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Getica CCS project – injection simulation scenario

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Abstract

One notable project in the Oltenia region is related to the development of the Turceni Energy Complex. The GETICA project aimed to retrofit some of the existing coal-fired units with CCS technology to capture and store carbon dioxide emissions. The objective is to make these units more environmentally friendly and align with European Union climate goals. Oltenia is an important industrial area in Romania, particularly known for its coal-fired power plants. The implementation of CCS in this region is part of broader efforts to reduce carbon emissions and transition to cleaner energy sources. Two zones: Zone 1 and Zone 5; have been selected out of an initial list of seven as presenting the best potential for future underground CO2 storage. Between these two candidates, Zone 5 seems to have higher performance indicators (in terms of capacity and injectivity), but this initial consideration has to be considered with caution, as very high uncertainties are attached to the figures currently calculated. After a review of the preliminary performance and risk assessments performed on the two zones, preliminary development scenarios and an appraisal strategy are proposed. A significant safety margin was applied within the model.

The parameters for run the dynamic simulations are presented below:

- analytical or numerical simulation of an aquifer;
- the daily injection flow was established based on Turceni CO2 emissions, accepting a daily mean value (Qinj = 2.07*106Sm3/day);
- The water mineralization value was taken from the existing data at a well situated on the Balteni structure (720 – 1150 Kg/car);
- the relative permeability curves for water and CO2;
- the reservoir temperature was established based on the geothermal gradient of the area Gt=3°C/100m (for temperature variation we take into account the depths 600 m and 4000 m with 28deg C respectively, 130 deg C).

The CO2 injection process (zone 1) was simulated in eight wells and nine wells (in this last case were developed additional scenarios with different distances between the wells – approx. 10000 m, 5000 m and 2500 m) and one case with two pseudo production wells.

The reasons behind choosing these specific simulations/development scenarios were:

a). the need to analyse the reservoir response and the behaviour of CO2 depending on the number of injection wells;

b). the gradual increase of the injectors number was determined to arrive the target of CO2 injection daily rate;

c). in the scenarios proposed the distance between the wells was established so that the interference phenomenon would be avoided, in the same time the entire area of interest would be covered and also the wells to be far away from the fault. Observing the evolution of the CO2 plume after 5 years of injection, at the end of injection period and after 300 years from the start of injection, it can be seen that CO2 tends to accumulate at the top layers of the reservoir and begins to extend significantly on horizontal after 300 years.

From the injection scenarios developed for Zone 5, the best scenario was selected CO2_INJ_5_AREA_V. Within this scenario the injection target is achieved with 5 injectors.

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The conclusions are the same for both zones:
•the CO2 injection pressure increases when the distance between the wells decreases;
•the pressure increases when the distance between the wells decreases;
•the field pressure is not influenced by the distance between the wells;
•the CO2 injection rate presents some variations with the distance, which can be considered insignificant;
The presence of the pseudo production wells doesn't influence the parameters of the wells (rates and pressures) and the reservoir pressure.

Keywords: CO_2 storage, CO_2 injection, reservoir, deposits

1. Introduction

Related to the Getica project[3], 7 potential zones for CO_2 storage have been selected in the study area (Fig 1). Only two zones: Zone 1 and Zone 5; have been selected out of an initial list of seven as presenting the best potential for future underground CO2 storage. Between these two candidates, Zone 5 seems to have higher performance indicators (in terms of capacity and injectivity), but this initial consideration has to be considered with caution, as very high uncertainties are attached to the figures currently calculated.

After a review of the preliminary performance and risk assessments performed on the two zones, preliminary development scenarios and an appraisal strategy are proposed.

No major and confirmed technical issue has been identified in either zone. It is however noted that Zone 1 might require a higher number of wells to compensate for the low injectivity., This has been taken into account in both preliminary schedule and cost plans. Furthermore, with respect to the risk of loss of containment, for both zones, a large number of existing wells as well as faults and fracture corridors have been identified and will have to be carefully studied to define the actual criticity of the associated risks.

