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REHABILITATION ANALYSIS OF A PETROLEUM RESERVOIR FROM THE MOESIAN PLATFORM

1. WORK TARGETS

- geological model review;
- production history evaluation;
- recovery mechanism evaluation;
- resources re-evaluation;
- workovers proposal, new wells analysis, production prediction;
- discounted cash flow analysis;
- reserves re-evaluation.

2. GEOLOGICAL MODEL REVIEW

2.1. Regional geology (Fig. 1)

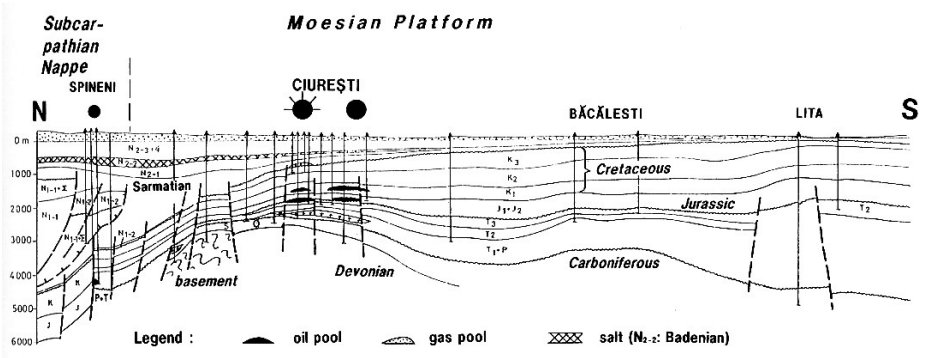

Fig. 1

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The *Moesian Platform sedimentation* is characterized by 4 cycles, separated by stratigrafic unconformities: Cambrian-Westfalian, Late Permian-Triassic, Dogger-Cretacic and Badenian-Pleistocen.

The *Moesian Platform tectonic* is extensional, characterized by 2 faulting systems: first one oriented East-West, which is parallel with the Carpathian Overthrust and the other one, oriented North-South, is crossing the first one. The Moesian platform is represented by a general monocline (with some gently folded shapes) sinking towards Carpathian Orogene and going up towards South.

The *Moesian Platform source rocks* are: Silurian shales, Early-Middle Devonian shales, Middle-Late Devonian carbonates, Middle Carbonifer shales, Middle Triassic carbonates, Liasic-Dogger siltstones and shales, Late Badenian shales.

The *Moesian Platform reservoir rocks* are: Middle-Late Devonian carbonates, Ordovician sandstones, Permo-Triassic sandstones, Middle Triassic carbonates, Dogger sandstones, Malm, Neocomian, Turonian, Senonian, Barremian and Albian calcarenites, Early Sarmatian limestones, Meotian and Dacian sands.

2.2. Representative well log and productive horizons (Fig. 2)

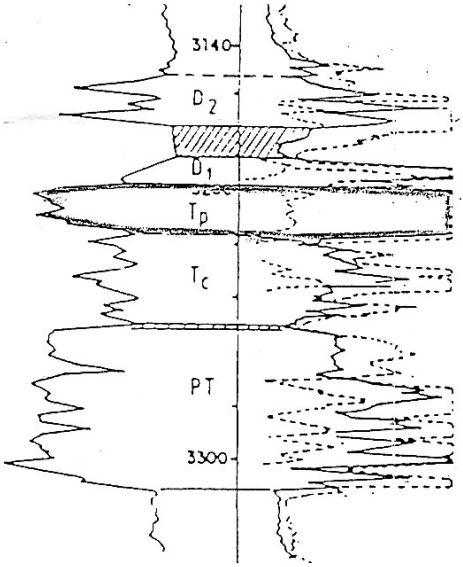

Fig. 2

Dogger 2 (D_2) horizon (represented by sandstones of 8–25 m thickness) has 5 oil and gas cap reservoirs in the blocks A+B, C, D, E and F.

Dogger 1 (D_1)horizon (represented by calcareous or siliceous sandstones of maximum 20 m thickness in the Western part of the structure and in the Northern part is not deposited) do not have hydrocarbon accumulations (it is not a continuous deposition, it overlaps only the lower areas of the Triassic).

