DEPROIL

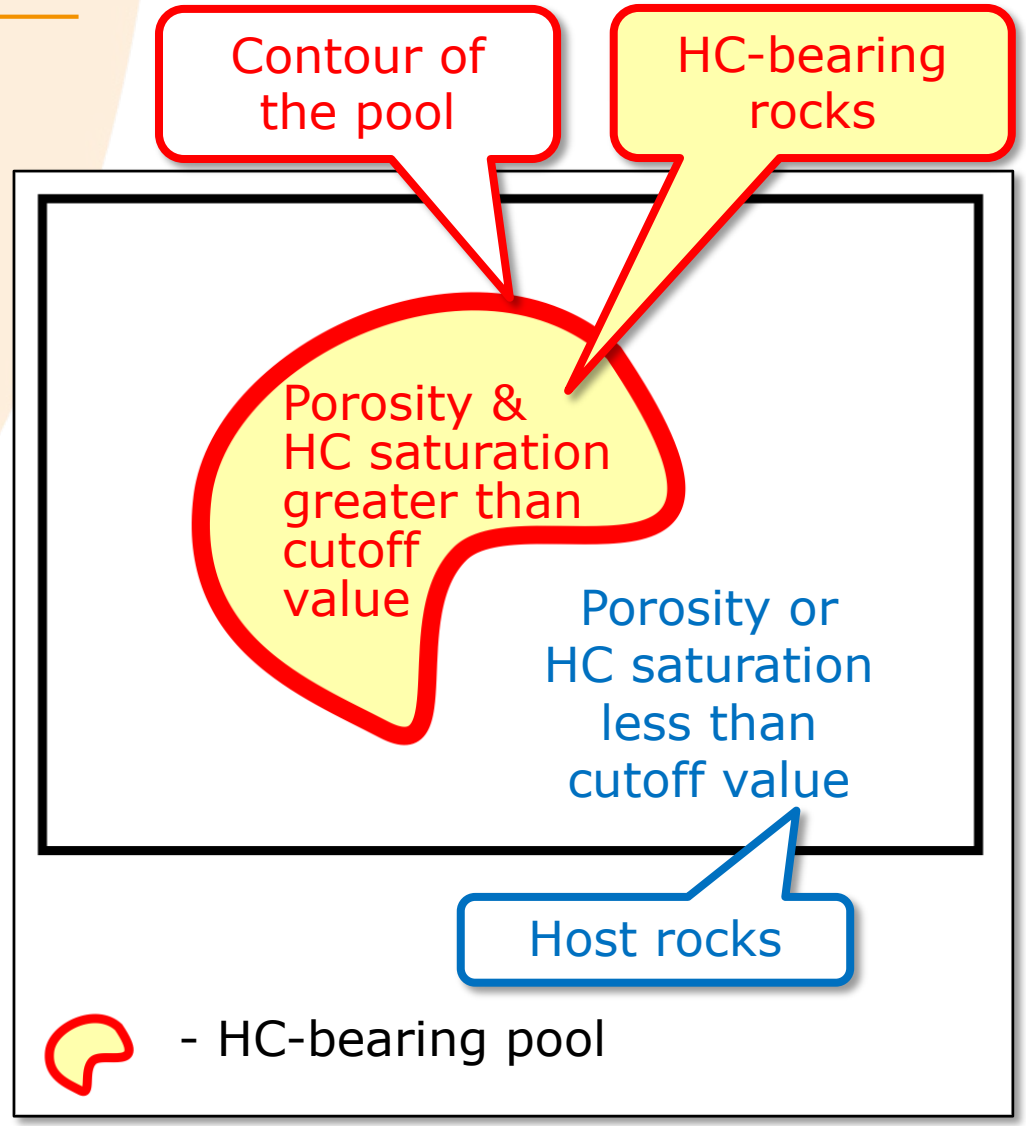
DETAILED OIL & GAS PROSPECTING

THE TECHNOLOGY OF MAPPING DYNAMIC GAS-BEARING POOLS WITNIN UNDERGROUND GAS STORAGES BY THE RESULTS OF GRAVITY MONITORING: PRACTICAL EXPERIENCE AND PERSPECTIVES

Mapping gas-bearing pools in Dashava UGS
Misfit of gas pressure prediction - 4%
Misfit of working gas volume prediction – 1%

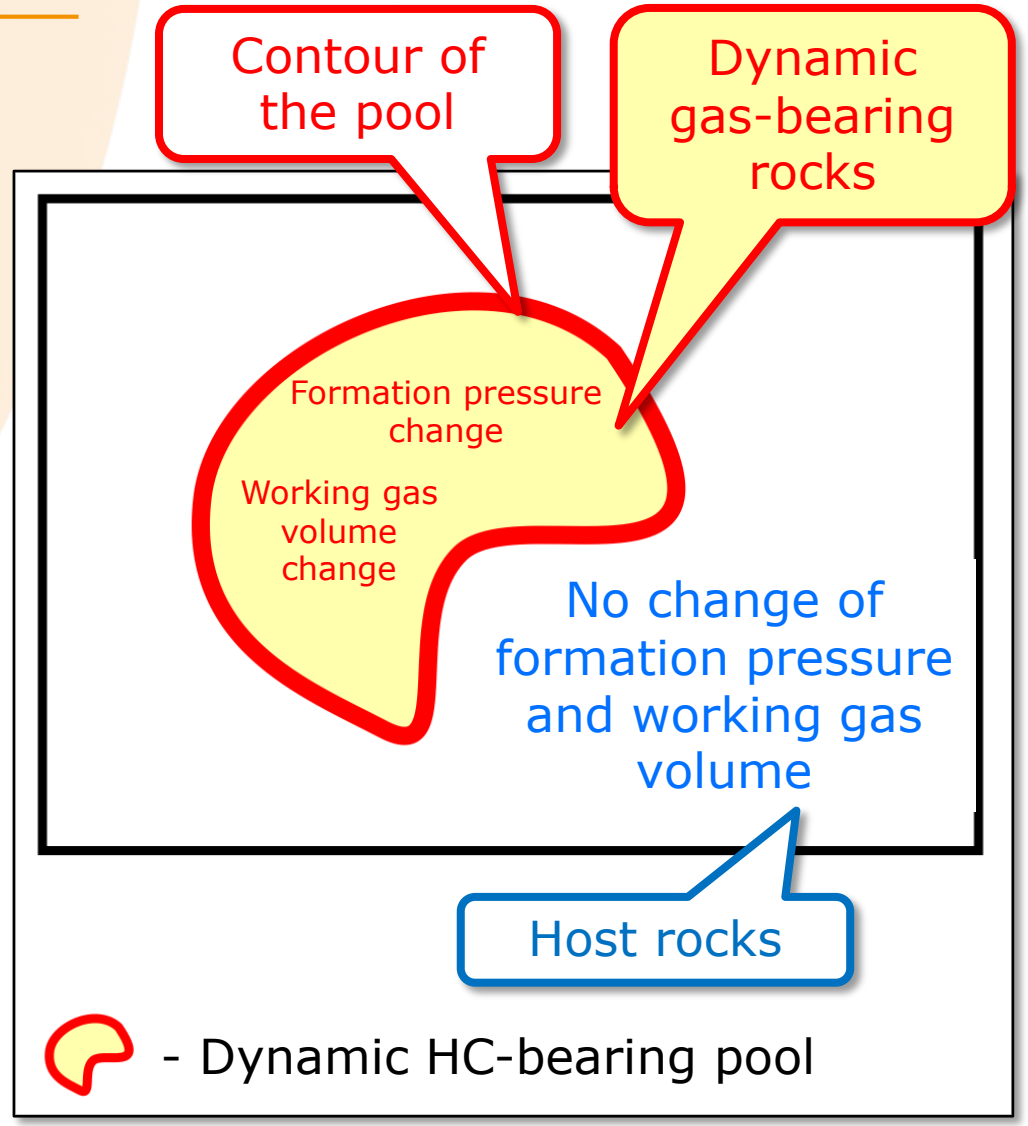
HYDROCARBON-BEARING ROCKS AND HYDROCARBON-BEARING POOLS