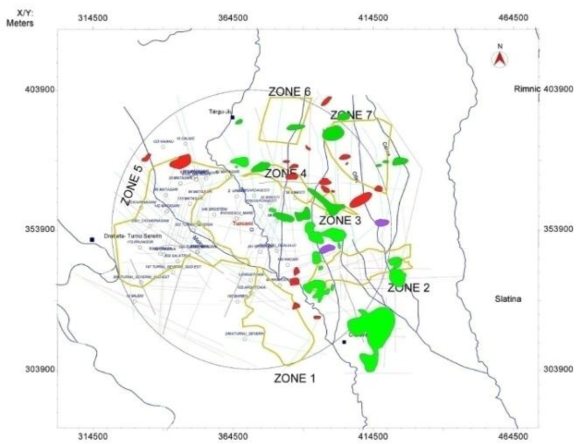

Fig.1 Location of potential sites for CO2 storage versus hydrocarbon fields

In terms of injection strategies, for either zone, a possibly large number of injector wells will have to be drilled and a compression of the CO2 performed at the storage site in order to inject the projected amount of CO2 in relatively low injectivity reservoirs, while appraisal wells will be recycled into deep monitoring wells[4]. The preliminary spatial distribution of these injector wells has been computed from the results of the injection simulations. The study area is an old oil and gas province, numerous hydrocarbon fields being discovered in the eastern and north eastern part of studied area (Fig.1). As you can see from the Figure.1, Zone 5 and 1 do not include hydrocarbon fileds, except 2 located on the margins of the reservoirs. For this reason we can assume that there will be no conflicts with oil and gas exploitation industry for these two sites.

A detailed analysis is required for a better understanding of the development of these fields and their interference with CO_2 storage sites.

From the analysis done before for each site we selected 2 sites (site 1 and site 5) with the best conditions for storage of CO2. This selection is based on the following criteria:

- the total volume of reservoir rocks , which is about 860x109 m3 (for site 5) and 72,55 x 109 m3 (for site 1);
- the sedimentary sequences create superpose structural – stratigraphic traps with different extension in the case of site 5 and only one for site 1;
- the seal rock are enough thick and continuous for both sites;
- the porosity and permeability of reservoirs are good.

In conclusion we have considered that zones 1 and 5 could be selected and between them Zone 5 has the best conditions for storage.

2. Injectivity assessment for zone 1and zone 5

The injectivity was assessed considering an initial injection rate of $Q_{inj} = 2.07*10^6$ Sm^3/day and a BHP of 0.9*0.18*H (where H is depth). The injectivity indexes were calculated using the relation:

Injectivity index= $Q_{inj} / \Delta p$,

where Δp is the pressure difference calculated at the top of the perforations.

$\Delta p = P_{INJ} - P_P$

P_{INJ} – injection pressure;

P_p – reservoir pressure.

The parameters for run the dynamic simulations are presented below:

- analytical or numerical simulation of an aquifer;
- the daily injection flow was established based on Turceni CO2 emissions, accepting a daily mean value (Qinj = 2.07*106Sm3/day);