Porous Triassic (T_p) (represented by fractured dolomites and limestones of 25–40 m thickness) has 5 oil and gas cap reservoirs in the blocks A+B, C, D, E and F.

Compact Triassic (T_c) horizon (represented by compact dolomites of 25–40 m thickness) has hydrocarbon accumulations in the block A and in the block B.

Permo-Triassic (PT) horizon (represented by sandstones of 50–90 m thickness) has 1 oil and gas cap reservoir in the block A.

2.3. Structural map: *Permo-Triassic* (Fig. 3)

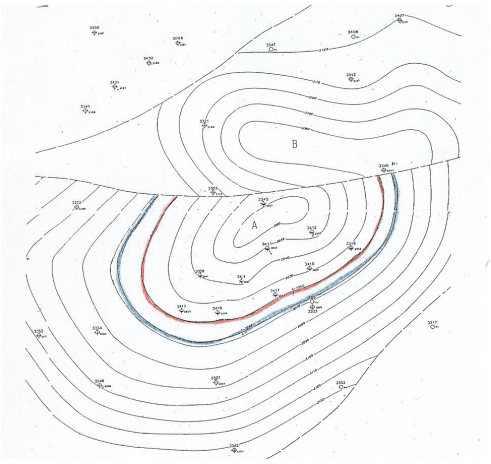

Fig. 3

The structure is represented by East-West anticlines, longitudinally faulted.

2.4. Structural map: *Triassic* (Fig. 4)

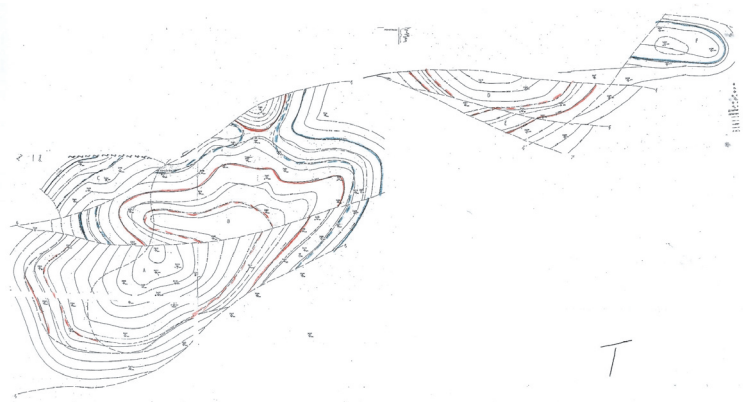

Fig. 4

The structure is represented by East-West anticlines, longitudinally faulted.

2.5. Structural map: *Dogger 2* (Fig. 5)

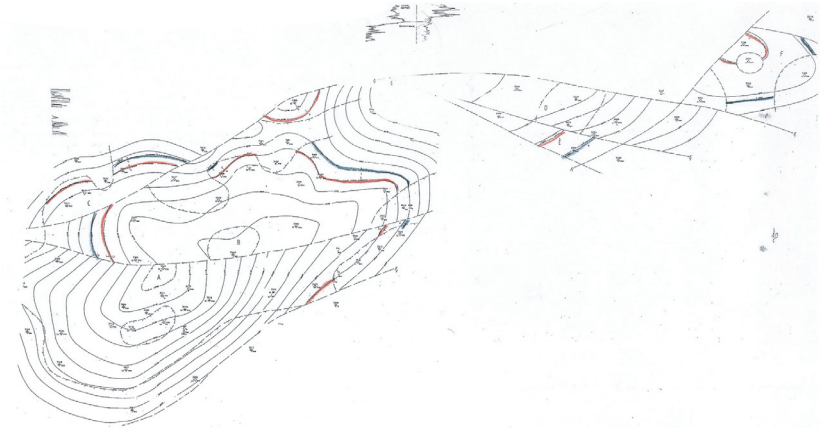

Fig. 5

The structure is represented by East-West anticlines, longitudinally faulted.

2.6. Cross section (N-S) (Fig. 6)

The structure is sinking towards Carpathian Orogene (North) and going up towards South.

