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CAN AN ELECTRO-KINETIC MECHANISM EXPLAIN ARTIFICIAL EARTHQUAKES?

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Introduction

- Deep within the mountainous regions of Kyrgyzstan the Russians are making earthquakes.
- Injection of thousands of amperes of electrical current into the ground causes earthquakes.
- No one knows why or how!
- Electro-kinetic mechanisms may supply the missing link
- This presentation describes recent numerical modelling that indicates EK mechanisms have the potential to be that link.

The Kyrgyz mountains south of Bishkek in Kyrgyzstan.

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Field results

- Pulsed magneto-hydrodynamic (MHD) generators.
  - 28500 amperes
  - 1350 volts
  - 8.5-9.5 seconds
  - 15 MW
- Operation:
  - Tubes produce a plasma that is fired through EM coils.
  - Extremely high magnetic fields produce very high current.
- Here there are 3 generators in parallel.

Pamir 3U 15 MW pulsed MHD generator at the Kyrgyzstan site.

- Portable: (18,000 kg, 10x2.4x2.4 m) Flatbed truck trailer

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Field results

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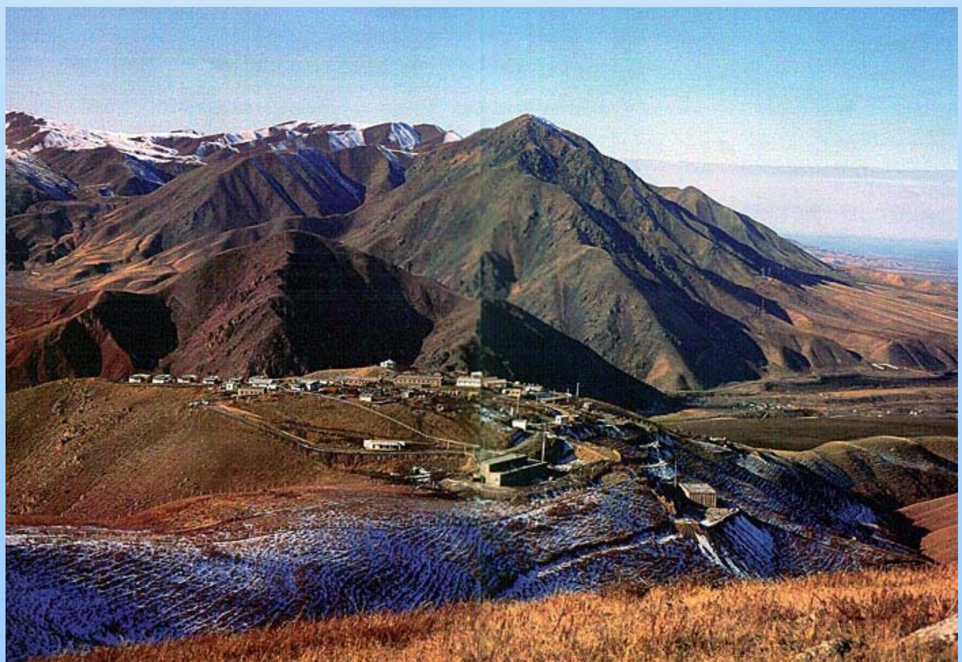
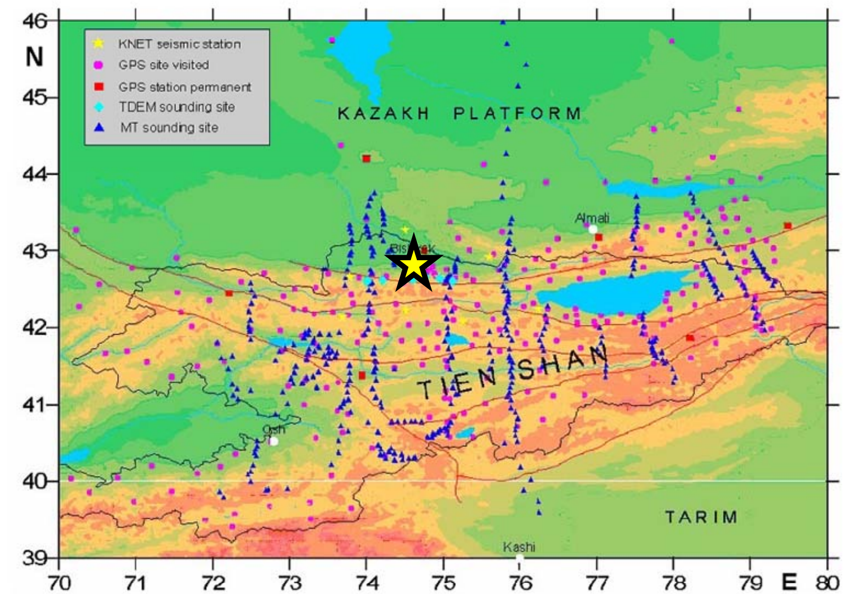
A large number of current injection experiments





