WTNP117 – Capillary rebalancing of bi--materials describes by models of Van-Genuchten Mualem

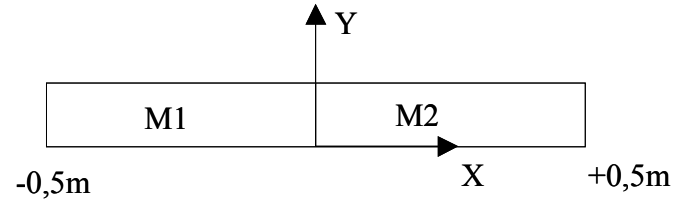
Summarized:

The test presented makes it possible to simulate a case of resaturation of a material by another, the 2 materials being described by a model of Mualem Van-Genuchten. It is about a classical case of type BO-BG which enables us to test the hydraulic model called by HYDR_VGM. It also allows the comparison of several numerical diagrams: eccentric finite elements and finished volumes.

1 Problem of reference

1.1 Geometry

the studied field is composed of two mediums of $0,5\,m$ each one.



The material $M1$ will be called worked barrier (BO) and the geological $M2$ material barrier (BG)

1.2 Properties of the materials

One gives here only the properties whose solution depends, knowing that the command file contains other data of material which do not play any part in the solution of with the dealt problem.

Liquid		
BO Eau	Density ($kg.m^{-3}$)	1000
	Viscosity	10^{-3}
homogenized Parameters	Permeability K	$10^{-20}\,m^2$
	Porosity	0.3
Parameters of Van-Genuchten	N	$1,064$
	Pr	$1,5\,Mpa$
	Sr	0
	$Smax$	$0,999$
State initial	liquid	$P_c^0 = 89\,MPa\,(S=0.77)$
		$P_{gz} = 1\,atm$
Pressure		
BG Eau	Density ($kg.m^{-3}$)	1000
	Viscosity	10^{-3}
homogenized Parameters	Permeability K	$10^{-19}\,m^2$
	Porosity	0.05

Parameters of Van-Genuchten	N	$1,7$
	Pr	$10\,Mpa$
	Sr	0
	$Smax$	$0,999$
State initial	Pressure	$P_c^0=0\,(S=1.)$
		$P_{gz}=1\,atm$

the curves of saturation and permeabilities obeys the model Mualem-Van-Genuchten (HYDR_VGM). It is thus necessary to define in the materials the parameters $N \quad Pr \quad Sr \quad Smax$.
It is pointed out that these models are:

$$S_{we}=\frac{S-S_{wr}}{1-S_{wr}} \text{ and } m=1-\frac{1}{n}$$

$$S_{we}=\frac{1}{\left[1+\left[\frac{P_c}{P_r}\right]^n\right]^m}$$

the permeability relating to water is expressed by integrating the model prediction proposed by Mualem (1976) in the model of capillarity of Van Genuchten.

$$k_r^w=\sqrt{S_{we}}\,(1-(1-S_{we}^{1/m})^m)^2$$

The permeability with gas is formulated in a similar way:

$$k_r^w=\sqrt{(1-S_{we})}\,(1-S_{we}^{1/m})^{2\mathrm{m}}$$

It is pointed out that for $S>Smax$, these curves are interpolated by a polynomial of degree 2 $C1$ in $Smax$.

1.3 Boundary conditions and initial

We are in boundary conditions: null flux everywhere (default).

BG is saturated ($S=1$) and BO is partially désaturée ($S=0,77$). Into capillary term of pressure, that results in $Pc=0 \quad BG$ and $Pc=89\,Mpa$ the worked barrier.

1.4 Bibliographical references

1.Granet, S. (2006). Thermohydraulic case test on bi--materials: Comparison of various numerical diagrams. Note HT-64-06-012.

