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REHABILITATION ANALYSIS OF A NATURAL GAS FIELD FROM THE TRANSYLVANIAN DEPRESSION

1. PAPER TARGETS

The paper has the following objectives:

- Physical-geological and production data analysis.
- Natural gas resources estimation using statistical and material balance methods.
- Production history analysis.
- Production problems identification.
- Rehabilitation possibilities recommendation.

2. RESERVOIR PROPERTIES AND PRODUCTION STATUS

From the geological point of view the structure is situated in the central part of the Transylvanian Depression.

There were discovered natural gas accumulations in Jurassic, Cretaceous and Miocene, in Badenian XII, Buglovian XI, X, int. (IX–X), IX, VIII, VII and Sarmatian VI, V, IV, III, II, I and superficial.

The production started in the year 1913 and till now there were extracted 99 000 MMscm of natural gas, representing 78.6% from OGIP, estimated at 126 000 MMscm of natural gas, which indicates the advanced status of the field exploitation.

There were drilled 332 wells and there are still producing 269 wells and among them 11 wells are producing through tubing and casing together.

The producing horizons were not exploited separately and are grouped in 8 main reservoirs: Sa superficial, Sa I+II, Sa III, Sa IV, Sa V+VI, Bg VII, Bg VIII+IX, Bg (IX-X)+X+XI+XII.

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

The gas produced from the field wells (over 1580 Mscm/d) is collected at 24 well groups, where the natural gas is separated from water and measured.

The field produced over 90 years with a cumulative of 99 000 MMscm of natural gas, with an average well production of about 300 MMscm and the higher well productions where obtained from the reservoirs Sa III (800 MMscm) and Sa IV (580 MMscm) and the smaller from Sa superficial (14 MMscm).

The present well flow rates are between 200 and 23 000 scm/d, the produced water is 1-350 l/d and the pressure after surface choke is between 2 and 16 bar.

3. THE PHYSICAL PARAMETERS

There were collected 736 cores from 48 wells and there were performed lab analysis in order to determinate the permeability, porosity, specific gravity, salt content.

In this paper the porosity and the natural gas saturation were estimated from statistical methods applied on core analysis (Tab. 1).

Table 1

The reservoir parameters values determined from core analysis

Reservoir parameter	Sa superf.	Sa I+II	Sa III	Sa IV	Sa V+VI	Bg VII	Bg VIII+IX	Bg (IX–X)+X+XI+XII sup
Porosity [%]	8	23	8	15	8	15	9	8
Initial gas saturation [%]	73	81	83	70	88	86	80	83
Permeability [md]	11	29	129	482	1	4	1	0.3

The Table 1 shows that the reservoirs Sa III and Sa IV have the biggest permeabilities.

There were drawn isoporosity, gas isosaturation and isopermeability maps for the main reservoirs, in order to underline the physical parameters distribution in the producing areas and for correlations between the wells productivity and the physical parameters.

The maps are more conclusive as more data are acquired: for the reservoir Bg (IX–X)+X+XI+XII are highlighted two areas with higher porosities and gas saturations, in the central-Western and Eastern parts of the field, which are the best producing areas (Figs 1–3).

4. GEOLOGICAL RESOURCES ESTIMATION

The primary data used for the reservoir model are: the well logs, core, fluids and pressure data analysis and wells workover results.