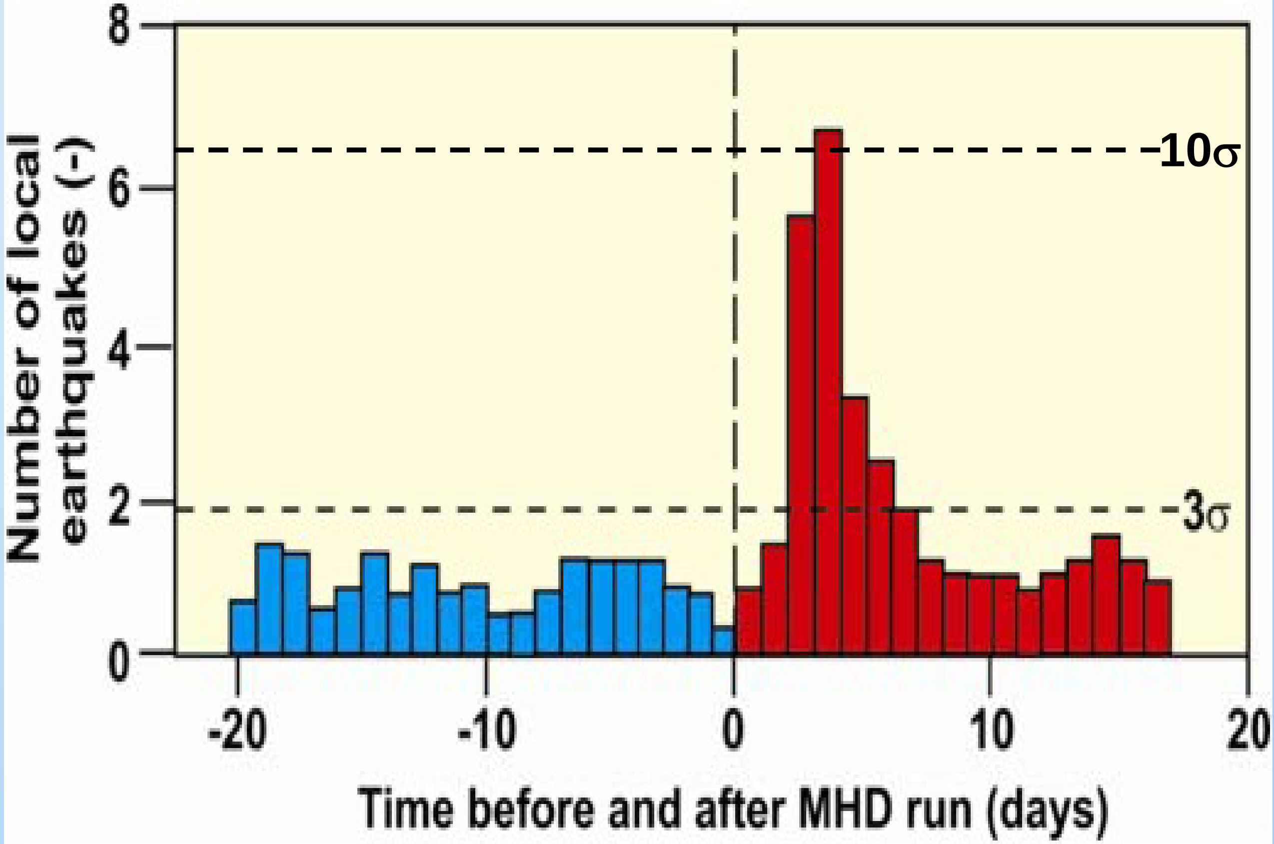
Integrated net of observations

Approximately 5 km long dipole.