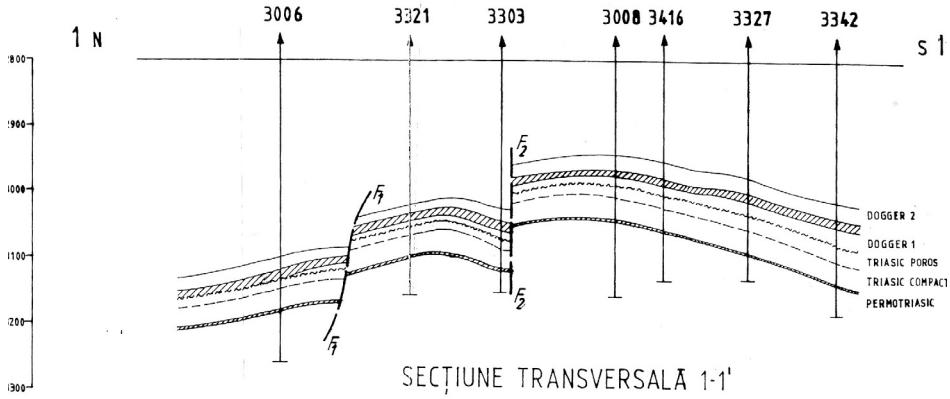

Fig. 6

2.7. Commentaries

The Permo-Triassic horizon was not tested in the wells situated in the upper part of the blocks B, C, D, E and F.

The compact areas from Triassic and Dogger could be revised.

Area of the well #3306 from the block B (only with condensate and non-associated gas in Triassic and Dogger) could be considered in other block (at North of fault F2).

Method used for resources estimation is volumetric.

Physical parameters has similar values for all reservoirs (maybe these can be revised depending on base analysis).

The geological model could be revised in accordance with seismic profiles.

3. PRODUCTION HISTORY

The accumulations were discovered in:

- Permo-Triassic in the year 1969, through the well #3008. The initial oil flow rate was 100 t/day, initial gas-oil ratio was 340 scm/cm.
- Triassic in the year 1967, through the well #P 20. The initial oil flow rate was 27 t/day, initial gas-oil ratio was 240 scm/cm.
- Dogger in the year 1968, through the well #3302. The initial oil flow rates were 15–50 t/day, initial gas-oil ratios were 200–800 scm/cm.

There were drilled 94 wells (among them 68 being exploration wells) and among them 54 wells produced an oil plus condensate cumulative of 1 092 987 tonnes and a gas cumulative of 3 233 586 Mscm (medium values are 20 240 tonnes/well and 59 881 Mscm/well):

- Permo-Triassic – 10 wells produced oil, condensate and gas, for oil plus condensate between 3726–41 880 tonnes/well, total 186 106 tonnes and for gas 6850–134 168 Mscm/well, total 509 187 Mscm (medium values are 18 600 tonnes/well and 50 900 Mscm/well).
- Triassic – 50 wells produced oil, condensate and gas, for oil plus condensate between 24–61 758 tonnes/well, total 713 821 tonnes and for gas 311–152 312 Mscm/well, total 1 787 175 MMscm (medium values are 14 270 tonnes/well and 35 740 Mscm/well).
- Dogger – 22 wells produced oil, condensate and gas, for oil plus condensate between 106–26 602 tonnes/well, total 193 059 tonnes and for gas 844–140 693 Mscm/well, total 937 224 MMscm (medium values are 8775 tonnes/well and 42 600 Mscm/well).

All the productive wells were drilled in 1969–1971 period.

From the year 1997 the exploitation was stopped:

- The fluid flow rates were low (0.1–0.2 t/day/well).
- The gas production was not recorded since the year 1994 (lack of measurement devices).
- During 1999–2005 period there were made some workovers in 5 wells: #3303, #3314, #3348, #3431 (technically damaged) and in the year 2002 for #3410 at Dogger with initial result of 5 cm x 85% = 0.6 t/day of condensate (beam pumping) and after acid stimulation the well was flooded (some gas flow).

4. PRODUCTION HISTORY COMMENTARIES

Oil elastic drive, dissolved gas drive, (water drive) at Permo-Triassic and Triassic + elastic gas expansion for the gas cap reservoirs.