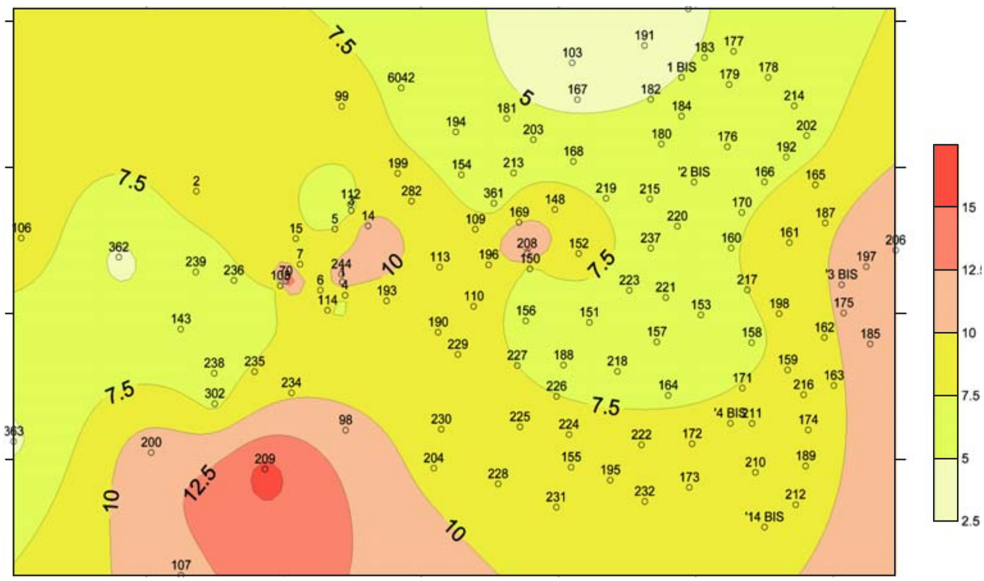

Fig. 1. Isoporosity map at Bg (IX–X)+X+XI+XII

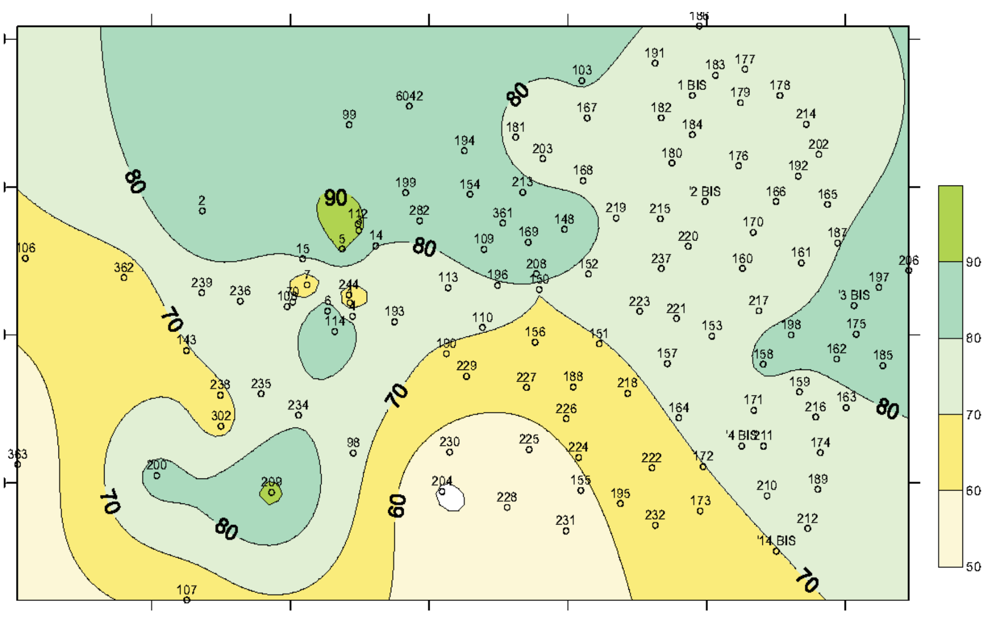

Fig. 2. Gas isosaturation map at Bg (IX-X)+X+XI+XII

The main uncertainties in natural gas resources estimation are related to the physical (porosity, initial gas saturation) and geometrical parameters (reservoir area and net pay).