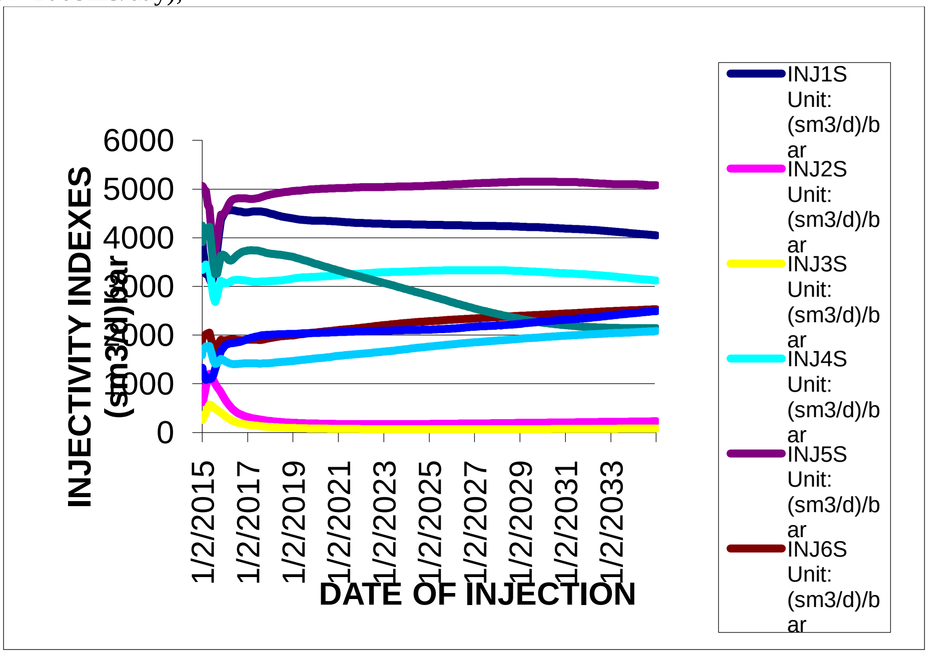

Fig. 2 Injectivity indexes for zone 1

- The water mineralization value was taken from the existing data at a well situated on the Balteni structure (720 – 1150 Kg/car);
- the relative permeability curves for water and CO2;
- the reservoir temperature was established based on the geothermal gradient of the area Gt=3°C/100m (for temperature variation we take into account the depths 600 m and 4000 m with 28deg C respectively, 130

deg C).

In order to accomplish the injection target (injection cummulative) of $4.78*10^{10}$ sm3, a number of 9 injection wells was required fact that may lead to the conclusion that the reservoir injectivity is relatively low.

The Figure below (Figure 2.) shows the variation of the injectivity indexes calculated for the nine wells within zone 1.

The injectivity for Zone 5 was assessed considering the same initial injection rate of $Q_{inj} = 2.07*10^6$ Sm^3/day as for Zone 1 and a BHP of 0.85*0.18*H (where H is depth). The injectivity indexes were calculated using the same relation used in the case of Zone 1.

