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COMSOL SIMULATION OF THE ELECTROKINETIC EFFECT IN GIDROGEOLOGY

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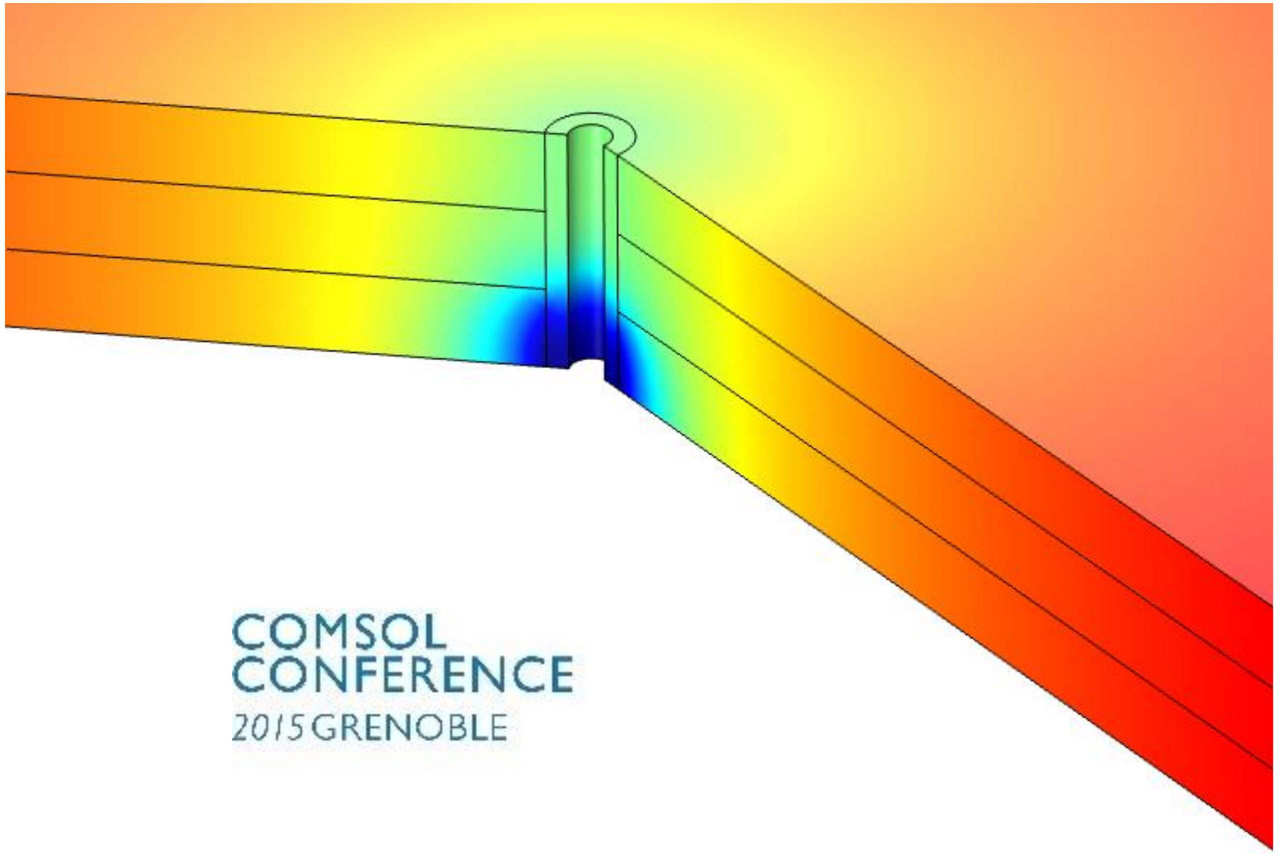
Thanks to

- COMSOL France leaders for their efforts to conduct this Conference
- COMSOL Moscow service for their help
- The COMSOL team for the COMSOL Multiphysics production

Underground Water Resourses and GeoElectrical Surface Measurements



The French School in Filtration, Geophysics and Gidrogeology:

- A.Darcy (1856)- The Law of filtration

$$w=K \text{ grad } H$$

- J.Dupuit (1857) – the basic formula of filtration

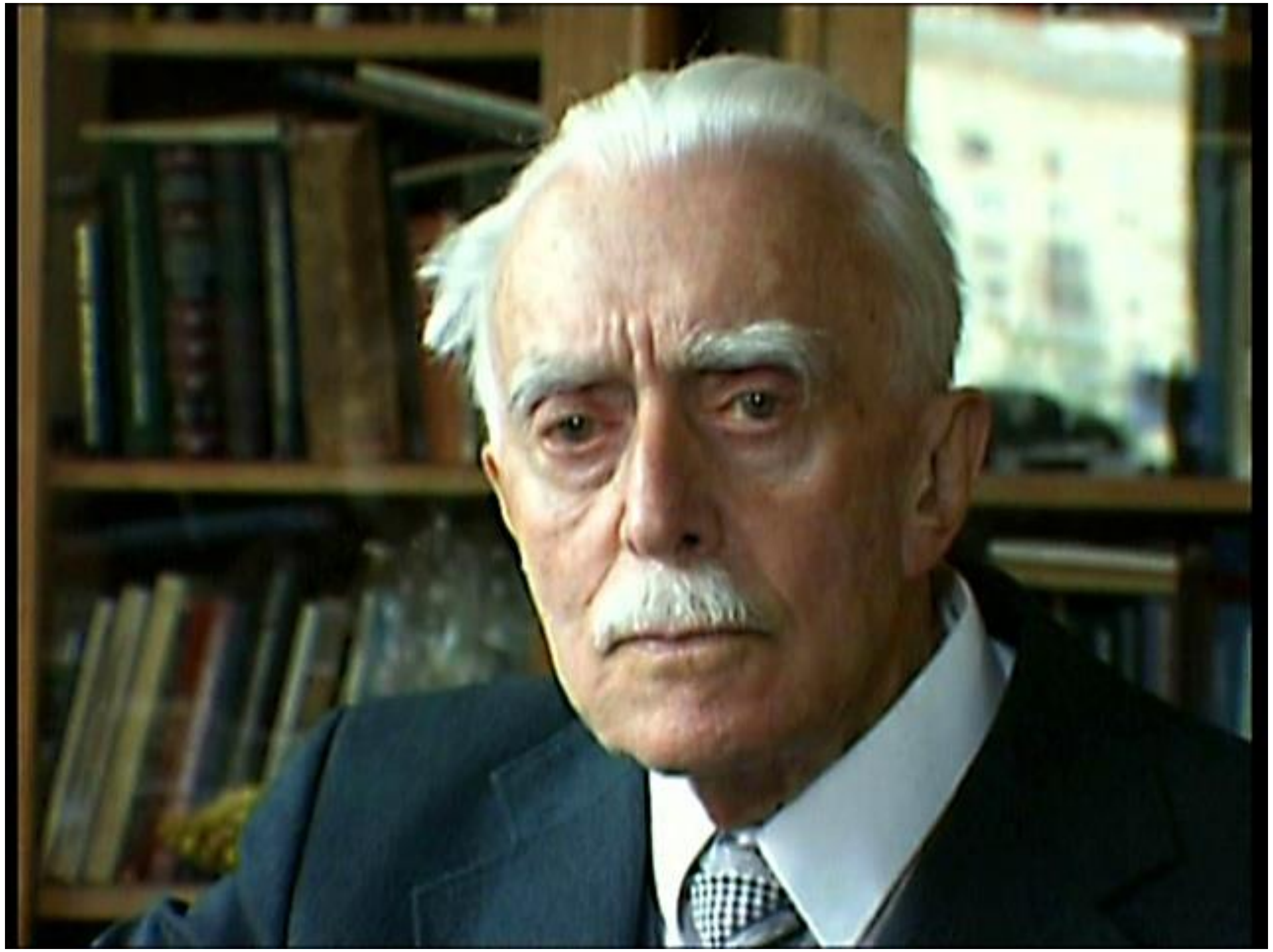
Modern contributers to the Self Potential theory