- HYDROCARBON-BEARING ROCKS – an isolated subsurface body of rock having porosity and hydrocarbon (HC) saturations rate greater than the cutoff value
- CONTOUR OF THE HC-BEARING POOL is mapped as a closed contour, which includes all hydrocarbon-bearing rocks
- HYDROCARBON-BEARING POOL – closed set in 3D space, which includes hydrocarbon-bearing rocks



DYNAMIC HYDROCARBON-BEARING ROCKS AND DYNAMIC HYDROCARBON-BEARING POOLS

- DYNAMIC GAS-BEARING ROCKS – gas-bearing mass of rocks where pressure and working gas volume change while gas injection and withdrawal
- CONTOUR OF DYNAMIC GAS-BEARING POOL is mapped as a closed contour, which includes dynamic gas-bearing rocks
- DYNAMIC GAS-BEARING POOL OR DYNAMIC POOL – closed set in 3D space, which includes dynamic gas-bearing rocks



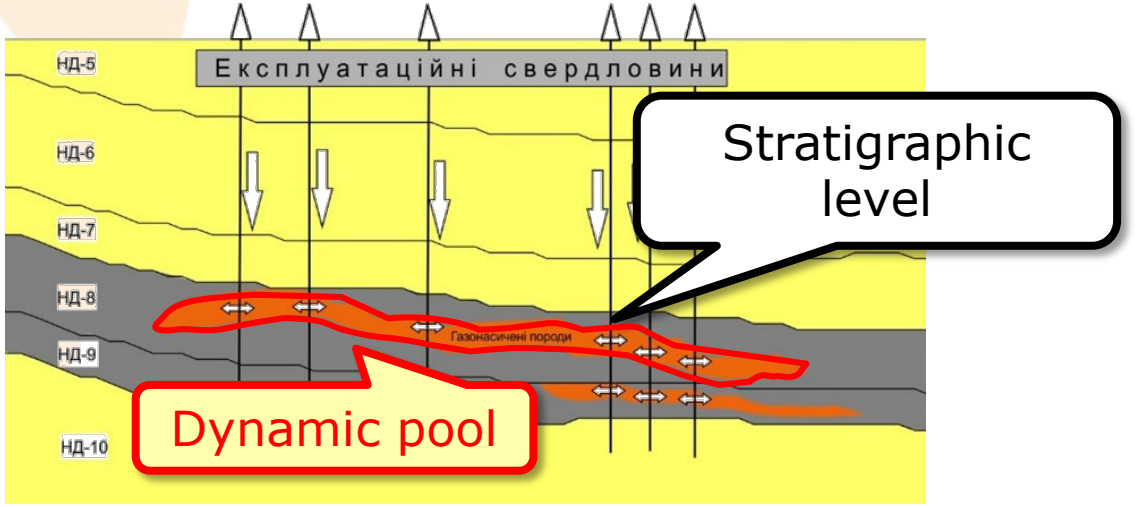
DEPROIL
DETAILED OIL & GAS PROSPECTING

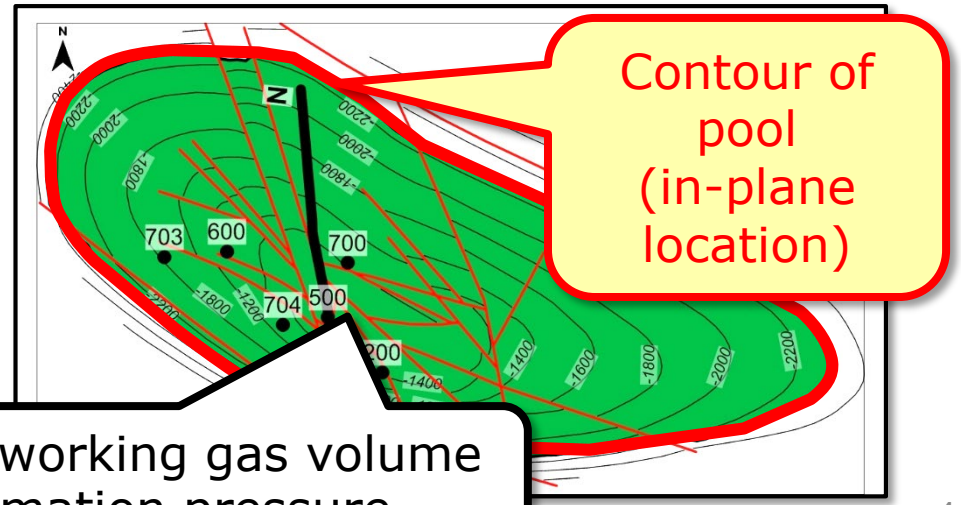
PROPERTIES OF DYNAMIC GAS-BEARING POOL

MAIN PROPERTIES OF DYNAMIC GAS-BEARING POOL:

- STRATIGRAPHIC LEVEL (DEPTH)
- CONTOUR (IN-PLANE LOCATION)
- GAS-SATURATED PORE VOLUME
- TOTAL VOLUME OF WORKING GAS
- FORMATION PRESSURE CHANGE

THE MAIN TASK - TO ESTIMATE THE PROPERTIES OF DYNAMIC POOL WITH MAXIMUM PROBABILITY OF SUCCESS?

