COMSOL CONFERENCE 2014 CAMBRIDGE

MODELLING SELF-POTENTIAL EFFECTS DURING RESERVOIR STMULATION IN ENHANCED GEOTHERMAL SYSTEMS

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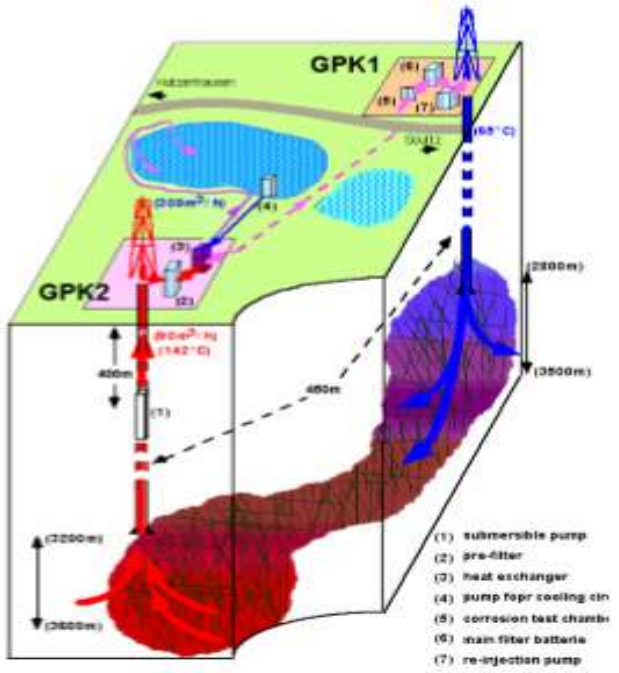
- Application of Self- Potential (SP) in geothermal area
- EGS System (Enhanced Geothermal System)
- Induced Seismicity

Numerical simulation for real case Soultz-sous-Forets



- Introduction of SP equation
- Presentation of results
- Conclusion

- Passive geophysical method
- Telluric currents originate spontaneously in the underground
- Using of impolarizable electrode and simple acquisition system for experimental measurements

- Equations used for our model are:

Convective current

1. $\vec{J} = -\sigma\vec{\nabla}V - l\left(\vec{\nabla}P - \rho_f\vec{g}\right)$

Conduction current

Darcy's law

2. $\vec{U} = -l\vec{\nabla}V - \frac{k}{\eta}\left(\vec{\nabla}P - \rho_f\vec{g}\right)$

electroosmosis

- In absence of external sources $\vec{\nabla}.\vec{J} = 0$ applying the divergence to the first equation we obtain:

$$\vec{\nabla}.\left(\sigma\vec{\nabla}V\right) = -\vec{\nabla}.\left[l\left(\vec{\nabla}P - \rho_f\vec{g}\right)\right]$$

- Developping the first equation we obtain Poisson's equation:

$$\nabla^2 V = -\frac{\vec{\nabla}\sigma}{\sigma}\vec{E} - \frac{1}{\sigma}\left[\vec{\nabla}l.\vec{\nabla}P - \rho_f\vec{\nabla}l.\vec{g} - l\nabla^2 P\right]$$

