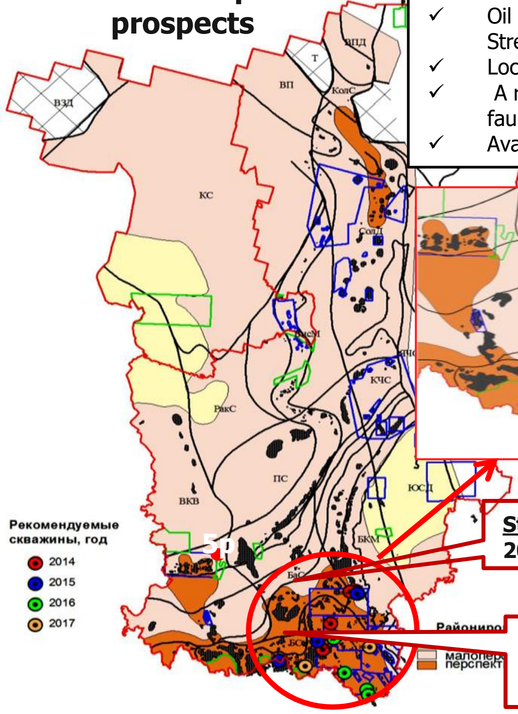
Electrical microimager (FMI/electric microscanner)

For efficient localization of highly productive zones and successful well locations, these parameters should be determined based on seismic exploration that in turn should be matched with regional surveys, core analysis and well-log data.

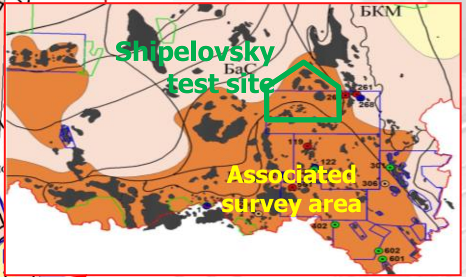
Future steps: program of additional studies of Domanik Shale at PJSC LUKOIL's license areas

Domanik deposit study program

Domanik deposit prospects



Justification for test site selection:
- ✓ Oil inflows from the Mendymsky horizon at well 72 of the Stretenskoye field.
- ✓ Location in a promising area based on R&D.
- ✓ A regional deep fault based on seismic data (the Kuliginsky fault).
- ✓ Availability of up-to-date 3D seismic survey data.



Stretenskoye field
2017: well 315 – well deepening

Batyrbayskoye field
2017: well 116 – well deepening

Stretenskoye field, **2017**

Proposals for extending the core analysis program in production drilling

Core analysis program for exploratory wells (suggestions)

Completed in 2015:
- ➢266 Zabrodovskaya
- ➢261 Zabrodovskaya
- ➢296 Pavlovskaya

2016:
- ➢ 402 N-Orlovskaya
- ➢ 1 Chukavinskaya
- ➢ 301 Pospelovskaya

2017:
- ➢ 290 Etyshskaya
- ➢ 1 Solodovskaya

2015–2017

Laboratory core analysis:
✓Geochemical core analysis of the domanik horizon (*PermNIPIneft, VolgogradNIPImorneft*);
✓Physical-mechanic core analysis of domanik deposits (*PermNIPIneft*);

2016

Compilation of data on lithological composition, facies conditions, geochemical survey, textural and structural features of domanik horizon deposits at licensed areas of LUKOIL PERM LLC (as a part of the "Geological Survey Data Analysis..." Contract in force)

2017

Development of appropriate well-logging set and resulting data interpretation method for clay-bituminous deposits of the domanik horizon. Rationale for 3D seismic survey procedures and interpretation methods (R&D 2016–2017);

2016–2017

Development of methods for estimating resources in unconventional reservoirs and **testing** on domanik deposits

2017–2018

Selection and adaptation of well completion techniques in domanik deposits of LUKOIL PERM LLC