2 Modelization A

2.1 Characteristic of the modelization A

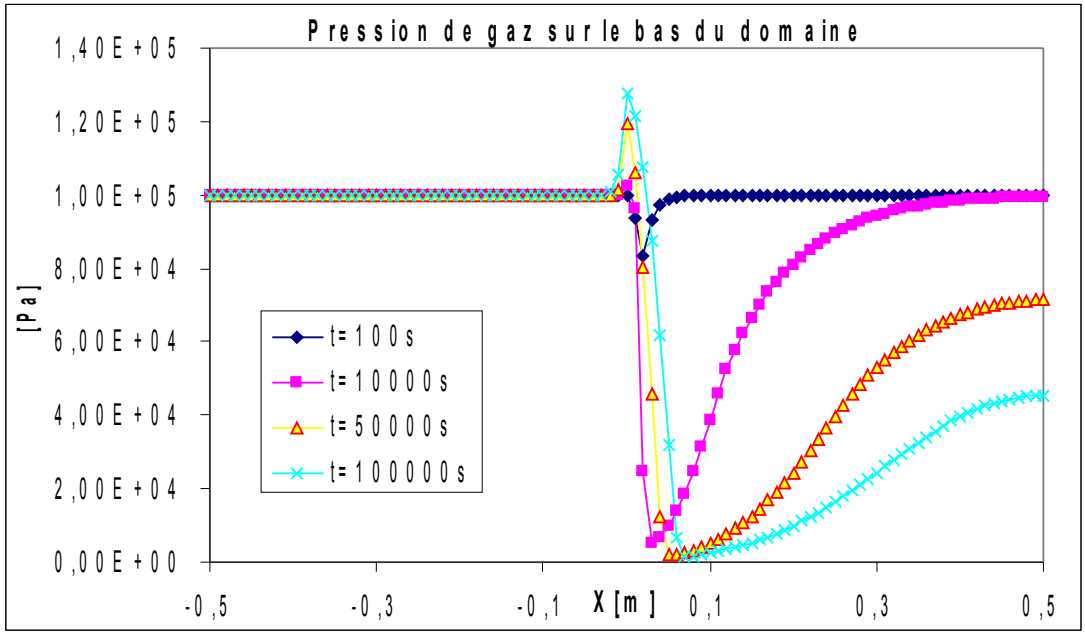
Modelization HHS in plane strains. Coupling LIQU_GAZ. 100 elements QUAD8.

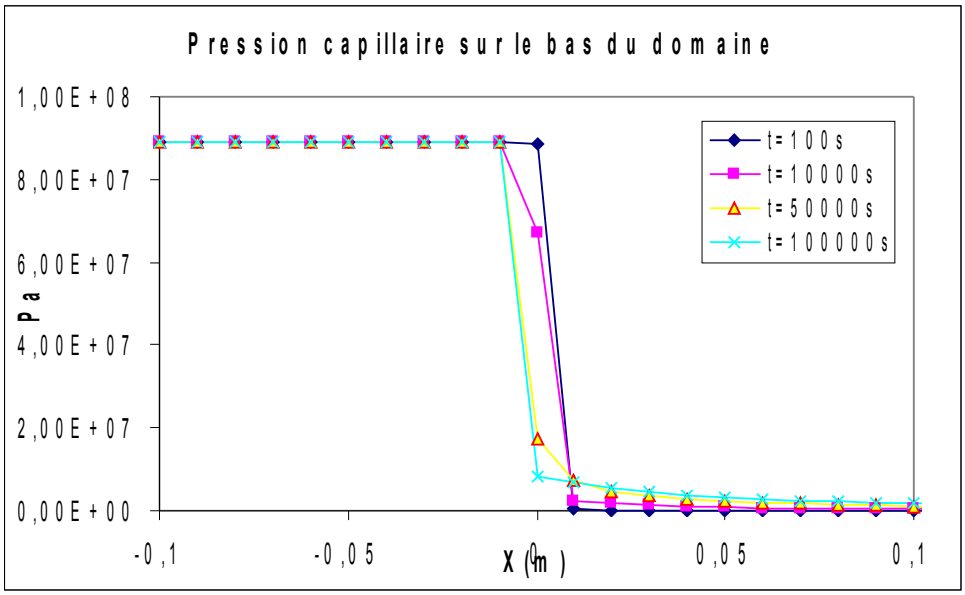
Discretization in time:

- $1000s$ in 20 time step
- $5000\,s$ in 20 time step
- $10000\,s$ in 10 time step
- $50000\,s$ in 20 time step
- $100000\,s$ in 20 time step

2.2 Results

the figures below present the profiles of gas pressures, capillary pressures and saturations along the bi--materials at various times:





One observes well the desaturation of the geological barrier by the worked barrier. The profiles of gas pressure are also characteristic of this kind of problem: one observes a peak of gas pressure to the interface of the two materials which is with the fact that the gas is compressed by the water which resature the worked barrier. If the existence of this peak has a physical reality, its width is on the other hand due to a problem of numerical diagram (known problem) as we will see it for the modelizations C or D.
The oscillations observed on saturations are also well-known (one will refer to [3]). The materials are indeed defined with the elements and not with the nodes. What means that on node located at the interface, 2 curves of capillary pressures are definite and different. This point explains why if the capillary continuity of pressure is assured it is not the same for saturation.

2.3 Values tested

This case test does not have a value of reference, one thus makes a case of non regression of them.
One carries out tests on two values:

X (m)	Time (s)	$PRE1$ **Aster**	authorized relative Error
0.03	5000	$7.5\,10^{5}$	1 %
0.03	100000	$4.48\,10^{6}$	1 %

3 Modelization B

3.1 Characteristic of the modelization B

Modelization HHS in plane strains. Coupling LIQU_VAPE_GAZ. 100 elements QUAD8.

In one the 2nd computation, one tests the automatic management of time step.

Discretization in time:

- $1000\mathrm{s}$ in 20 time step
- $5000\ s$ in 20 time step
- $10000\ s$ in 10 time step
- $50000\ s$ in 20 time step
- $100000\ s$ in 20 time step

With the automatic management of time step, one gives only 1st time step and the urgent one of transition obliged (for the TEST_RESU):

- $50\ s$
- $5000\ s$
- $100000\ s$

The code manages itself time step.

3.2 Results

the results are practically the same ones as for the modelization A what is logical since there is no thermal.

The automatic management of time step makes it possible to make 5 times less time step.

3.3 Values tested

One carries out 2 tests of non regression for each computation:

computation n°1

X (m)	Time (s)	$PRE1$ **Aster**	authorized relative Error
0.03	5000	$7.5\,10^5$	1 %
0.03	100000	$4.48\,10^6$	1 %

computation n°2 (automatic management of the list of times)

X (m)	Time (s)	$PRE1$ **Aster**	authorized relative Error
0.03	5000	$7.5\,10^5$	1 %
0.03	100000	$4.48\,10^6$	4 %