- A. Jardany
- A. Revil
- A.Maineult and others

The Russian School in Filtration, Geophysics and Gidrogeology:

- N. Pavlovsky
- P. Polubarinova-Kochina
- L. Leibenzon
- V. Shchelkachev
- V. Schestakov

Vladimir Shchelkachev



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$$\Delta p = \frac{1}{\eta}\frac{\partial p}{\partial t}$$

$$p = \rho g H$$

$$\Delta H = \frac{1}{\eta}\frac{\partial H}{\partial t}$$

$$w = -K\nabla H$$

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$$\nabla \cdot (K \nabla H) = S \frac{\partial H}{\partial t}$$

$$Q = 2\pi K h r \frac{\partial H}{\partial r}\bigg|_{r=0} = Q_0$$

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$$H = \frac{Q}{4\pi K h}\overline{H}$$

$$\frac{\partial}{\partial r}\left(r\frac{\partial H}{\partial r}\right)+\frac{\partial}{\partial z}\left(r\frac{\partial H}{\partial z}\right)=r\frac{\partial H}{\partial t}$$

$$k=x, C=x, \rho=1, f=0$$

$$x=r, y=z$$

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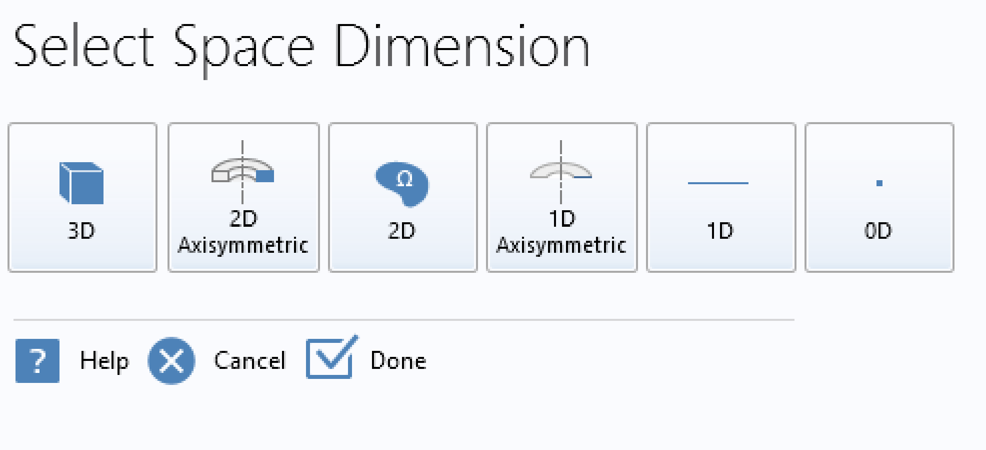

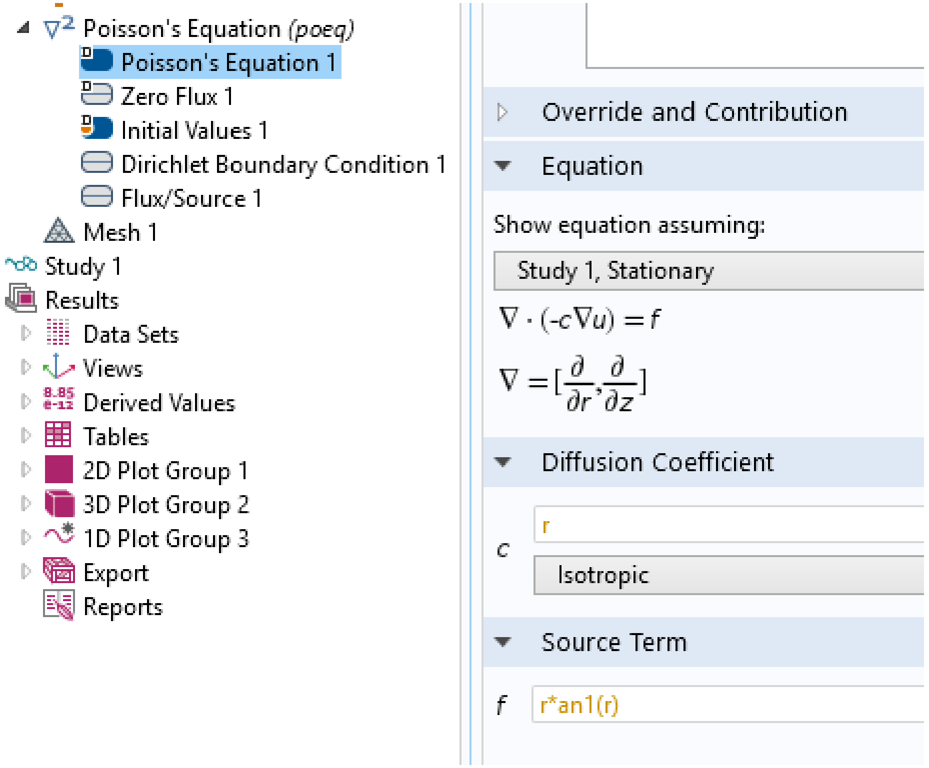
Poisson's Equation (poeq)
Poisson's Equation 1
Zero Flux 1
Initial Values 1
Dirichlet Boundary Condition 1
Flux/Source 1
Mesh 1
Study 1
Results
Data Sets
Views
Derived Values
Tables
2D Plot Group 1
3D Plot Group 2
1D Plot Group 3
Export
Reports
Override and Contribution
Equation
Show equation assuming:
Study 1, Stationary
$\nabla \cdot (-c\nabla u) = f$
$\nabla = [\frac{\partial}{\partial r}, \frac{\partial}{\partial z}]$
Diffusion Coefficient
c
r
Isotropic
Source Term
f
r*an1(r)

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial H}{\partial r}\right)=\frac{\partial H}{\partial t}$$