Secondary source

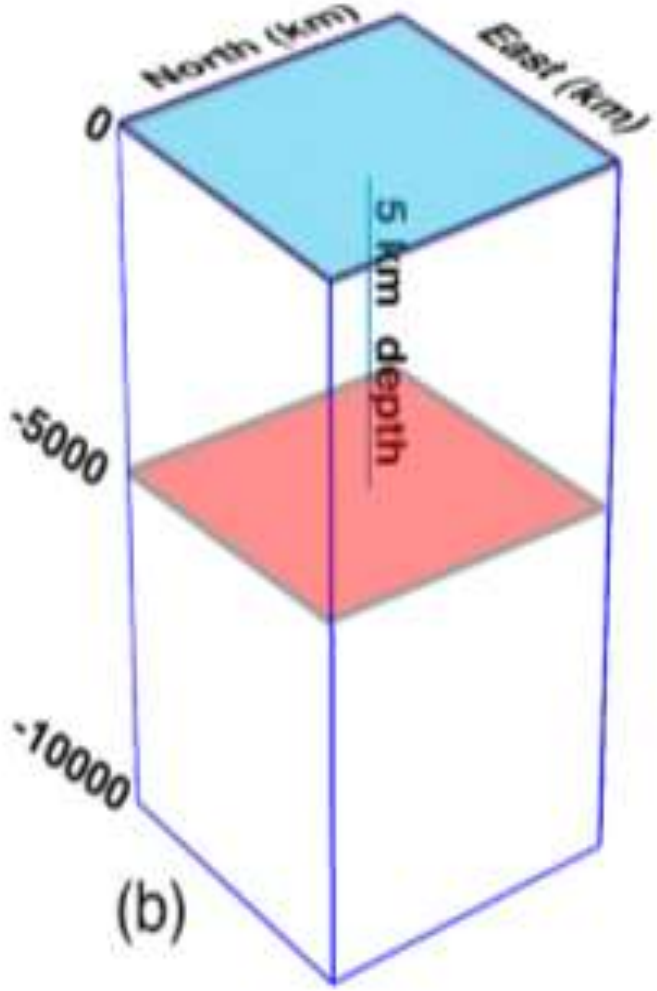
Primary source

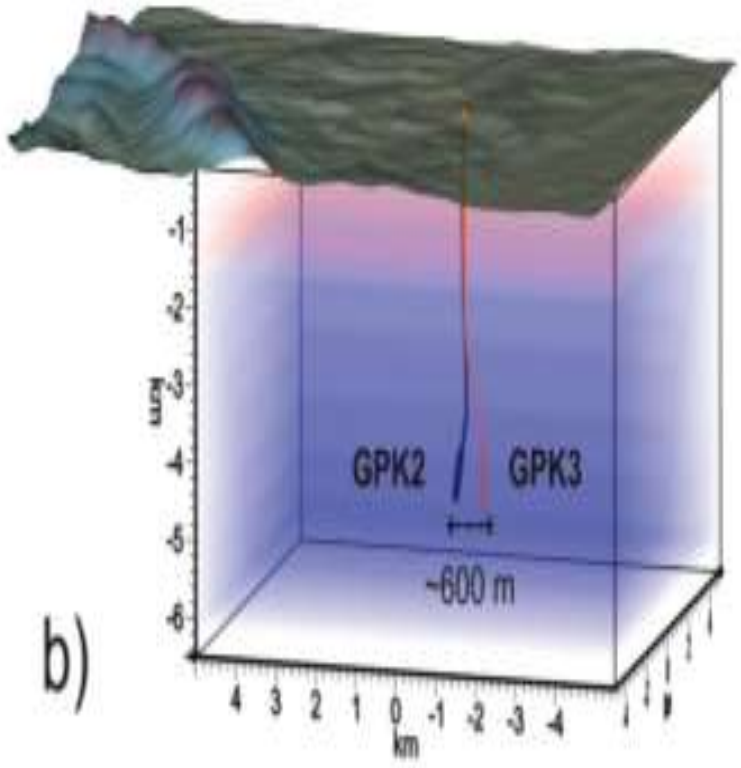
- Numerical stimulation present a semplificative geometry and follow real stimulation cicle

- Source term: $\frac{\vec{\nabla}\sigma}{\sigma}\vec{E} + \frac{l\nabla^2 P}{\sigma}$

- Pressures have been calculated using a termo-fluid dynamic model (Troiano et al.2013)

- The costant l choosed ad hoc for Soultz-sous-Forets.