4 Modelization C

4.1 Characteristic of the modelization C

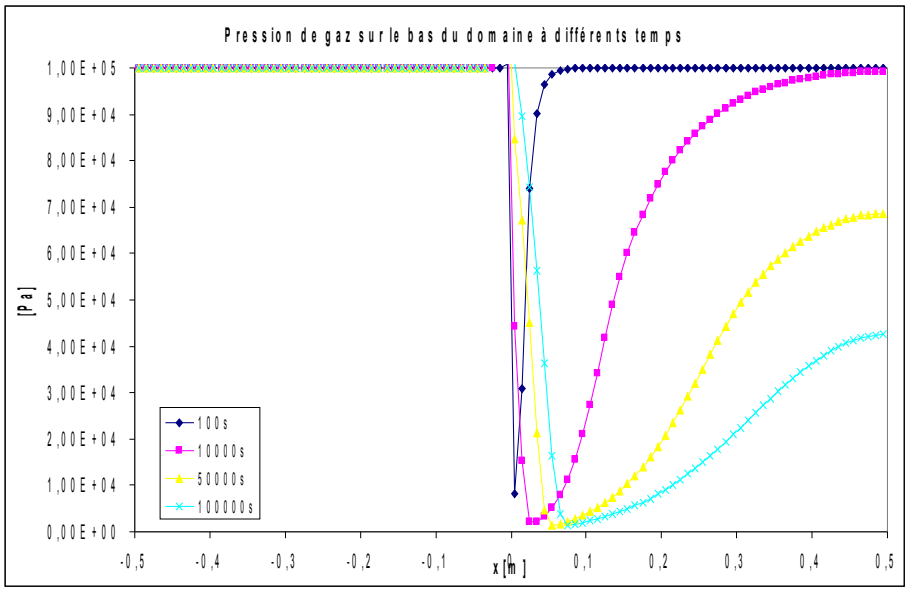
Modelization D_PLAN_HH2SUDM. This modelization corresponds to the Eccentric Finished diagram Volume Nets. Coupling LIQU_AD_GAZ. One uses a mesh made up of 100 elements QUAD8.
One is into immiscible and one uses a coefficient of infinite Henry of $10^{20}\ Pa.mol^{-1}.m^3$,

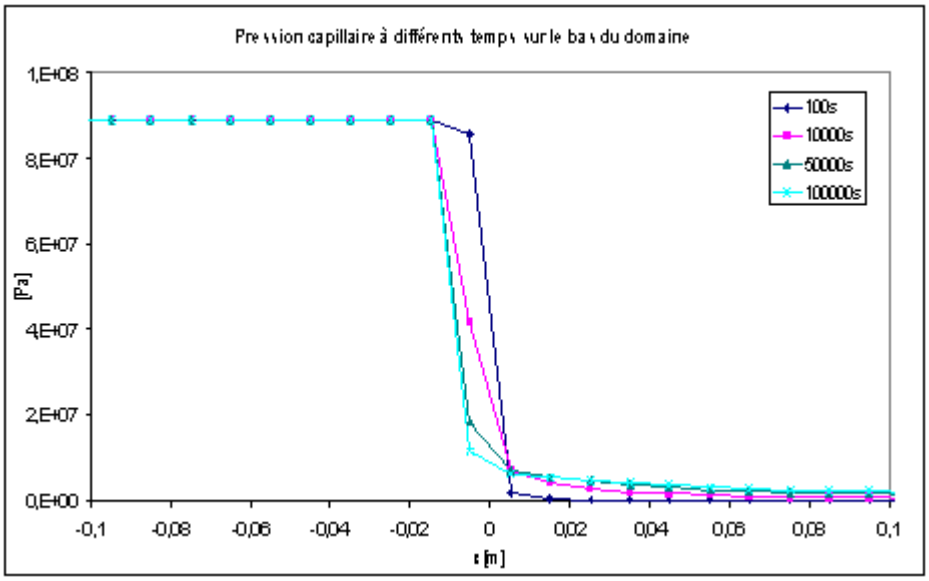
Discretization in time:

- $1000s$ in 20 time step
- $10000\ s$ in 20 time step
- 1 month in 20 time step
- 2 months in 20 time step
- 6 months in 40 time step
- 1 year in 50 time step
- 10 years in 50 time step
- 50 years in 50 time step
- 100 years in 50 time step
- 500 years in 50 time step
- 1000 years in 50 time step
- 5000 years in 50 time step
- 10.000 years in 50 time step
- 100.000 years in 50 time step
- 1.000.000 years in 50 time step

4.2 Results

the figures below presents the profiles of gas pressures and capillary pressures along the bi-- materials to various times :





The results are those expected. It is noticed that compared to the diagrams finite elements, the gas peak to the interface is almost unperceivable here. It is until one waited of the diagrams eccentric finished volumes. The results are thus coherent.

