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STUDY OF UNDERGROUND NATURAL GAS STORAGE IN A RESERVOIR FROM THE TRANSYLVANIAN DEPRESSION

1. PAPER TARGETS

The paper has the following targets:
- the analysis of the geological model,
- the determination of the optimum storage and exploitation conditions,
- the evaluation of the possibilities of increasing the storage capacity of the reservoir.

2. RESERVOIR PROPERTIES AND PRODUCTION STATUS

The structure was discovered through drilling wok in the year 1909 and from the geological point of view is situated in the Northern part of the Transylvanian Depression.

The production started in the year 1914. There were drilled 186 wells and there are still producing 100 wells.

There were identified gas accumulations in 15 commercial horizons: Sarmatian (horizons I–IV), Buglovian (horizons VI–IX) and Badenian (horizons X–XV).

The gas production for the horizon Bg VII a+b started in the year 1946, through one well and there were added later other 11 wells. The gas cumulative is 1300 MMscm, representing a recovery factor of 75%. In January 1995, before starting the underground gas storage, there were 10 producing wells.

The gas production for the horizon Bg VI a started in the year 1933, and the gas cumulative till 1996 was 1700 MMscm (through 9 wells), representing a recovery factor of 75%. In July 1996, before starting the underground gas storage, there were 5 producing wells.

The field hydrocarbon displacement mechanism considered is the elastic gas drive.

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3. UNDERGROUND GAS STORAGE RESERVOIRS

There were identified gas accumulations in 15 commercial horizons: Sarmatian (horizons I–IV), Buglovian (horizons VI-IX) and Badenian (horizons X-XV), based on production tests, production history and well log analysis.

After the horizons Buglovian VII a+b and Buglovian VI were depleted, starting with 1995–1996, those horizons were converted to underground natural gas storage reservoirs.

There were drawn top structural maps at Bg VI, Bg VII a and Bg VII b (Figs 1–3).

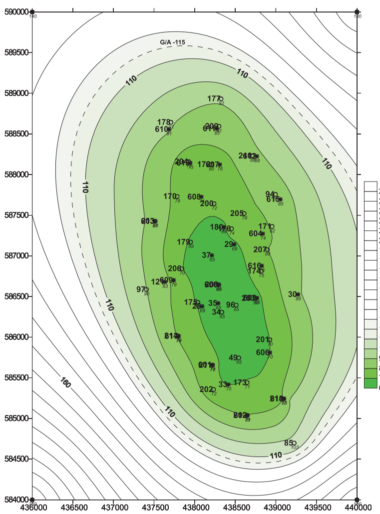

Fig. 1. Structural map at Bg VI

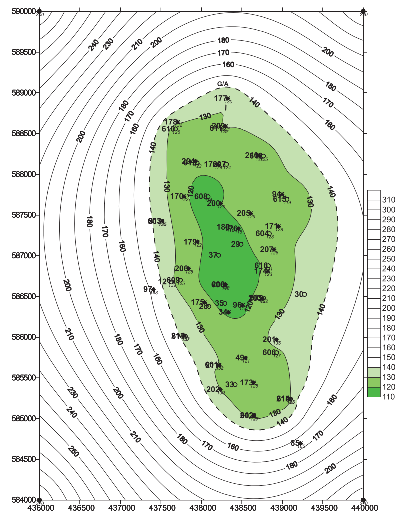

Fig. 2. Structural map at Bg VII a

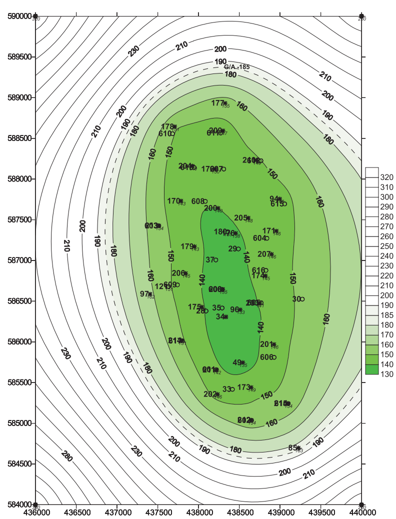

Fig. 3. Structural map at Bg VII b

4. UNDERGROUND GAS STORAGE HISTORY

The underground gas storage work was initiated in the year 1995 for the horizon VII and in the year 1996 for the horizon VI, in order to assure natural gas for the consumers from the North and North-West during cold weather, when the demand is higher.