$$r\frac{\partial H}{\partial r}\bigg|_{r=0}=2$$

$$H=-\mathrm{expint}\left(\frac{r^2}{4t}\right)$$

$$Ei(x)=\mathrm{expint}(x)=\int_x^{\infty}\frac{e^{-u}}{u}du$$

$$\nabla(\sigma\nabla\varphi) = -\nabla(L\nabla H)$$

$$\varphi = \frac{Q}{4\pi hK}\frac{L}{\sigma}\overline{\varphi}$$

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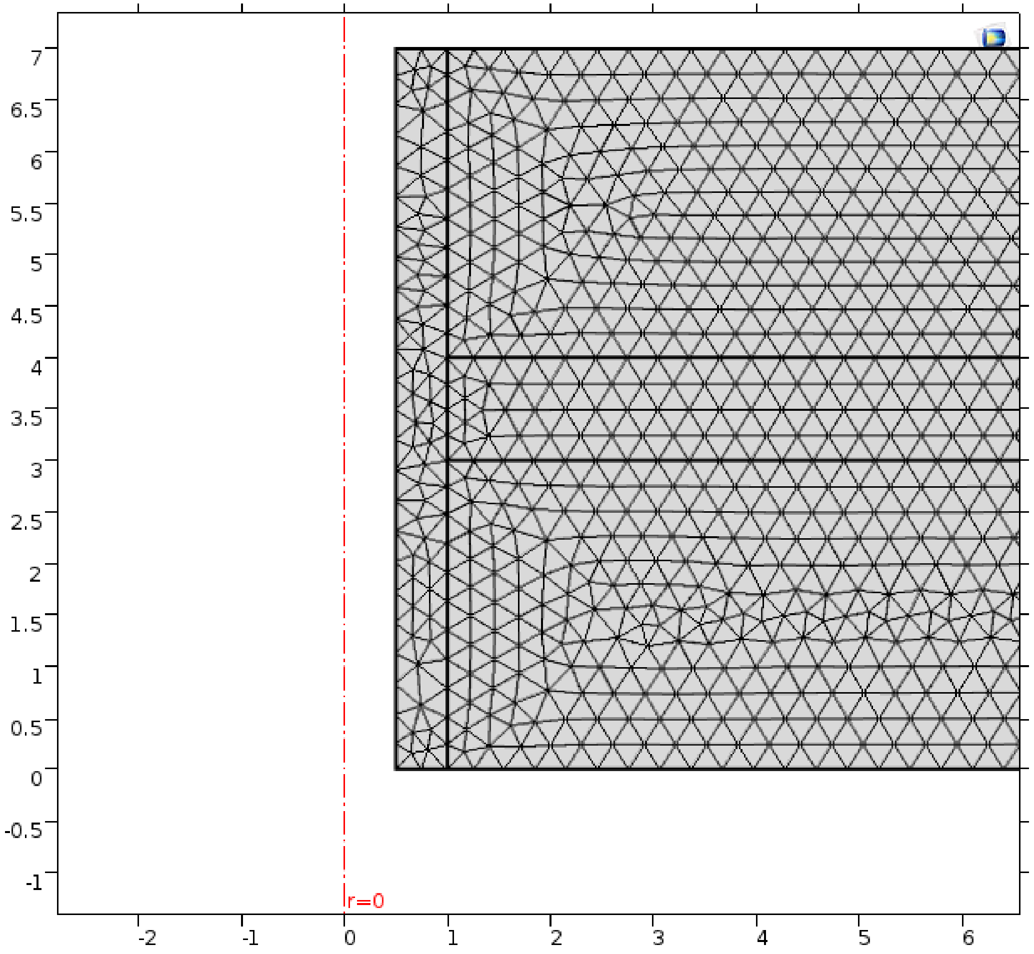
$$\Delta\varphi = -\Delta H$$

$$r\frac{\partial\varphi}{\partial r}\bigg|_{r=0} = -2$$

$$\Delta\varphi = \frac{1}{t}e^{-\frac{r^2}{4t}} \qquad \varphi = \mathrm{expint}\left(\frac{r^2}{4t}\right)$$


7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
r=0
-2
-1
0
1
2
3
4
5
6

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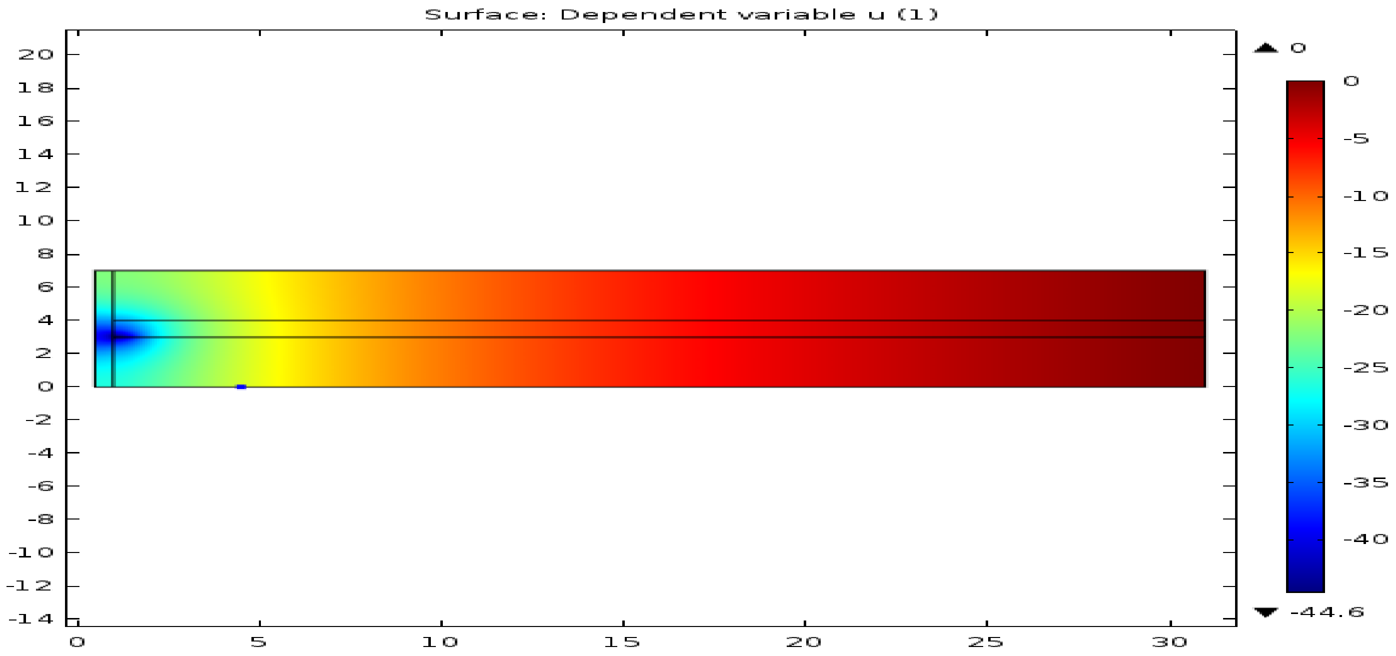