Bishkek Research Station in the Chu valley area of the Kyrgyz mountains (northern Tien Shan)

Field results

- Increase in EQ within 150 km range
- Increase over 3σ (1:400)
- Increase over 10σ (1:10^{15})
- Increase occurs 3 days after current injection
- Increase continues for about 5 days

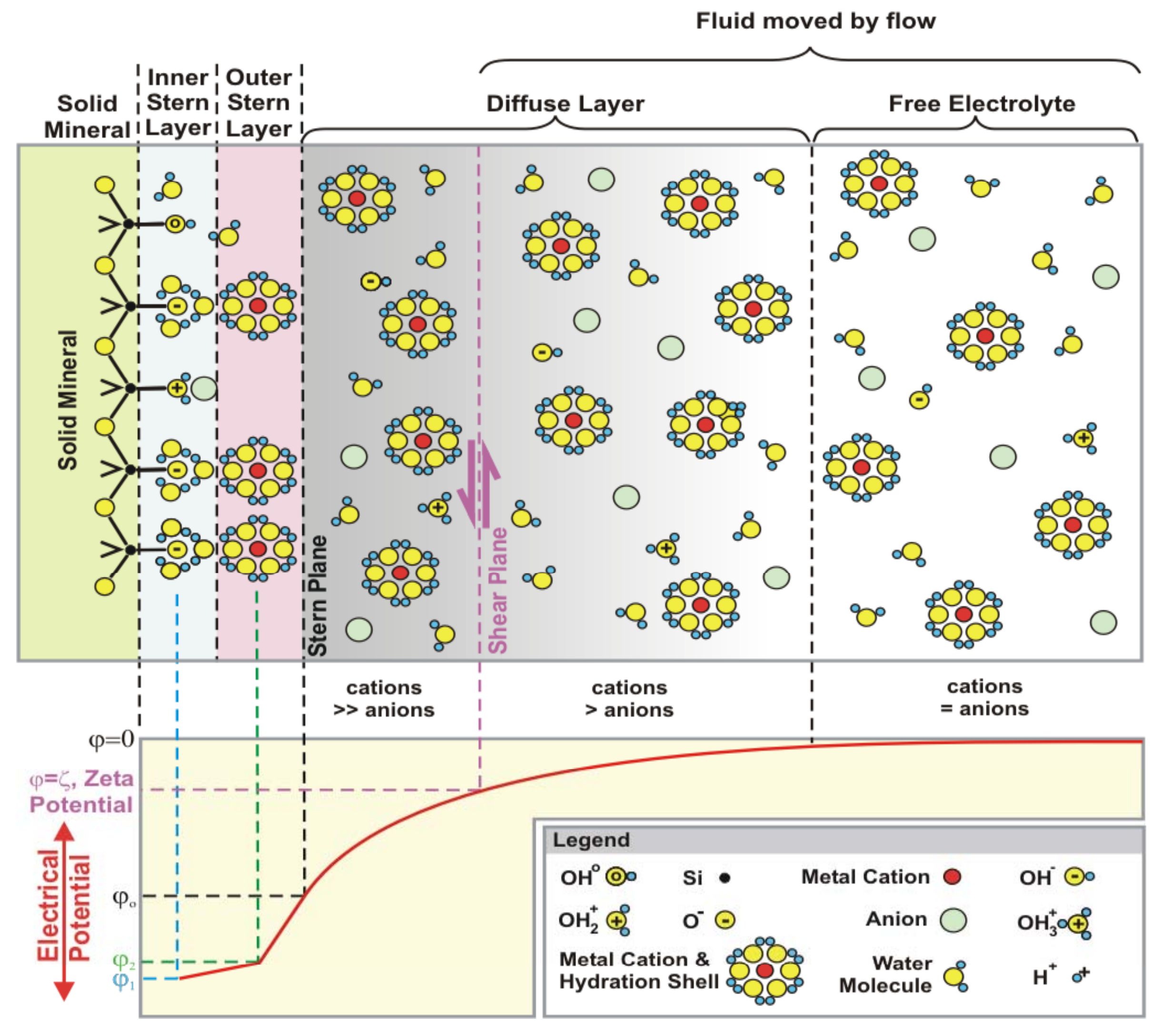


- Increased EQ have $m_b \leq 5.0$

Mechanism

In rocks, fluid flow causes electrical potentials due to the charge imbalance that occurs in the EDL at the fluid-solid interface.