4.3 Values tested

This case test does not have a value of reference, one thus makes a case of non regression of them. One carries out tests on two values:

Points (x, y)	**Time (s)**	*PRE1* **Aster**	*PRE2* **Aster**	**authorized relative Error**
$(-0{,}005, 0)$ *N105*	100	$8.57\,10^{7}$	734	1 %
	100000	$1.121\,10^{7}$	$2.171\,10^{4}$	1 %
$(0{,}035, 0{,}005)$ *NQ54*	100	55790	-9789	1 %
	100000	$3.921\,10^{6}$	$-4.367\,10^{4}$	1 %

5 Modelization D

5.1 Characteristic of the modelization D

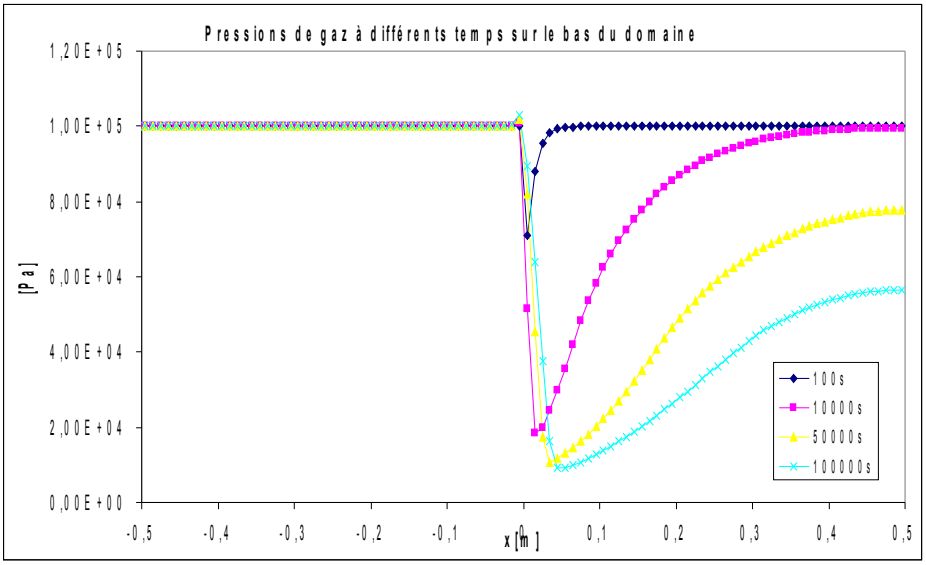
Modelization D_PLAN_HH2SUDA. This modelization corresponds to the Eccentric Finished diagram Volume Edge. Coupling LIQU_AD_GAZ. One uses a mesh made up of 100 elements QUAD8.
One is into immiscible and one uses a coefficient of infinite Henry of $10^{20}\ Pa.mol^{-1}.m^3$,

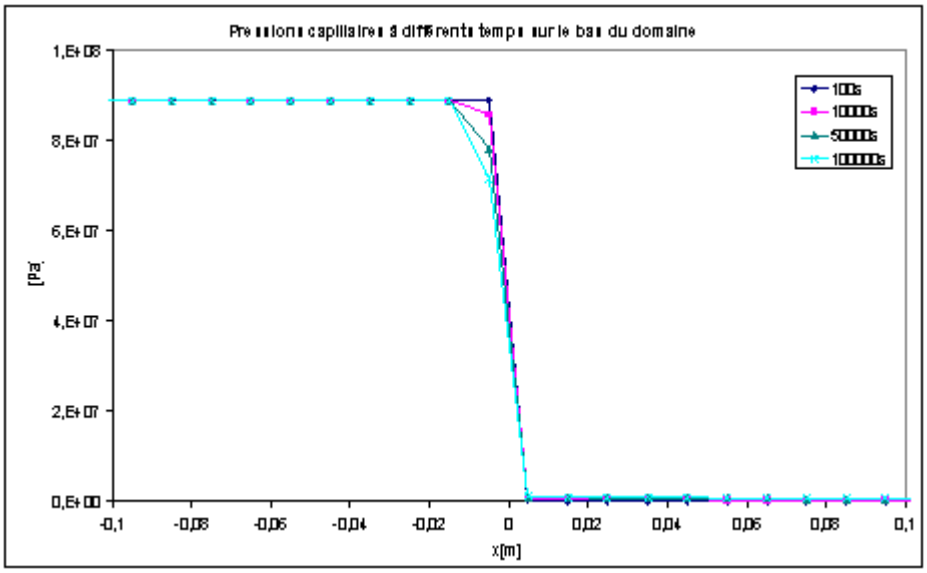
Discretization in time:

- $1000s$ in 20 time step
- $10000\ s$ in 20 time step
- 1 month in 20 time step
- 2 months in 20 time step
- 6 months in 40 time step
- 1 year in 50 time step
- 10 years in 50 time step
- 50 years in 50 time step
- 100 years in 50 time step
- 500 years in 50 time step
- 1000 years in 50 time step
- 5000 years in 50 time step
- 10.000 years in 50 time step
- 100.000 years in 50 time step
- 1.000.000 years in 50 time step

5.2 Results

the figures below presents the profiles of gas pressures and capillary pressures along the bi-- materials to various times :





The results are those expected. It is noticed that compared to the diagrams finite elements, the gas peak to the interface is almost unperceivable here. It is until one waited of the diagrams eccentric finished volumes. The results are thus coherent.

5.3 Values tested

This case test does not have a value of reference, one thus makes a case of non regression of them. One carries out tests on two values:

Points (x, y)	**Time (** s **)**	*PRE1* **Aster**	*PRE2* **Aster**	**authorized relative Error**
$(-0{,}005, 0)$ *N105*	100	$8.89\,10^{7}$	19	1 %
	100000	$7.175\,10^{7}$	2952	1 %
$(0{,}035, 0{,}005)$ *NQ54*	100	10160	-1745	1 %
	100000	$8.532\,10^{5}$	-83702	1 %

6 Modelization E

6.1 Characteristic of the modelization E

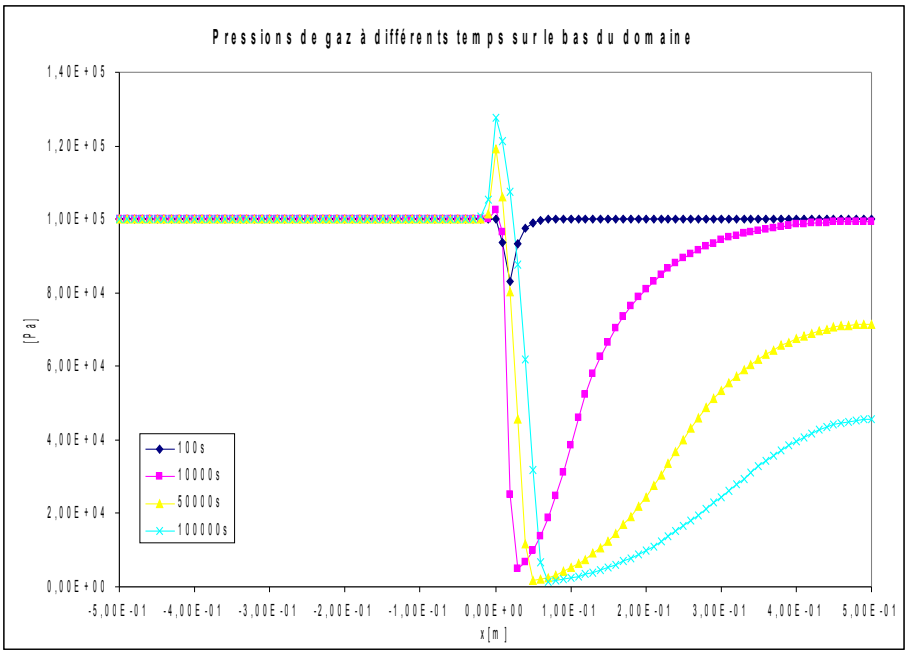
Modelization D_PLAN_HH2S, this modelization corresponds to the modelization Finite elements. Coupling LIQU_AD_GAZ. One uses a mesh made up of 100 elements QUAD8
One is into immiscible and one uses a coefficient of infinite Henry of $10^{20} Pa.mol^{-1}.m^3$,