In order to accomplish the injection-extraction capacities necessary to the storage process at Bg VII a+b, from the year 1995 till March 1996 there were prepared 7 wells from the existing 10 and there were drilled 23 new wells, there were performed separation-completion works at the gas collection technological system and extension operations of the compressor station.

In order to carry out the injection-extraction capacities necessary to the storage process at Bg VI, starting from the year 1999 there were drilled 18 new wells.

During the hot season, from April till September (about 150 days/year), gas is injected in the horizons Bg VI and Bg VII a+b (Figs 5 and 7), when the gas demand is low and there is a gas excess and during the cold season, from October till March (about 150 days/year), the injected gas during hot weather is extracted (Figs 4 and 6), in order to be consumed.

From underground gas storage starting, the injection-extraction process varied from 125 MMscm/cycle through 16 wells, at injection pressures of 24 bar, reaching 700 MMscm/cycle through 50 wells, at injection pressures of 35 bar.

In the present there are achieved injection-extraction sequences of 700 MMscm/cycle and 150 days/year, the gas injection pressures are about 34 bar, the extraction pressures are about 17 bar and the cushion gas is 1400 MMscm (34% from OGIP).

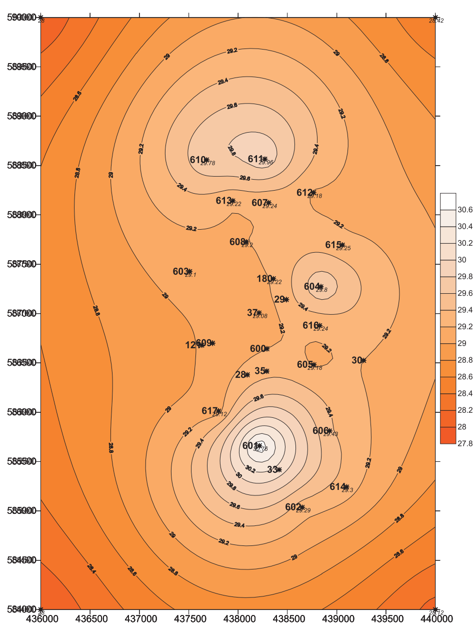

Fig. 4. Isobar map at Bg VI (before extraction)

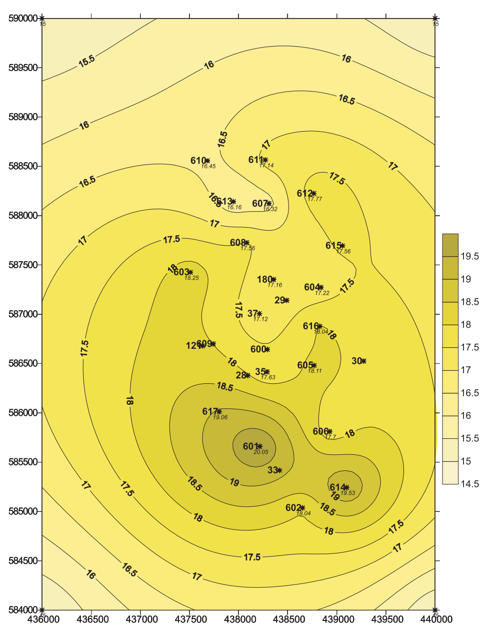

Fig. 5. Isobar map at Bg VI (before injection)

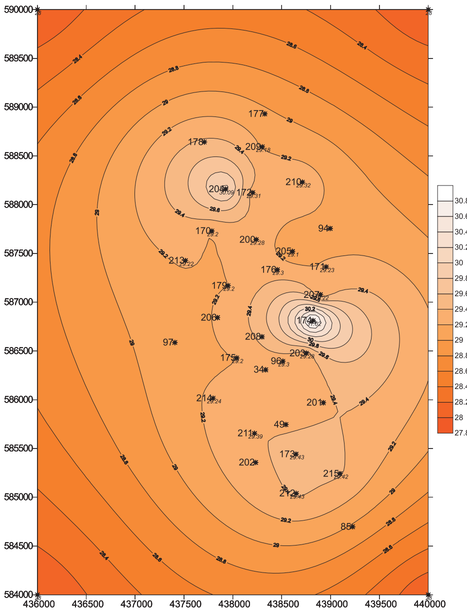

Fig. 6. Isobar map at Bg VII (before extraction)