North (km)
East (km)
0
-5000
-10000
5 km depth
(b)


GPK2
GPK3
~600 m
km
b)

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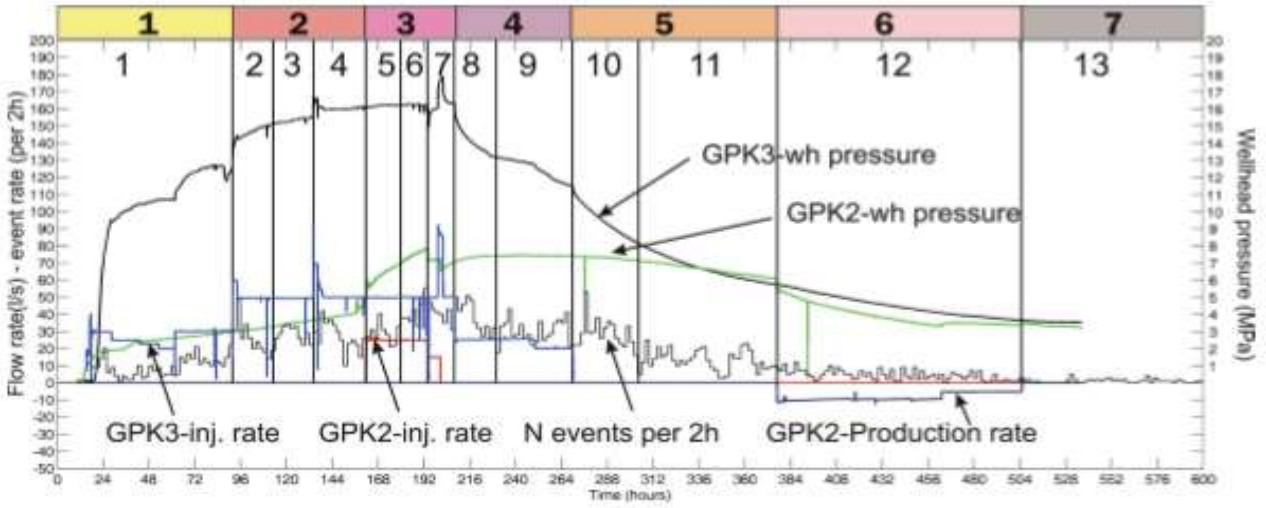
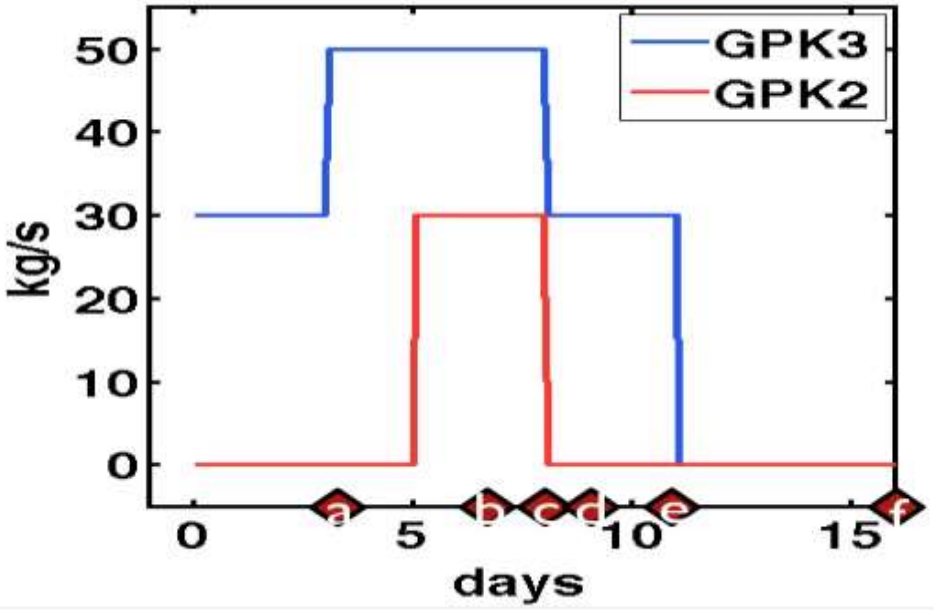