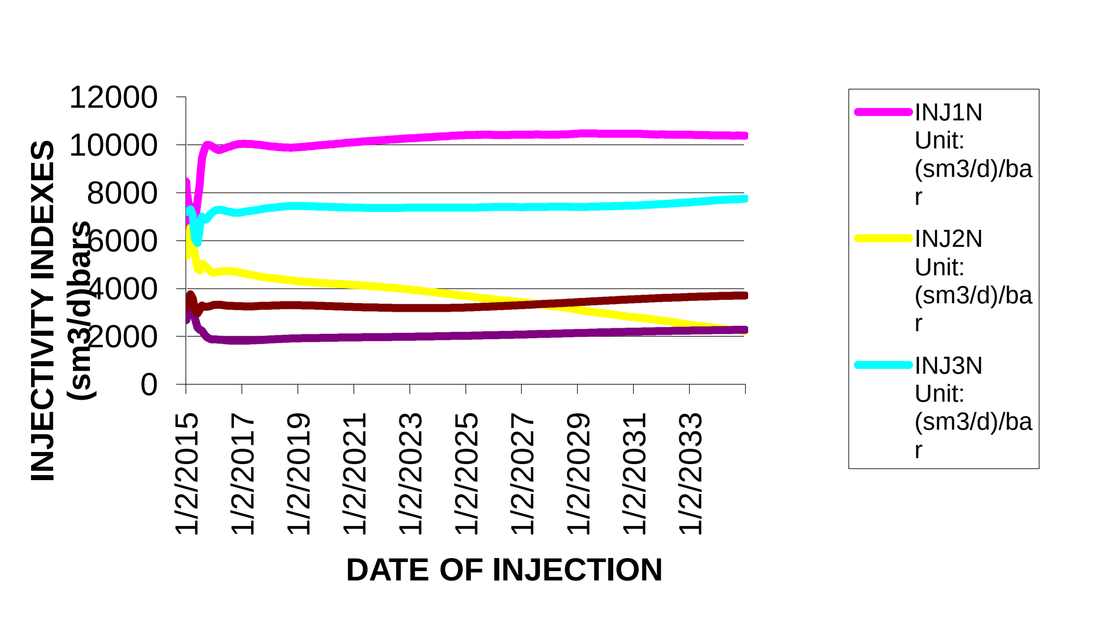

Fig.3 Injectivity indexes for zone 5

In order to accomplish the injection target (injection cummulative) of $5.13*10^{10}$, a number of 5 injection wells was required (see the location of injection wells in fig. 3), fact that may lead to the conclusion that the reservoir injectivity relatively low.

The figure below (fig.3) shows the variation of the injectivity indexes calculated for the five wells within zone 5. Comparing the injectivity indexes of Zone 5 and Zone 1, one could conclude that the injectivity of the reservoir is higher in zone 5 than in Zone 1. However, considering the limited knowledge that we have on the reservoir characteristics in this preliminary stage, it would be too early to draw such a conclusion.

3. Development scenarios for zone 1

The injection simulations were made using ECLIPSE 300 and CO2STORE option activated.

The assumption made in order to run the dynamic simulations are presented below.

- The analytical or numerical simulation of an aquifer introduced uncertainties which could not be evaluated, therefore the simulation grid was chosen so that the dimension of the cell in the furthermost areas would be 2000 X2000 and for each scenario the dimension of LGR (Local Grid Refinement) cells is gradual increasing from 100 X100 near the wells until 700 X 700, for the purpose of highlighting the behaviour of CO2 in the vicinity of the injection wells, first and to be taken into consideration the static proprieties of the geological model from the resolution point of view, secondly;
- The daily injection flow was established based on Turceni CO2 emissions, accepting a daily mean value (Qinj = 2.07*106Sm3/day);
- The water mineralization value was taken from the existing data at a well situated on the Balteni structure (720 – 1150 Kg/car);

- The relative permeability curves for water and CO2 correspond to the data from the table below;

The reservoir temperature was established based on the geothermal gradient of the area G_t=3°C/100m (for temperature variation we take into account the depths 600 m and 4000 m with 28deg C respectively, 130 deg C).

Sw	Krw	Sg	Krg
0.30	0.000000	0.00	0.000000
0.38	0.000152	0.08	0.000000
0.46	0.002439	0.16	0.000407
0.53	0.012346	0.23	0.005831
0.61	0.039018	0.31	0.024131
0.69	0.095260	0.39	0.064892
0.77	0.197531	0.47	0.140566
0.84	0.365950	0.54	0.269314
0.92	0.624295	0.62	0.484797
1.00	1.000000	0.70	1.000000

Table.1 Permeability data for water and CO2

The CO2 injection process was simulated in eight wells and nine wells (in this last case were developed additional scenarios with different distances between the wells – approx. 10000 m, 5000 m and 2500 m) and one case with two pseudo production wells. The injection scenarios and their dynamic parameters are summarized in the next table.

Data	**Injection pressure**	**Pressure**	**Field pressure**	**Injection rate**	**Production rate PSEUDO**		**Injectivity index**	**PSEUDO well pressure**	
	bars	**bars**	**bars**	**10^6 Sm3/d**	**Sm3/d**		**10^3(Sm3/d)/br**	**bars**	
CO2_INJ_9_AREA_I									
2015	220-260	196-233	244	0.06-0.48	-		0.26-5.1		
2035	244-287	226-290	257	0.007-0.48	-		0.08-5.1		
2335	209-245	209-245	257	0	-		0		
CO2_INJ_9_AREA_I_2K									
2015	218-231	196-211	244	0.08-0.34	-		0.9-3.7		
2035	269-289	260-278	257	0.02-0.41	-		0.3-4.5		
2335	210-225	210-225	257	0	-		0		
CO2_INJ_9_AREA_I_5K									
2015	224-245	198-216	244	0.03-0.46	-		0.30-4.9		
2035	242-266	245-272	257	0.01-0.43	-		0.16-4.6		
2335	212-231	212-256	257	0	-		0		
CO2_INJ_9_AREA_I_PSEUDO_OB									
2015	220-260	196-233	244	-	1.6	3.28	-	237	209
2035	244-297	227-290	257	-	102	56	-	237	209
2335	212-250	212-250	257	-	0	0	-	258	227

