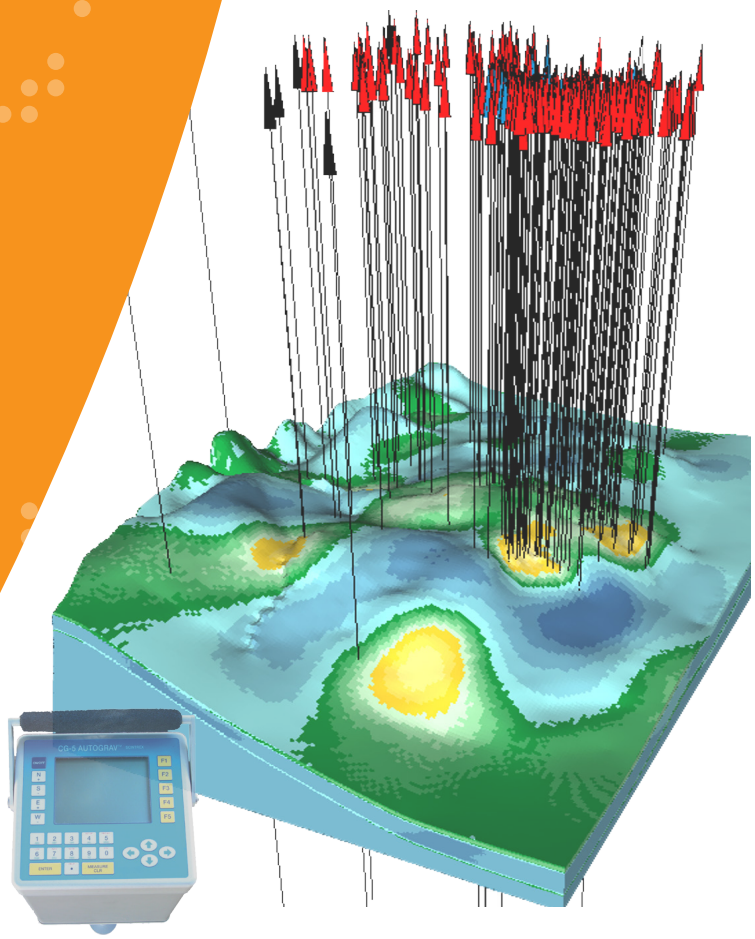
DEPROIL

DETAILED OIL & GAS PROSPECTING

- Ultra-high-precision (4,3 mkGal) time-lapse gravimetric survey
- 4D models of:
  - reservoir density,
  - formation pressure,
  - gas-saturation,
  - density of active and cusion gas reserves
- Location of dynamic gas reservoirs
- Estimation of active and cusion gas volumes and gas movement pathways



UNDERGROUND GAS STORAGE MONITORING

TIME-LAPSE GRAVITY SURVEY
FOR THE LOCATION OF CUSHION GAS ACCUMULATION
AT DASHAVA UNDERGROUND GAS STORAGE

DYNAMIC 4D MODEL OF THE RESERVOIR SYSTEM OF THE DASHAVA UNDERGROUND GAS STORAGE BASED ON THE HIGH-PRECISION TIME-LAPSE GRAVITY SURVEY

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

STUDY OBJECTIVES

Time-lapse gravity survey was carried out to find the location of cushion gas accumulation at Dashava Underground Gas Storage.

Dashava UGS was created in 1972 and comprises of 6 depleted reservoirs of the Dashava gas field. Depleted gas reservoirs are confined to two Lower-Dashava horizons (LD-8 and LD-9) of Sarmatian, Neogene. Reservoir depths range between 570-590 mTVD. Lithologically, reservoirs are mainly represented by sandstones, with an average porosity of 26.1% and gas saturation of 90%. The trap is an irregular-shaped brachyanticline with an effective reservoir thickness of 10-60 meters. Area of the UGS is 45,8 km^2. The gas-drive regime is in place, with a total of 100 storage wells operating across the Dashava UGS. Operational reservoir pressure ranges between 19,7 and 58,6 kgf/cm^2. The total project gas volume is 5,34 Bcm, while the projected active gas volume is 2,15 Bcm. During 27 complete injection/withdrawal cycles continuous decrease of formation pressure has been observed under the equal gas volume in place. These caused an increase in cushion gas volume. Such a situation indicates a complexity of the gas-hydrodynamic system of the UGS and a constant involvement of additional reservoir volume to cyclic gas storage process. An absence of 3D models of porosity and permeability makes unpromising the application of dynamic modeling or reservoir simulation for the UGS reservoir system. Considering the dependence between gas density and formation pressure, gravity was chosen to model changes in the UGS.

4D MODELLING TECHNIQUE

Four seasons of time-lapse high-precision gravity measurements were taken for two years. Two series were carried out over the empty UGS and two series, over full UGS (Figure 1). Twofold gravity measures were provided on 530 stations (Figure 2). An average standard deviation of gravity measurements was 4,3 mkGal. To map gravity changes related to gas injection, 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 withdrawal/injection (brown areas on Figure 4). The 3D model of Dashava UGS was created at the next stage. At the next step, we created a 3D model explaining processes that take place in the UGS. A structural framework of the 3D model was built using 2D and 3D seismic data. Well logging and gas pressure measurements in wells were used to build an initial 3D density model under depletion of the Dashava UGS as of 2012. The 3D density model consisted of 29,8 million cells (cell dimensions 100 x 100 x 1 m). Lateral dimensions of the 3D model were 8 x 12 km. The depth interval of the 3D model was 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 log data, while using gravity on a period when UGS was full of gas in 2013. The standard deviation for the final 3D density model was 3,6 mkGal (Figure 5). A 3D model of density variations was transferred to a 3D model of gas pressure change using dependencies between gas pressure variations from wells and reservoir density change from obtained 3D density models. A 4D model of cushion and working gas distribution was calculated based on the obtained 4D gas pressure model. A relative error of gas pressure prediction in the 4D model was 3,7 % for the empty UGS and 3,5 % for the full UGS. A relative error of working gas volume prediction was 1.0 %.