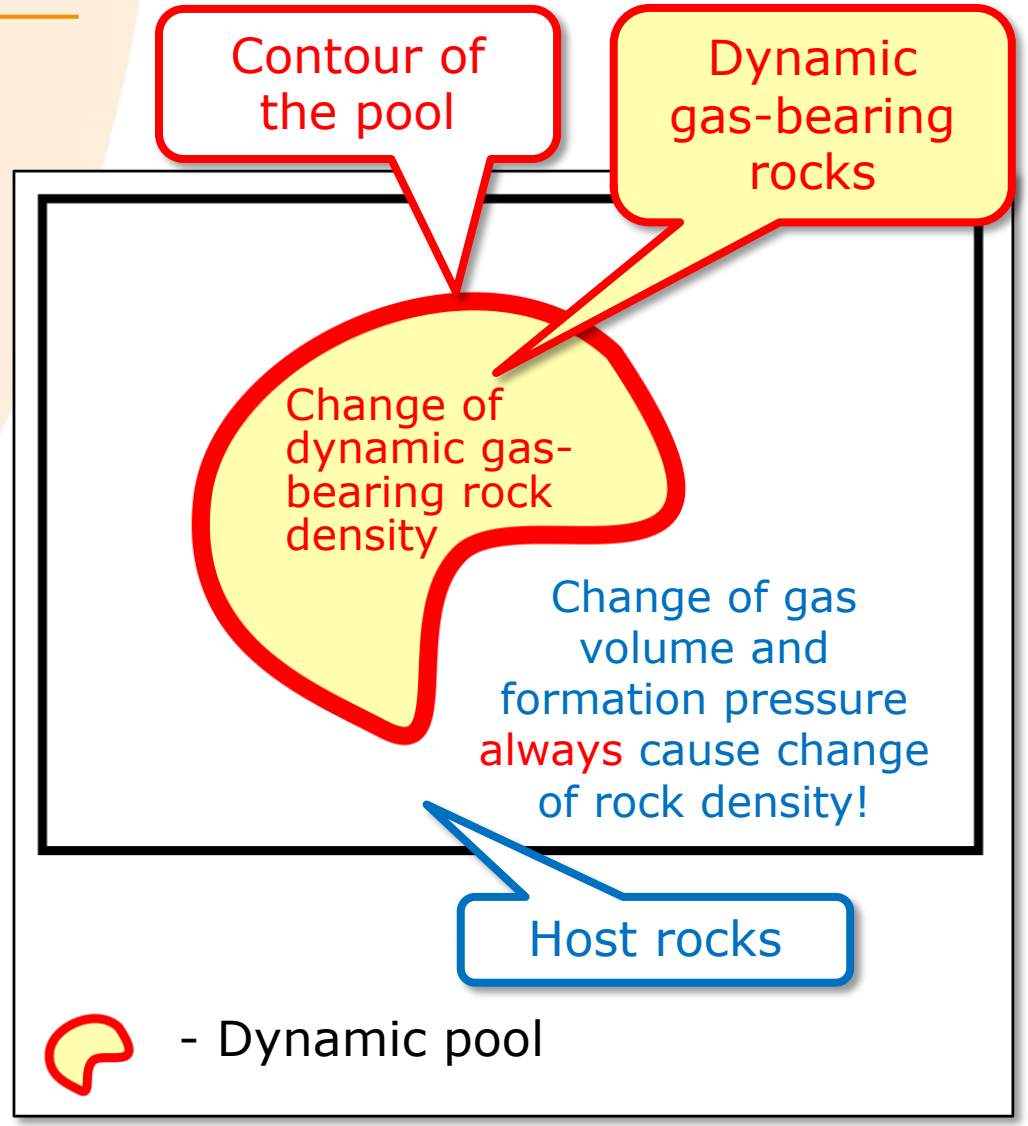




DENSITY OF DYNAMIC GAS-BEARING ROCK IN TERMS OF DYNAMIC POOLS MAPPING

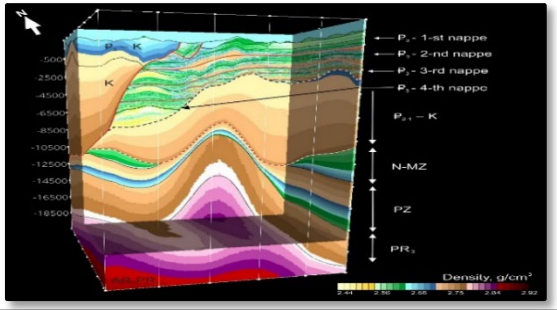
DEPROIL
DETAILED OIL & GAS PROSPECTING

- ROCK DENSITY is the most sensitive physical property of gas-bearing pool, which depends on porosity, gas saturation and formation gas density
- FOMATION GAS DENSITY depends on chemical composition of gas, formation pressure and temperature
- CHANGE OF FORMATION PRESSURE AND WORKING GAS VOLUME in dynamic gas-bearing rock ALWAYS causes change of gas density and consequently change of rock density
- CONTOUR OF DYNAMIC GAS-BEARING POOL can be mapped as a contour of dynamic gas-bearing rock density change
- TIME-LAPSE HIGH-PRECISION GRAVIMETRIC OBSERVATION is the only remote geophysical method that allows to measure rock density change



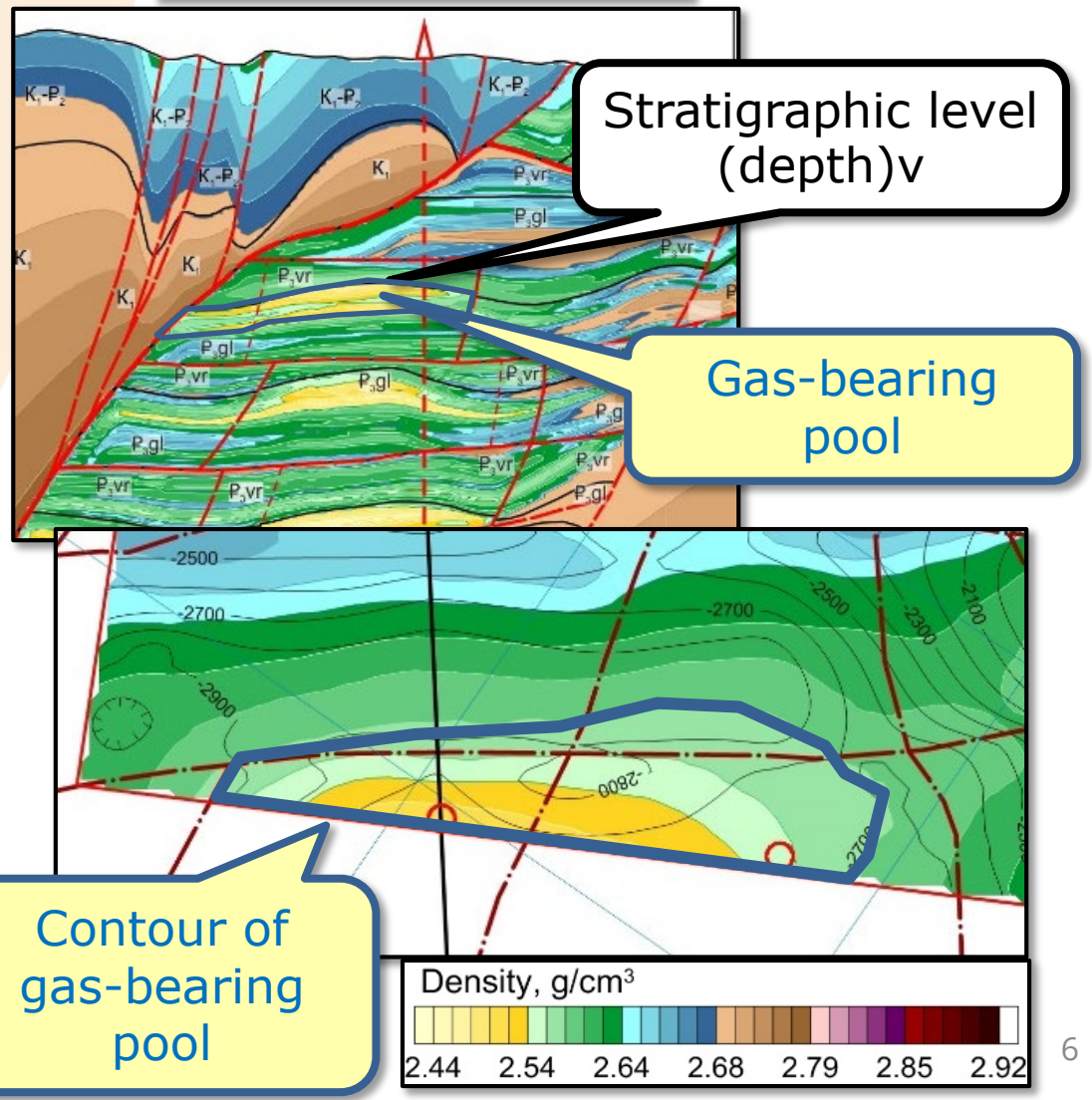
REVOLUTIONARY SOLUTIONS FOR MAPPING DYNAMIC GAS-BEARING POOLS WITHIN UNDERGROUND GAS STORAGES

DEPROIL
DETAILED OIL & GAS PROSPECTING



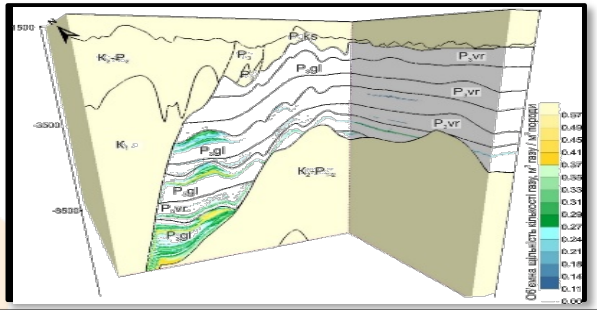
DEPROIL LTD DEVELOPED:

- REVOLUTIONARY TECHNOLOGY for mapping commercial hydrocarbon-bearing pools of different morphology and origin
- REVOLUTIONARY MATHEMATICAL THEORY for the construction of geologically consistent subsurface models of density based on 3D gravity data inversion with well and seismic acquisitions
- REVOLUTIONARY in-house software GCIS (Geophysical Complex Interpretation System) for support of the TECHNOLOGY



