



**Development of an Updated Induced Seismicity
Protocol for the Application of Microearthquake
(MEQ) Monitoring for Characterizing Enhanced
Geothermal Systems**

May 19, 2010

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Seismicity and Seismic

- Timeline
 - Start: 2009
 - End: Continuing
 - Status: 60% complete?
- Budget
 - Total project funding: \$396,000
 - DOE share: \$396,000 (FY 10 = \$246K)
 - Awardee share: NA
 - Funding received in FY09: \$150,000
 - Funding for FY10: \$246,000
- Barriers
 - Siting, Leasing, and Permitting Issues
 - Public acceptance of EGS technology
 - Cost effective and timely implementation of EGS technology
 - Reservoir Validation Barrier
 - Barrier I: Images of Fractures After Stimulation – Inability to characterize the physical parameters of potential EGS reservoirs after stimulation.
 - Partners
 - Numerous Industry and Universities

Objectives:

- Develop an updated protocol/best engineering practices to address public and industry issues associated with induced seismicity
- Identify critical technology and research needs/approaches to advance the understanding of induced seismicity associated with deep well injection and production, such that:
 - The risk associated with induced seismicity can be reduced to a level that is acceptable to the public, policy makers and regulators, and
 - The seismicity can be utilized/controlled to monitor, manage and optimize the desired fluid behavior in the reservoir
- Perform community outreach and education
- Address the hypothesis : ***With proper study and technology development induced seismicity will not only be mitigated but will become a useful tool for reservoir management***

- The success of EGS technologies will depend on the ability to successfully inject/withdraw fluids in high volumes
 - Seismicity can be (must be) used as a resource management tool
- High-profile press coverage has focused attention on induced seismicity related to energy projects in the U.S. and Europe
 - The Geysers, CA; Basel, Switzerland; Soultz, France; Landau, Germany
 - Oil and gas: Texas
 - Potential CO₂ sequestration sites
- Public, economic and regulatory concerns could delay and possibly cancel projects (already has)
- Risk must be assessed properly to assure public
 - Place risk analysis on a solid scientific and technical basis
- Industry must feel confident that if proper procedures are followed induced seismicity issues can be addressed and projects move forward

- Continuation of a 2004-2006 process
 - Draft LBNL internal whitepaper (2004)
 - Three international workshops (2005-2006)
 - Form technical basis for understanding induced seismicity and a strategy for developing a protocol for designing “induced-seismicity friendly” EGS projects
 - Gather international group of experts to identify critical issues (technical and non technical) associated with EGS induced seismicity
 - Products of work shops and activities
 - Peer reviewed white paper (IEA Report, Majer et al., 2007)
 - Protocol for the development of geothermal sites and a good practice guide (IEA Report, Majer et al, 2009)
 - Majer, E.L, Baria , R., Stark, M., Oates, S., Bommer, J., Smith, B., and Asanuma, H., 2007, Induced seismicity associated with Enhanced Geothermal Systems, *Geothermics* 36, 185-227. LBNL- 61681
 - Majer, E., Baria, R. and Stark, M., 2009. Protocol for induced seismicity associated with enhanced geothermal systems. Report produced in Task D Annex I (2008), International Energy Agency-Geothermal Implementing Agreement (incorporating comments by: C. Bromley, W. Cumming, A. Jelacic and L. Rybach). Available at: <http://www.iea-gia.org/publications.asp>

- Current efforts
 - Public education and outreach
 - Establish website for community and scientific collaboration
 - Brief/educate DOE, regulators and policy makers on induced seismicity
 - Require all DOE EGS projects to follow protocol
 - Establish international collaborations (Iceland, Australia, GEISER)
- Conduct workshops to:
 - Identify critical technology and research needs in order to implement EGS safely
 - Identify the critical elements of a protocol/best practices that industry can confidently follow
- Produce updated protocol/best practices

- **Two main elements of a protocol**
 - **Technical**
 - Identify and understand factors controlling microseismicity
 - Effect of microseismicity on community and operations
 - **Legal – Community interaction**
 - Propose guidelines for a geothermal developer to deal with the issue of induced seismicity.
 - Inform and interact with the community to understand their concerns and partner with them to achieve a win-win situation

Both are linked and overlapping

- **Example of technical concerns to address**
- What controls the limit of seismicity (time and space)?
- Does induced seismicity follow Omori's law?
 - What controls the decay of seismicity after injection?
- Radius of influence (how close to a critically stressed fault can one be?)
 - If “natural seismicity” is known to occur deep, can one safely inject shallow?
- What are the similarities and differences between natural and induced earthquakes?
 - Foreshocks, aftershocks, b-values, etc.
- Will risk assessment be based on past seismicity, “physics” or some combination? (PSHA?)