Inversely, electrical potential differences cause a current to flow which is balanced by a fluid flow to ensure that concentrations are globally conserved.



Mechanism

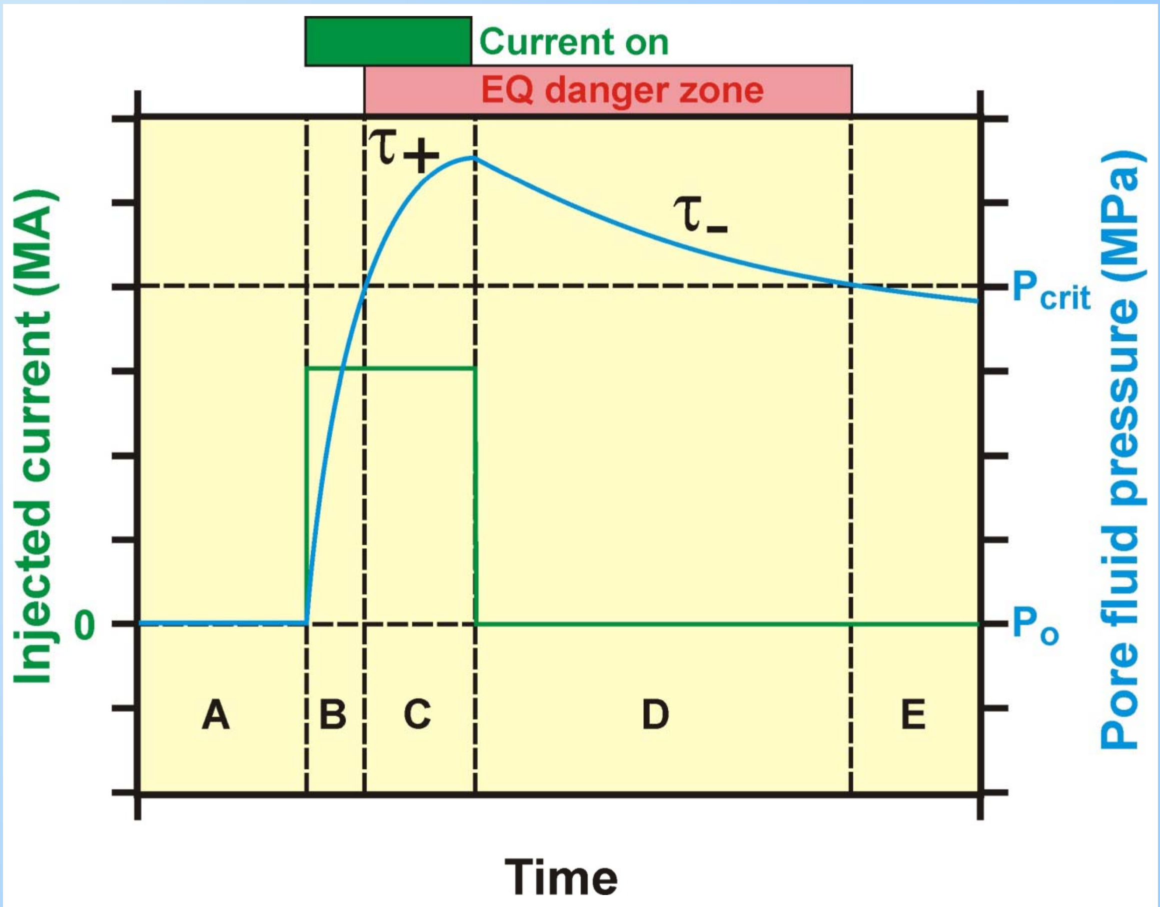
- Electro-osmosis: Due to interfacial chemistry.
- The application of an electrical potential ΔV between two points in the subsurface causes a fluid pressure difference ΔP to build-up between the two points.