1
2
3
4
5
6
7
GPK3-wh pressure
GPK2-wh pressure
GPK3-inj. rate
GPK2-inj. rate
N events per 2h
GPK2-Production rate
Flow rate(l/s) - event rate (per 2h)
Wellhead pressure (MPa)
Time (hours)


GPK3
GPK2
kg/s
50
40
30
20
10
0
0
5
10
15
days
a
b
c
d
e
f

- Numerical stimulation present a semplificative geometry and follow real stimulation cicle

- Source term: $\frac{\vec{\nabla}\sigma}{\sigma}\vec{E} + \frac{l\nabla^2 P}{\sigma}$

- Pressures have been calculated using a termo-fluid dynamic model (Troiano et al.2013)

- The costant l choosed ad hoc for Soultz-sous-Forets.

- Poisson's equation:

$$\nabla^2 V = -\frac{\vec{\nabla}\sigma}{\sigma}\vec{E} - \frac{1}{\sigma}[\vec{\nabla} l.\vec{\nabla} P - \rho_f \vec{\nabla} l.\vec{g} - l\nabla^2 P\ ]$$

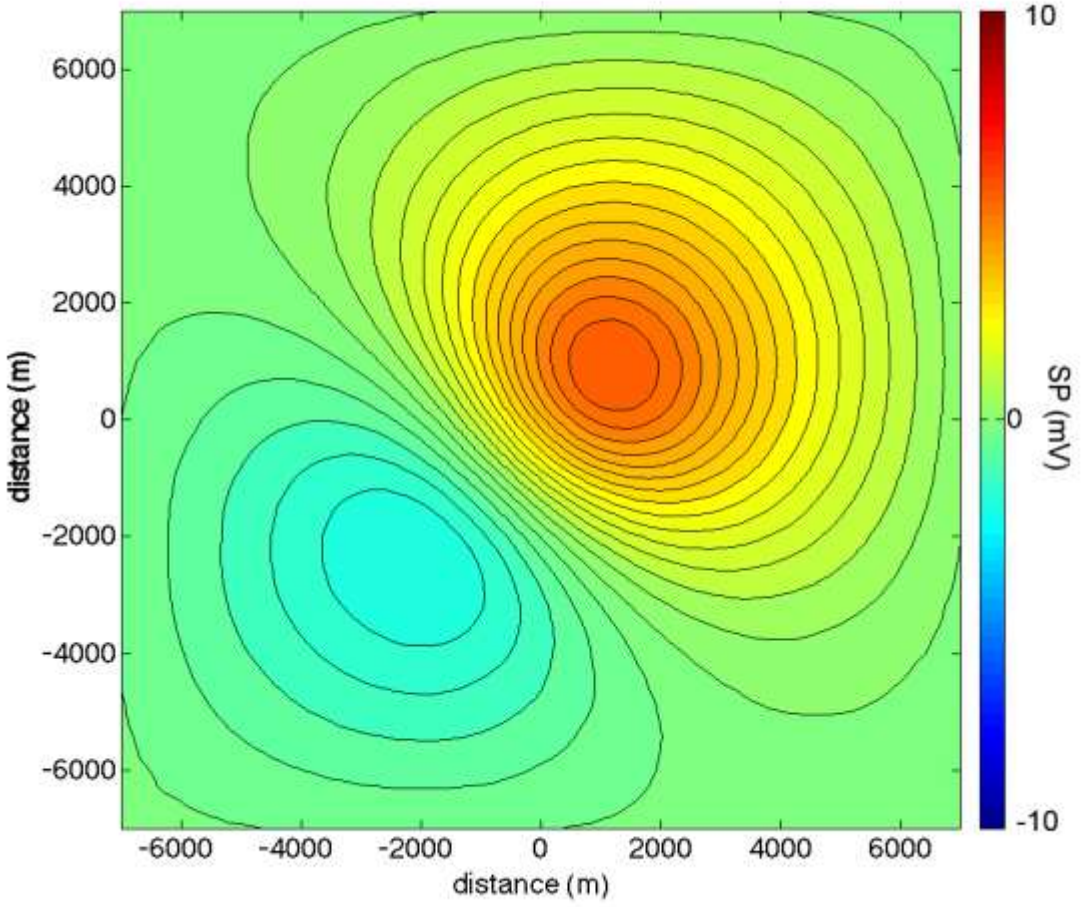
- Numerical stimulation present a semplificative geometry and follow real stimulation cicle