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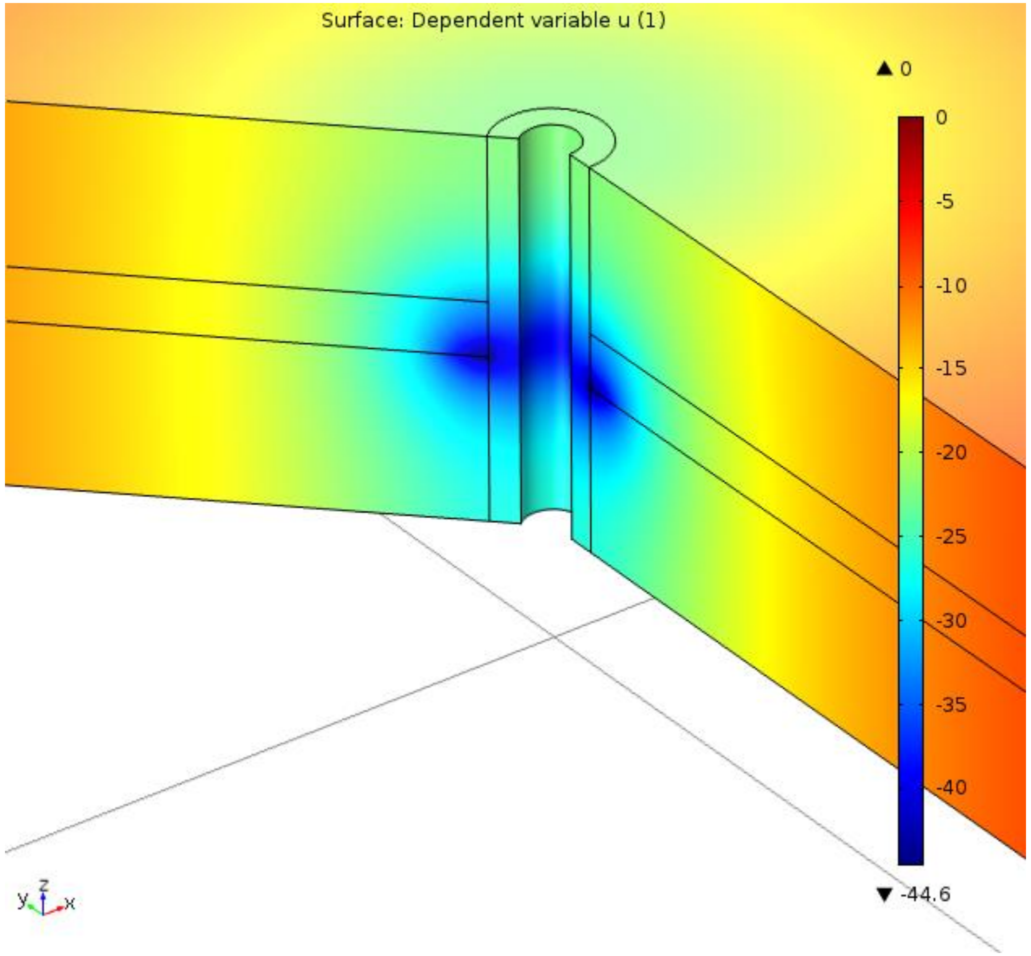
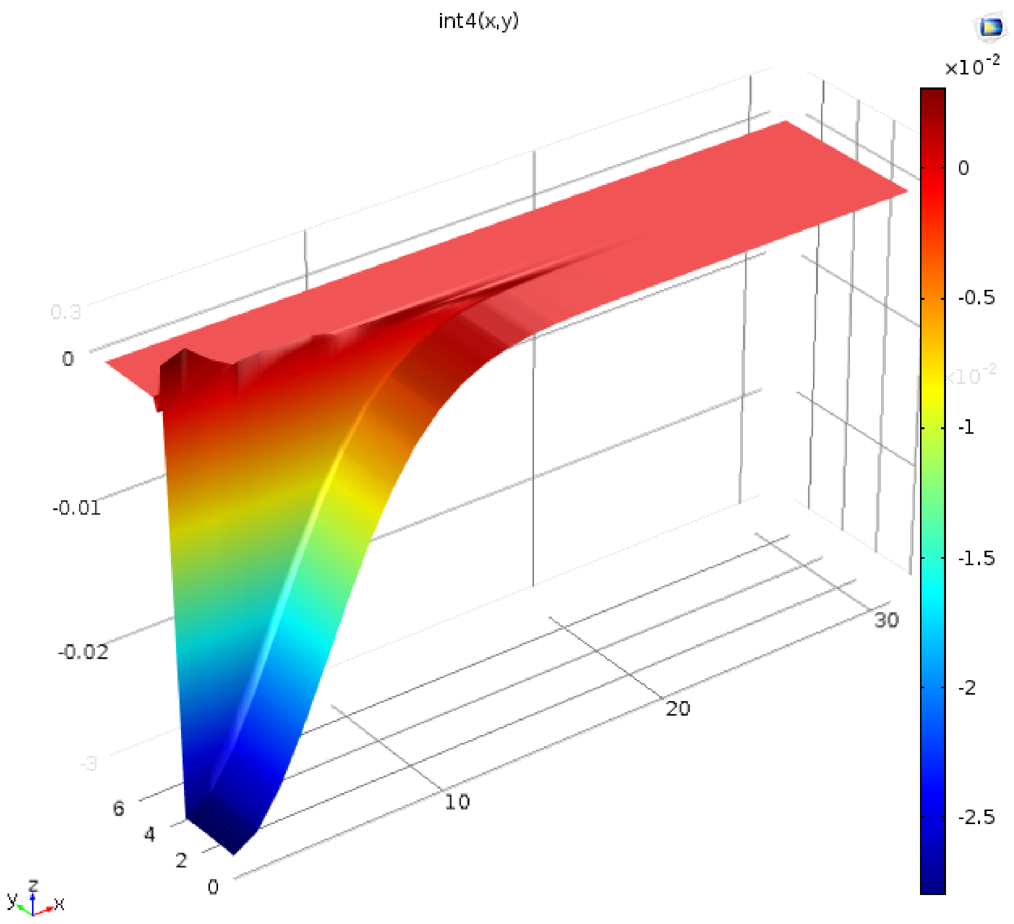
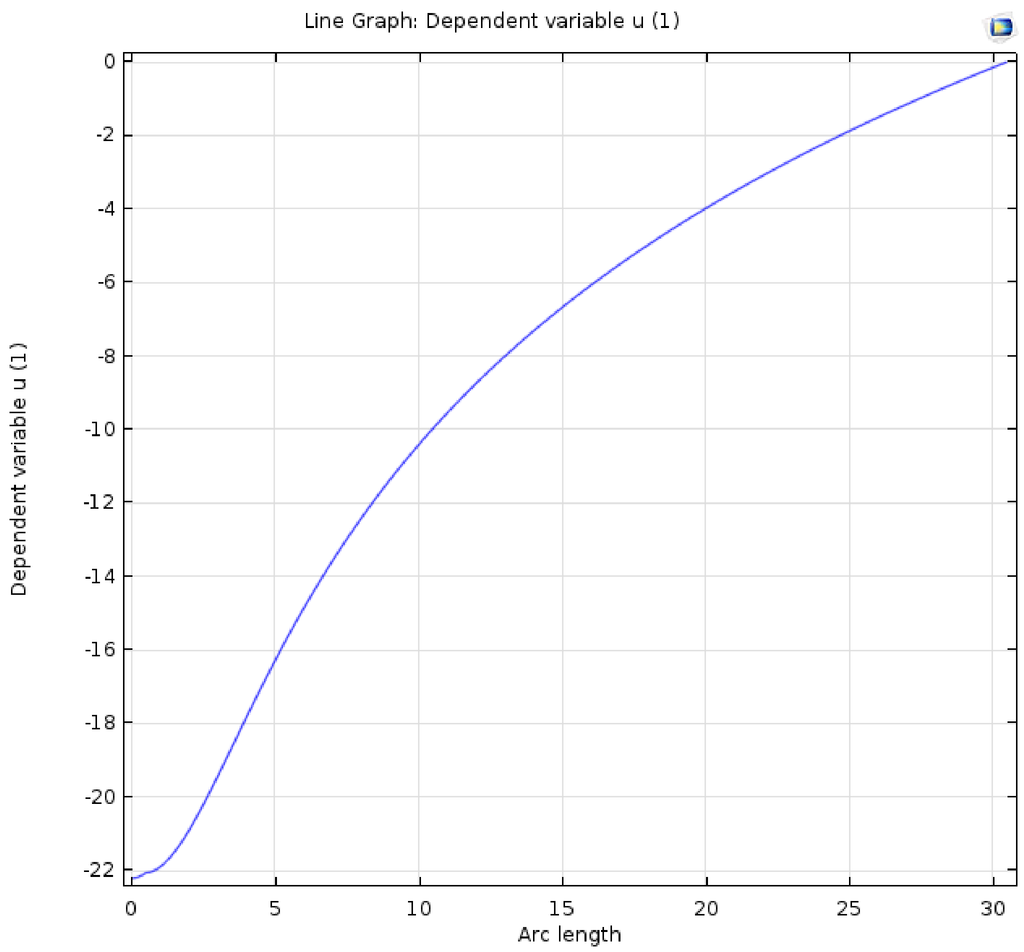
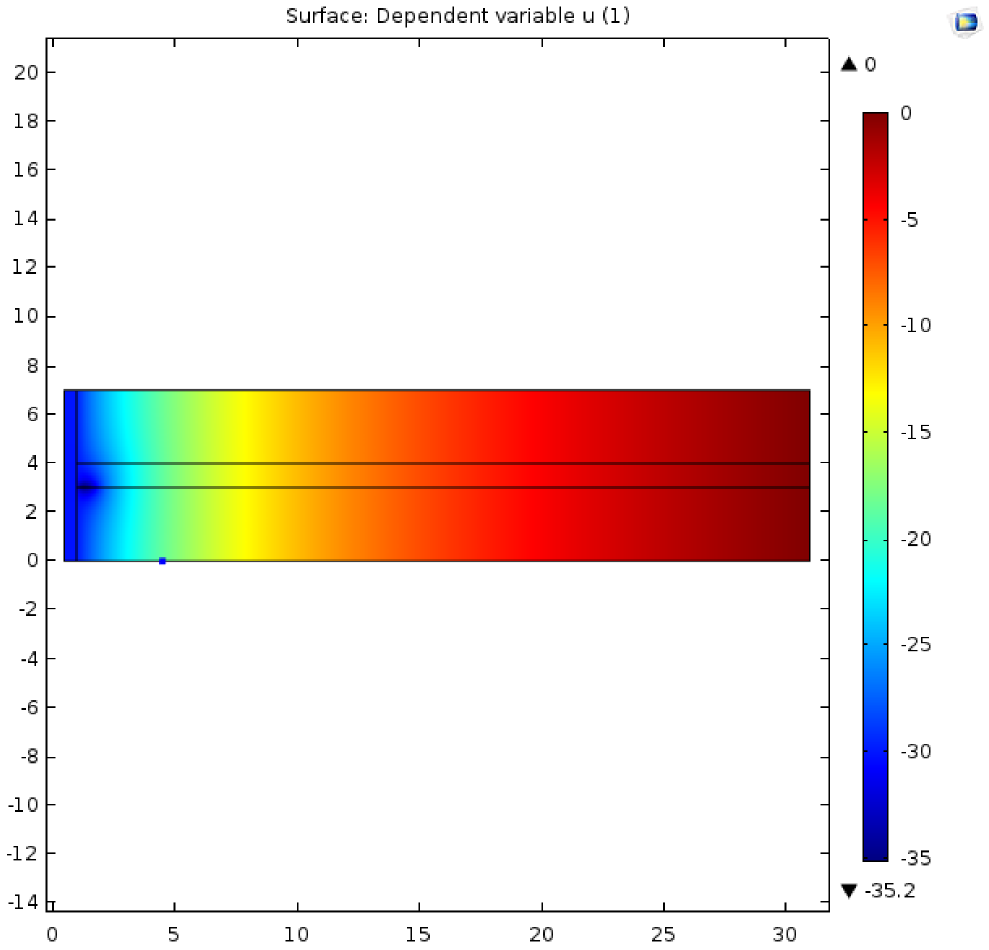