Table 2. Summary of the dynamic parameters resulting from the injection scenarios developed for Zone 1

The reasons behind choosing these specific simulations/development scenarios were:

a). The need to analyse the reservoir response and the behaviour of CO_2 depending on the number of injection wells;

b). The gradual increase of the injectors number was determined to arrive the target of CO2 injection daily rate;

c). In the scenarios proposed the distance between the wells was established so that the interference phenomenon would be avoided, in the same time the entire area of interest would be covered and also the wells to be far away from the fault.

From the injection scenarios developed for Zone 1 and presented in Table 3.7.3., the best scenario was selected CO2_INJ_9_AREA_I. Within this scenario the injection target is achieved with 9 injectors. The coordinates and the perforations are presented in Table 3.

Well name	**Coordinates (m)**		**Perforations**	
	X	Y	TOP MD (m)	BOTTOM MD (m)
INJ1S	380860	301355	1904.62	2207.53
INJ2S	389812	315853	1864.88	2282.41
INJ3S	386047	331373	1816.36	2134.61
INJ4S	382261	309422	1672.74	2134.61
INJ5S	386549	307257	1820.79	2208.69
INJ6S	382472	323974	1849.07	2183.66
INJ7S	378110	333404	1738.42	2081.19
INJ8S	376906	295598	1972.77	2108.96
INJ9S	382322	318143	1792.79	2127.39

Table 3. Coordinates and perforations for the nine injection wells used within scenario CO2_INJ_9_AREA_I

Observing the evolution of the CO2 plume after 5 years of injection (see Fig.4), at the end of injection period (see Fig.5) and after 300 years from the start of injection (see Fig. 6), it can be seen that CO2 tends to accumulate at the top layers of the reservoir and begins to extend significantly on horizontal after 300 years.

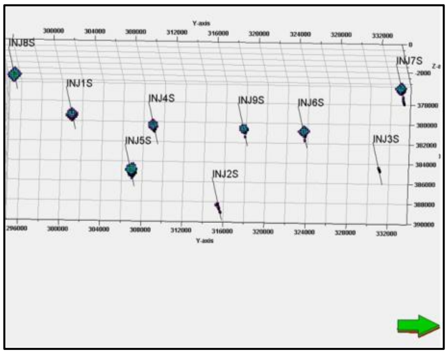

Fig.4 CO2 saturation Plume for scenario *CO2_INJ_9_AREA_I* at 1 Jan 2020 (The big cells dimensions are 650X650 m, while the small cells dimension is 165X165 m)

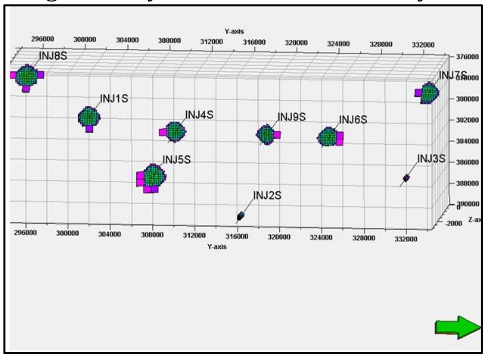

Fig.5 CO2 saturation Plume for scenario *CO2_INJ_9_AREA_I* at 1 Jan 2035 (The big cells dimensions are 650X650 m, while the small cells dimension is 165X165 m)