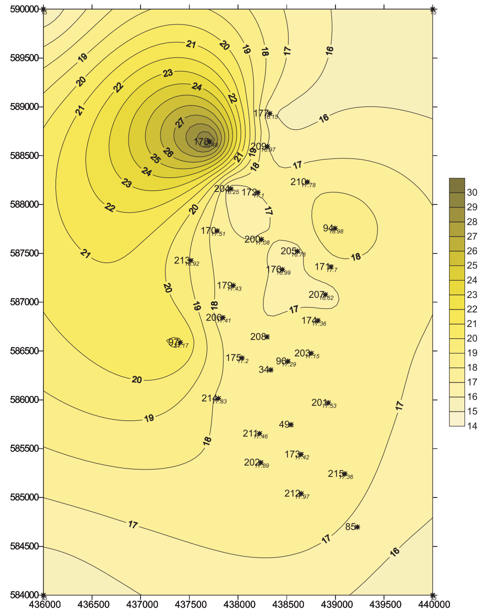

Fig. 7. Isobar map at Bg VII (before injection)

The underground gas storage reservoir evolution is presented in the Figure 8.

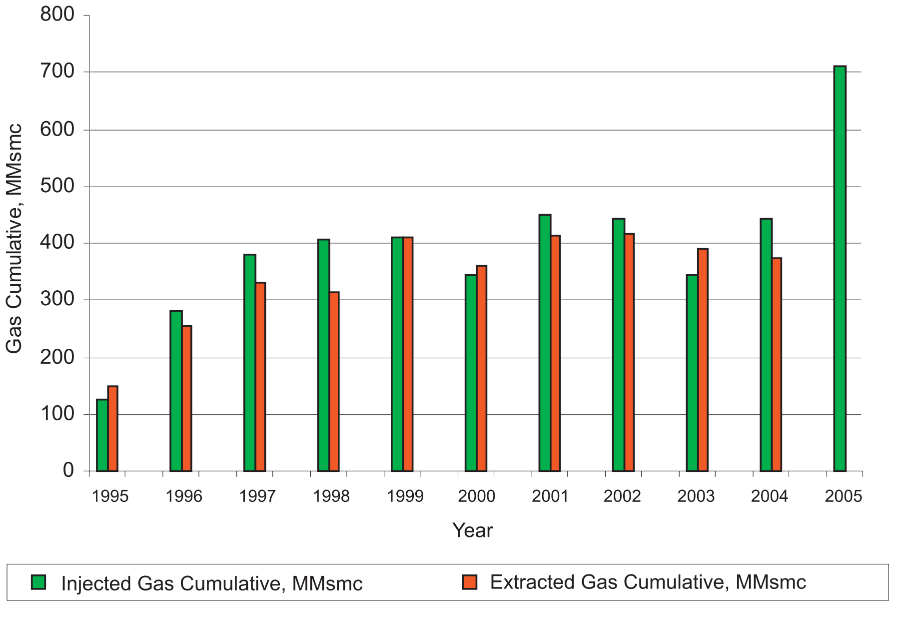

Fig. 8. Field gas storage evolution

5. PROPOSED WORK IN ORDER TO DEVELOP THE FIELD AND THE STORAGE CAPACITY

The structure is in an advanced exploitation stage, although there are still producing 100 wells, thus some reservoirs are almost depleted, with a recovery factor of over 80% (Sa V, Bn X+XI and Bn XII+XIII).

In order to develop the storage capacity of the entire field it was proposed to analyze the possibilities of converting the horizon Sa V to storage and to increase also the existing capacities (Bg VI and VII).

6. UNDERGROUND GAS STORAGE INCREASE CAPACITY DESIGN

Underground gas storage analysis in Bg VI

The pressure-volume diagram (Fig. 9) shows a translation towards the right side of the cycles representation, which could signify gas loss. Anyway it is observed that in most of the cycles (from the year 1996 till 2003), the extracted gas volume is smaller than the injected gas volume.