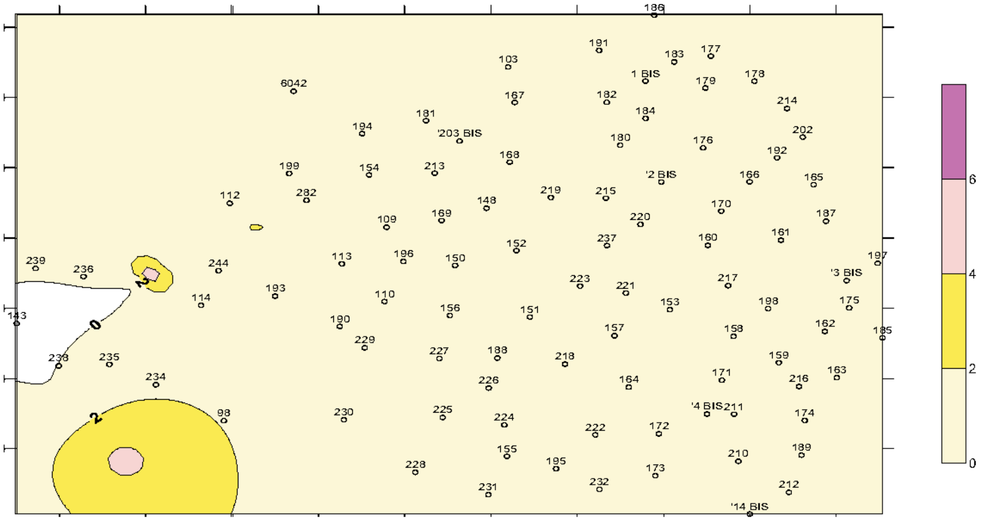

Fig. 3. Isopermeability map at Bg (IX-X)+X+XI+XII

In the previous studies the resources were estimated through the volumetric method for the reservoirs: Sa superficial and Bg (IX–X), Bg X, Bg XI, Bg XII sup and Bg XII inf only. For the reservoirs with higher production history it was used also the material balance method. It was observed a good correlation between the cumulatives and the resources estimated through the material balance method, showing the advanced depletion of the field.

The available data regarding porosity and gas saturation from core analysis (736 cores from 48 wells) allowed the natural gas resources estimation check through a statistical method.

For the statistical interpretation it was used the Latin Hypercube method, which is an improved Monte Carlo method, regarding iterations number, simulation and convergence speed and natural gas resource probability distribution shape also.

For this purpose it was used the software package @Risk, in order to simulate the input parameters: producing area (uniform distribution), net pay (triangular distribution), porosity (lognormal distribution), gas saturation (normal distribution) and gas volume factor (triangular distribution),the histograms and the probabilistic distributions and finally the output parameter (lognormal distribution): the natural gas resource (Fig. 4).

The probabilistic simulation for natural gas resource estimation conducted to the most probable value of 127 MMscm, compared to the result obtained through the volumetric method: 126 MMscm (0.8% difference).

On the other hand it should be underlined that either the volumetric or the material balance method do not offer an evaluation of the confidence range for the determined value and only a probabilistic model can evaluate the risk assumed for the resource value.

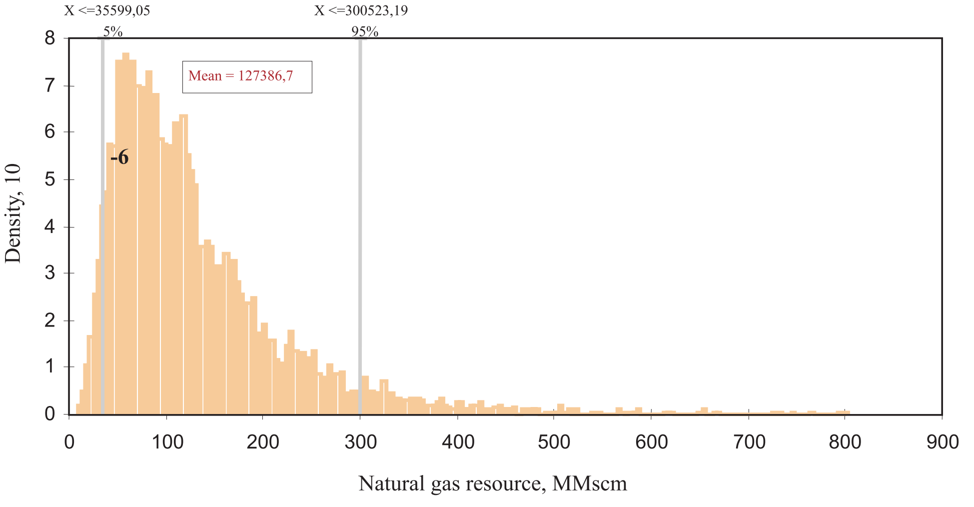

Fig. 4. Latin Hypercube natural gas resource distribution

5. RESERVOIR DEVELOPMENT AND REHABILITATION POSSIBILITIES

The field wells production analysis consisted in:

– Production history update.
– Natural gas production decline and water cut variation building for each well.
– Isocumulative, isoflow-rate, isoimpurity and isobar maps created for each producing reservoir (Figs 5–8).
– The well production analysis mode and foam treatment analysis.

The problems identified in the present production status are as following:

– The stratum perforation mode on large thickness (even over 500 m), conducted to gas flow behind production casing and strata communication (with different reservoir pressures).
– The field has an advanced depletion more accentuated in the central part of the structure and diminished on the wings.
– The collecting pressures vary from 2 till 16 bar, depending on the aspiration and consuming directions.
– Due to the low field energy most of the wells accumulate water during production;
– Plenty wells from the reservoir Bg (IX–X)+X+XI+XII produce large quantities of water and mud.
– There are wells which have the tubing plugged and have a bad production or are stopped.
– There are wells which produce low flow rates because are marginal, are situated in depleted areas or they are flooded.

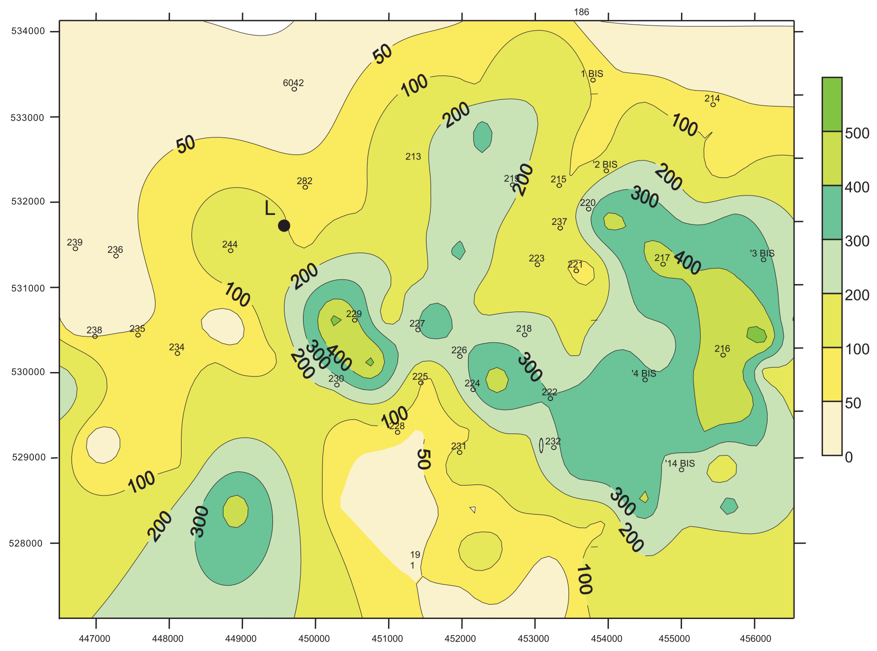

Fig. 5. Isocumulative map at Bg (IX–X)+X+XI+XII

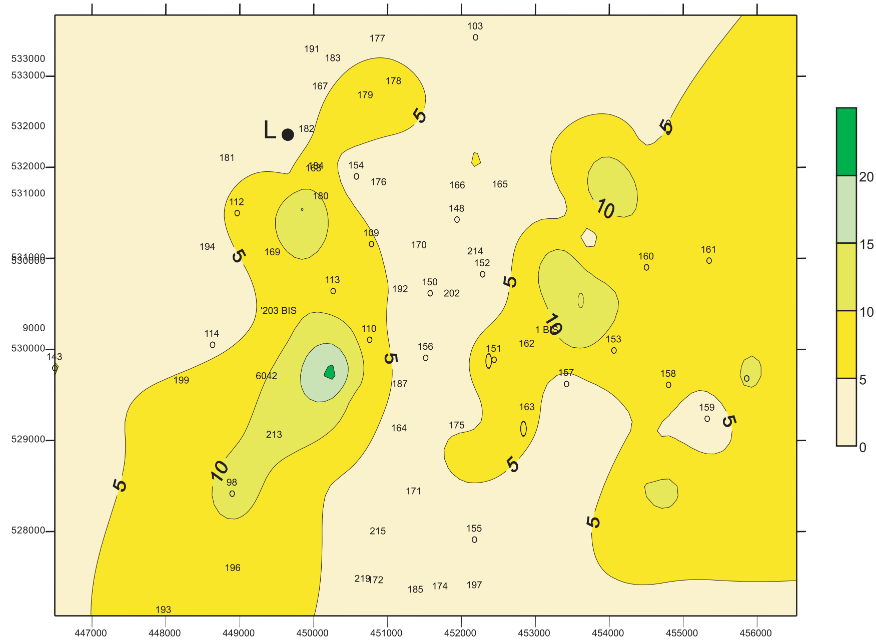

Fig. 6. Isoflow-rate map at Bg (IX–X)+X+XI+XII

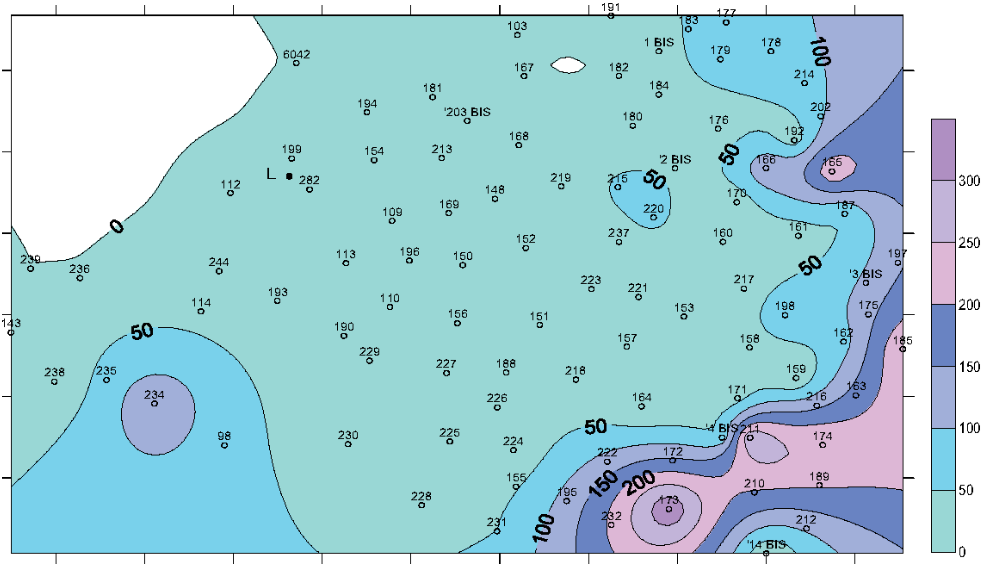

Fig. 7. Isoimpurity map at Bg (IX–X)+X+XI+XII

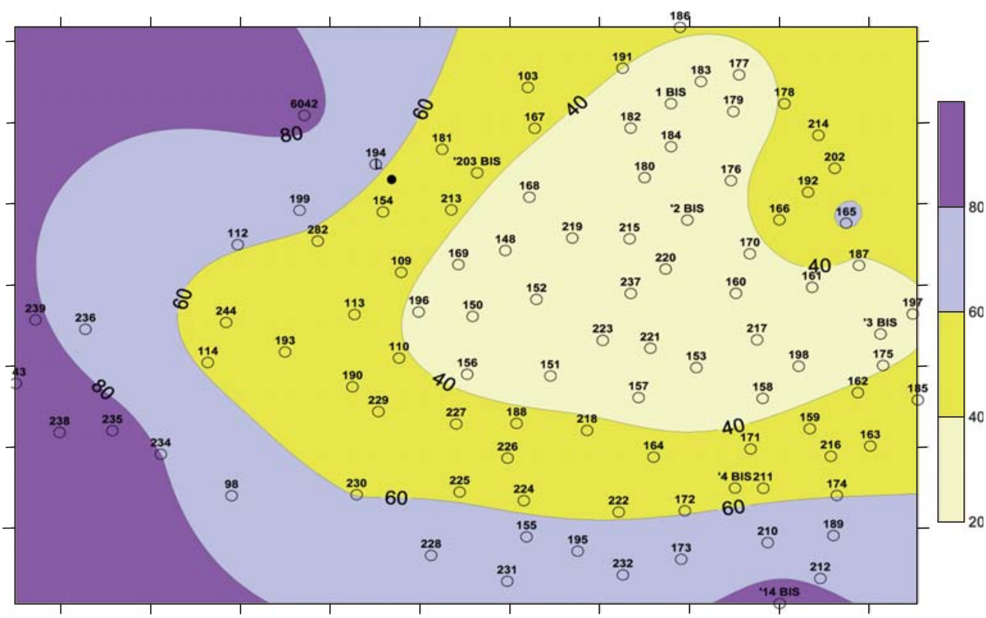