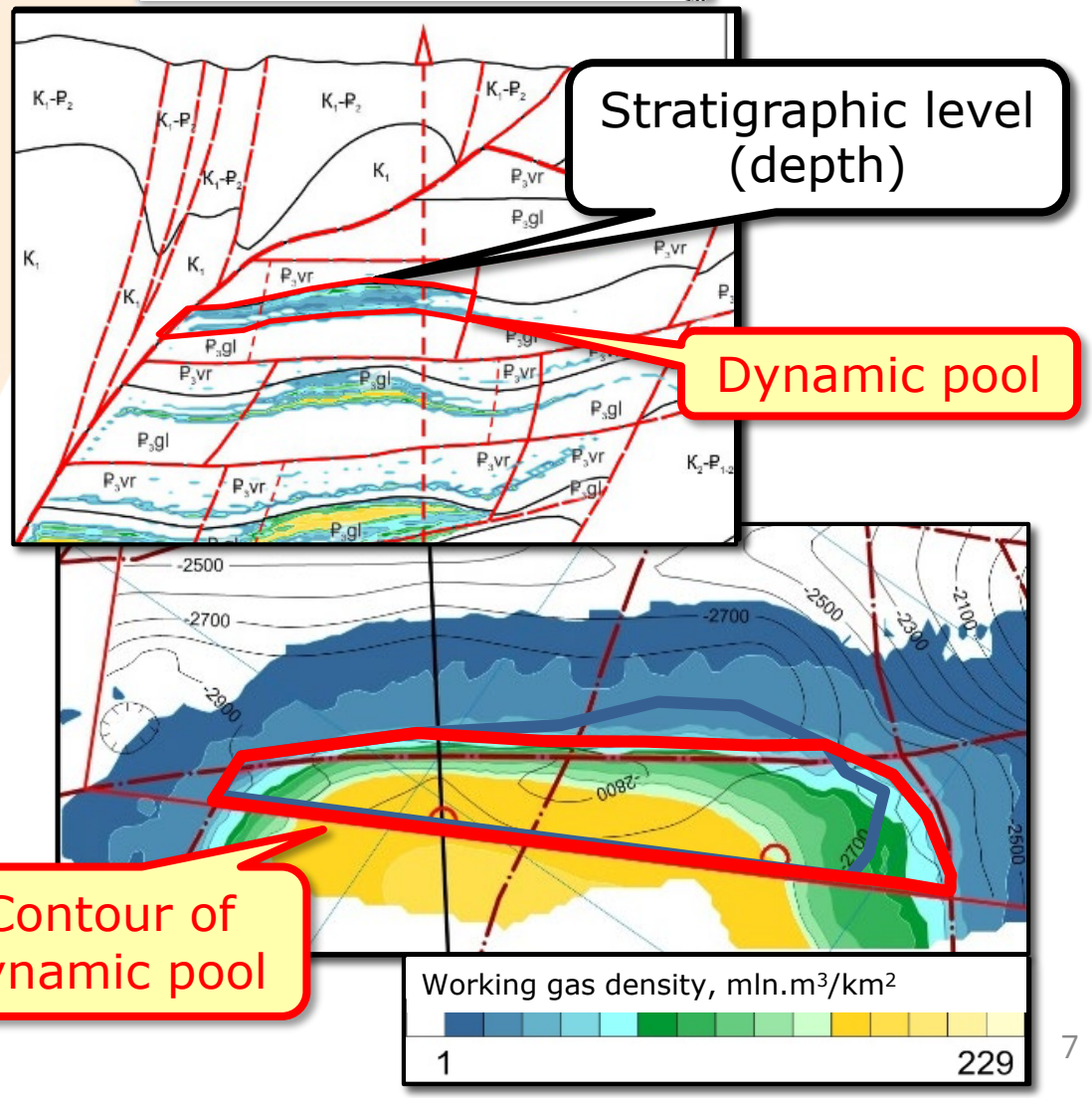
REVOLUTIONARY SOLUTIONS FOR MAPPING DYNAMIC GAS-BEARING POOLS WITHIN UNDERGROUND GAS STORAGES

DEPROIL
DETAILED OIL & GAS PROSPECTING



DEPROIL LTD DEVELOPED:

- 3D MODEL OF THE DENSITY OF WORKING GAS VOLUME is the most informative property of dynamic gas-bearing pool because it includes the amount of working gas in one unit of dynamic gas-bearing reservoir rocks (m^3 of working gas in m^3 of rock)
- ESTIMATION OF TOTAL VOLUME OF WORKING GAS within dynamic gas-bearing pool is based on integrating the 3D model of density inside the pool contour



REVOLUTIONARY SOLUTIONS FOR MAPPING DYNAMIC GAS-BEARING POOLS WITHIN UNDERGROUND GAS STORAGES

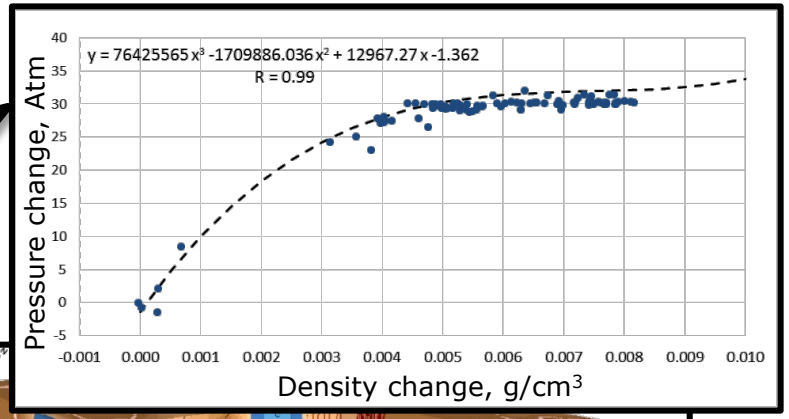
DEPROIL
DETAILED OIL & GAS PROSPECTING

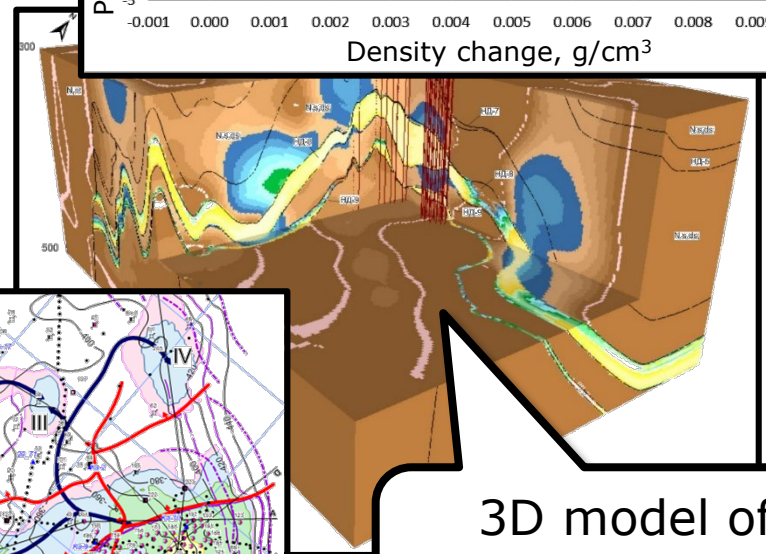
DEPROIL LTD DEVELOPED:

- **FORMATION PRESSURE CHANGE**
  within dynamic gas-bearing poll is defined basing on the relationship between rock density change and formation pressure change

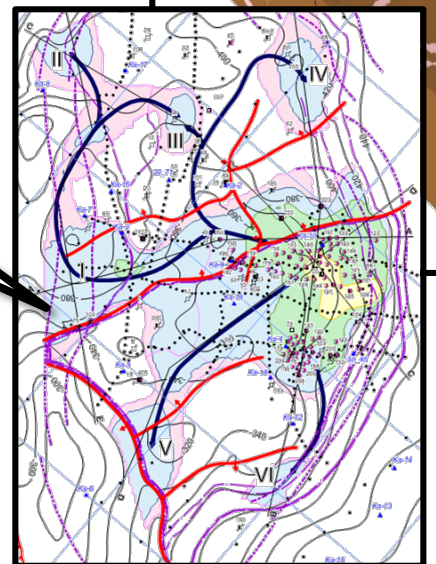
- **WORKING GAS PATHWAYS**
  between active zone of producing wells and dynamic gas-bearing pools are traced basing on formation pressure change data