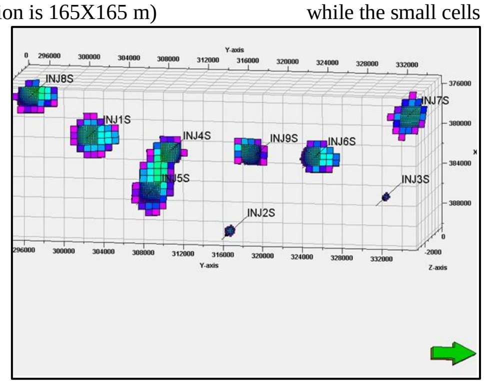

Fig.6 CO2 saturation Plume for scenario CO2_INJ_9_AREA_I at 1 Jan 2335 (The big cells dimensions are 650X650 m, while the small cells dimension is 165X165 m)

4. Development scenarios for zone 5

The injection simulations made for Zone 5 were based on the same assumptions and the same reasons as those run for Zone 1.

The CO2 injection process was simulated in three wells, four wells and five wells (in this last one case were developed additional scenarios with different distances between the wells – approx. 10000 m, 5000 m and 2500 m). The injection scenarios and their dynamic parameters are summarized in the next table.

From the injection scenarios developed for Zone 5 and presented in table 4, the best scenario was selected CO2_INJ_5_AREA_V. Within this scenario the injection target is achieved with 5 injectors. The coordinates and the perforations are presented in Table 5

Data	**Injection pressure** **bars**	**Pressure** **bars**	**Field pressure** **bars**	**Injection rate** **10^6 Sm3/d**	**Production rate PSEUDO** **Sm3/d**	**Injectivity index** **10^3 (Sm3/d)/bar**	**PSEUDO well pressure** **bars**
CO2_INJ_5_AREA_V							
2015	180-258	165-238	228	0.23-0.69	-	2.7-8.5	-
2035	173-244	187-268	237	0.14-0.85	-	2.2-10.4	-
2335	172-244	187-268	237	0	-	0	-
CO2_INJ_5_AREA_V_2K							
2015	254-282	217-240	228	0.22-0.64	-	2.7-8.1	-
2035		259-292	235	0.15-0.75	-	1.9-9.5	-
2335	222-246	221-245	235	0	-	0	-
CO2_INJ_5_AREA_V_5K							
2015	214-263	193-238	227	0.22-0.59	-	2.5-6.1	-
2035	231-284	223-271	237	0.15-0.68	-	1.7-7.5	-
2335	200-245	200-245	236	0	-	0	-
CO2_INJ_5_AREA_V_PSEUDO_OB							
2015	181-258	165-238	228	-	405	-	232
2035	191-276	187-268	237	-	279	-	232
2335	173-245	173-237	237	-	0	-	241

Table 4. Summary of the dynamic parameters resulting from the injection scenarios developed for Zone 5

Well name	**Coordinates (m)**		**Perforations**	
	X	Y	TOP MD (m)	BOTTOM MD (m)
INJ1N	347907	373310	1915.34	2341.11
INJ2N	334353	353365	1417.44	1775.53
INJ3N	342369	352624	1773.33	2155.11
INJ4N	349066	365153	2018.83	2448.28
INJ5N	344068	358597	1879.81	2117.76

Table 5. Coordinates and perforations for the five injection wells used within scenario CO2_INJ_5_AREA_V

Observing the evolution of the CO2 plume after 5 years of injection (see Fig.7), at the end of injection period (see Fig.8) and after 300 years from the start of injection (see Fig.9), it can be seen that CO2 tends to accumulate at the top layers of the reservoir and begins to extend significantly on horizontal after 300 years[2].