int4(x,y)
×10⁻²
0
-0.5
-1
-1.5
-2
-2.5
0.3
0
-0.01
-0.02
6
4
2
0
10
20
30
y
z
x


Line Graph: Dependent variable u (1)
Dependent variable u (1)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
0
5
10
15
20
25
30
Arc length


Surface: Dependent variable u (1)
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
0
5
10
15
20
25
30
▲ 0
0
-5
-10
-15
-20
-25
-30
-35
▼ -35.2

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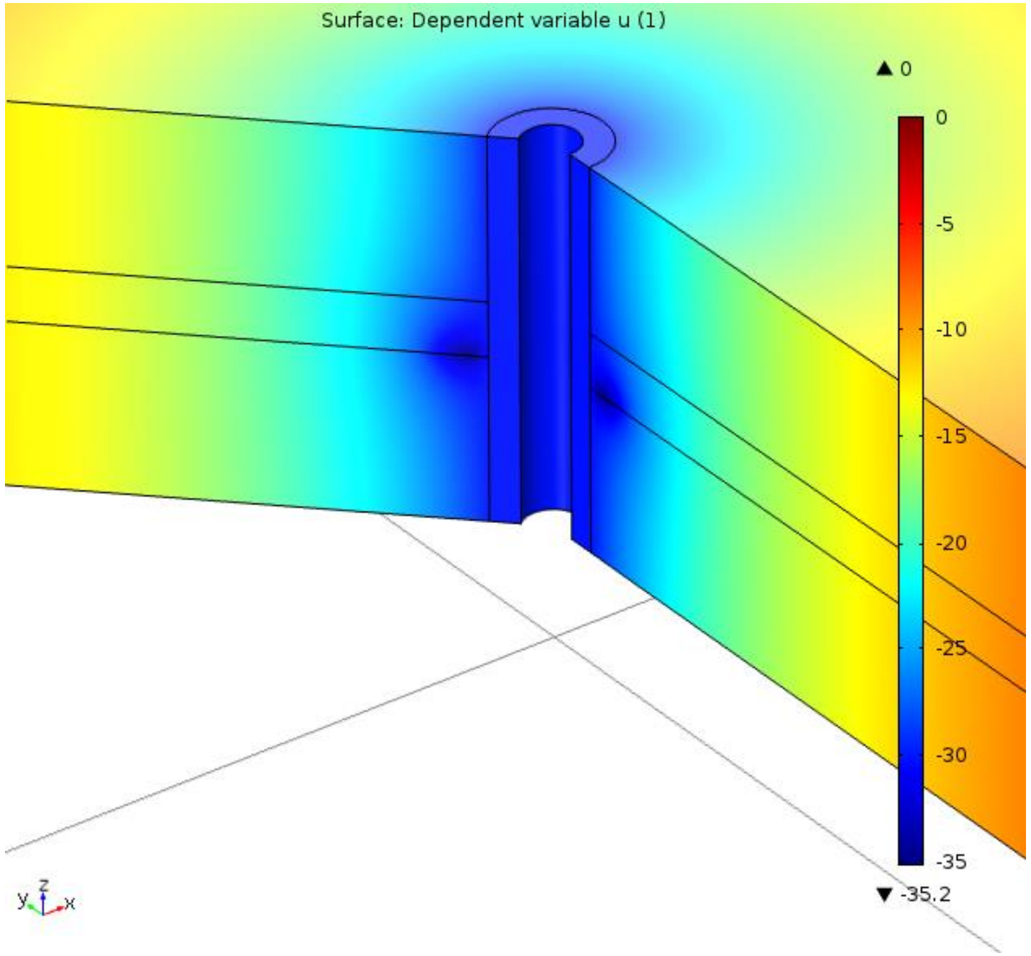