2018–2019

Conducting special 3D seismic survey at Bikbayskaya and Uinskaya areas

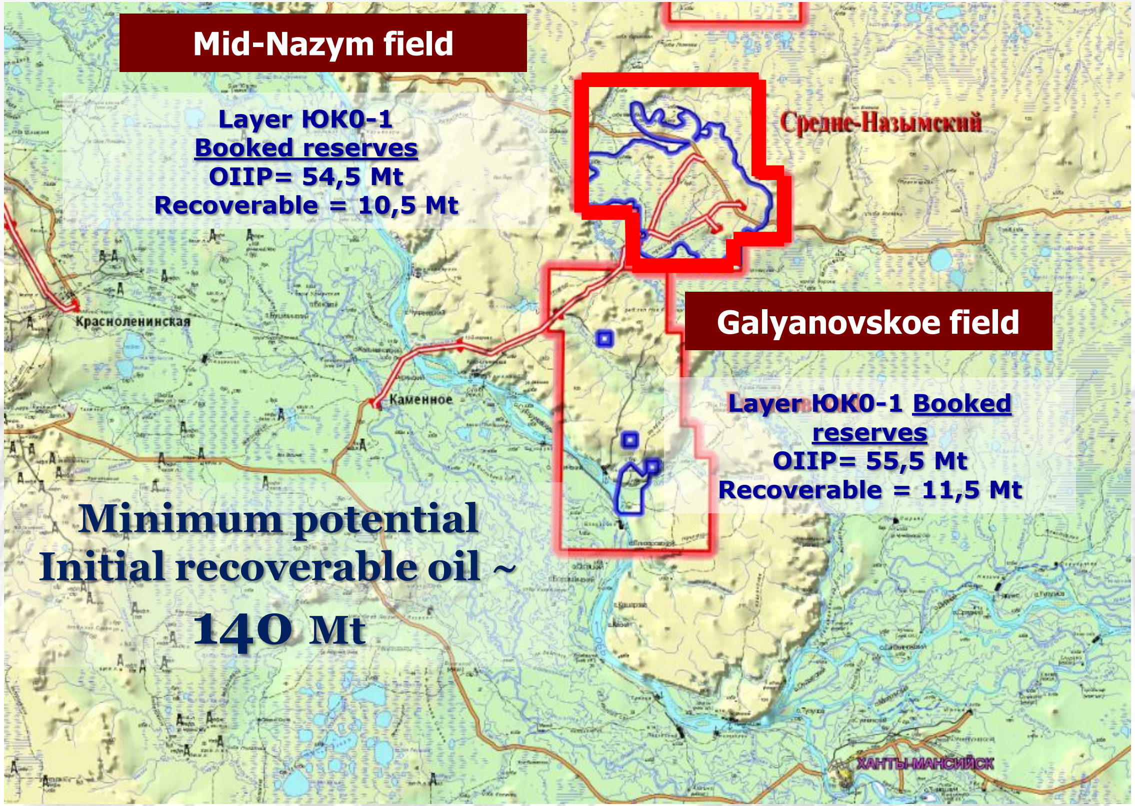
The domanik-type deposit study program has been drawn with required surveys indicated. Candidate wells have been selected in the most promising zones.

Conclusions (Domanik shale)

- Domanik deposits are understudied as a source of Unconventional Resources
- Domanik deposits are prospective as a target for shale oil exploration
- Comprehensive program of additional studies and development of Unconventional Resources in LUKOIL's license areas has been established
- It is advisable to allocate experimental sites for testing of unconventional technologies to develop the Domanik formation in a cost-efficient manner

Main results of Bazhenov Shale Studies by PJSC LUKOIL

Mid-Nazym field in South Kanty-Mansiysk

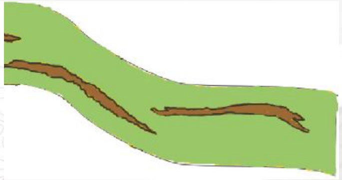


Start year	**1980**
Operator	**AO RITEK**
Share	**100%**
Current stage of development	**Pilot projects**
Information about extraction tax raise	Bazhenov deposits, Tyumen deposits, September 2013

25 ЛЕТ ЛУКОЙЛ

Scenarios for selection of effective oil-saturated thickness in the sediments of the Bazhenov formation

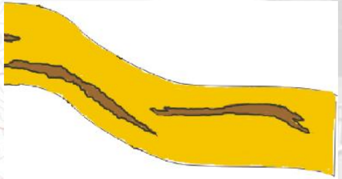
Field:



Effective thickness includes the carbonate-silica layer thickness with fractures

Heff = H carb-silic; Кп.вт = *f* (Кп общ, Кп.блок), Кн = 0,9 -0,95

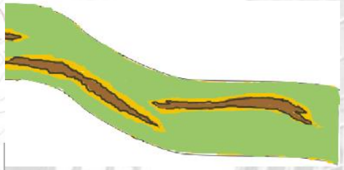
Em-Egovskaya



Effective thickness includes thickness of carbonate layers + total matrix thickness:

Heff = Htot= Heff мат + Hcarb-silic; Кп.вт = *f* (Кп общ, Кп.блок), Кп матр = Кп.тр = 0,1-0,5%, Кн = 0,9 -0,95

Stone and East-Stone

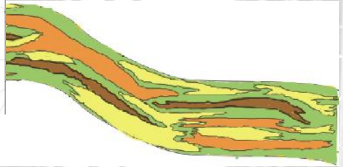


Effective thickness includes thickness of fractured carbonate layers + matrix bordering the layer:

Heff = Hcarb-silic + n × Нмат;

Кп, Кн – also

Mid-Nanzym (RITEK)

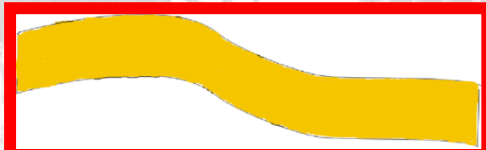


Effective thickness includes thickness of the selected porous-fractured, cavernous fractured and fractured reservoirs (based on wireline)

Hef = Hfract + H cavern.fracture +H pore.fracture;

Кп,ср=(Кп,карб-крем*Нкарб-крем+Кп,тр*Нтр) / Нобщ

Em-Egovskaya, Stone, Lempinsky



Total effective thickness included

1/3 of the total thickness from Bazhenov, Кп ≈ 8%, Кн = 0,9

.

Palyanovksoye (northern part), Lempinsky

Characteristics of the Bazhenov formation

HC resources in the Bazhenov formation

Residue of organic matter – kerogen
(average content 23.3% of rock vol.)

Light oil
product generation of organic matter

Oil+kerogen containing rocks

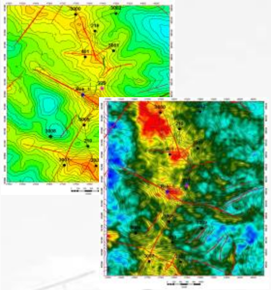
Micro-fractured reservoir (matrix)

Doesn't work without stimulation

Macro-fractured reservoir

Geology guides the technology

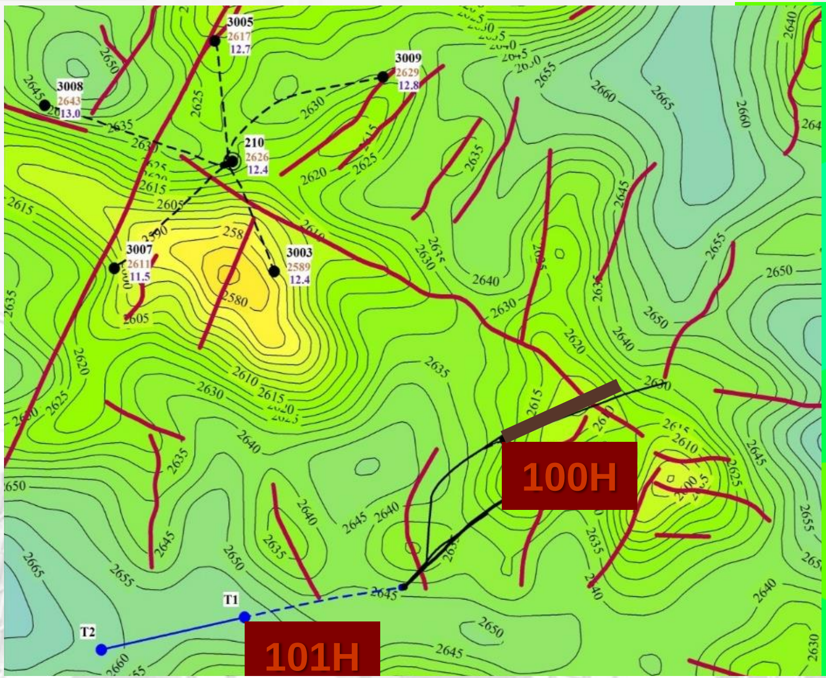
Almost no permeability deters from developing the Bazhenov formation through conventional methods