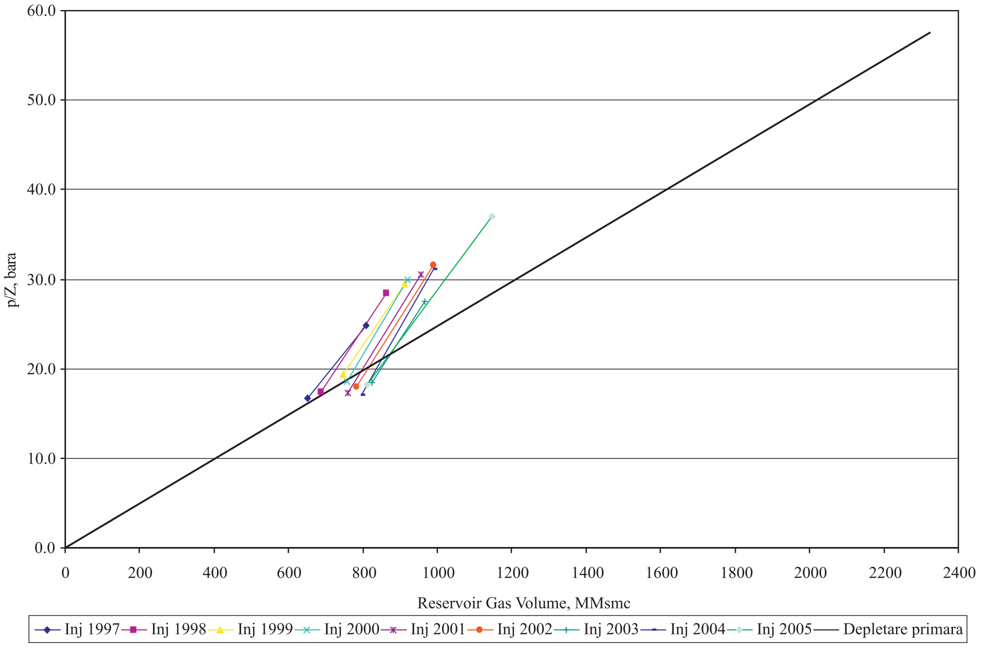

Fig. 9. Pressure-volume diagram at Bg VI

The dispersion of the pressure-volume values towards the natural depletion variation shows the insufficient accuracy of the parameters measurement: reservoir pressures and injected/extracted volumes.

Underground gas storage analysis in Bg VII

Put side by side with Bg VI chart, the lines represented in the pressure-volume graph are more grouped (Fig. 10) and from one sequence to the other, they are translated to the right or to the left side, depending on the smaller or higher extracted gas volume, compared to the volume from the former injection cycle.

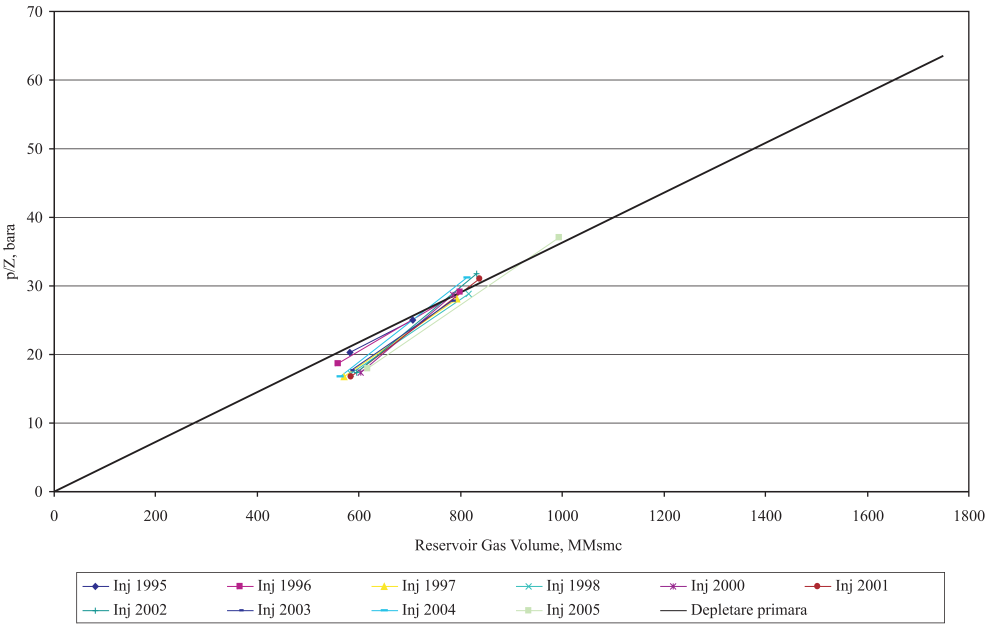

Fig. 10. Pressure-volume diagram at Bg VII

Storage capacity enhancement

In order to enlarge gas storage capacity there were performed numerical simulations on the main process parameters in 2 options as following:

Option A – fulfillment the capacity of 700·MMscm/cycle (370 MMscm at Bg VII and 330 MMscm at Bg VI) and transferring to the cushion gas of 150·MMscm. This option does not involve new wells investments, but requires retreating of 3 wells from Bg VII to Bg VI.