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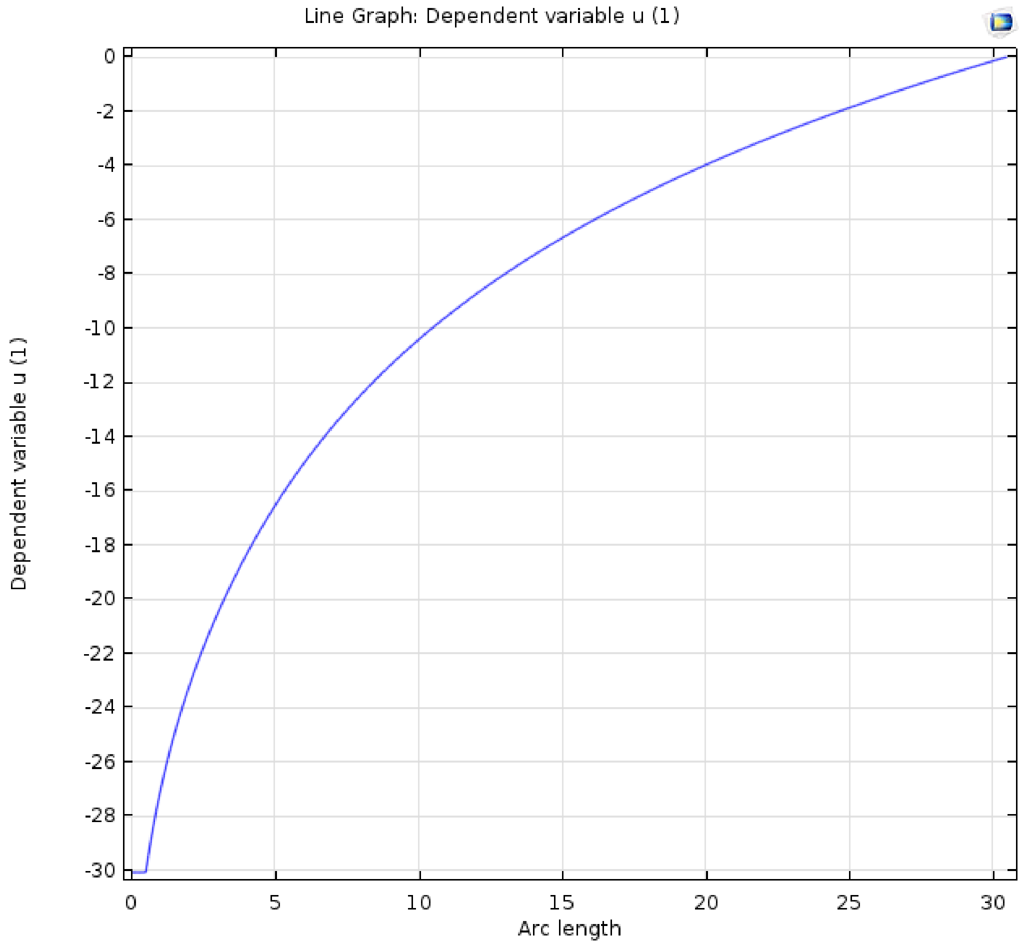
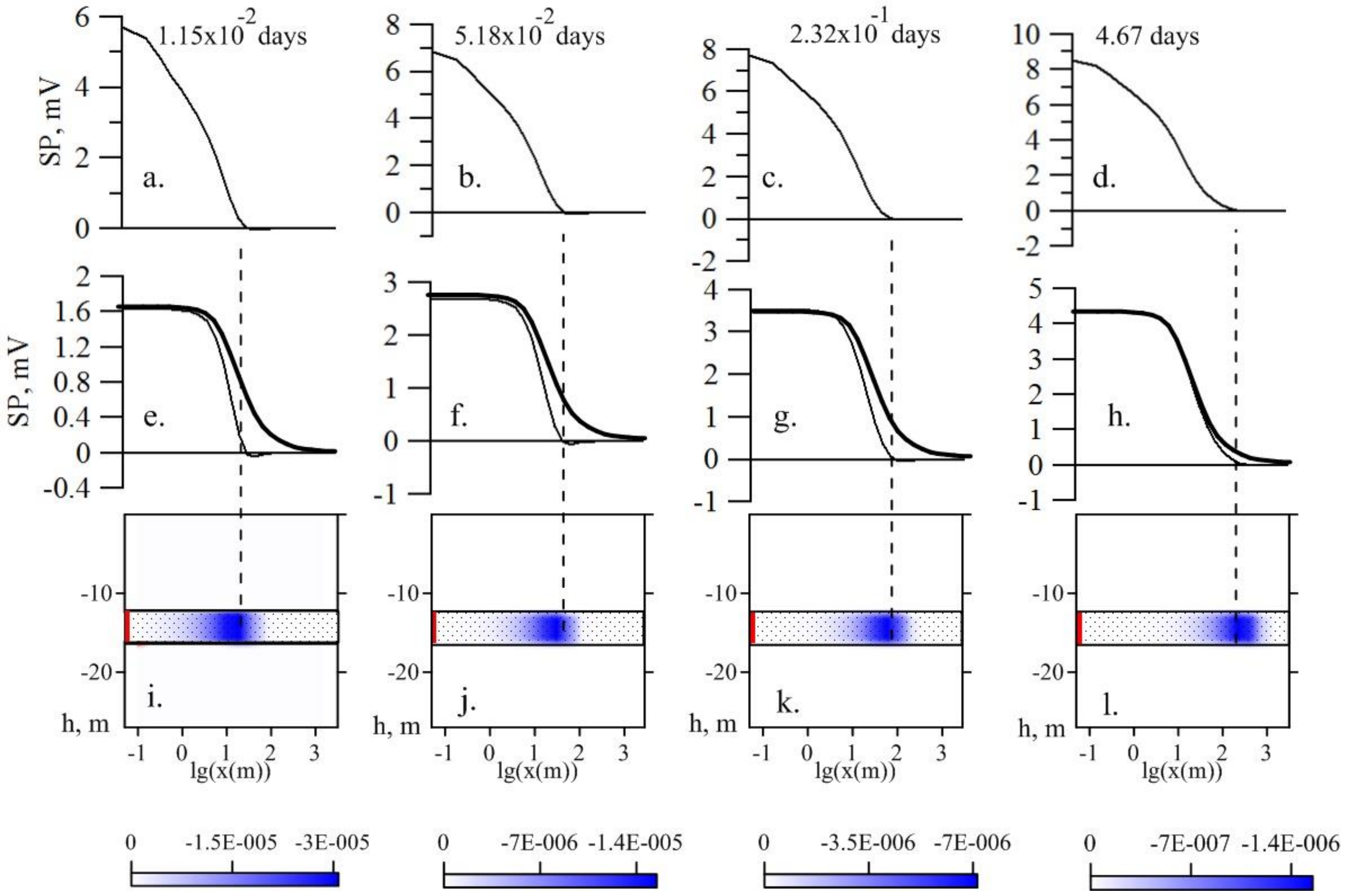
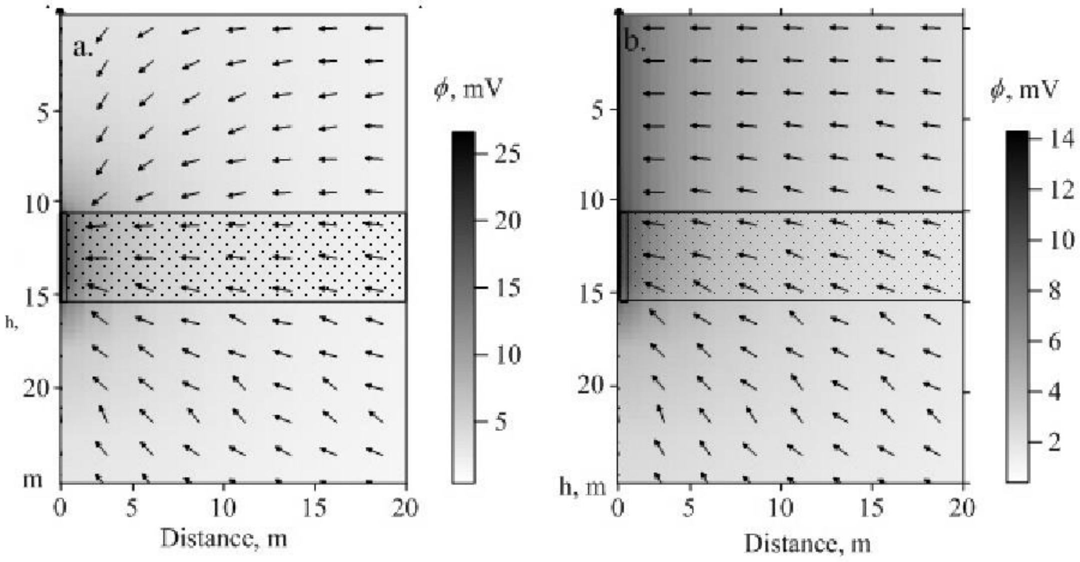



1.15x10-2 days
5.18x10-2 days
2.32x10-1 days
4.67 days
SP, mV
SP, mV
h, m
lg(x(m))
a.
b.
c.
d.
e.
f.
g.
h.
i.
j.
k.
l.
0 -1.5E-005 -3E-005
0 -7E-006 -1.4E-005
0 -3.5E-006 -7E-006
0 -7E-007 -1.4E-006

Cross section of radial distribution of the electrical potential around the pumping well, which is located at distance .