Relationship between rock density change and formation pressure change

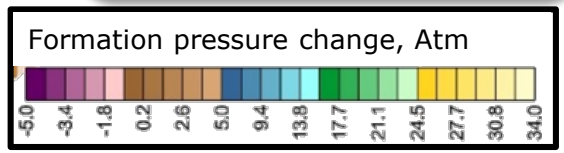




Working gas pathways



3D model of formation pressure change



EXPERIENCE IN APLYING THE TECHNOLOGY OF MAPPING DYNAMIC GAS-BEARING POOLS IN DASHAVA UGS

DEPROIL
DETAILED OIL & GAS PROSPECTING

Date of UGS establishment: 1972

Operation mode: gas

The area of the gas-bearing pool in UGS: 45.8 km^2

Pools: depleted gas deposits in producing horizons НД-8 and НД-9 of Sarmatian (Neogene)

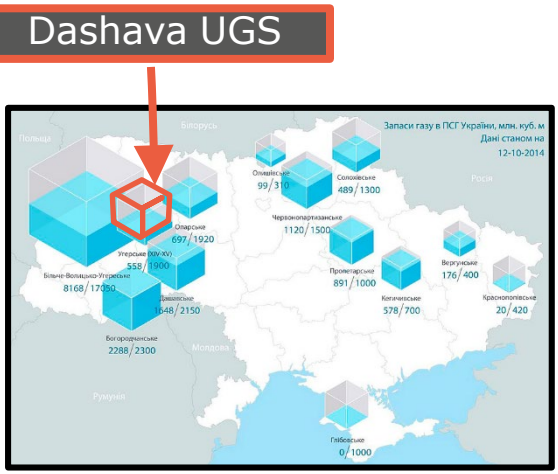
Reservoir rocks: mainly sandstone

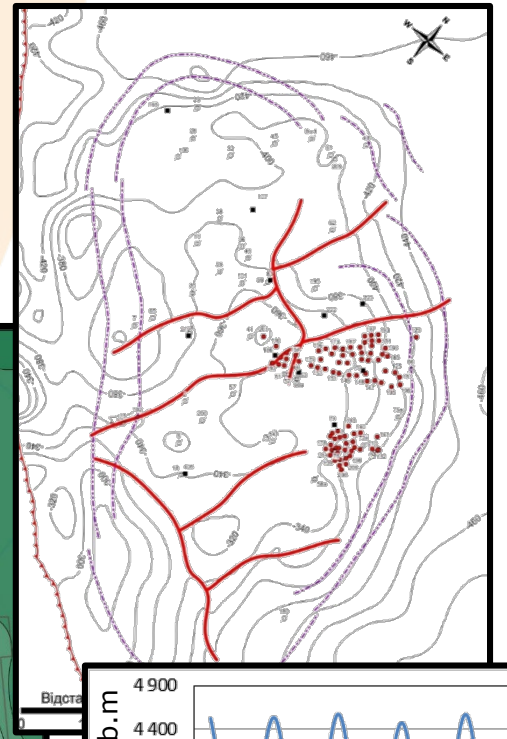
Average porosity: 26.1%

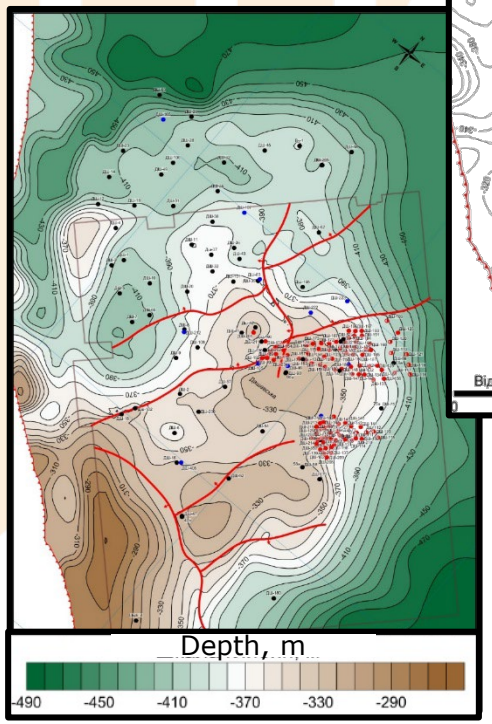
Average gas saturation: 90%

Project indicators for Dashava UGS

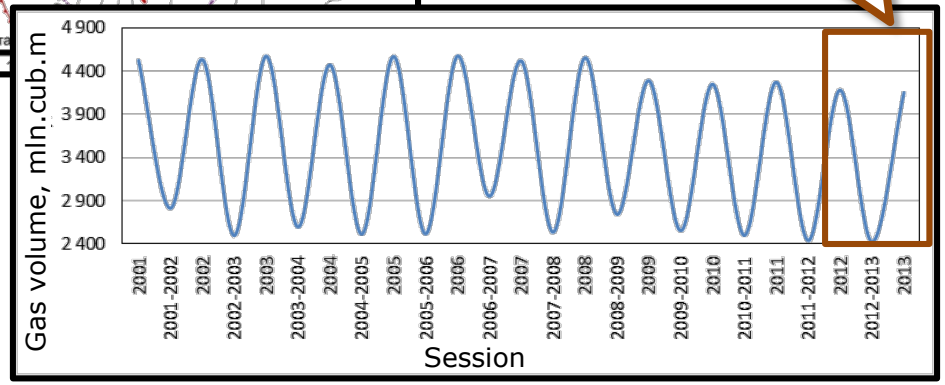
Parameter	Value
Total gas volume	5 339 mil.m³
Working gas volume	2 150 mil.m³
Cushion gas volume	3 189 mil.m³
Formation pressure: – maximum – minimum	 58.6 kgf/cm² 19.7 kgf/cm²
Average production	17 mil.m³/day
Duration of session depletion / injection	160 days







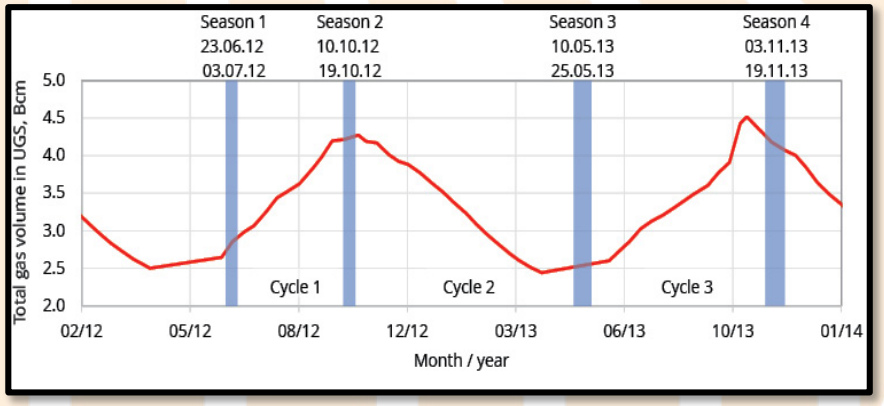
Time-lapse gravimetric observations of 2012-2013



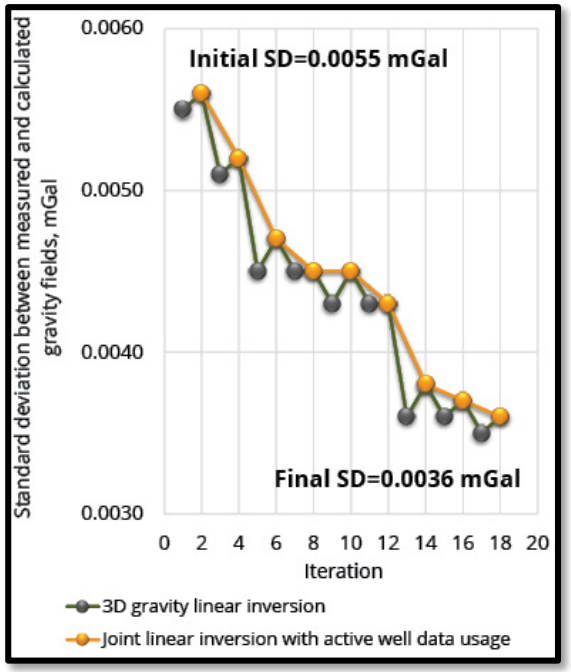
THE ALGORITHM OF MAPPING DYNAMIC GAS-BEARING POOLS IN DASHAVA UGS

