How to Make Artificial Earthquakes

Guillaume Cyr and Paul Glover

Deep within the mountainous regions of Kyrgyzstan➔ ground-breaking experiments are being carried out. The Russians are making earthquakes. In a research project more akin to that visited by Tintin in Syldavia than the real world, scientists are using large pulsed MHD generators to inject thousands of amperes of current into the ground. The current causes earthquakes to occur up to 150 km away. No one knows the real mechanism that causes the artificial earthquakes, but they are linked inextricably to the injection of the electrical current. Paul Glover, the professor of petrophysics at Université Laval (Québec), has suggested a mechanism, and it is the job of his student Guillaume Cyr to model the mechanism in order to see if it is capable of producing pore fluid pressures sufficient to trigger an earthquake.

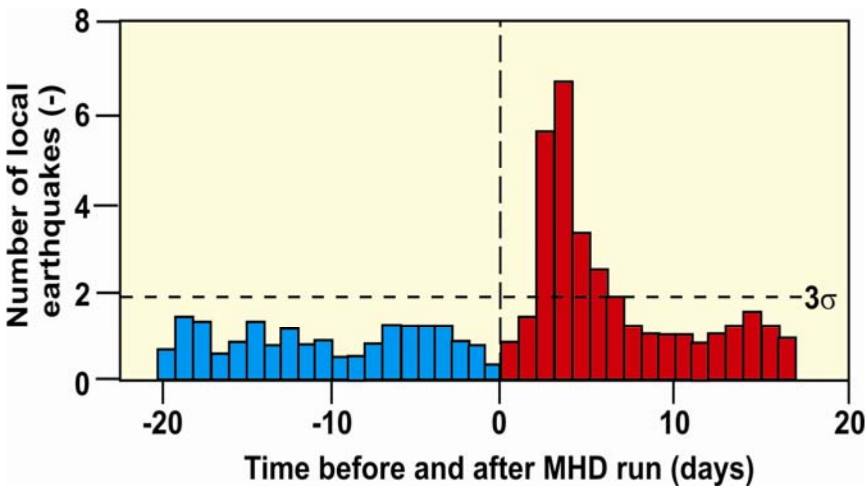
The Kyrgyz mountains south of Bishkek in Kyrgyzstan.

A 1500 MA pulsed MHD generator at the Kyrgyzstan site.

Pulsed magneto-hydrodynamic (MHD) generators tap into the extremely high magnetic fields generated by a moving plasma to produce extremely high electrical currents. The generators used to trigger earthquakes can produce 2800 amperes at 1350 volts for up to 12.1 seconds, in other words energies as high as 23 megajoules. In the image 🡐, the three long tubes generate the plasma and fire it through a non-conducting cavity that is surrounded by electrical coils housed in the large circular enclosures. Effectively, this is three pulsed MHD generators in parallel. When the plasma moves at high speed through the non-conducting cavity it generates an extremely high magnetic field perpendicular to the movement. The magnetic field then generates a large electrical current in the coils.

Viktor Novikov and his colleagues of the Institute for High Energy Densities of the Russian Academy of Sciences have carried out a large number of current injection experiments using an approximately 5 km long dipole at the Bishkek Research Station of the Russian Academy of Sciences in the Chu valley area of the Kyrgyz mountains (northern Tien Shan). They found that the number of earthquakes in the region within 150 km of the injection site increased by over 10 standard deviations (σ) of the background seismicity🡻. To put this in context, statistics tells us that the number of earthquakes would exceed 3σ only once in every 400 samples (99.75%) if the earthquakes are not related to the current injections. The probability of the signal being more than 10 standard deviations from the mean by chance is so minuscule, it would be expected to occur only once in every 10^{15} measurements (i.e., for only a few microseconds since the beginning of the universe, about 10 billion years!).

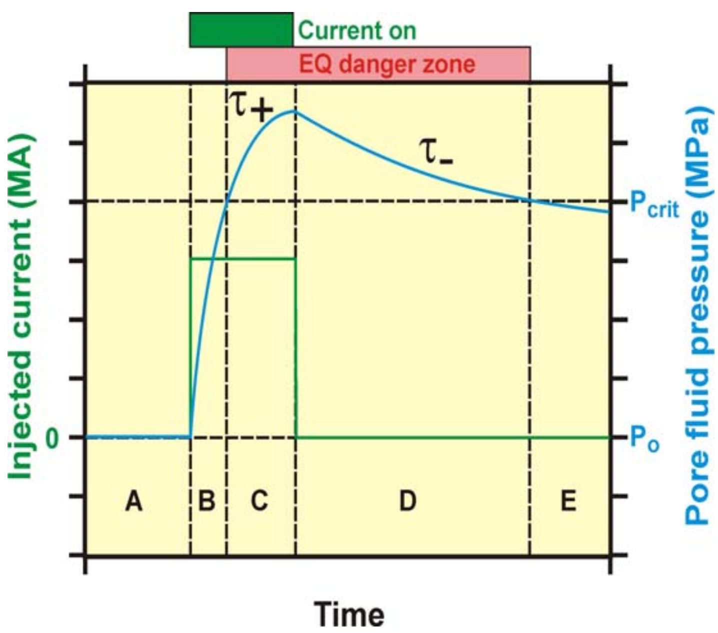
The increase in the earthquakes starts a few days after each injection and continues for about 5 more days🡺. The earthquakes generally occur along previously known fault zones showing that the current injection is triggering slippage where there is already accumulated strain energy. Where earthquakes are not distributed along known fault zones, new fault zones may be mapped. The artificial earthquakes had magnitudes up to m_b=5 (Gutenberg-Richter).