$$\Delta P = \frac{\Delta V \eta_f \left(1.623\, d_{PT} \sqrt{a}\, \sigma_f + 8 \Sigma_s \sqrt{2}\right)}{1.623\, d_{PT}\, \varepsilon_f\, \zeta \sqrt{a}}$$

- where the equation depends upon the pore throat diameter of the rock d_{PT}, the conductivity of the fluid σ_f, the surface conductance Σ_s, the dielectric permittivity ε_f, the zeta potential ζ, the fluid viscosity η_f and a factor $a \approx 8/3$.
- The equation is valid for random porous media.

Mechanism

- Current injection leads to rise in pore fluid pressure.
- Pore fluid pressure decays away after current is switched off.
- While pore fluid pressure exceeds a critical level earthquakes can occur.



- B = Delay, C+D = Length of earthquake production

Key questions

- Can the EK mechanism provide sufficient fault fluid pressure to trigger an earthquake?
- Is the EK mechanism compatible with a range of 150 km?
- Can the EK mechanism explain the time delay and length of the effect?

Modelling

- 2 dimensions
- Model size: ±200 km x 100 km deep
- Zone of interest: ±100 km x 5 km deep
- Dipole length 4.5 km at surface and centre
- Point source and sink of current ±500 V (I=2800 A)
- Isotropic homogeneous earth
- >100,000 triangles in a Delaunay triangulation
- Solved using stationary FEM solver

