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**PRODUCTION AND EVALUATION STUDY
FOR A NATURAL GAS FIELD
IN THE NORTH – EASTERN PART OF THE GETIC DEPRESSION**

1. WORK TARGETS

The work targets are:

- additional data analysis to the study (1998) and confirmed at 01.01.2000 and to the last study at reference date 01.01.2005,
- geological model update according to 3D seismic data interpretation performed at the beginning of the year 2007,
- resources and reserves reevaluation in order to be confirmed,
- optimum production scenario set up,
- discounted cash flow analysis.

2. RESERVOIRS PARAMETERS AND PRODUCTION STATUS

The field is located in the North – Eastern part of the Getic Depression.

From the geological point of view is represented by an West – East oriented anticline, transversal and longitudinal faulted. There are only non-associated gas accumulations in Burdigalian (Helvetian).

The first wells in the field (#11 and #12, located in a not favourable position) were drilled in the year 1955. The drilling was restarted in the year 1977, when there were drilled 5 wells (based on the information from the exploration well #5007): #2240, with no results (in the year 1980), #2235, #2225, #1800, with results (in the period 1981–1988) and #1805, with no results (in the year 1988). The well #2235 found the non-associated gas accumulations from Burdigalian (Helvetian).

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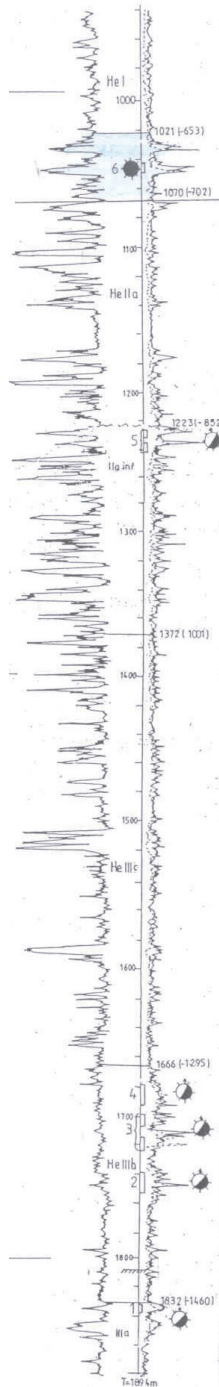


Fig. 1. Representative well log

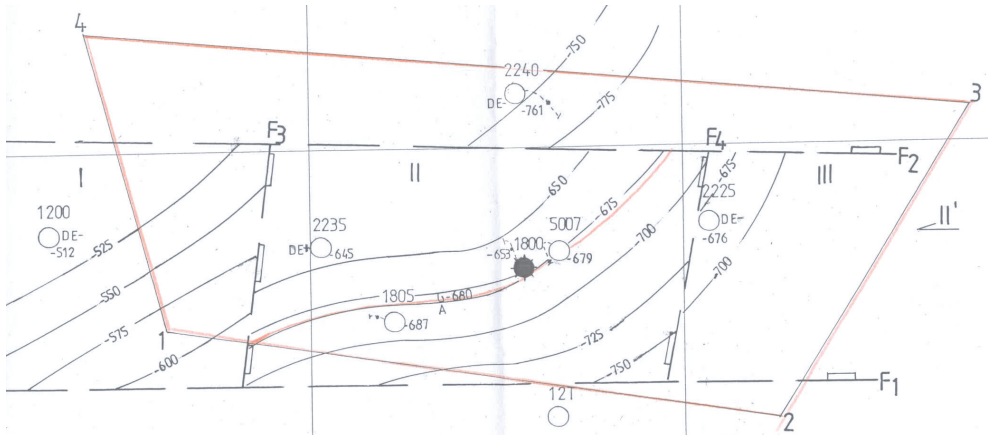


Fig. 2. Structural map – *Burdigalian II b*

The production started in the year 1986 through the wells #2225 and #2235 and in the year 1988 it was started the production for the well #1800.