Fig. 8. Isobar map at Bg (IX–X)+X+XI+XII

In order to rehabilitate the field there are proposed:

- Production monitoring through build up pressure analysis in each producing well, every year.
- Cased hole investigations in order to determinate the present hydrocarbon saturations.
- Wells with very low flow rate workover (under 1000 scm/d):
  - retire to upper reservoirs,
  - lower strata isolation and retire to upper strata of the same reservoir,
  - tubing unplugging.
- Plunger-lift completion for the wells from Bg (IX–X)+X+XI+XII which are producing over 100 l/d water and have the flow rate higher than 5000 scm/d.
- Foam treatment in the other wells which accumulate water.
- Fulfillment of a specific study in order to analyze the natural gas collection.
- Infill drilling analysis.

6. PRODUCTION PREDICTION

Production prediction was performed taking into consideration the following:

- physical properties (natural gas composition, porosity, permeability, initial gas saturation, resource volume, initial pressure, reservoir temperature etc.);
- reservoir pressure over deviation factor versus gas cumulative variation;
- field hydrocarbon displacement mechanism;
- natural production decline;
- natural gas flow from the stratum till the borehole;
- natural gas flow through tubing;
- natural gas flow through surface pipelines.

Production prediction was performed for 32 low productivity wells and it was analyzed the opportunity of drilling a new well.

7. FINAL RESULTS

Based on production history there were performed 2 options for production continuation and infill drilling option, which were analyzed through Discount Cash-Flow method, in $.

- Option A – with the present wells, till the pressure after surface choke of 2.5–6.5 bar.
- Option B – with the present wells, workover in 32 wells and investments:
  - retire to upper reservoirs, lower strata isolation and retire to upper strata of the same reservoir, in 25 wells;
  - tubing unplugging in 7 wells;
  - investments for plunger-lift completion in 8 wells from Bg (IX–X)+X+XI+XII which are producing over 100 l/d water and have the flow rate higher than 5000 scm/d.
- Option C – drilling a new well analysis at the reservoir Bg (IX–X)+X+XI+XII.

8. CONCLUSIONS AND PROPOSALS

Due to the advanced depletion of the reservoirs, the high investment for drilling a new well (1 500 000 $), the long pay out time, the rather small extra production (32 MMscm) and a net present value of 514 M$ only till reaching the economic limit (year 2030), it is not recommended to drill a new well.

It is proposed to continue the natural gas exploitation through Option B.

The economical analysis shows that it is obtained a net present value of 15 MM$ till reaching the economic limit (year 2027), higher with 13 MM$ than Option A and an extra production of 391 MMscm of natural gas.

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