- Public Education and Outreach
 - Established induced seismicity website
 - Briefed DOE and Congressional staffers
 - Senator Feinstein (CA)
 - Senator Wyden (OR)
 - Senator Murkowski (AK)
 - Senate Committee on Energy and Natural Resources
 - DOE Under Secretary for Science
 - Many interactions with press and during public meetings

- Induced seismicity website

http://esd.lbl.gov/research/projects/induced_seismicity/egs/

induced SEISMICITY

U.S. DEPARTMENT OF **ENERGY** | Energy Efficiency & Renewable Energy

Home EGS CO₂ Oil & Gas

Induced Seismicity

Seismicity associated with energy production and waste disposal will become an increasingly important issue, (geothermal, oil and gas, and CO₂ sequestration, etc.) as energy production in a climate constrained earth progresses. Although induced seismicity has been noted for many years and associated with a variety of causes, recent attention has been focused on oil and gas, geothermal and potential CO₂ sequestration sites. This web site is meant to provide the public with useful information regarding these three areas in order to inform the public and provide a resource on the latest information. Initial emphasis will be placed on geothermal applications, but as this web site is developed oil and gas as well as CO₂ sequestration applications will be added.

- What is Induced Seismicity?
- What causes Induced Seismicity?
- What controls the amount and size of the seismicity?
- How much shaking could one expect from an earthquake?
- What are the impacts of Induced Seismicity?
- References

Research Areas

- Enhanced Geothermal Systems (EGS)
- Geologic Carbon Sequestration
- Oil & Gas

Additional Information

General Earthquake Information	Related Links
<ul style="list-style-type: none">• What is Richter Magnitude?• How do I compute the energy released by an earthquake?• Earthquake Seismometer Equations and Formulas Calculator	<ul style="list-style-type: none">• USGS

image courtesy of EGS Soutlz

- **Workshops**
 - **Workshop on Induced Seismicity due to Fluid Injection/Production from Energy Related Applications**
 - **Place: Stanford University, Bechtel Conference Center**
 - **Time: Feb 4, 2010**
 - 50 participants from around the world and US
 - **Goals**
 - Identify critical roadblocks that are preventing the necessary understanding of human-related seismicity. These road blocks could be technology related, research related or a combination of both research and technology.
 - Identify the technology development and research activities that can be implemented in the short term (one to two years) and intermediate (five years) to address the first goal, with the overall objective of obtaining the necessary understanding to manage and control human-related seismicity associated with deep well injection.

Workshop Summary

- It is critical to address issues associated with induced seismicity to allow the implementation of injection technology associated with current and future geothermal technology
- The barriers that must be overcome to safely and effectively advance the subject:
 - Focused field, modeling and lab studies
 - Performing research in certain key areas (rock mechanics, source mechanisms)
 - There is also a wealth of data that needs to be analyzed.
 - A general consensus that high quality data are still lacking for certain studies that could be obtained by deploying state-of-the-art instrumentation at current and future sites of injection.
 - There was considerable support for dedicated field sites, preferably not under commercial control and/or constraints.
 - Identified key instrumentation needs for high temperature applications as well as drilling technology needs (mainly for obtaining wide bandwidth data in a cost effective fashion)
 - Focus on long term impact of injections as well as initial EGS related injections.
 - Develop as soon as possible an updated engineering guide/protocol that identifies a means to accurately assess risk and mitigate unacceptable seismicity such that industry can advance with confidence, i.e., if followed by industry the public and regulators would allow projects to proceed.

- Project Management
 - PI: E. Majer (LBNL) Overall responsibility for all aspects of project
 - Participation and coordination with industry, USGS and Universities
- Schedule
 - Finish workshops this year (FY10)
 - Prepare Updated Protocol (FY10)
 - Update protocol with improved understanding from research results in program
 - Continue website and updates/improvements
- Application of resources and leveraged funds/budget/spend plan
 - Industry is participating in all workshops and some public outreach
 - In FY 10, \$75K spent on website
 - Remaining funds
 - Planning, organizing, hosting, documenting and synthesizing results
 - Public interaction and outreach
- How is this project integrated with other projects in the program?
 - Will draw on research results and field demonstration results to update Protocol
- Coordination with industry & stakeholders
 - Industry and public will rely upon results to continue geothermal energy production

- Continue public outreach activities
 - Public meetings
 - Presentations at Geothermal meetings
 - Maintain website and add EGS sites as they come on line
 - Brady's Hot Springs (NV)
 - New York Canyon (NV)
 - Raft River (ID)
 - Naknek (AK)
 - Newberry Caldera (OR)
- Second Workshop to address critical elements of a protocol/best practices
- Decision points, remaining issues, alternative pathways
 - Accurate risk analysis may be problematic if not physics based
 - Cannot apply conventional PSHA
- Results of workshops will be part of a NRC review of EGS induced seismicity

- Induced seismicity issues are not new
- General causes of earthquakes related to fluid injection (e.g., EGS) are known and can be mitigated
- Successful utilization of induced microseismicity is critical to successful energy extraction and mitigation activities (benefit)
- Large base of available technology and expertise to draw upon to address issues
- Recent experiences point out a critical need to develop policy in parallel with technology-community education
- Increased understanding of the physics of induced seismicity will enable development of more robust mitigation and control procedures
- Induced seismicity issues need to be addressed - but dealt with properly the negative issues can be mitigated and the risk will be low compared to benefits
- Develop as soon as possible an updated engineering guide/protocol that identifies a means to accurately assess risk and mitigate unacceptable seismicity