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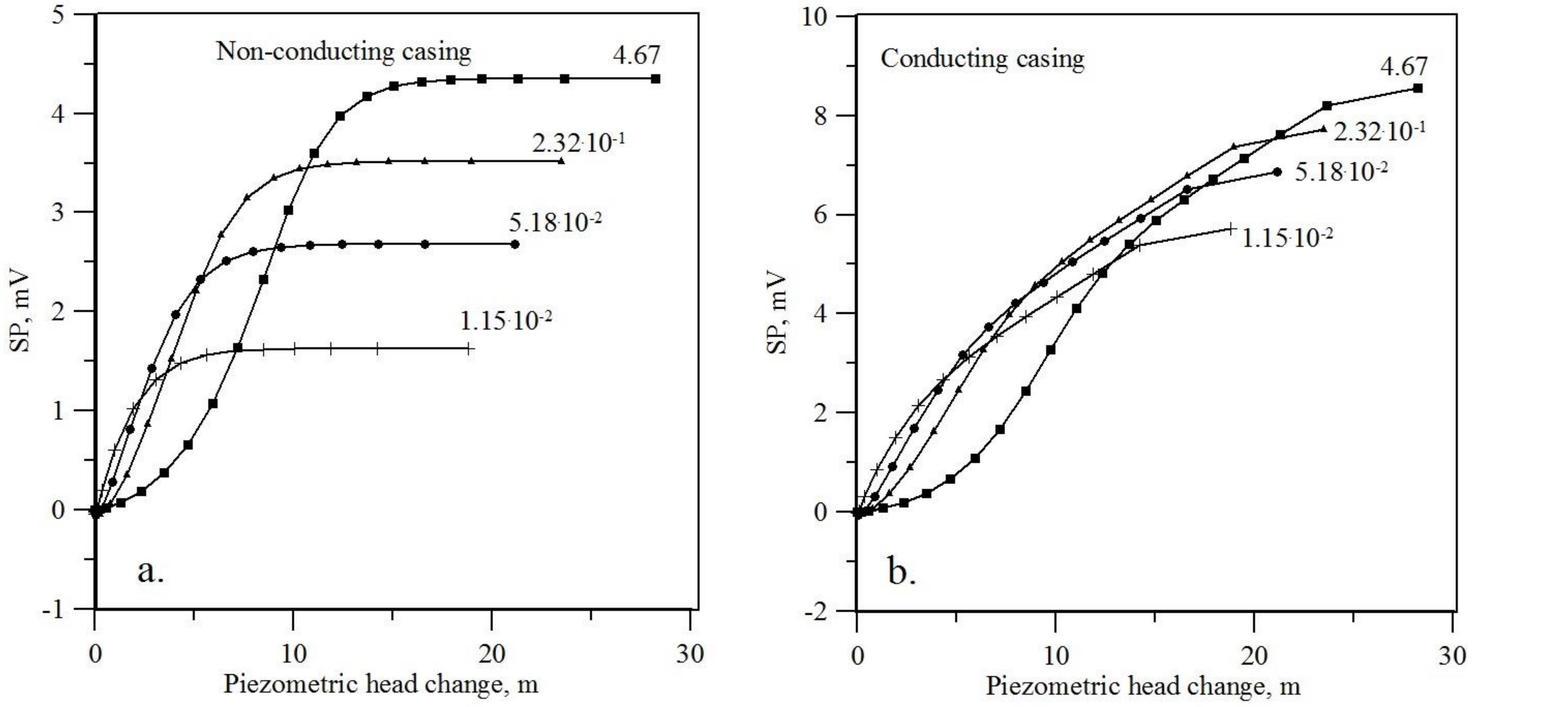
SP signals vs. piezometric head change produced in the course of a pumping test in an individual confined aquifer.



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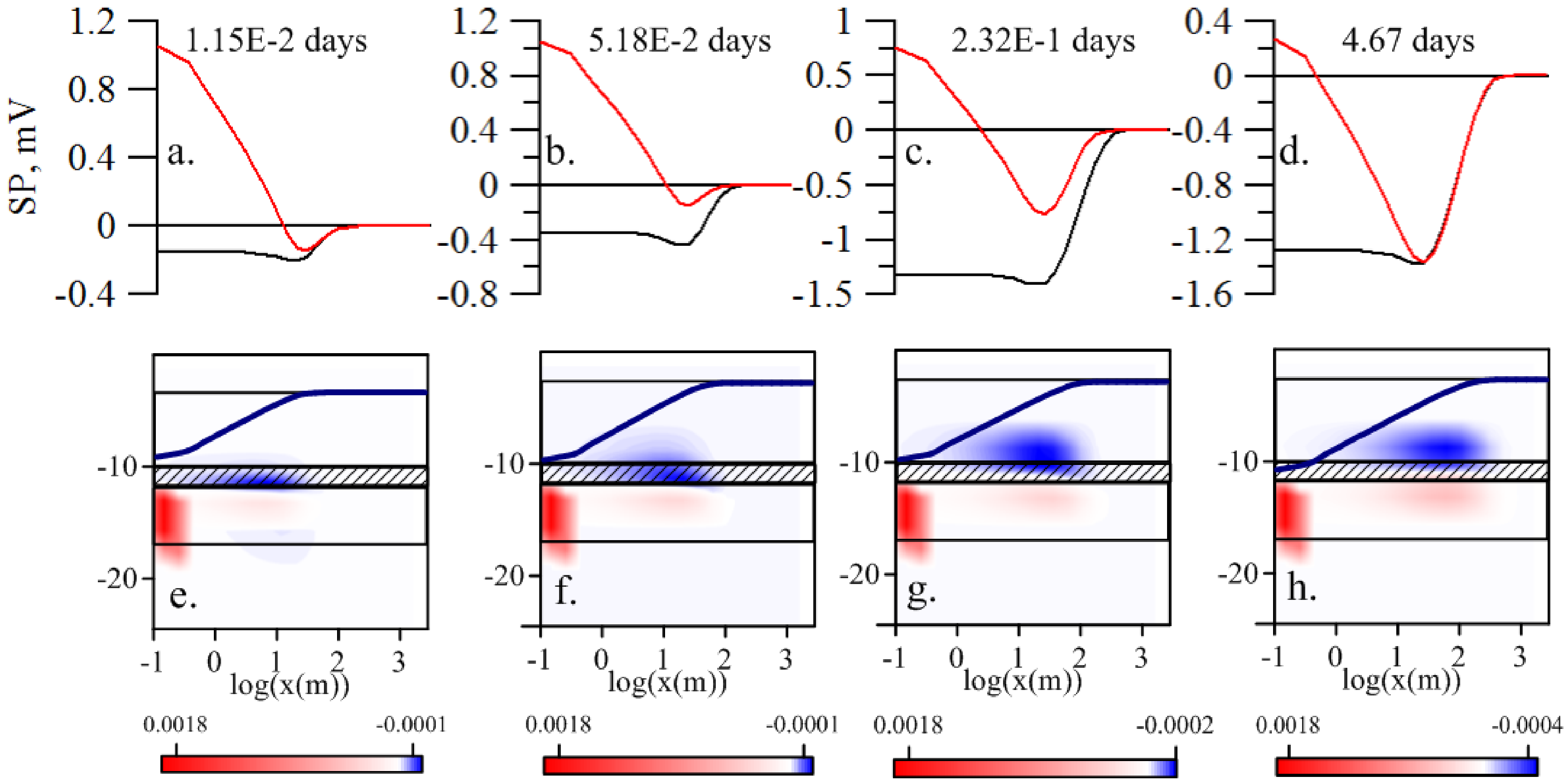
Self-potential signals (a – d) and respective electrical sources in amperes (e – h) produced by a pumping test in a layered aquifer