GEOLOGICAL RESULTS

Results of time-lapse gravity measurements confirmed the presence of gravity anomalies ranging from 12 to 24 mkGal which are related with gas volume change in UGS. Direct proportional dependence between gravity change and gas volume was observed at 60 % of stations. Inversely proportional dependence was observed at 40 % of stations. Created 4D density, gas pressure, and gas volume models allowed for mapping the location of dynamic reservoirs accumulating cushion gas. Also, these 4D models allowed for the calculation of gas volume within dynamic reservoirs, mapping working gas migration pathways from storage wells to dynamic reservoirs (Figure 6). In order to prevent cushion gas congestion it was recommended to block pathways of gas migration to dynamic reservoirs.

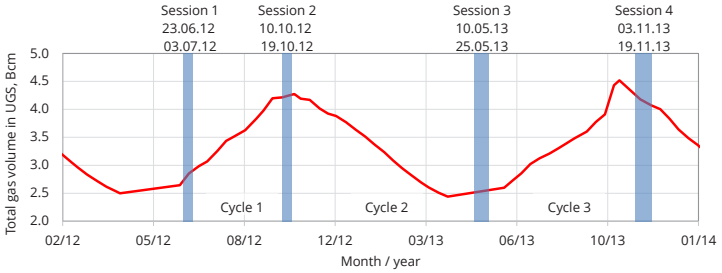


Figure 1. Periods of the time-lapse gravity surveys and dynamics of gas volume change in the Dashava UGS

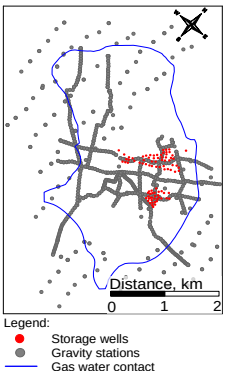
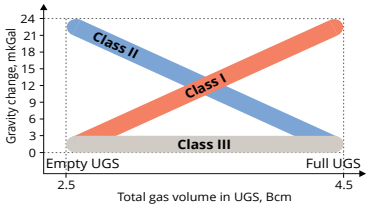


Figure 2. Stations of the time-lapse gravity survey



Cycle	Activity	Year	Quantity of gravity stations in different classes		
			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 stations			60.2%	39.8%	

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

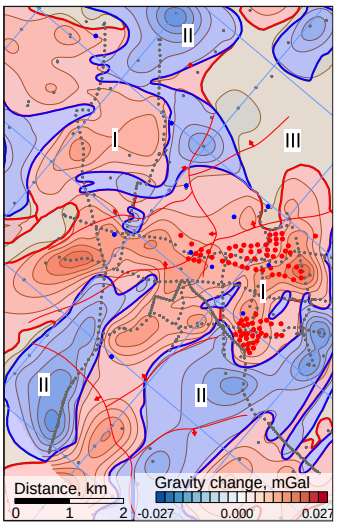


Figure 4. Gravity change caused by gas injection into the UGS

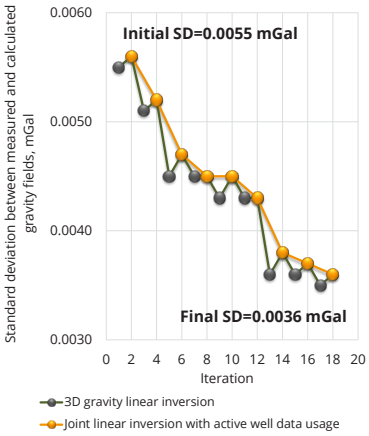


Figure 5. Iterational refining of the 3D density model during 3D gravity-inversion

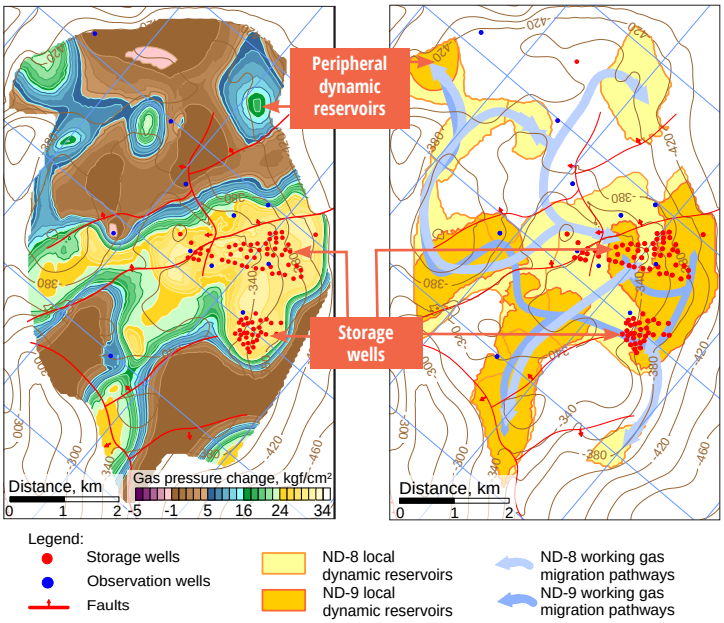


Figure 6. Gas pressure change (left) in the ND-8 horizon of UGS. Location of dynamic reservoirs and working gas pathways (right)