Modelling

$$J = -L_{21}\nabla p - \sigma_f \nabla V$$

$$u = -\frac{-\kappa}{\eta}\nabla p - L_{12}\nabla V$$

$$\alpha = \frac{\varepsilon\zeta\phi^m}{\eta}$$

Electrical transport

$$-\nabla \cdot d(\sigma\nabla V - J^e) = dQ_j$$

$$J^e = -\alpha\nabla P$$

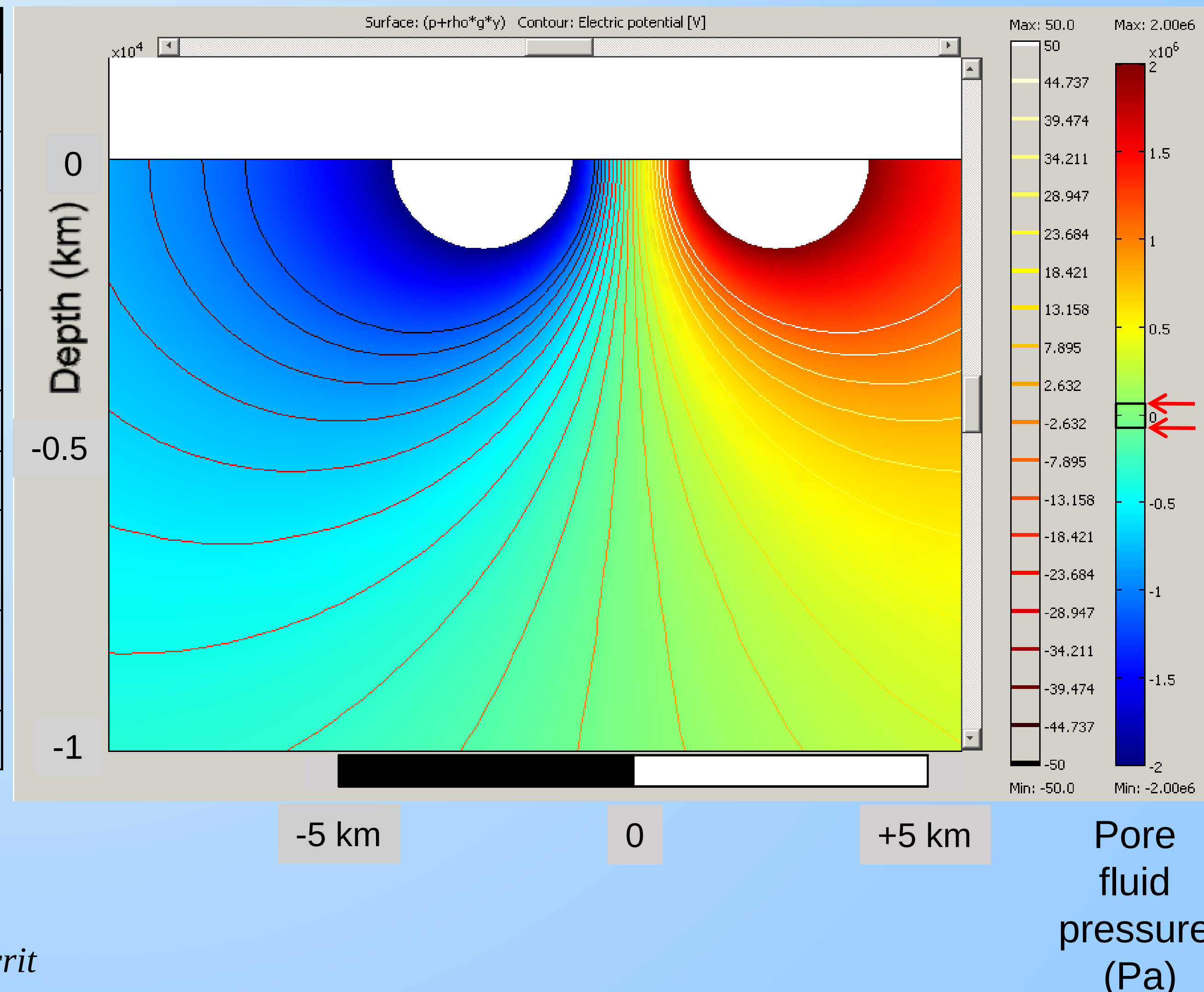
Hydraulic transport

$$\nabla \cdot \left[-\frac{\kappa}{\eta}\left(\nabla p + \rho g \nabla D\right)\right] = Q_s$$

