DEPROIL
DETAILED OIL & GAS PROSPECTING

UNDERGROUND GAS STORAGE MONITORING

OVER TWO DECADES OF RELIABLE HYDROCARBON-BEARING RESERVOIR EXPLORATION

85% - SUCCESS RATE
25 fields
81 wells
166 well tests

- High precision time-lapse gravity survey
- Detailed spatial models of the storage tank:
- 4D model of rocks density
- 4D model of formation pressure
- 4D model of working and base gas volume in place
- Dynamic gas reservoirs
- Working gas movement pathways

4D MODEL OF THE GAS STORAGE TANK, FORMATION PRESSURE AND TECHNOGENIC RESERVOIRS BASED ON THE HIGH-PRECISION TIME-LAPSE GRAVIMETRIC OBSERVATIONS

Dashava underground gas storage (UGS), Bilche-Volytsa zone of Pre-Carpathian Depression, Ukraine. Time-lapse gravity survey period: 2012-2013.

GEOLOGICAL PROBLEM

Dashava UGS was created in 1972 and comprises of 6 depleted reservoirs of the Dashava gas field. The depleted gas reservoirs belong to the two lower-Dashavian horizons (LD-8 and LD-9) of the Sarmatian interval of Neogene period. Reservoir depths range between 570-590 mTVD. Lithologically, reservoirs are mainly represented by sandstones, with average porosity of 26.1% and gas saturation of 90%. Reservoir structure is an irregular-shaped brachyanticline with an effective reservoir thickness of 10-60 meters. Area of the UGS is 45,8 km^2. Gas drive regime is in place, with a total of 100 storage wells operating across the Dashava UGS.. Operational storage pressure range is 19,7-58,6 kgf/cm^2. The total project gas volume is 5,34 Bcm, the project active gas volume is 2,15 Bcm. During 27 complete injection/withdrawal cycles continuously decreasing of gas pressure within pore space had been observed when total gas volume in place was equal. These occurred cushion gas volume increasing. The situation that has developed indicates a difficulty of the gas-hydrodynamic system of UGS and a constant attraction of additional reservoir volume to cyclic gas storage process. An absence of 3D models of porosity and permeability makes unpromising an application of dynamic modeling or reservoir simulation for the UGS reservoir system. Gravity was chosen for UGS property changing monitoring taking into account dependence between gas density and storage pressure. A time-lapse gravity survey was taken for finding reasons and location of cushion gas accumulation.

3D GRAVITY INVERSION WORKFLOW

Four seasons of time-lapse high precision gravity measurements were taken for two years. Two series were taken at empty UGS and two series were taken at full UGS (Figure 1). Twofold gravity measures were provided on 530 stations (Figure 2). The average standard deviation of gravity measurements was 4,3 mkGal. A gravity change map that was related to gas injection was built. For map building, all gravity measurements were divided into three classes (Figure 3). Class I - gravity field was changed proportionally with storage pressure change (red areas on Figure 4); Class II - gravity field was changed inversely proportionally with storage pressure change (blue areas on Figure 4); Class III - gravity field wasn`t changed after gas withdraw/injection (brown areas on Figure 4). The 3D model of Dashava UGS was created at the next stage. The 3D model should explain processes which take place in UGS. A structural framework of the 3D model was built using the results of 2D and 3D seismic data. Well logging and gas pressure measures in wells were used to define an initial 3D density model in depletion condition of Dashava UGS as of 2012. The 3D density model consists of 29,8 million cells (cell dimensions 100 x 100 x 1 m). Planar 3D model dimensions are 8 x 12 km. The depth interval of the 3D model is from 0 to 790 meters. The standard deviation between observed and calculated gravity fields for the initial 3D density model was 5,5 mkGal. The 3D density model was refined by a joint full-depth inversion of gravity and well data on a period when UGS was full of gas in 2013. The standard deviation for the completed UGS 3D density model was 3,6 mkGal (Figure 5). A 3D density change model was transferred to a 3D gas pressure change model using dependencies between gas pressure change which was measured in wells and reservoir density change in the obtained 3D density change model. A 4D model of cushion and working gas distribution was calculated based on the obtained 4D gas pressure model. A relative misfit of gas pressure prediction in the 4D model was 3,7 % for empty UGS and 3,5 % for full UGS. A relative misfit of working gas volume prediction was 1.0 %.

GEOLOGICAL RESULTS

Results of time-lapse gravity measurements confirmed the presence of gravitational anomalies 12-24 mkGal which are related with gas volume change in UGS. Directly proportional dependence between gravity change and gas volume was observed on 60 % of stations. Inversely proportional dependence was observed on 40 % of stations. Created 4D density, gas pressure, and gas volume models allowed mapping of dynamic reservoirs location in which cushion gas is accumulated. Also, these 4D models allowed to calculate gas volume within dynamic reservoirs, to map working gas migration pathways from storage wells to dynamic reservoirs (Figure 6). Blocking pathways of gas migration to dynamic reservoirs was recommended for cushion gas accumulation congestion.

