Lessons Learned from Romgaz experience during Fracturing Campaign in Transylvanian Basin

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Agenda

1. Introduction
2. Fracturing campaign program workflow
3. Criteria for candidate selection
4. Wells performance before and after frac operation
5. Case study
6. Lessons learned
7. Conclusions

Introduction

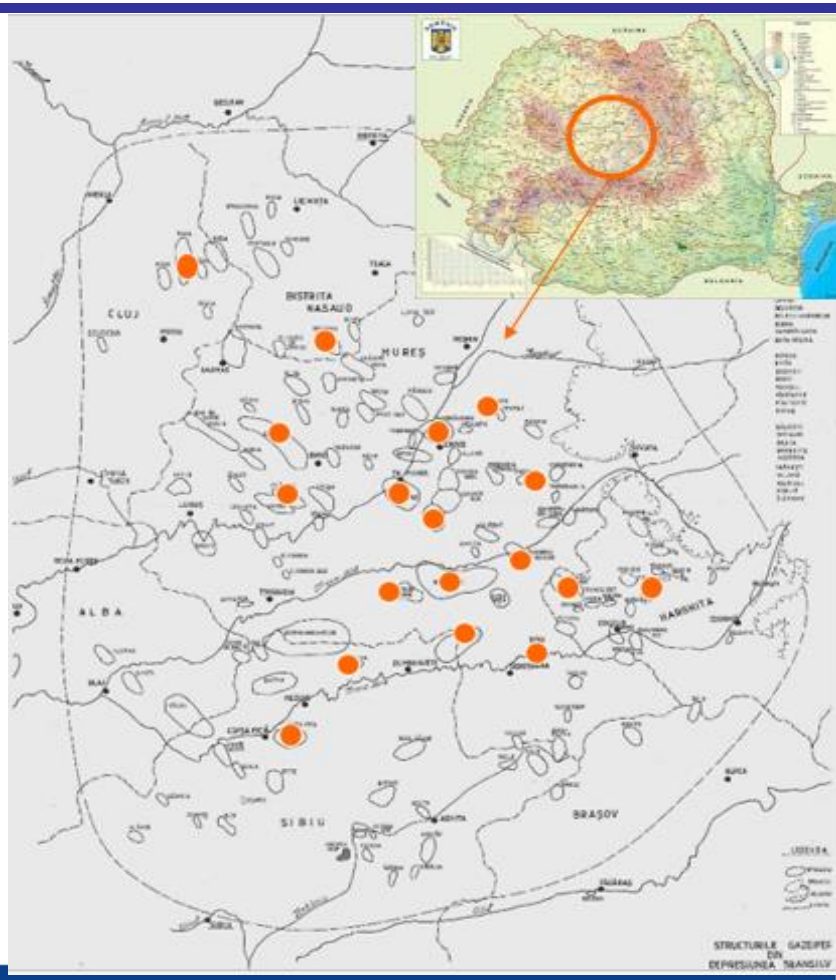
Romgaz company included in own strategy (short and medium term) a Testing, Research and Complex Analysis Program to use the fracturing technology.

Fracturing campaign in Transylvanian Basin :

- 8 complete frac jobs
- 11 minifrac jobs

Objective:

1. Test and evaluate fracturing technology
2. Improve the well productivity



4 frac jobs

1994

4 frac jobs
11 minifrac

1995

Fracturing campaign program workflow

Pre-job preparation
- Developing a complete and accuracy data set
- Measurements, well tests, interpretation of existing and obtained data

Design
- Service company Methodology
- Simulation, preliminary sensitivity analysis
- Fracturing Design Program

Execution
- Datafrac/minifrac to calibrate the model
- Fracturing program execution