The smoking gun! Earthquakes occurring 2 to 7 days after current injection.

What are the applications of artificial earthquakes? Each time an earthquake occurs some of the accumulated strain energy is released. Hence if small controlled earthquakes can be generated in an area the strain accumulation may be allayed, making the occurrence of a large destructive earthquake less likely. This is analogous to an inoculation : the artificial generation of an attenuated earthquake or earthquakes protects against a large quake just as the presence of a weak form of a disease allows the body to develop antibodies to fight the attack of a dangerous disease. The difference is that here we are inoculating the earth! However, the logarithmic nature of the scales for earthquake measurement implies that it would need over 172,000 artificial earthquakes of m_b=5 to protect against one destructive earthquake (m_b=7), and that is clearly impractical. Maybe then the technique could be used to trigger a large earthquake that is overdue, giving at least the advantage of knowing when the earthquake will occur. Unfortunately this application is probably politically impossible. The real advantage of the technique may be found at smaller scale, in the mapping of fault zones, and the triggering of rock and mud slides that would otherwise remain a danger, and of course, in the understanding of the earthquake process in general.

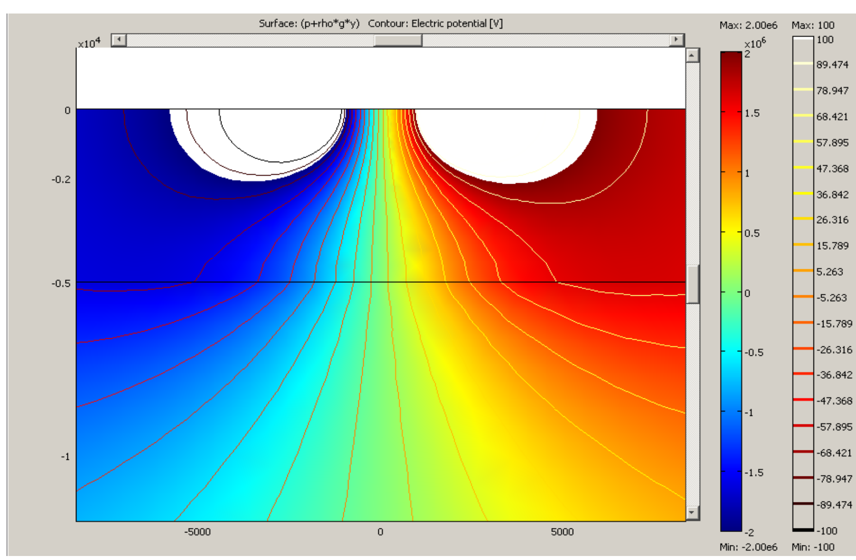
At least, it would give us more of an insight into the earthquake process if we knew the mechanism that caused the artificial earthquakes.



The theoretical variation of pore fluid pressure caused by current injection

Professor Paul Glover of Université Laval in Québec has suggested that an electro-kinetic mechanism may be the missing causal link. In his theory the injected current creates a three-dimensional electric field in the subsurface. The electro-kinetic mechanism uses the electric field to move the pore fluid at depth. If the pore fluid flows into a fault zone it may accumulate and raise the pore fluid pressure within the fault zone. It is known that increases of pore fluid pressure within fault zones more than a critical pressure of 0.05 MPa are sufficient to trigger an earthquake if the fault has sufficient accumulated strain. In the graph of pore fluid pressure against time 🡐 the pore fluid pressure increases very quickly at a rate τ_+ because it is being driven by the electro-kinetic drive and then decreases more slowly at a rate τ_- because the pressure dissipates passively. Earthquakes are possible while the pore fluid pressure is over a certain critical level.

While the electro-kinetic drive has been confirmed in the Petrophysics Laboratory of Université Laval and a few other laboratories around the world, it is uncertain if the mechanism can provide fluid pressures sufficient to trigger earthquakes up to 150 km from the injection point. Guillaume Cyr, a student at Université Laval has been modelling the process numerically. His two dimensional models of the subsurface are created in a software package Comsol Multiphysics🡒.



Model showing pore fluid pressures over 2 MPa (red) are generated to the right of the first layer (500 m thick). Areas in white have pressures greater than 2 MPa and surround each electrode of the injection dipole.

After defining the structure of the model he is able to solve the differential equations that describe fluid flow, electrical flow, electro-kinetic coupling, mass balance and thermal effects in parallel on a finite element grid. The modelling is still a work in progress. However early steady state solutions in a horizontally layered earth indicate that pore fluid pressures over 3 MPa can be achieved easily with a current injection of 1500 amperes, and that the pressure remains higher than the critical value of 0.05 MPa up to 150 km from the injection point.

We now know that sufficient fluid pressures can be generated using a steady state differential equation solution. So far the modelling does not contain any information about how the fluid pressures vary with time. This is actually extremely important because it may be that activating the pulsed MHD generator for only 10 seconds is insufficient to obtain the steady state values. Solving these complex differential equations as a function of space and time is an extremely complex task and represents the next step for M. Cyr. It is hoped that we will have some initial solutions by December 2009.

Until then, we can confirm that plugging your electricity supply into your garden is not only dangerous, it will not cause an earthquake – please do not try it at home.