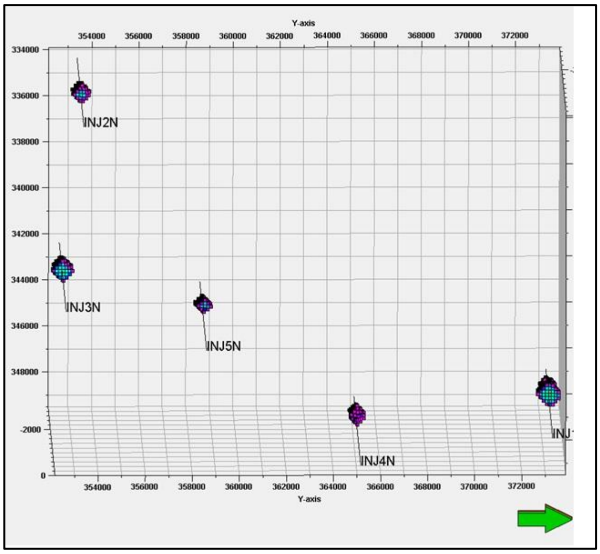

Fig.7 CO2 saturation Plume for scenario *CO2_INJ_5_AREA_V* at 1 Jan 2020 (The dimension of the big cells is 500 x 500 m, while the small cells are of 125 x 125 m)

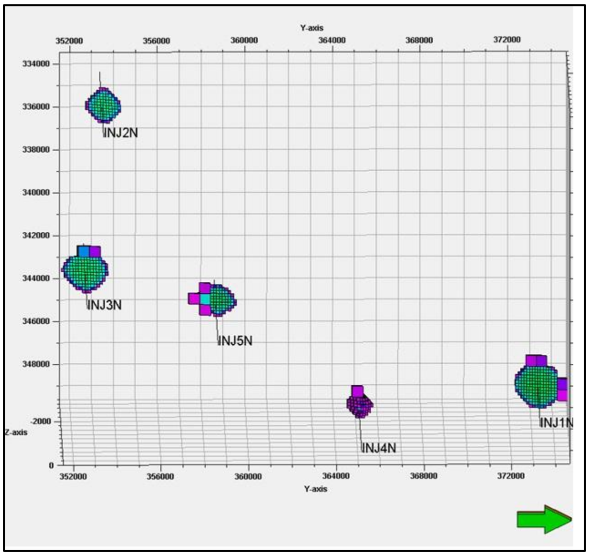

Fig.8 CO2 saturation Plume for scenario *CO2_INJ_5_AREA_V* at 1 Jan 2035 (The dimension of the big cells is 500 x 500 m, while the small cells are of 125 x 125 m)

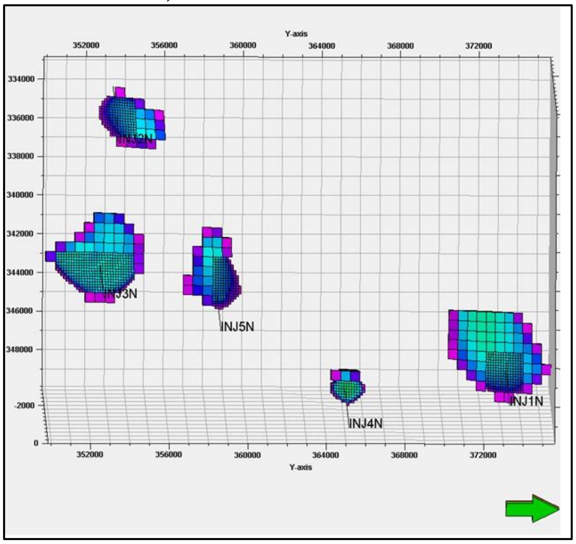

Fig.9 CO2 saturation Plume for scenario *CO2_INJ_5_AREA_V* at 1 Jan 2035 (The dimension of the big cells is 500 x 500 m, while the small cells are of 125 x 125 m)

The reasons behind choosing these specific simulations/development scenarios were:
a). the need to analyse the reservoir response and the behaviour of CO2 depending on the number of injection wells;
b). the gradual increase of the injectors number was determined to arrive the target of CO2 injection daily rate;
c). in the scenarios proposed the distance between the wells was established so that the interference phenomenon would be avoided, in the same time the entire area of interest would be covered and also the wells to be far away from the fault. Observing the evolution of the CO2 plume after 5 years of injection, at the end of injection period and after 300 years from the start of injection, it can be seen that CO2 tends to accumulate at the top layers of the reservoir and begins to extend significantly on horizontal after 300 years. Indeed, as shown on Figures 4-5 below, the low relative permeability of CO2 in the initial phase of injection creates a peak of required injection pressure during that period that goes up to 150/140 bars according to these preliminary results[1].