$$Q_s = \alpha\nabla^2 V$$

Results

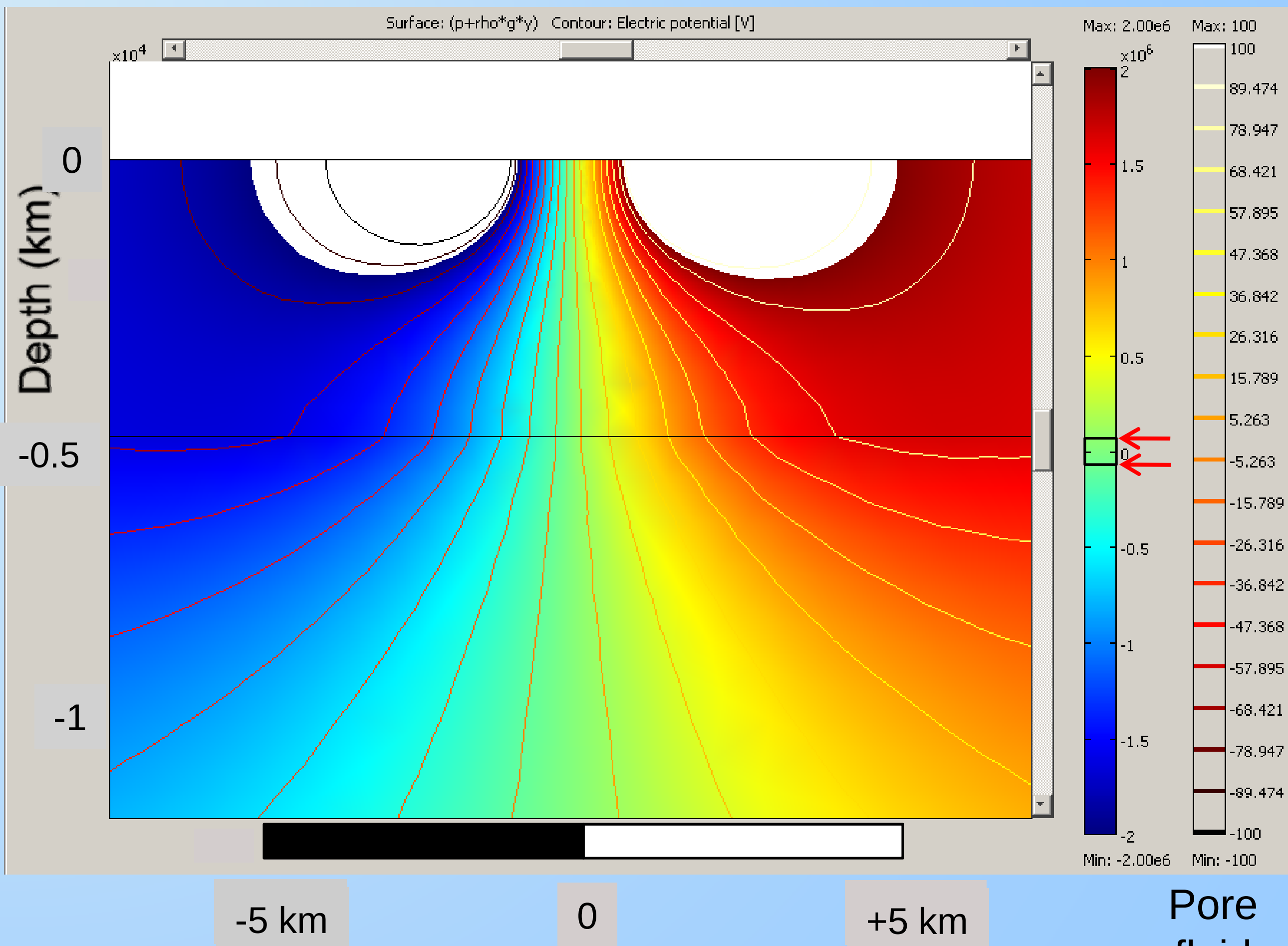
Parameter	Value
Porosity	0.02
Pore diameter	5×10^{-7} m
Fluid conductivity	0.5 S/m
Surface conductivity	5×10^{-9} S
Zeta potential	-0.5 V
Fluid viscosity	8.9×10^{-4} Pa.s
Dielectric permittivity	7×10^{-10} F/m
Cementation exponent	1
Permeability	6.25×10^{-16} m2



- At 5 km $\Delta P_f \approx 30 P_{crit}$

Results

Parameter	Value
Porosity	0.02 & 0.01
Pore diameter	5×10^{-7} m 1×10^{-7} m
Fluid conductivity	0.5 S/m
Surface conductivity	5×10^{-9} S
Zeta potential	-0.5 & -0.2 V
Fluid viscosity	8.9×10^{-4} Pa.s
Dielectric permittivity	7×10^{-10} F/m
Cementation exponent	1
Permeability	6.25×10^{-16} m^2 1.25×10^{-17} m^2



Pore fluid pressure (Pa)