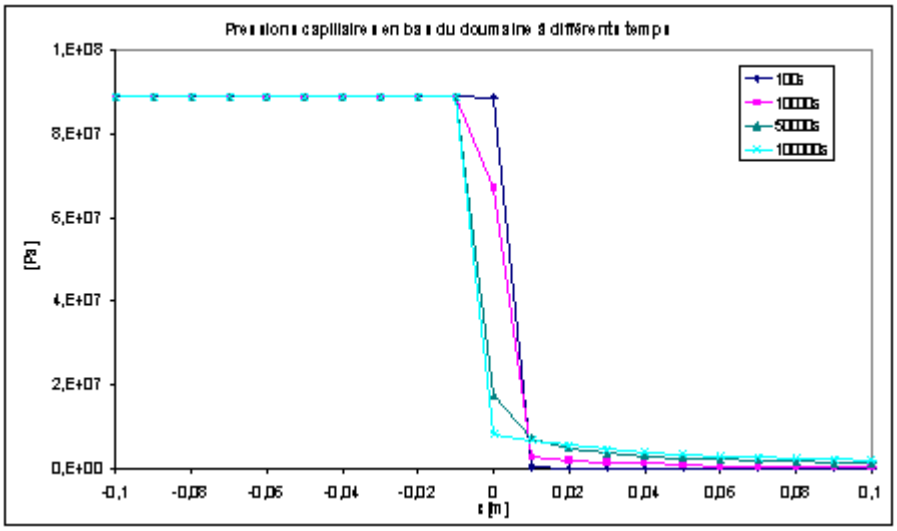
Discretization in time:

- 1000s in 20 time step
- $10000\,s$ in 20 time step
- 1 month in 20 time step
- 2 months in 20 time step
- 6 months in 40 time step
- 1 year in 50 time step
- 10 years in 50 time step
- 50 years in 50 time step
- 100 years in 50 time step
- 500 years in 50 time step
- 1000 years in 50 time step
- 5000 years in 50 time step
- 10.000 years in 50 time step
- 100.000 years in 50 time step
- 1.000.000 years in 50 time step

6.2 Results

the figures below presents the profiles of gas pressures and capillary pressures along the bi-- materials to various times :





As for the modelization A in finite elements, the peak of gas pressure to the interface is very important here. It is seen well that the finite elements are adapted to this kind of problem than the finite elements.

6.3 Values tested

This case test does not have a value of reference, one thus makes a case of non regression of them. One carries out tests on two values:

Points (x, y)	Time (s)	$PRE1$ **Aster**	$PRE2$ **Aster**	authorized relative Error
$N111$	100	37569	-6536	1 %
	100000	$4.486\,10^{6}$	-12413	1 %

7 Summary of the results

This case test meets its main objective well: to test functionality HYDR_VGM. Moreover it makes it possible to have a classical problem of modelization $« BO-BG »$ with stiff processing of front. We do not have reference solutions with which to compare to us, however the got results take the classical form of this kind of resolution. We thus make a case of non regression of them.
3 numerical diagrams are tested here: finite elements and the eccentric finished volumes edges or meshes. If the total pace of the results is the same one for the 3 diagrams, it is seen clearly that finished volumes very strongly decrease the gas peak observed with the interface between the materials. If this gas peak has a physical reality, its width is amplified considerably by the diagrams finite elements. Centered finished volumes are not tested here because unsuited.

One recommends for this kind of problem the diagrams eccentric finished volumes edges (less expensive than the eccentric ones meshes).