Evaluation
- Results analysis, Lessons Learned and Recommendation

Criteria for Candidate Selection

1 Tectonic, Lithologic and Geologic conditions

- Tectonic history of the zone where the fields were formed must be relatively “quiet”; Transylvanian Basin, except S-E part it’s a low “disturbed” zone – tectonic conditions are important for “in situ” stress analysis;
- Presence of impermeable barriers on top and base of the formation; characteristic parameters limits the fracture growth on vertical direction;
- The formation that is subjected to fracturing should consist in well cemented sandy limestone rock, without marly interbedded layers or aquifers;
- Net pay thickness must be of “tenths” in meters, as a lesson learned must be higher than 10-15m (33-50ft);

Criteria for Candidate Selection

2 Reservoir conditions

- BHSP is a key factor in candidate selection, a higher BHSP will allow a rapid clean up after frac operation, reduce the prolonged and unwanted frac fluid contacts with the formation; as a lesson learned out of this campaign , BHSP must be at least 60-80 bar (870-1160 psi)

- Formation permeability is another key parameter, a low permeability formation is preferable, knowing that the fracturing fluid filtration increases with the increased permeability; as a recommendation permeability values can range between 0.1 to 10 mD

- Other reservoir key parameters are porosity and interstitial water saturation

Criteria for Candidate Selection

3 Technical conditions

- Production casing should be well cemented, the cement adherence between casing and formation being critical for fracture propagation direction
- Well completion issues should be absent; the limitations imposed by completion may lead to unwanted results (early pug back of the fracturing support material before it reaches the fracture)
- Wellsite space should be enough to ensure the efficiency of operation, small area restricts the position of equipment
- Proper fracturing equipment

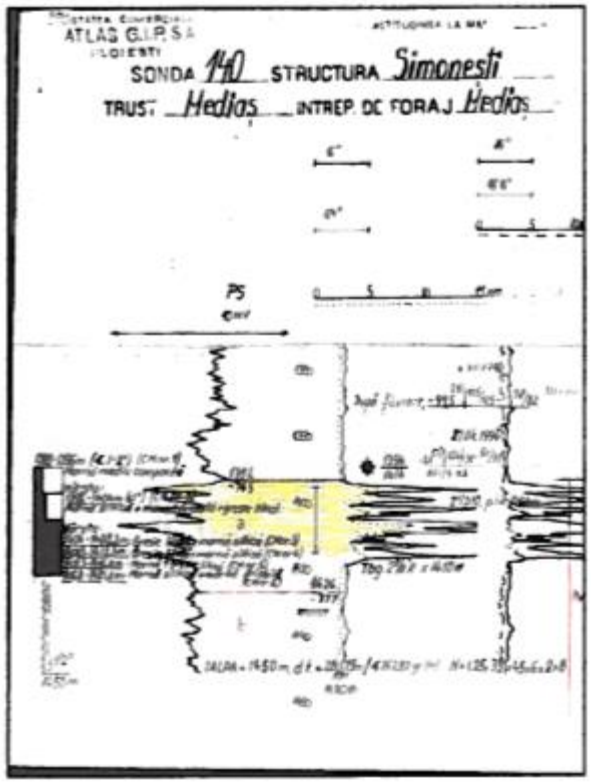
Wells Performance before and after frac operations

Well	Dynamic parameters before frac				Dynamic parameters after frac			
	THP (bar)	CHP (bar)	Q (kscm/d)	Water (l/d)	THP (bar)	CHP (bar)	Q (kscm/d)	Water (l/d)
140 Simonesti	48	50	41.4	80	68	74	131.6	0
20 Sacel	78	88	15	0	41	70	36	36000
190 Soimus	3	40	25	0	83	0	53	960
107 Copsa Mica	13.8	28	4.5	150	17	20	3	0
182 Delureni	12	19	9.3	40	15	23	9.3	720
170 Sangiorgiu de Padure	50	52	56	150	32	34	42	0
13 Petrilaca	34	36	35	50	63	66	69	800
* 15 Eremieni	41	42	52	1200	62	66	70	960
*114 Laslau	19	21	22.5	40	17	26	3.8	0