The producing horizons from Burdigalian (Helvetian) are developed in sandy-shaly facies and are belonging to Burdigalian (Helvetian) inferior (III a, III b, III c) and superior (II a, II b and I).

A representative well log and a structural map are presented in Figure 1 and Figure 2, respectively.

The reservoir parameters are presented in Table 1.

There were drilled in the field 12 wells and among them only 3 wells produced (#2235, #2225 and #1800), the other wells being abandoned or waiting for workover. In the present is producing only the well #1800.

The accepted hydrocarbon displacement mechanism is elastic gas drive for free gas reservoirs.

Till the reference date of the study there were extracted 53 MMscm non-associated natural gas, representing 47.7% from OGIP, estimated at 111 MMscm non-associated natural gas.

From the last confirmation there were performed the following works:

- Restarting production for the well #1800 in September 2000 till April 2001, when it was sand plugged. It was repaired and produced from January 2004 till February 2007, when it was plugged again. In April 2007 the well was repaired and will be completed with prepacked gravel filter, the production data being as follows: gas flow rate = 2000 scm/d, choke $\Phi = 4$ mm, $p_{t/c} = 8/25$ bar.
- In the year 2005 it was carried out a 3D seismic panel, there were processed the seismic data and there were reinterpreted at the beginning of the year 2007 and also the seismic model was correlated with the well logs, which has conducted to the modification of the geological model.

Table 1
Main physical parameters

Reservoir parameter	Bgl (He) III a	Bgl (He) III b	Bgl (He) III c	Bgl (He) II a inf	Bgl (He) II a	Bgl (He) II b
Average depth, H_i (m)	1820	1695–1795	1420	1220	1065	1020
Average elevation, E_i (m)	370	370	370	370	370	370
Strata inclination, degrees	30	30	30	30	30	30
Initial pressure, p_i (bar)	173	161–171	135	116	101	97
Temperature, T_z (°C)	73	69–72	59	52	47	45
FLUIDS						
A. Oil properties						
Saturation pressure, p_s (bar)	–	–	–	–	–	–
Initial solution ratio, r_{si} (Stm ³ /m ³)	–	–	–	–	–	–
Formation volume factor at the initial pressure and reservoir temperature, B_o	–	–	–	–	–	–
Dynamic viscosity at the saturation pressure and reservoir temperature, μ_s (cP)	–	–	–	–	–	–
Dynamic viscosity in standard conditions, μ_{st} (cP)	–	–	–	–	–	–
Density in standard conditions, ρ (kg/m ³)	–	–	–	–	–	–
Oil molecular mass, M.A.U.	–	–	–	–	–	–
Oil type	–	–	–	–	–	–
Congelation point, (°C)	–	–	–	–	–	–
B. Reservoir water properties						
Composition						
a. $\text{Ca}(\text{HCO}_3)_2$, (mg/l)	227–616	162–470	–	–	–	–
b. CaSO_4 , (mg/l)	8–1135	30–105	–	–	–	–
a. CaCl_2 , (mg/l)	9000	8400	–	–	–	–
Salinity, (kg/10 000 kg)	935	770	1220	–	1220	125
Type	CaCl_2	CaCl_2	CaCl_2	CaCl_2	CaCl_2	CaCl_2
C. Natural gas properties						
Methane, (%) content	94,98	94,9–95,6	92,1	–	92,48	93,86
Ehtane, (%)	3,38	3,35–2,65	4,18	–	4,55	4,07
Propane, (%)	1,02	0,89–0,94	1,03	–	1,25	1,1
C_4+ , (%)	–	–	–	–	–	–
Relative density, δ	0,591	0,593	0,635	–	0,619	0,601
Formation volume factor at the initial pressure and reservoir temperature, B_g	0,0061	0,0062–0,0064	0,0073	0,0083	0,0094	0,0097

Table 1 cont.