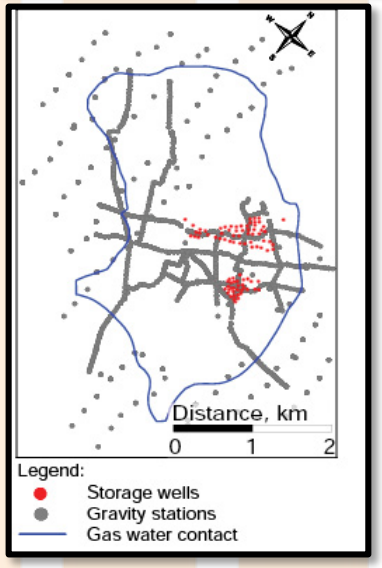
DEPROIL
DETAILED OIL & GAS PROSPECTING

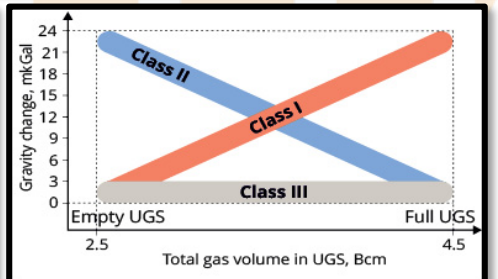
- Gravity survey area: 80.6 km^2
- Observation network: 530 stations
- Gravity measurements error: 4 mkGal
- Height measurements error: 3 mm
- Final 3D model error: 3.6 mkGal



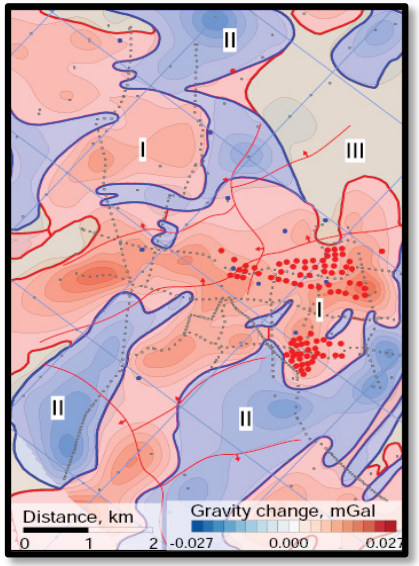
Class I
In-phase change
Class II
Change in antiphase
Class III
No change

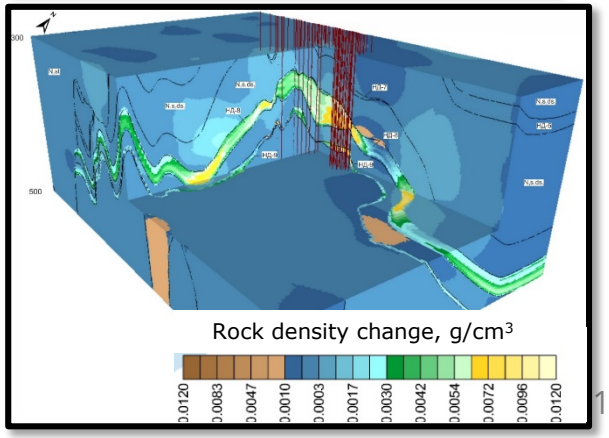






Cycle	Activity	Year	Different classes gravity station ratio		
			I	II	III
1	Injection	2012	32.3%	37.7%	30.0%
2	Withdrawing	2012-2013	52.8%	22.3%	24.9%
3	Injection	2013	55.2%	20.9%	23.9%
Quantity of I and II class gravity station			60.2%	39.8%	





RESULTS OF MAPPING DYNAMIC GAS-BEARING POOLS IN DASHAVA UGS

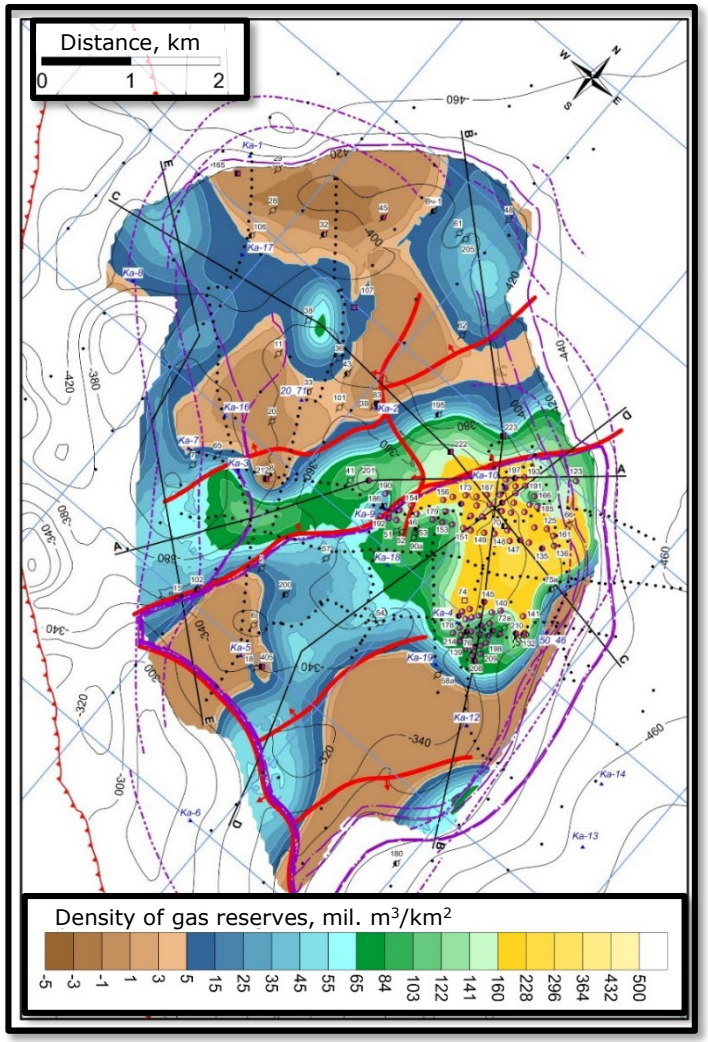
DEPROIL
DETAILED OIL & GAS PROSPECTING

THE ACCURACY OF THE PREDICTION WORKING GAS VOLUME IN DYNAMIC GAS-BEARING POOLS IN DASHAVA UGS 99%

Producing horizon	Operation period	Estimated volume of gas, mil.m³	Balance gas volume, mil.m³	Deviation from the balance gas volume, mil.m³	Relative error, %
НД-8	Depletion, Q_{depl}	1 796,9			
НД-9		788,7			
Total		**2 585,6**	**2 426,1**	**159,5**	**6,6 %**
НД-8	Injection, Q_{inj}	3297.1			
НД-9		1060.7			
Total		**4 357.8**	**4 180,6**	**177,3**	**4,2 %**
НД-8	Injection - Depletion, $Q_{act} = Q_{inj} - Q_{depl}$	1 500.2			
НД-9		272.0			
Total		**1 772.2**	**1 754,5**	**17,1**	**1,0 %**

Gas-saturated pore volume in Dashava UGS (Voytsitskyy I., 1999)	**118,2**
Calculated gas-saturated pore volume in Dashava UGS	**120,4**
Relative error in defining gas-saturated pore volume	**1,9 %**