*minifrac

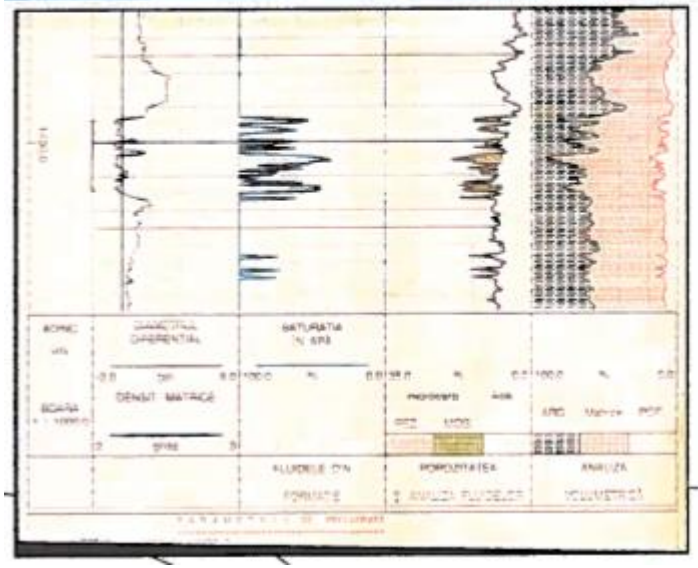
Case study- **Well 140 Simonesti**

Standard electrical log

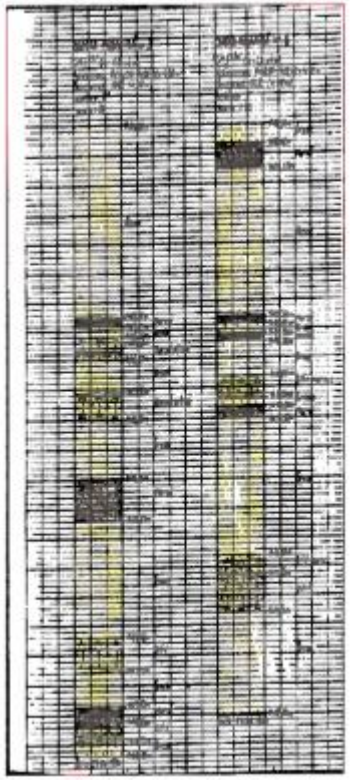


Petrophysical interpretation

Porosity = 15 – 18 %
Gas saturation = 50 -60 %



Cores



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Case study-**Well 140 Simonesti**