D. Reservoir rock						
Porosity, Φ (%)	10	10	10	28	28	28
Horizontal absolute permeability, k_o (md)	1,12	15,84	4,6	1174,8	469	132,2
Vertical absolute permeability, k_v (md)	1,12	14,06	1,65	1174,8	446,8	132,2
Lithology	nisipuri	nisipuri	nisipuri	nisipuri	nisipuri	nisipuri
E. Rock-fluids system						
Connate water saturation, S_{ai} (%)	45	45	45	18	18	18
Oil residual saturation at water flush, S_{ri} (%)	–	–	–	–	–	–
Oil effective permeability, k_{ef} (mD)	–	–	–	–	–	–
Skin factor	–	–	–	–	–	–
Total compressibility, c_t (1/bar)	–	–	–	–	–	–
Net pay, h_{ef} (m)	1	1,5–1,6	5,4	1,7	6,5	3,8
Net pay / overall thickness	–	–	–	–	–	–

It was established a workover for the well #2235 in the year 2007, in order to verify the technical status and eventually to verify and exploit the probable reserves from Bdg (He) IIb, block II. The reservoirs production status is presented in Table 2.

Table 2
Production indicators

Indicators, M.U.	Reservoirs						Total
	Bdg (He) IIIa	Bdg (He) IIIb	Bdg (He) IIIc	Bdg (He) IIa inf	Bdg (He) IIa	Bdg (He) IIb	
1. Production wells	1	2	1	1	1	1	3
2. Waterflooding wells	–	–	–	–	–	–	–
3. Working wells							
3.a. extraction	–	–	–	–	–	1	1
3.b. waterflooding	–	–	–	–	–	–	–
4. Liquid flow rates, cm/reservoir							
4.a. per reservoir	–	–	–	–	–	–	–
4.b. per average well	–	–	–	–	–	–	–
5. Associated gas flow rates, scm/reservoir							
5.a. per reservoir, Mscm/d	–	–	–	–	–	–	–
5.b. per well, Mscm/d/well	–	–	–	–	–	–	–
6. Non-associated natural gas flow rates, scm/reservoir:							
6.a. per reservoir, Mscm/d	–	–	–	–	–	2	2
6.b. per well, Mscm/d/well	–	–	–	–	–	2	2

Table 2 cont.

Indicators, M.U.	Reservoirs						Total
	Bdg (He) IIIa	Bdg (He) IIIb	Bdg (He) IIIc	Bdg (He) IIa inf	Bdg (He) IIa	Bdg (He) IIb	
7. Oil flow rate, t/reservoir:							
7.a. per reservoir	–	–	–	–	–	–	–
7.b. per average well	–	–	–	–	–	–	–
8. Gas oil ratio	–	–	–	–	–	–	–
9. Water cut, %	–	–	–	–	–	–	–
10. Cumulative productions per reservoir							
10.a. oil, Mtons	–	–	–	–	–	–	–
10.b. associated gas, MMscm	–	–	–	–	–	–	–
10.c. non-associated natural gas, MMscm	1	3	4	1	24	20	53
11. Injection flow rates							
11.a. water, cm/d/reservoir	–	–	–	–	–	–	–
11.b. water, cm/d/well	–	–	–	–	–	–	–
12. Cumulative injected fluids per reservoir							
12.a. water, Mcm	–	–	–	–	–	–	–
12.b. water, per pore volume, %	–	–	–	–	–	–	–
13. Reservoir waterflooding replacement factor							
13.a. current	–	–	–	–	–	–	–
13.b. cumulative	–	–	–	–	–	–	–
14. Injection pressure, bar	–	–	–	–	–	–	–
15. Starting data / ending data							
15.a. production	1988/ 1988	1986/ 1989	1987/ 1992	1989	1987/ 1993	1991/ present	1986/ present
15.b. waterflooding	–	–	–	–	–	–	–
16. OOIP, 10 ³ t/d	–	–	–	–	–	–	–
17. OGIP associated natural gas, MMscm	–	–	–	–	–	–	–
18. OGIP non-associated natural gas, MMscm	2	11	5	14	43	36	111
19. Present recovery factor, %							
19.a. oil	–	–	–	–	–	–	–
19.b. associated natural gas	–	–	–	–	–	–	–
19.c. non-associated natural gas	50	27.2	20	7.1	55.8	55.5	47.7
20. Present reservoir pressure, bar	–	–	–	–	–	26	