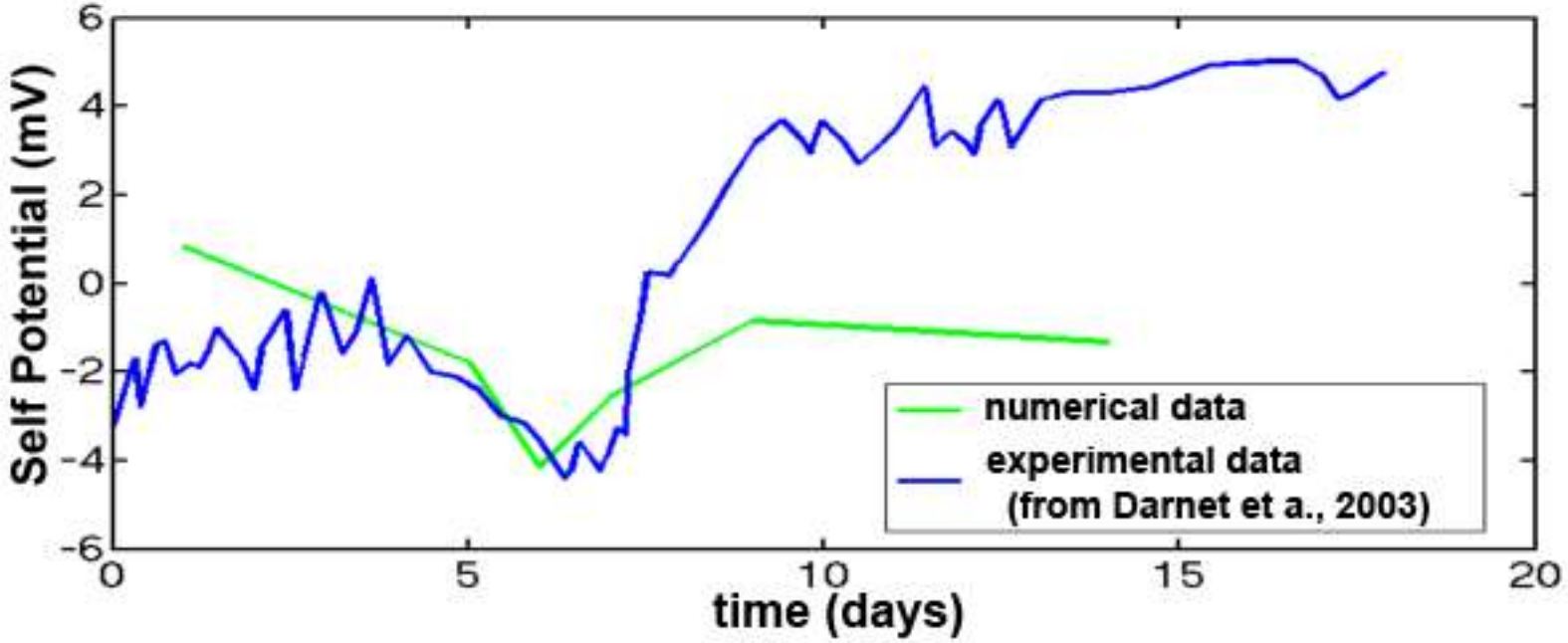
- Source term: $\frac{\vec{\nabla}\sigma}{\sigma}\vec{E} + \frac{l\nabla^2 P}{\sigma}$