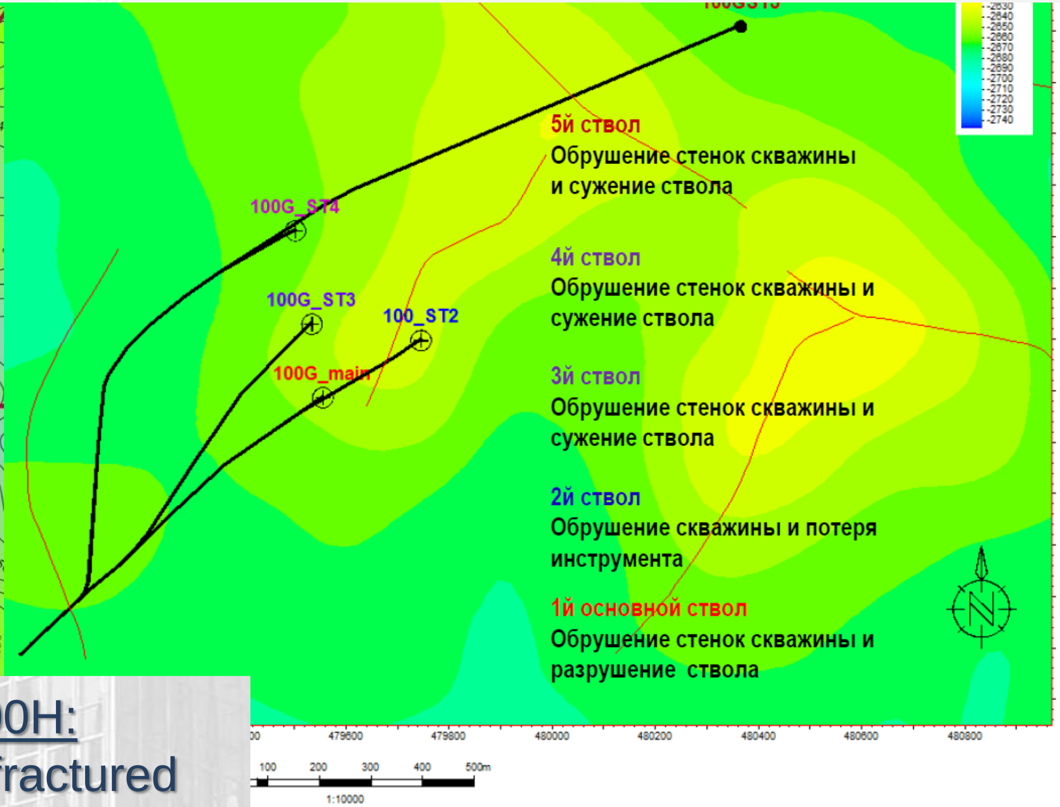


Main steps:

- ✓ **Analysis and mapping** of high-potential areas **(fracture zones)**;
- ✓ **Drilling of horizontal wells** with long laterals (1000-1500m and more);
- ✓ **Multistage hydraulic-fracturing** to form multiple fractures and/or system of natural fractures;
- ✓ **Development and application** of techniques to prevent the rapid decline in oil and gas rates (60-80% in the first 12 years). Implementation of thermogas impact.

Appraisal drilling of horizontal wells with multi-stage fracturing of the Bazhenov formation