3. ANALYSIS AND EVALUATION METHODS

Due to 3D seismic data reinterpretation at the beginning of the year 2007, came out the necessity of the modification of the geological model from the previous study with reference date 01.01.2005. In the year 2005 the 3D seismic data reinterpretation was finalized as tectonic model only.

In the present study, the reflecting horizons from the time seismic cross-sections were converted in depth and then were correlated with the horizons detected in the well logs, as correlation at Burdigalian (Helvetian) level is often difficult.

For the geological model completion it was used information from the tectonic model detected on the seismic cross-sections: faults *F1*, *F2*, *F3* and *F4*. The fault *F3* was interpreted even through the well #2235.

The new reservoir model for the field is based on:

- Burdigalian (Helvetian) horizons re-correlation, in accordance with the reflecting horizons from the seismic cross-sections,
- New faults detection from the seismic profiles or through the wells,
- New reservoirs identifying and fluids contacts settlement,
- Average reservoir depths, initial reservoir pressures, reservoir temperatures and reservoir Z deviation factors recalculation,
- Reservoir rock (porosity) and reservoir rock-fluids system (connate water saturation) physical parameters verifying.

OGIP for non-associated natural gas was estimated through the volumetric method.

It was reanalysed the wells production history of the field, reaching to the following proposals in order to restart production:

- Restart production at the well #1800 at Bdg (He) II b, block II (developed proved reserves), in April 2007 and completion with prepacked gravel filter,
- Check the technical status of the well #2235 and if it is successfully, restart production at Bdg (He) II a, block II (no reserves, because of the high risk) and then perforating of the upper horizon Bdg (He) II b, block II (probable reserves).

The production predictions were performed per well, per reservoir and per total field.

It is pursued to restart production in order to exploit the proved reserves and to promote the lower level reserves.

In the general concept design there were used the following working items:

- 330 producing days per year;
- 1000 scm non-associated natural gas/d/well was accepted as abandonment technical limit flow rate;
- The line collecting pressure is 3 bar;
- The wells production will be performed in normal conditions, without early ending production because of technical reasons.

4. STUDY RESULTS

OGIP was recalculated regarding the previous study and the difference between them and the confirmed value is 14 MMscm non-associated natural gas (14.4%).

The initial proved reserves calculated in the study are 55 MMscm non-associated natural gas, higher with 8 MMscm (14.5%) than the confirmed ones.

The probable reserves proposed in the study are 3 MMscm non-associated natural gas, related to the workover proposed in the well #2235 at Bdg (He) II b, block II, in order to verify and eventually to exploit them.

The probable reserves proposed in the study decreased with 3 MMscm non-associated natural gas, regarding the last confirmation, due to reanalyzing the possibilities of coming back to the well #2225 (technically damaged – blade lost in the borehole).

5. CONCLUSIONS AND PROPOSALS

The non-associated natural gas reservoirs exploitation from the field started in the year 1986. There were drilled 12 wells and among them only 3 wells produced (#2235, #2225 and #1800). Till the reference date of the study, 01.01.2007, there were extracted 53 MMscm non-associated natural gas, representing circa 47.7% from OGIP of non-associated natural gas, estimated at 111 MMscm.

Based on production history analysis it was carried out a single option in order to continue the exploitation of the field:

- **Option 1** – the well #1800 producing at Bdg (He) II b, block II, from April 2007 and completion with prepacked gravel filter.