The wells entered eruptive into production, eruption period being 1–10 years and after that the exploitation continued in gas-lift.

The reservoir energy decreased quickly because of gas cap exploitation in the same time with oil.

It is difficult to estimate the actual reservoir pressure because the last pressures measurements were performed in 1976 for Permo-Triassic, or there are different pressure values in the same reservoir (Dogger).

The watercut values are different in the same period and in the same reservoir (Permo-Triassic: 9–99%, Triassic: 40–99%, Dogger: 40–99%), that means the wells were flooded because of the local waterflooding or technical damages.

The productivity decreased due to condensate around the well hole.

The majority of the wells were technically damaged because of the corrosion (CO_2 content is over 2%) and crusts.

In 1970–1983 period were conducted some water injection experiments through 4 wells (#3312, #3406, #3408, #3417) in Triassic, blocks A+B. There were injected 50–150 cm/day/well at surface pressures between 40–67 bar. There were injected 130 400 cm of water through the well #3312 (in the gas cap) in 1970–1972 period, there were injected 149 000 cm of water through the well #3406 in 1976–1983 period, there were injected 110 000 cm of water through the well #3408 in 1971–1978 period, there were injected 267 400 cm of water through the well #3417 (in the gas cap) in 1976–1983 period. It was no supplementary production associated with water injection experiment.

The production at Permo-Triassic is finished practically since 1976, because after that period produced only the well #3345 small quantities of condensate and gas.

The production at Triassic is finished practically since 1982–1983, because after that period produced only the well #3303 small quantities of oil, condensate and gas.

The production at Dogger is finished practically since 1982–1986, because after that period produced only 2 wells (#3311 and #3407) small quantities of condensate and gas.

The actual recovery factor for oil is relatively small (12–14%).

During exploitation, there were performed 23 stimulation operations (21 acid and 2 fracturing) and among them 13 had flow rate increase result or differential pressure decrease.

During 2000–2003 period there were tried workovers in 4 wells (#3410 at Permo-Triassic, #3303 and #3314 at Triassic and #3431 at Dogger), but with no success because of casing damage.

After 1993 the wells produced in tanks and the production was transported at a tank farm. The residual water was separated in the field and transported by a 5 in x 15 km pipeline to another tank farm. Since 1997 there are no producing wells in the field.

5. EXPLOITATION PERSPECTIVES

There were identified the actual oil and gas saturated areas (based on production available data, physical parameters maps, production maps, static pressures measurements).

There were proposed 2 new exploitation vertical wells in the blocks A and B (because the majority of the existent wells are damaged and that is why workover or re-entry is uncertain).

In the *block A* it was proposed a vertical well L1 for Permo-Triassic – the thickness for oil is only 8 m and for the gas cap is 40 m. In this area the reservoir parameters are good (oil saturation is 72%, porosity is 12% and permeability is 50 md), the neighbour wells #3008 and

#3345 had good initial flow rates (21–100 t/day oil and 100–110 Mscm/day gas) and there were obtained important cumulative of oil and condensate (40 000 tonnes/well) and gas (85–130 MMscm/well). The distance between the other wells is 400–500 m. This area is not exploited since 1974–1978 and probably the fluid saturation was re-established. The actual static pressure is 250 bar (in the year 1976). The oil recovery mechanism is dissolved gas expansion with water drive. The initial flow rates for L1 were estimated as 32 t/day for oil and condensate and 30 Mscm/day for gas and the predicted cumulative is 36 Mtonnes oil and condensate and 41 MMscm gas.

In the *block B* it was proposed a vertical well L2 for Triassic – the thickness for oil is 40 m and for the gas cap is 20 m. In this area the reservoir parameters are good (oil saturation is 75%, porosity is 12% and permeability is only 4 md), the neighbour wells #3301 and #3405 had good initial flow rates (40–60 t/day oil and 50–180 Mscm/day gas) and there were obtained important cumulative of oil and condensate (40 000 tonnes/well) and gas (60–150 MMscm/well). The distance between the other wells is 600–700 m. This area is not exploited since 1976–1978 and probably the fluid saturation was re-established. The actual static pressure in the area is 230 bar (in the year 1980). The oil recovery mechanism is dissolved gas expansion with water drive. The initial flow rates for L2 were estimated as 26 t/day oil and condensate and 24 Mscm/day gas and the predicted cumulative is 32 Mtonnes oil and condensate and 38 MMscm gas.