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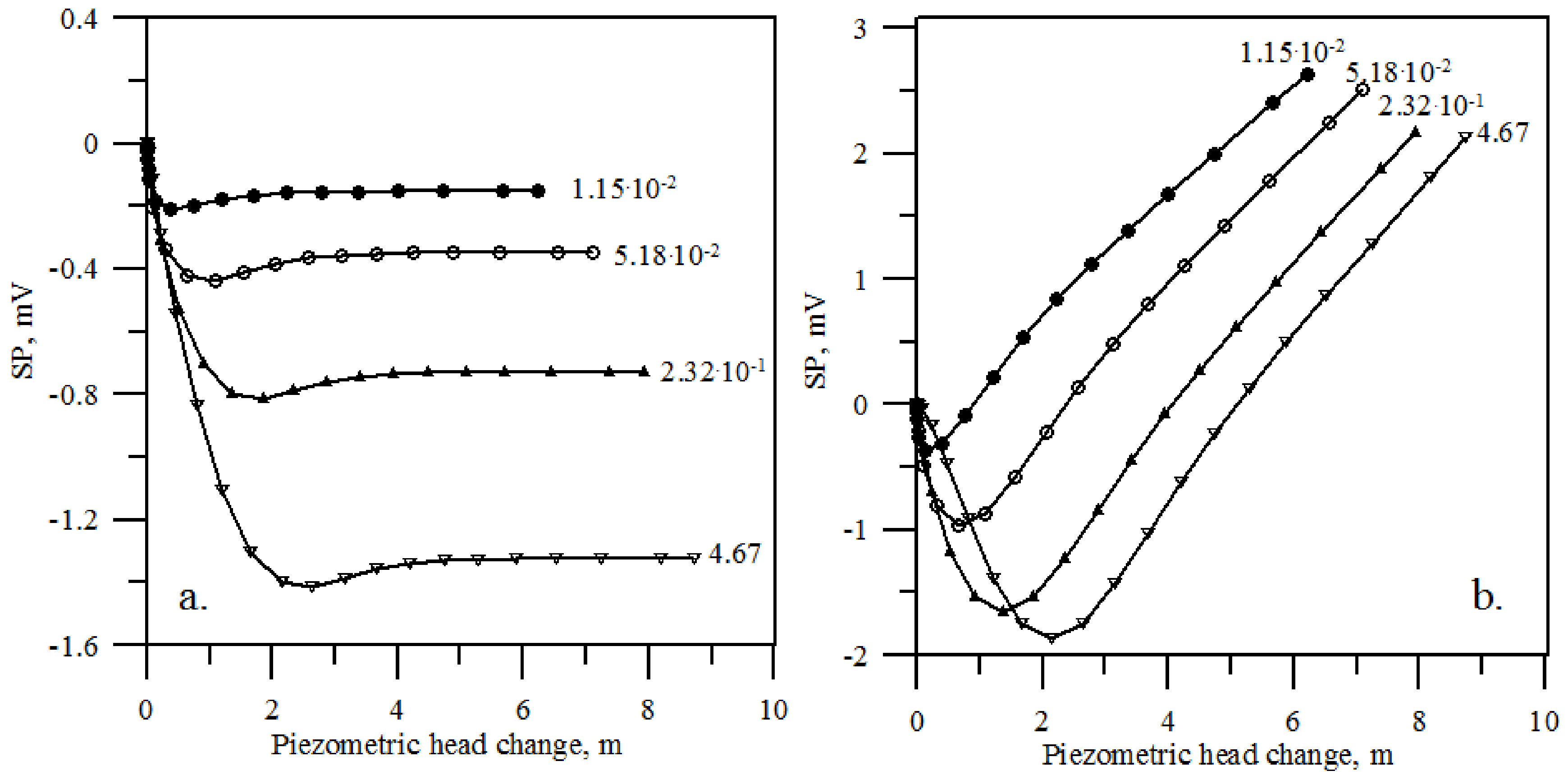
SP signals vs. piezometric head change produced in the course of a pumping test in a layered aquifer



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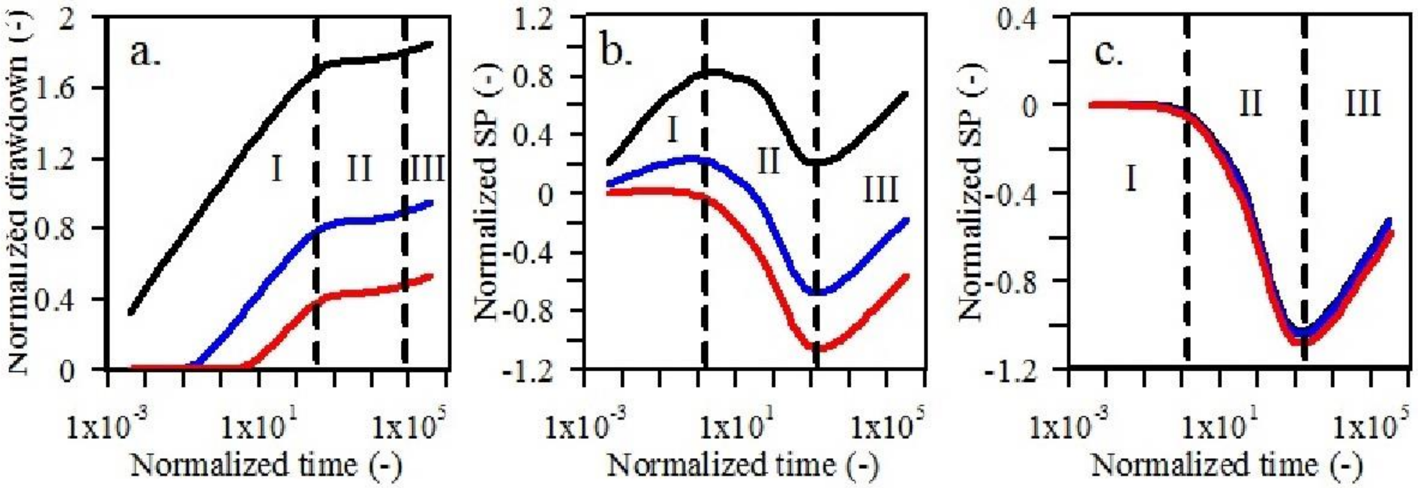
Normalized drawdown (a) and normalized SP signals (b and c) for the cases of conductive (b) and insulating (c) pumping well casing.



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