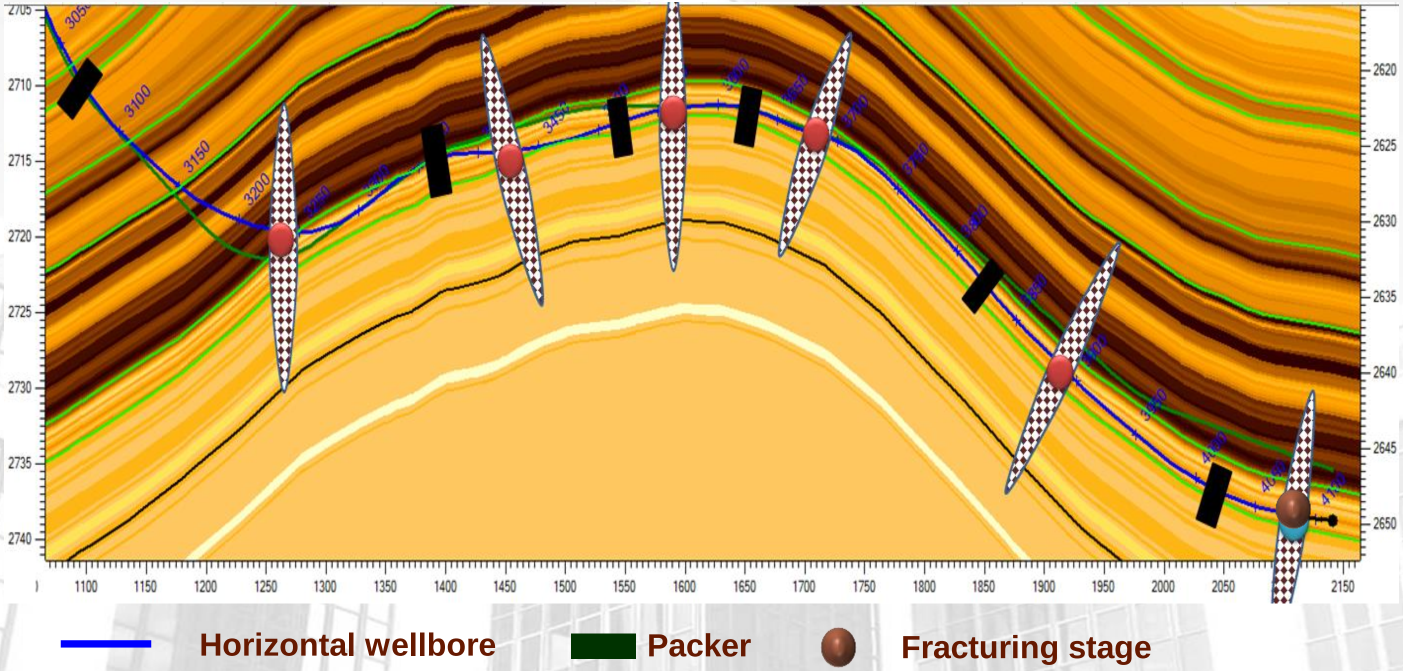
Well101H:

•Goal – confirm productivity potential

Well100H:

• drilling in fractured zone;