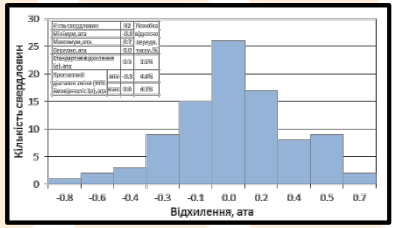
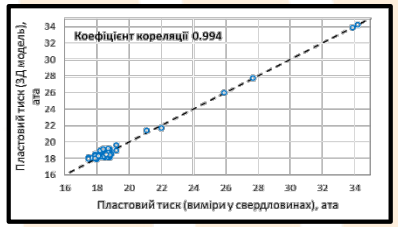
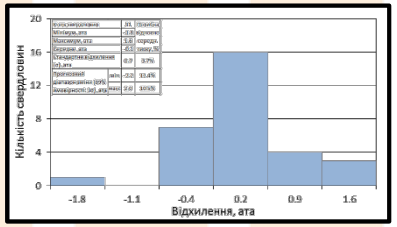
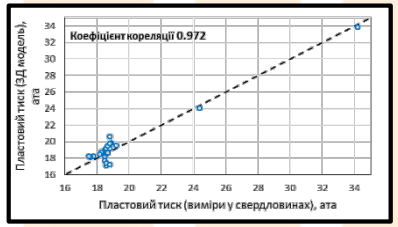
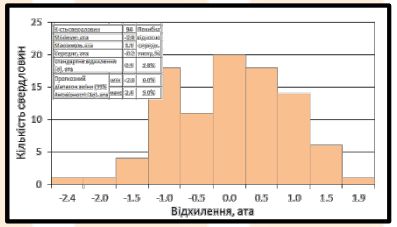
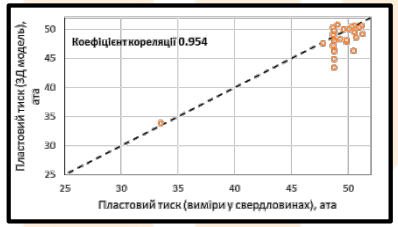
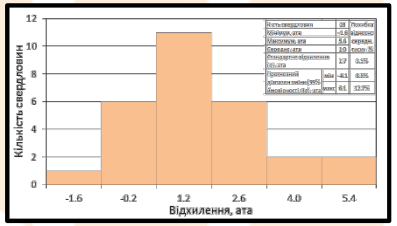
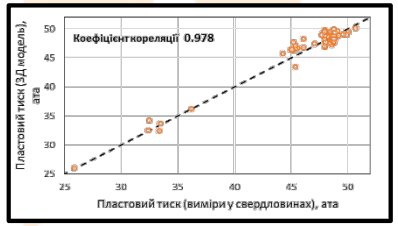
Density of working gas volume in producing horizon НД-8



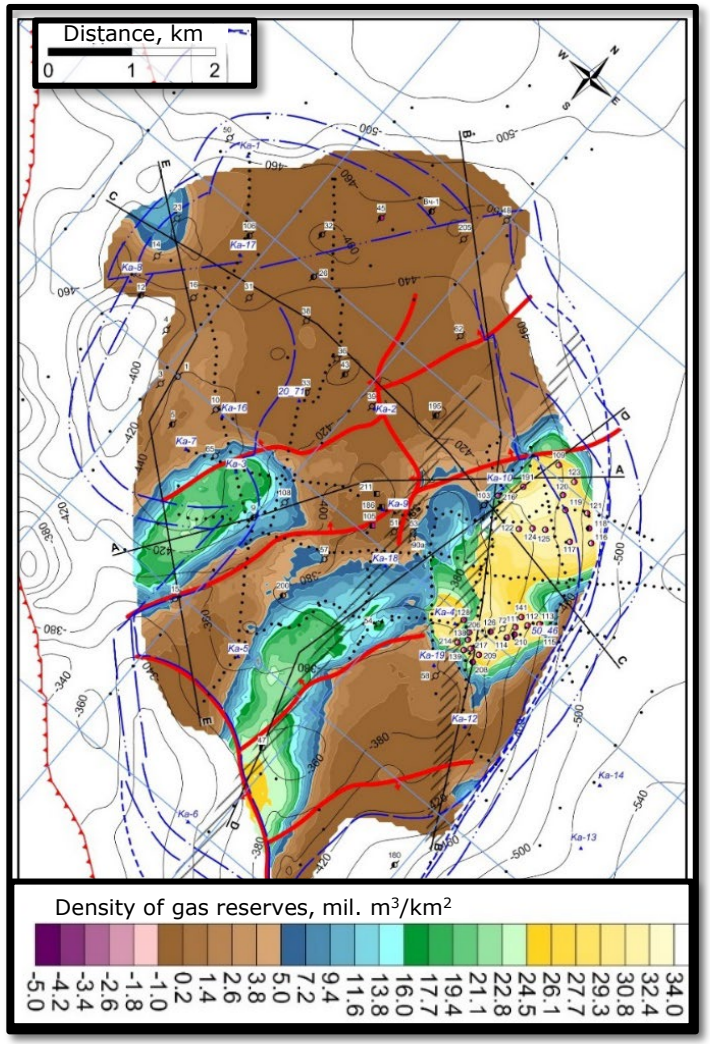
RESULTS OF MAPPING DYNAMIC GAS-BEARING POOLS IN DASHAVA UGS

DEPROIL
DETAILED OIL & GAS PROSPECTING

RELIABILITY OF PROGNOSIC OF FORMATION PRESSURE AT DIFFERENT STAGES OF UGS OPERATION IS >96.3%

Depletion UGS	НД-8			Error relative to mean value of pressure 1.5%
	НД-9			Error relative to mean value of pressure 3.7%
Injection UGS	НД-8			Error relative to mean value of pressure 1.8%
	НД-9			Error relative to mean value of pressure 3.5%

Formation pressure change in producing horizon НД-9



PARAMETERS OF MAPPED DYNAMIC GAS-BEARING POOLS IN DASHAVA UGS

DEPROIL
DETAILED OIL & GAS PROSPECTING

Parameters of dynamic gas-bearing pools in Dashava UGS

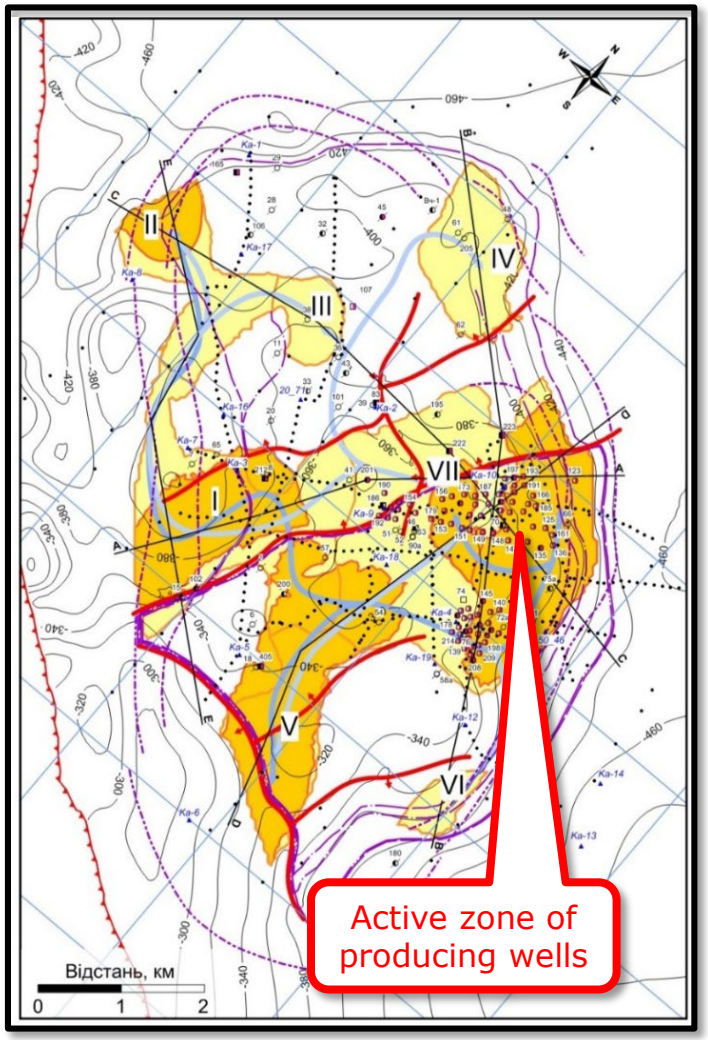
Parameter	Active zone	Dynamic gas-bearing pool							Total
		I	II	III	IV	V	VI	VII	
Producing horizon НД-8									
Area, km²	8.3	4.7	2.0	0.7	1.7	2.1	0.4		19.9
Working gas volume, million m³	998.7	227.4	45.1	21.7	46.5	79.3	20.2		**1438.9**
Particle of total volume of working gas	66.6%	15.2%	3.0%	1.4%	3.1%	5.3%	1.3%		95.9%
Producing horizon НД-9									
Area, km²	3.3	2.3	0.6			3.7		0.6	10.6
Working gas volume, million m³	163.5	29.1	9.4			42.5		6.8	**251.4**
Particle of total volume of working gas	60.1%	10.7%	3.5%			15.6 %		2.5%	92.4%
Dashava UGS									
Area, km²	11.6	7.0	2.7	0.7	1.7	5.8	0.4	0.6	30.5
Working gas volume, million m³	1162.2	256.5	54.5	21.7	46.5	121.9	20.2	6.8	**1690.4**
Particle of total volume of working gas	65.6%	14.5%	3.1%	1.2%	2.6%	6.9%	1.1%	0.4%	95.4%