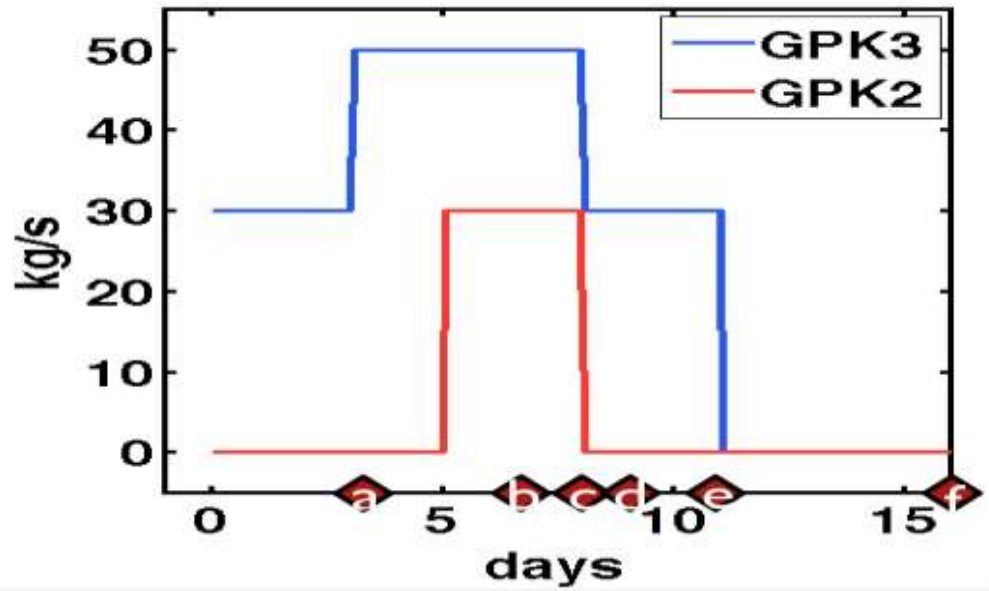
- Pressures have been calculated using a termo-fluid dynamic model (Troiano et al.2013)

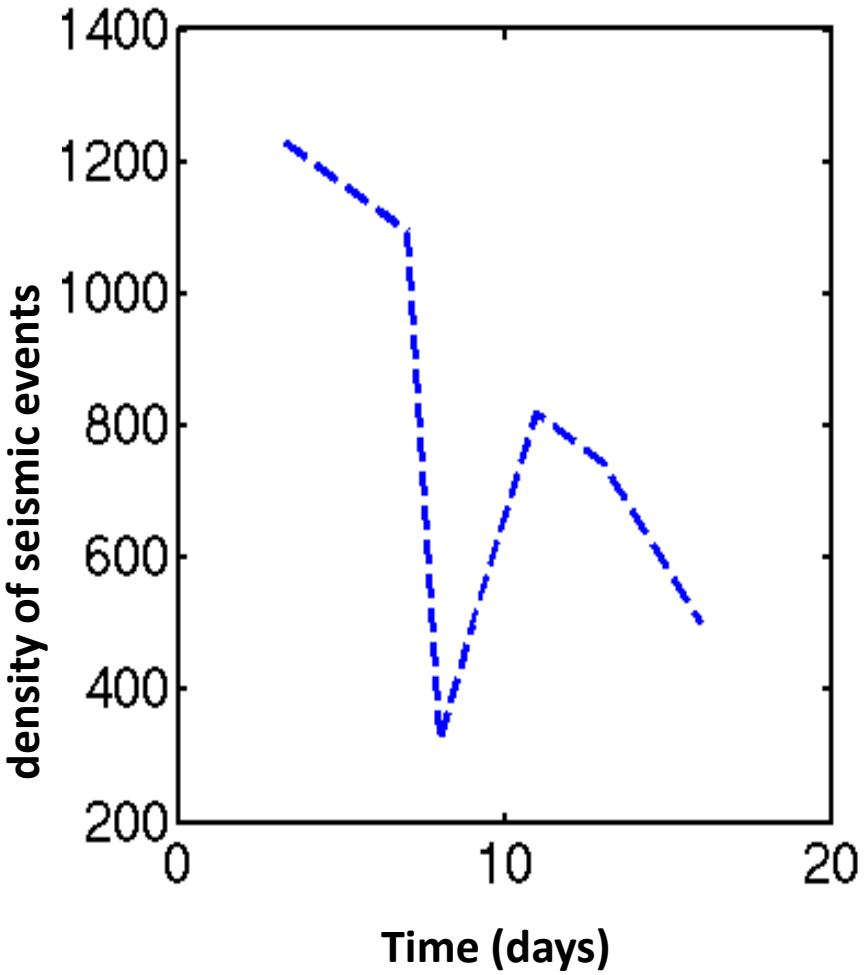
- The costant l choosed ad hoc for Soultz-sous-Forets.