Option B – accomplishment of growing capacities from cycle to cycle, from 700 MMscm, till the maximum cycle of 1160·MMscm, in the year 2012 and transferring to the cushion gas of 200·MMscm. This option involves the well pattern to be increased with 4 wells till the year 2010, in order to reach 1100·MMscm/cycle.

The underground gas storage design was performed separately for each horizon (Bg VI and Bg VII, respectively).

Storage capacity enhancement predictions

Based on production and injection-extraction history and present capacity of the reservoirs, there were achieved two options in order to continue the storage:

Option A – basic:

- Injection-extractions sequences of 700 MMscm/cycle and 150 days/year.
- 150 MMscm from the inactive working gas will be moved to the cushion gas.
- The cushion gas represents 1400 MMscm (34% from OGIP) and will reach 1550 MMscm (38% from OGIP).
- The cushion gas + annual gas volume injected will reach 2250 MMscm (55% from OGIP).
- The injection gas pressures will be about 34.6–36.7 bar and the gas extraction pressures will be about 16.4–18.8 bar.
- The necessary well pattern in order to guarantee an optimum injection-extraction cycle is 54 wells (29 for Bg VI and 25 for Bg VII).
- The well deficit from Bg VI (there are only 21 active wells and 5 inactive wells) will be worked out through the activation of 5 wells from Bg VI and through retreating 3 wells from Bg VII (29 active wells and 3 inactive wells).
- Other investments refer to the measurement system and the compressor station modernizing.

Option B – enlarging the storage capacity gradually:

- Injection-extraction sequences raised with 100 MMscm/cycle till the year 2012, when will reach 1160 MMscm/cycle and 150 days/year.
- 150 MMscm from the inactive working gas will be moved to the cushion gas and in the year 2011 other 50 MMscm from the inactive working gas will be transferred to the cushion gas.
- The cushion gas represents 1400 MMscm (34% from OGIP) and will reach 1600 MMscm (39% from OGIP).
- The cushion gas + annual gas volume injected will reach 2760 MMscm (67% from OGIP).
- The injection gas pressures will be about 36.4–52.1 bar, and the gas extraction pressures will be about 16.4–21.2 bar.
- The necessary well pattern in order to assure an optimum injection-extraction cycle is 58 wells (31 for Bg VI and 27 for Bg VII).
- The well deficit from Bg VI (there are only 21 active wells and 5 inactive wells) will be worked out through the activation of 5 wells from Bg VI and through retreating 5 wells from Bg VII (29 active wells and 3 inactive wells).
- Other investments refer to the measurement system and the compressor station modernizing and also to a new compressor station.

In order to minimize the gas loss there are proposed:

- Replacement of the measurement devices with modern ones.
- Gas heaters metering.
- Testing the cement ring for all the wells.
- Monitoring the storage process through wells pressure measurement.

– Dynamic tubing/casing pressures measurement, pressures before choke/pressures after choke (p_1/p_2) measurement and wells choke examination.
– Pressure measurement devices calibration.
– Continuous recording of gas flow rates metering and well impurities accumulation survey.

7. CONCLUSIONS AND PROPOSALS

1) It was initiated in the field an underground gas storage process, starting with the year 1995 for Bg VII, respectively with the year 1996 for Bg VI.
2) In the present there are achieved injection-extraction sequences of 700 MMscm/cycle and 150 days/year, the gas injection pressures are about 34 bar, the extraction pressures are about 17 bar and the cushion gas is 1400 MMscm (34% from OGIP).
3) From the economical Discount Cash-Flow analysis it is drawn the conclusion that the underground gas storage is profitable and for Option B is obtained a net present value of 170 MM $ and an internal rate of return of 33%, for an injected volume of gas 21 520 MMscm till the year 2025.

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