The present proved developed reserves calculated in the study are 2 MMscm non-associated natural gas and will be exploited through the well #1800.

The probable reserves proposed in the study are 3 MMscm non-associated natural gas, related to the workover proposed in the well #2235 at Bdg (He) II b, block II, in order to verify and eventually to exploit them.

The economical analysis shows that Option 1 with restarting production for the well #1800 at Bdg (He) II b, block II is profitable till the year 2011, with NPV@5% of 21 000 Euro, NPV@11% of 25 000 Euro and NPV@15% of 27 000 Euro and is assured an existent proved developed reserve of 2 MMscm non-associated natural gas.

The existent non-associated natural gas reserves at 01.01.2007 are:

- proved developed reserves 2 MMscm;
- probable reserves 3 MMscm.

REFERENCES

- [1] **Grigoraş I.D.**, Grigoraş G. ş.a.: *Studiu de fezabilitate a exploatării şi evaluare a potenţialului tehnologiilor alternative de exploatare (IOR şi EOR) pentru un zăcământ comercial. ADDECO S.R.L., Ploieşti, aprilie 2007*

- [2] Paraschiv D.: *Geologia zăcămintelor de hidrocarburi din România*. București, 1975
- [3] Mutihac V.: *Structura geologică a teritoriului României*. Editura Tehnică, București 1990
- [5] Beca C., Prodan D.: *Geologia zăcămintelor de hidrocarburi*. Editura Didactică și Pedagogică, București 1983
- [6] Bradley H.B.: *Petroleum Engineering Handbook*. S.P.E., Richardson, Texas, USA, 1987
- [7] Cârcoană A., Aldea Gh.: *Mărirea factorului final de recuperare la zăcămintele de hidrocarburi*. Editura Tehnică, București 1976
- [8] Crețu I.: *Hidraulica zăcămintelor de hidrocarburi*. Editura Tehnică, București 1987
- [9] Crețu I., Ionescu E.M., Stoicescu M.: *Hidraulica zăcămintelor de hidrocarburi. Aplicații numerice în exploatarea primară*. Editura Tehnică, București 1993
- [10] Crețu I., Ionescu E.M., **Grigoraș I.D.**: *Hidraulica zăcămintelor de hidrocarburi. Aplicații numerice în recuperarea secundară și terțiară a petrolului*. Editura Tehnică, București 1996
- [11] **Grigoraș I.D.**: *Depozitarea fluidelor*. Editura Universității din Ploiești, 2002
- [12] **Grigoraș I.D.**, Crețu I.: *Reserves Estimation Methodology*. "Petroleum-Gas" University of Ploiești, for *AMOCO CORPORATION*, 1996
- [13] **Grigoraș I.D.**, Crețu I.: *Applied Reserves Estimation Methodology*. "Petroleum-Gas" University of Ploiești, for *AMOCO CORPORATION*, 1996
- [14] Lee J., Wattenbarger R.A.: *Gas Reservoir Engineering*. Richardson, TX, 1996
- [15] McCray A.W.: *Petroleum Evaluations and Economic Decisions*. Prentice Hall Inc., Englewood Cliffs, New Jersey 1975
- [16] Pușcoiu N.: *Extracția gazelor naturale*. Editura Tehnică, București 1986
- [17] Smith R.V.: *Practical Natural Gas Engineering*. PennWell Publishing Company, Tulsa, Oklahoma, 1990
- [18] Soare Al. et al.: *Ingineria zăcămintelor de hidrocarburi*. Editura Tehnică, București 1981
- [19] Svoronos P., Oltean I.: *Proiectarea exploatării zăcămintelor de gaze*. Editura Tehnică, București 1979
- [20] Vernescu Al.: *Mecanica zăcămintelor petrolifere*. Editura Tehnică, București 1966
- [21] *** "Pachet de programe pentru industria petrolieră. Manual de utilizare", **ADDECO S.R.L.**, Ploiești, 1992–1993