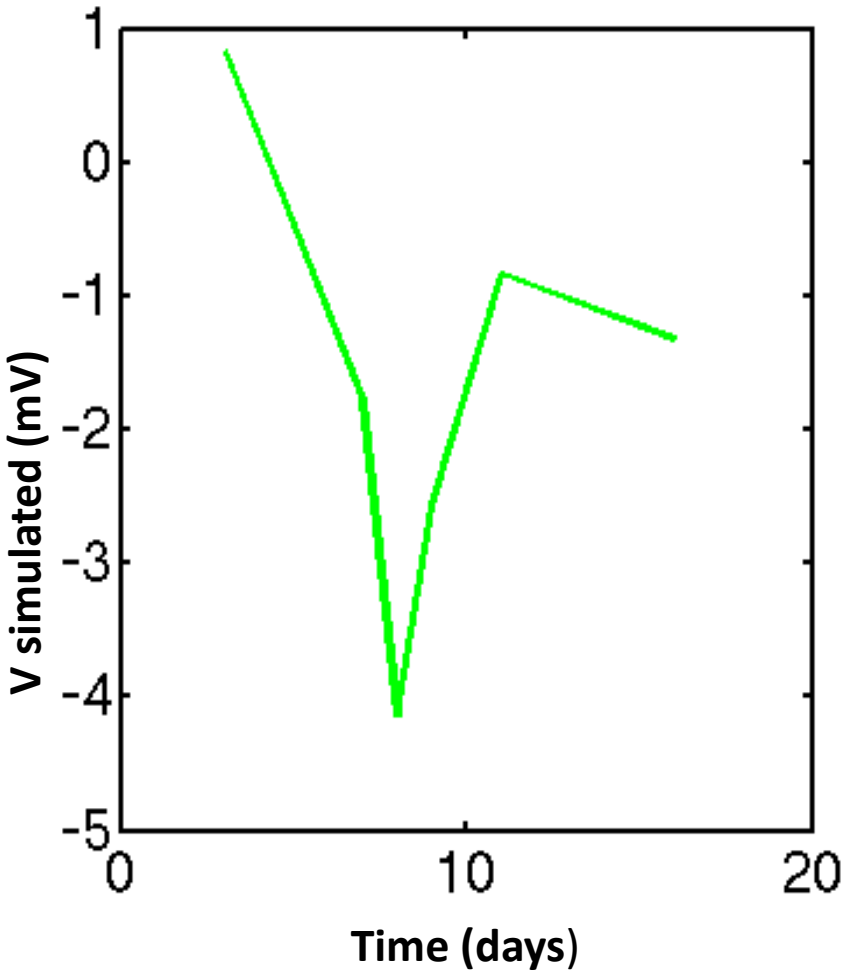
An example of our results:




Self Potential (mV)
time (days)
numerical data
experimental data
(from Darnet et a., 2003)


GPK3
GPK2
kg/s
days
a
b
c
d
e
f


1400
1200
1000
800
600
400
200
0
10
20
density of seismic events
Time (days)


1
0
-1
-2
-3
-4
-5
0
10
20
V simulated (mV)
Time (days)

CONCLUSION

- Choice of the best l value to use in our model
- Electric potential obtained through numerical simulation in agreement with experimental data recorded
- A significative good matching has been found between density of seismic events and the trend of Self- Potential for the same pumping stimulation

THANKS FOR ATTENTION