Results of drilling and completion of Well 100H

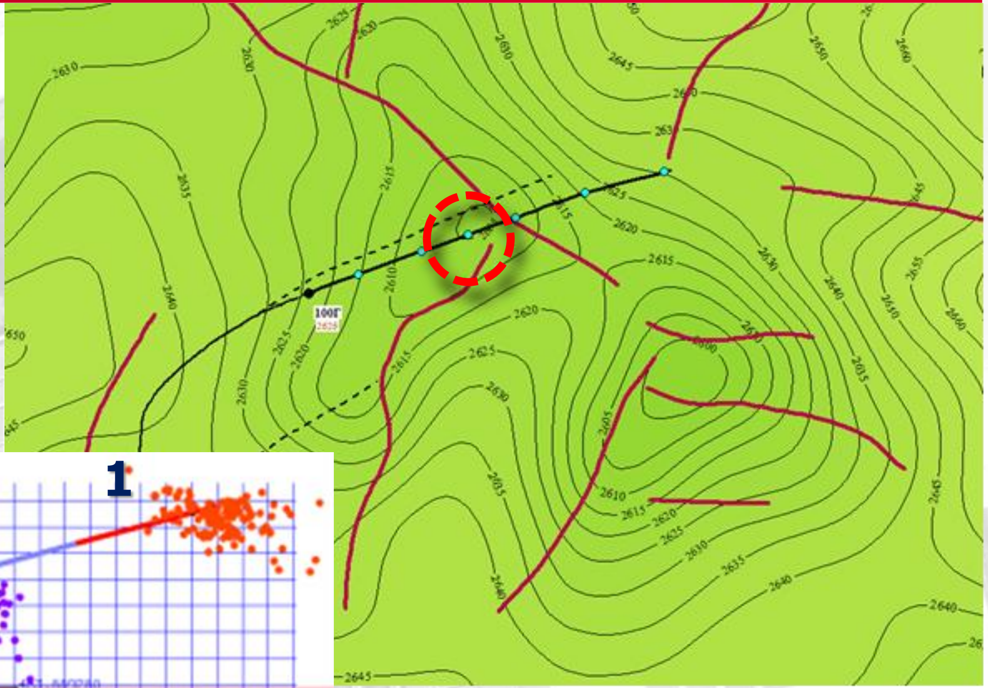


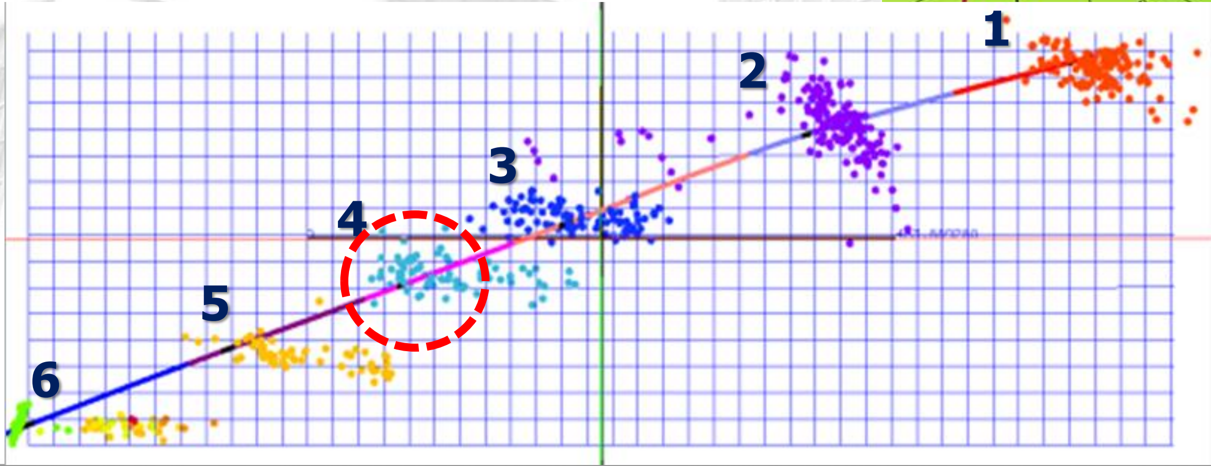
- Horizontal length – 1000m
- Number of stages - 6;
- Proppant volume – 197t (fracturing fluid vol. – 1500m^3)

•Commissioned on 30/12/2013 with a initial daily rate of 80t/day

Fracture propagation during multi-stage fracturing and flow profile in the wellbore

45% of the inflow into the wellbore comes from the 4th frac stage (32m^3/day)





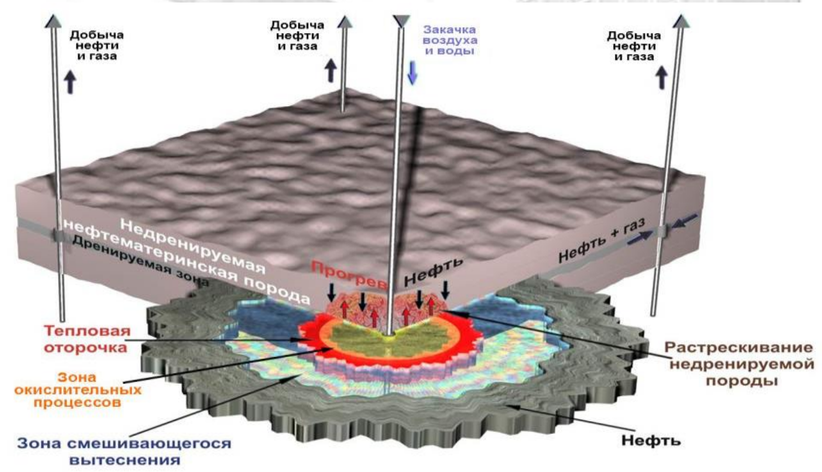
Thermogas Impact (TGI) on the Bazhenov formation deposits

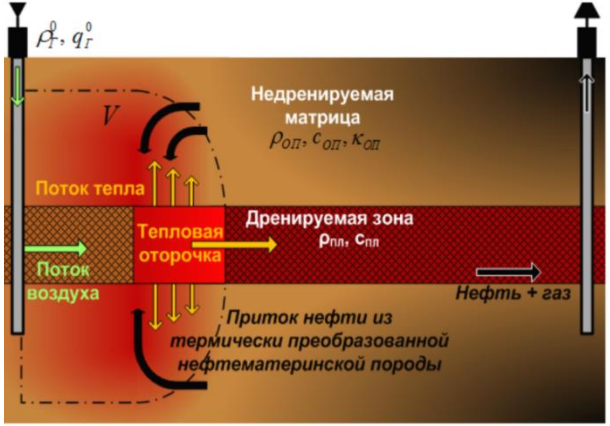
When implementing TGI oil production consists of 3 components:

1) **Oil production from the drained area;**
2) **Oil production by pyrolysis of kerogen in the drained areas;**
3) **Oil production by thermodynamic impact on non –drained area (matrix)**

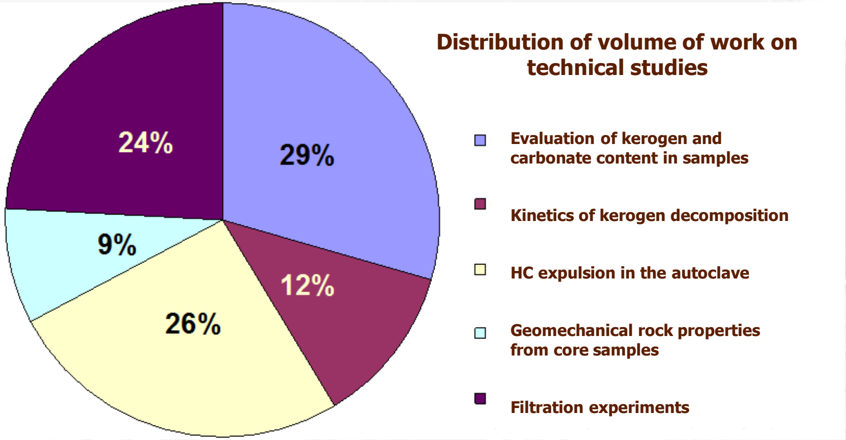
Production wells

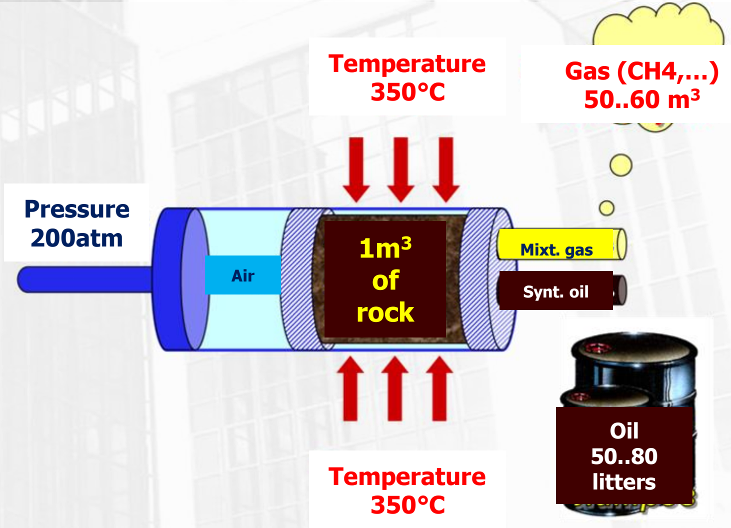
Injection wells





Results of Bazhenov formation core material studies



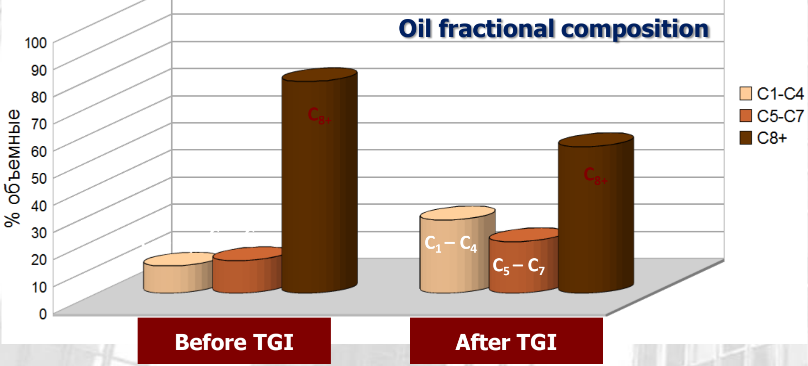


Results of air injection experiments

Fractional composition and oil physical properties analysis

- ✓ Oil density decrease.
- ✓ Fractional composition altered toward lighter fractions.

Oil physical properties (well 3000)	before TGI	after TGI
Oil density (at T = 20 ºC)	837 kg/m³	800 kg/m³

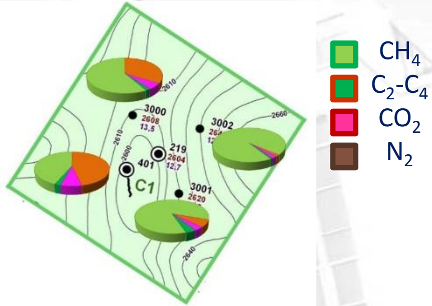


Oil density decreased from 837 to 800 kg/m³, oil dynamic viscosity from 6,26 to 1,9 mPa*s.
All reactive wells experienced increase formation pressure from 20 to 100 atm.