29,8% of working gas is concentrated within the active zone of producing wells

Mapped contours:

- Zones of local dynamic pools (signing – pool number) horizon НД-8
- Zones of local dynamic pools (signing – pool number) horizon НД-9
- Working gas pathways in horizon НД-8
- Working gas pathways in horizon НД-9

Dynamic gas-bearing pools



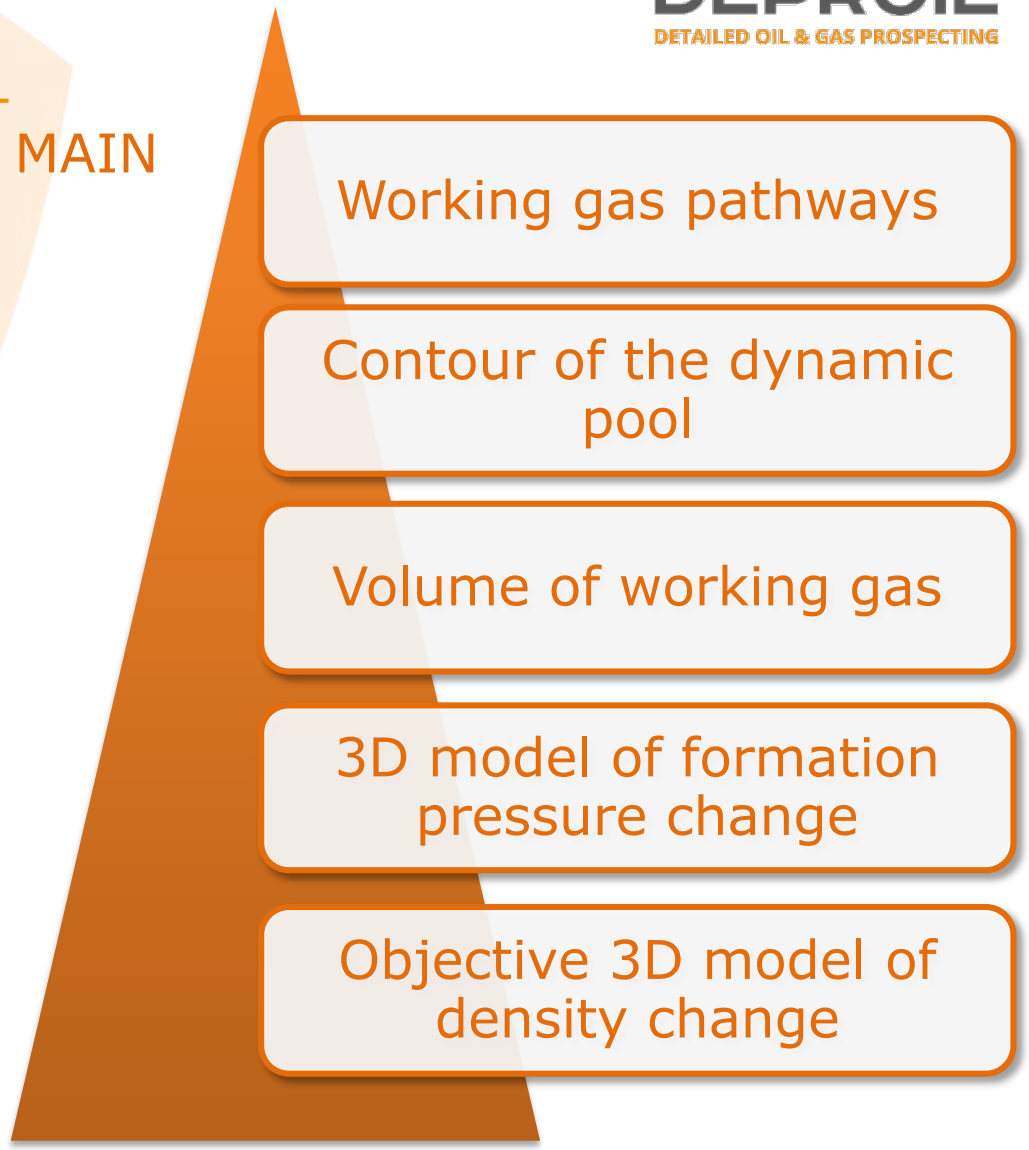
DEPROIL
DETAILED OIL & GAS PROSPECTING

FROM THE POSIBILITY TO SUCCESS

POSSIBILITY OF SUCCSSES OF MAPPING DEFINING MAIN PARAMETRS OF THE DYNAMIC GAS-BEARING POOL:

- STRATIGRAPHIC LEVEL (DEPTH)
- CONTOUR (IN-PLANE LOCATION)
- GAS-SATURATED PORE VOLUME – 98%
- TOTAL VOLUME OF WORKING GAS – 99%
- FORMATION PRESSURE CHANGE – 96%

THE ACTUAL SUCCESS RATE OF MAPPING DYNAMIC GAS-BEARING POOLS AND DEFINING THEIR PARAMETERS – 96%



APPLYING THE TECHNOLOGY OF MAPPING DYNAMIC GAS-BEARING POOLS WITHIN UNDERGROUND GAS STORAGES IN UKRAINE

DEPROIL
DETAILED OIL & GAS PROSPECTING

№	Underground gas storage	Area, km^2	Calculated volume of working gas in UGS, million m^3
1	Bilche-Volytsko-Ugerske	110.6	17 640
2	Ugerske (XIV-XV)	21.5	2 000
3	Dashava	54.6	2 150
4	Oparske	40.4	2 400
5	Bogorodchanske	8.6	2 300
6	Solokhivske	9.5	1 200
7	Olyshivka	32.7	310
8	Chervonopartyzanske	9.3	1 500
9	Kegychivske	40	700
10	Proletarske	11.5	1 000
11	Chervonopopivske	12.9	425
12	Glibivske	6.2	1 000
13	Vergunske	3.9	400
Total		361.7	33 025

DEPROIL
DETAILED OIL & GAS PROSPECTING

THE TECHNOLOGY OF MAPPING DYNAMIC GAS-BEARING POOLS WITNIN UNDERGROUND GAS STORAGES BY THE RESULTS OF GRAVITY MONITORING: PRACTICAL EXPERIENCE AND PERSPECTIVES

Mapping gas-bearing pools in Dashava UGS
Misfit of gas pressure prediction - 4%
Misfit of working gas volume prediction – 1%