❖ At 5 km $\Delta P_f \approx 30 P_{crit}$

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Results

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Parameter	Value
Porosity	0.02
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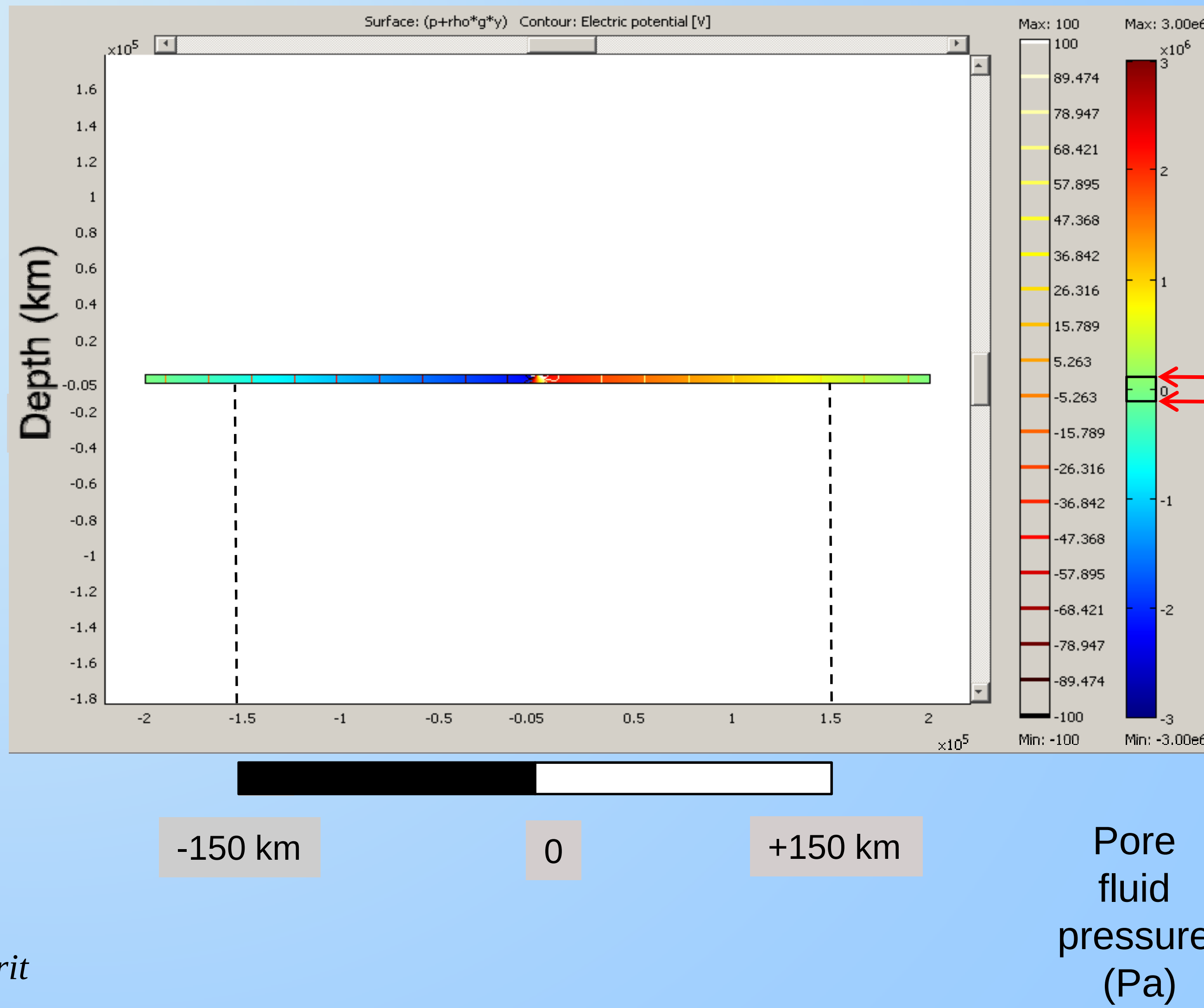

- At 150 km $\Delta P_f \approx P_{crit}$

Conclusions

- The pore fluid pressure in the top 10 km of the crust is modified by the injection of electrical current *via* the EK mechanism.
- The increase in pore fluid pressure exceeds that required to trigger an earthquake, $\Delta P_f > P_{crit}$.
- $\Delta P_f \approx 30 P_{crit}$ within 5 km of the injection dipole.
- $\Delta P_f > P_{crit}$ to a range of about 150 km.
- The pore fluid pressure variations are quasi-instantaneous

  $\rightarrow$ no explanation of the time delay or length of earthquake production.
- The numerical modelling contains no account of fluid storativity.
- Future work may account for the temporal aspects of the data.

Acknowledgments

This work has been made possible thanks to funding by the

Natural Sciences and Engineering Research Council of Canada (NSERC)

Discovery Grant Programme