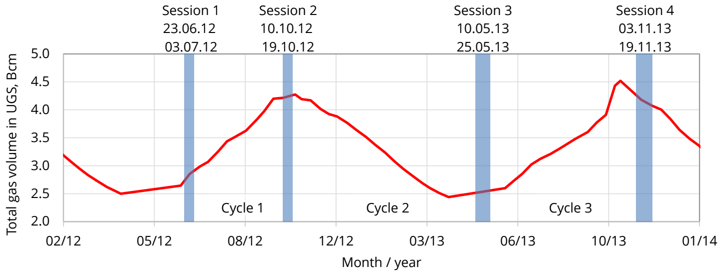


Figure 1. Gas drive regime is in place, with a total of 100 storage wells operating across the Dashava UGS

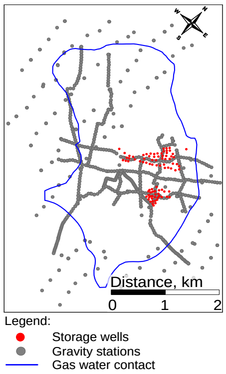
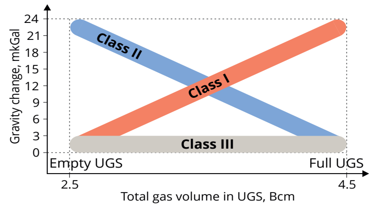


Figure 2. Location of stations with time lapse gravity measurement



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%	

Figure 3 Classification of gravity stations based on the dependence between UGS gas volume and gravity change

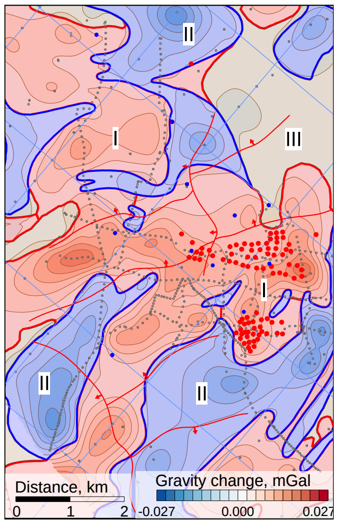


Figure 4. Gravity change caused by gas injection in UGS

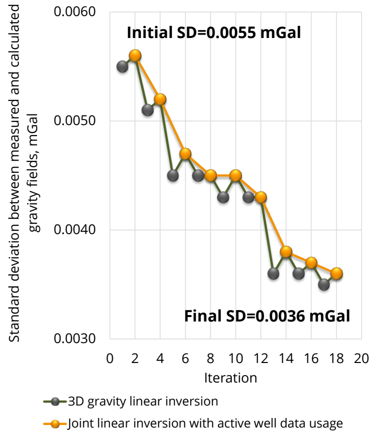


Figure 5. Iterational refining of 3D density model

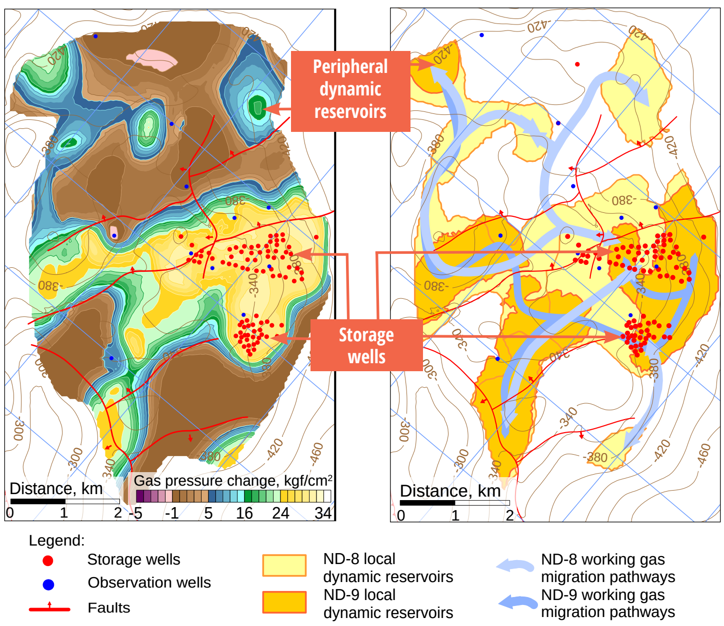


Figure 6. ND-8 gas pressure change (left). Location of dynamic reservoirs and working gas pathways (right)