5. Conclusions

The reasons behind choosing these specific simulations/development scenarios were:
a). the need to analyse the reservoir response and the behaviour of CO2 depending on the number of injection wells;
b). the gradual increase of the injectors number was determined to arrive the target of CO2 injection daily rate;
c). in the scenarios proposed the distance between the wells was established so that the interference phenomenon would be avoided, in the same time the entire area of interest would be covered and also the wells to be far away from the fault. Observing the evolution of the CO2 plume after 5 years of injection, at the end of injection period and after 300 years from the start of injection, it can be seen that CO2 tends to accumulate at the top layers of the reservoir and begins to extend significantly on horizontal after 300 years. Indeed, as shown on Figures 10-11 below, the low relative permeability of CO2 in the initial phase of injection creates a peak of required injection pressure during that period that goes up to 150/140 bars according to these preliminary results[5].

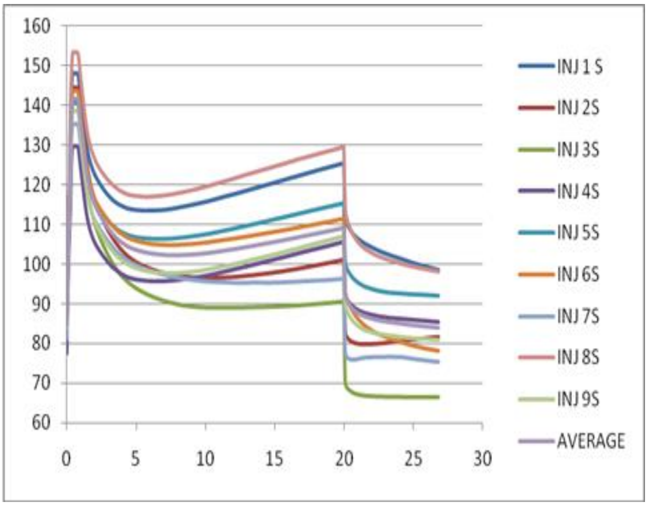

Fig.10 Expected surface pressures required at the injectors for Zone 1

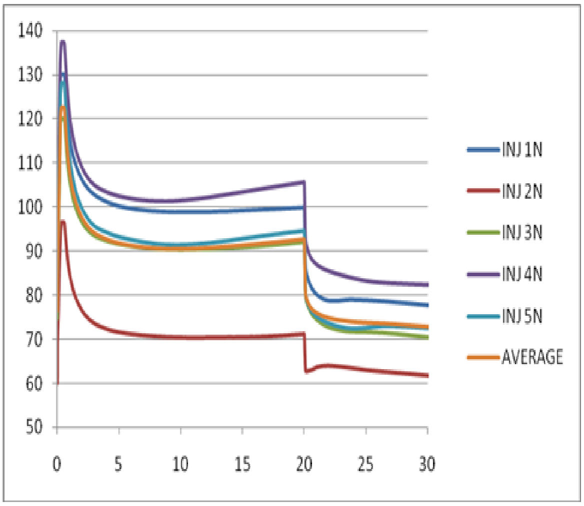

Fig.11 Expected surface pressures required at the injectors for Zone 5

The conclusions are the same for both zones:
• The CO2 injection pressure increases when the distance between the wells decreases;
• The pressure increases when the distance between the wells decreases;
• The field pressure is not influenced by the distance between the wells;
• The CO2 injection rate presents some variations with the distance, which can be considered insignificant;

The presence of the pseudo production wells doesn't influence the parameters of the wells (rates and pressures) and the reservoir pressure.

Acknowledgements

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