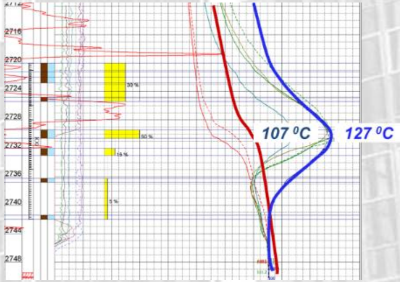
Composition and evolution of GOR analysis

- ✓ Doubled HC gases
- ✓ Increased fraction of CO2 and N2 in produced gas.
- ✓ No oxygen in produced gas.

Gas composition in production wells



Temperature profile in well 219



Temperature measurements made during the implementation of the second cycle of the experiment showed that temperatures rose to 127°C, i.e. increased by 20°C relative to $T_{initial}$

Results of thermogas impact (TGI) technology

FIRST PHASE

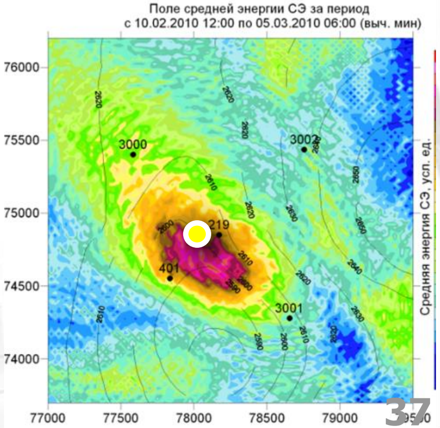
Well №219. Mid-Nazym field:

- Injected more than 7 million m³ of air
- Estimated additional oil production – 23,000 tons
- No O2 in produced gas, indicative of oxidation processes
- Increased fraction of Co2 and N2 in the produced gas
- Oil density decreased by 5%
- Increased fraction of lighter components in crude production
- Increased volume of produced HC gas
- Special well drilling
- Primary core analysis confirmed the passage of the thermal front

PERSPECTIVES

- Displacement chamber oxidation;
- Core research to assess the spread of oxidation reactions

Results of seismic-location of emission centers



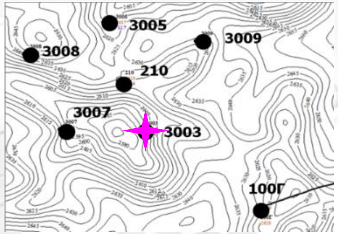
Development perspectives of thermal gas impact technology

SECOND PHASE
Well 210.
Mid-Nazym field, South Khanty-Mansiysk.

- Commissioning – February 2015
- Injected more than 1.2 million m^3 of air
- Horizontal well 100H with multistage fracturing

Challenges

- Project implemented on old sites
- Unsatisfactory condition of wells



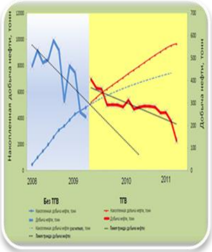
THIRD PHASE – IMPROVING EFFICIENCY

- Selection of optimal well location and well design
- Mode optimization of the stimulation (Air injection and water-air ratio)
- Cyclical impact on the reservoir
- Use of air enriched with oxygen

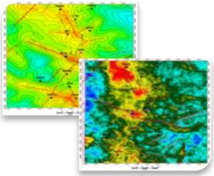
Thermal gas impact technology road map

2009	2015	2017	2019
Phase I	**Phase II**	**Phase III**	**Commercial implementation**
TGI Test	Test TGI on site with horizontal drilling and multi-stage fracturing	New location with special wells for TGI	Commercial implementation of TGI
TGI Regulation and process management	Cyclic process	Experimental area for TGI with horizontal drilling and multi-stage fracturing	Injection of oxygen enriched air
Equipment tests for TGI	–	–	–

Conclusions (Bazhenov Shale)



Experimental work is continued at the TGI sites. Evidence of oxygenation processes are obtained during the experiments



Implementation of LUKOIL's program to optimize the development technology will effectively unlock resources and increase production capacity

THANK YOU FOR YOUR ATTENTION