L1 will have as secondary target Triassic and Dogger and L2 will have as secondary target Dogger (there were estimated probable reserves because the time then will be exploited is uncertain).

6. FIELD DEVELOPMENT PLAN

Drilling a vertical oil & gas production well L1 in the block A at Permo-Triassic horizon (undeveloped proved reserves) as main target, during the year 2008 and at Triassic and Dogger horizons as secondary target (probable reserves).

- depth = 3300 m (vertically);
- reserves to be exploited from the year 2009.

Drilling a vertical oil & gas production well L2 in the block B at Triassic horizon (undeveloped proved reserves) as main target, during the year 2009 and at Dogger horizon as secondary target (probable reserves).

- depth = 3300 m (vertically);
- reserves to be exploited from the year 2010.

Depending on the results of the wells L1 and L2 a program will be developed for full field development. This is likely to require individual development of the main reservoir targets with the development of a *pattern waterflooding using horizontal wells* (probable reserves). *Field facilities*:

- 10 km gas pipeline till the main pipeline;
- three-phase separator + tank;
- old well conversion to residual water injection well;
- recovery and treating condensate plant;
- gas desiccation plant.

REFERENCES

[1] Grigoraş I.D., Grigoraş, G. ş.a.: *Studiu de prefezabilitate pentru estimarea resurselor şi rezervelor de hidrocarburi.* ADDECO S.R.L., Ploieşti, AURELIAN OIL & GAS, februarie 2008

[2] A.N.R.M.: *Pachet de date generale.* Apel public de ofertă pentru concesionarea a 26 de perimetre de exploatare petrolieră, Runda a VIII-a, Bucureşti, 2007

[3] Mutihac V.: *Structura geologică a teritoriului României.* Editura Tehnică, Bucureşti, 1990

[4] Kulke H.: *Regional Petroleum Geology of the World, Part I: Europe and Asia.* Gebrüder Borntraeger, Berlin, Stuttgart, 1994

[5] Cârcoană A., Aldea Gh.: *Mărirea factorului final de recuperare la zăcămintele de hidrocarburi.* Editura Tehnică, Bucureşti 1976

[6] Crețu I., Ionescu E.M., Stoicescu M.: *Hidraulica zăcămintelor de hidrocarburi. Aplicații numerice în exploatarea primară.* Editura Tehnică, Bucureşti, 1993

[7] Crețu I., Ionescu M., Grigoraş I.D.: *Hidraulica zăcămintelor de hidrocarburi. Aplicații numerice în recuperarea secundară şi terțiară a petrolului.* Editura Tehnică, Bucureşti, 1996

[8] Grigoraş I.D.: *Depozitarea fluidelor.* Editura Universității din Ploieşti, 2002

[9] Grigoraş I.D., Crețu I.: *Reserves Estimation Methodology.* ”Petroleum-Gas” University of Ploieşti, for AMOCO CORPORATION, 1996

[10] Grigoraş I.D., Crețu I.: *Applied Reserves Estimation Methodology.* ”Petroleum--Gas” University of Ploieşti, for AMOCO CORPORATION, 1996.

[11] Svoronos P., Oltean I.: *Proiectarea exploatării zăcămintelor de gaze.* Editura Tehnică, Bucureşti, 1979

[12] Puşcoiu N.: *Extracția gazelor naturale.* Editura Tehnică, Bucureşti, 1986

[13] Lee J., Wattenbarger R.A.: *Gas Reservoir Engineering*. Richardson, TX, 1996

[14] Smith R.V.: *Practical Natural Gas Engineering.* PennWell Publishing Company, Tulsa, Oklahoma, 1990

[15] Al-Hussainy R., Ramey H.J.Jr., Crawford P.B.: *The Flow of Real Gases Through Porous Media*. J.P.T., May 1966, p. 624–635

[16] Addeco S.R.L.: *Pachet de programe pentru industria petrolieră.* Manual de utilizare”, Ploieşti, 1992–1993