Experimental results

BEFORE

Choke d= 7 mm
THP/CHP=48/50 bar

Q=41.42 kscm/d

K=2,69 mD
S=37,12
R=450m
ϕ=16%

F
R
A
C

AFTER

Choke d=7 mm
THP/CHP=86/87 bar
Q= 67.4 kscm/d

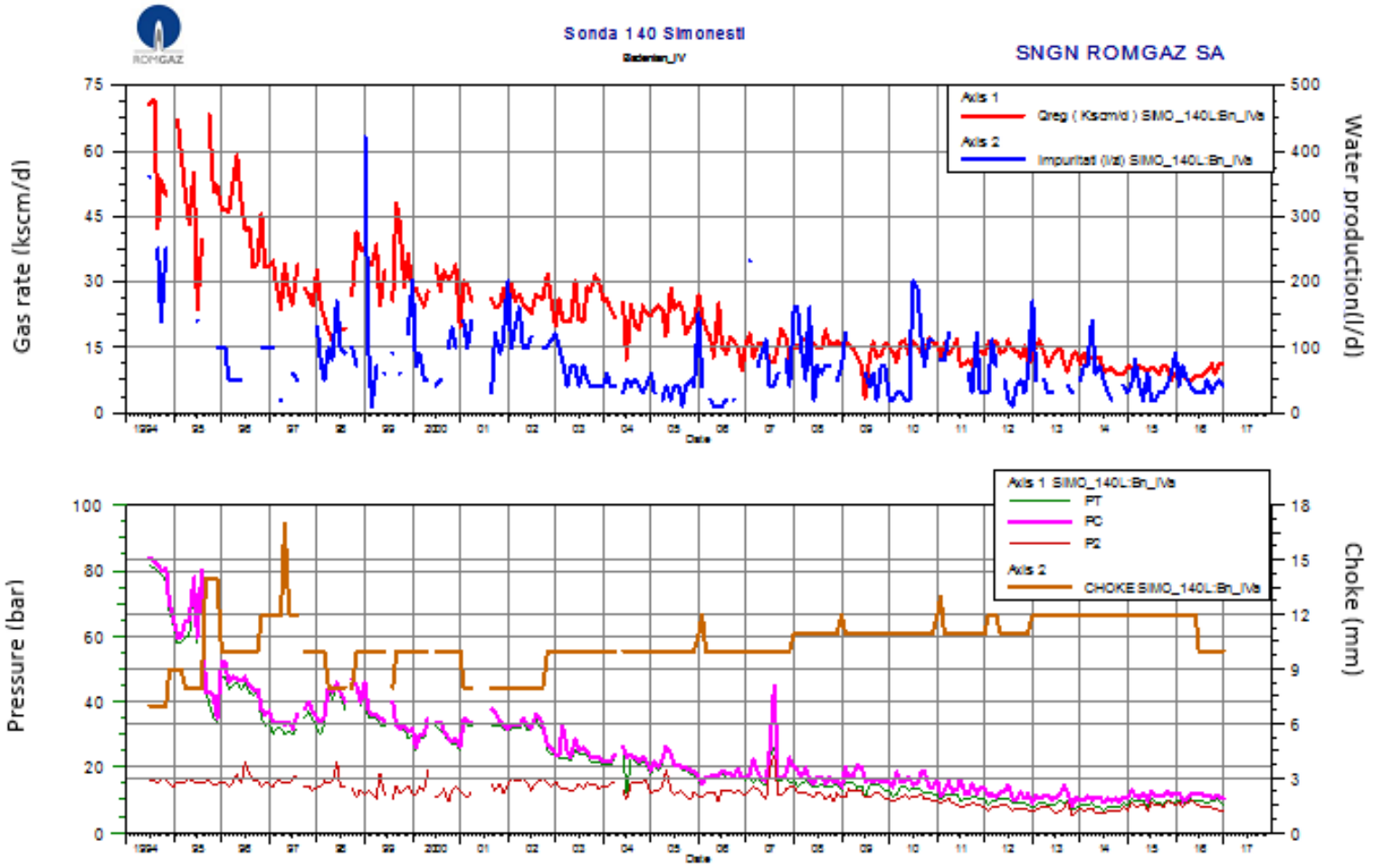
Choke d=11 mm
THP/CHP=68/74 bar
Q=131.6 kscm/d

k=5,15 mD
S=0,35

Case study-**Well 140 Simonesti**

Production history

Average gas production : ~11 kscm/d
Average water production: 50 l/d
Well under compression since 2011



Lessons learned from fracturing campaign

Success or failure of the fracturing operation depends on several factors that must be considered for the optimization of future fracturing programs. Many lessons were learned out from this pilot project of using fracturing technology in Transylvanian Basin:

1. Gas reservoirs from Transylvanian Basin are characterized by lithological contrast
2. Heterogeneous formation affects the propagation direction of fracture
3. BHSP value must be as close as possible to initial reservoir pressure for rapid clean up (at least 80 bar)
4. Cement bond behind production casing influences the fracture orientation
5. Net pay thickness must be higher than 10-15 m

Lessons learned from fracturing campaign

6. Fracturing fluids needs to be properly selected (including the fluids used for minifrac)
7. Pre-job preparation is critical for frac design program
8. Data accuracy contributes to success or failure
9. Appropriate equipment will ensure safe operation without NPT

Conclusions

1. Fracturing technology application in Transylvanian Basin represents a big challenge which is not excluded from Romgaz portfolio
2. Fracturing technology progress shows that it might be a good opportunity for Romgaz to evaluate the potential of unconventional gas reservoirs

Thank you for your attention!