CAN AN ELECTRO-KINETIC MECHANISM EXPLAIN ARTIFICIAL EARTHQUAKES?

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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.
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.

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

Pamir 3U 15 MW pulsed MHD generator at the Kyrgyzstan site.
A large number of current injection experiments

Approximately 5 km long dipole.

Bishkek Research Station in the Chu valley area of the Kyrgyz mountains (northern Tien Shan)
- Increase in EQ within 150 km range
- Increase over $3\sigma$ (1:400)
- Increase over $10\sigma$ (1:10$^{15}$)
- Increase occurs 3 days after current injection
- Increase continues for about 5 days
- Increased EQ have $m_b \leq 5.0$
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.
Electro-osmosis: Due to interfacial chemistry.

The application of an electrical potential $\Delta V$ between two points in the subsurface causes a fluid pressure difference $\Delta P$ 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 $\sigma_f$, the surface conductance $\Sigma_s$, the dielectric permittivity $\varepsilon_f$, the zeta potential $\zeta$, the fluid viscosity $\eta_f$ and a factor $a \approx 8/3$.

The equation is valid for random porous media.
- 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.

- $B = \text{Delay}$, $C+D = \text{Length of earthquake production}$
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?
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
\[ J = -L_{21} \nabla p - \sigma_f \nabla V \]
\[ u = -\frac{-\kappa}{\eta} \nabla p - L_{12} \nabla V \]

**Electrical transport**

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

\[ J^e = -\alpha \nabla P \]

**Hydraulic transport**

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

\[ Q_s = \alpha \nabla^2 V \]
**Parameter** | **Value**
---|---
Porosity | 0.02
Pore diameter | $5 \times 10^{-7}$ m
Fluid conductivity | 0.5 S/m
Surface conductivity | $5 \times 10^{-9}$ S
Zeta potential | -0.5 V
Fluid viscosity | $8.9 \times 10^{-4}$ Pa.s
Dielectric permittivity | $7 \times 10^{-10}$ F/m
Cementation exponent | 1
Permeability | $6.25 \times 10^{-16}$ m²

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

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

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

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1. Introduction  
2. Field results  
3. Mechanism  
4. Modelling  
5. Results  
6. Conclusions
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**Graph:**

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

**Graph image:**

Pore fluid pressure (Pa)
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, $\Delta P_f > P_{\text{crit}}$.

$\Delta P_f \approx 30P_{\text{crit}}$ within 5 km of the injection dipole.

$\Delta P_f > P_{\text{crit}}$ to a range of about 150 km.

The pore fluid pressure variations are quasi-instantaneous → 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.
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