

USC Program on Induced Seismicity Consortium (ISC)

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AQMD Workshop on Hydraulic Fracturing

Diamond Bar CA
September 18, 2012

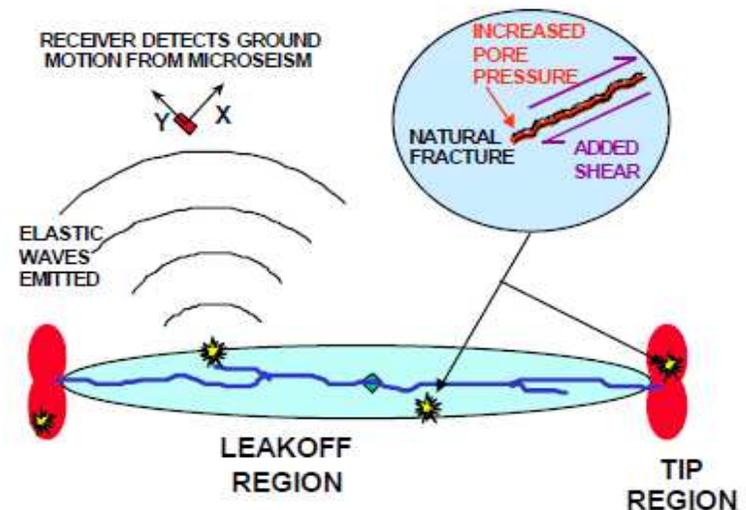
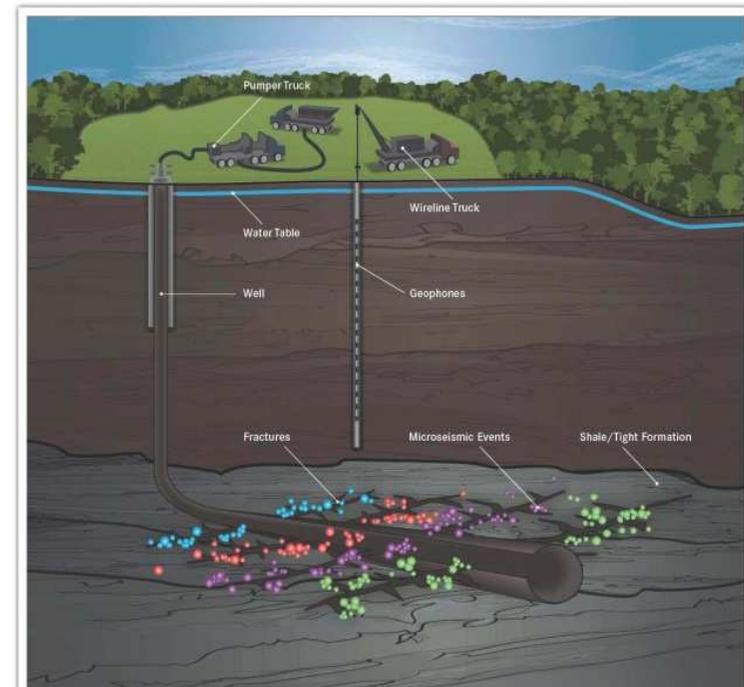
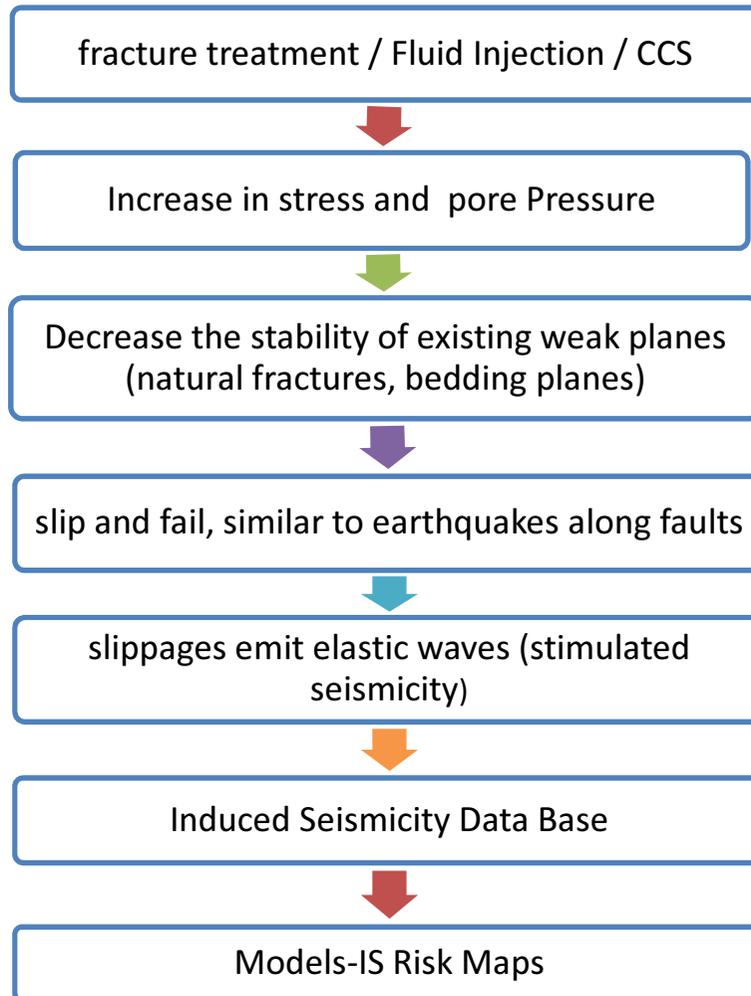
Summary

- Introduce USC capabilities on IS from a variety of disciplines
- Discuss the main sources of IS from different Energy Related Operations (ERO)
 - Hydraulic fracturing (HF)
 - Fluid Injection or Removal (Production, Waste Disposal, etc.)
 - CO₂ Capture and Sequestration (CCS)
 - Highlight the state of the art on IS
- To Introduce USC Induced Seismicity Consortium (ISC) and to discuss the Research Education and Public Outreach Plans

Goals of ISC

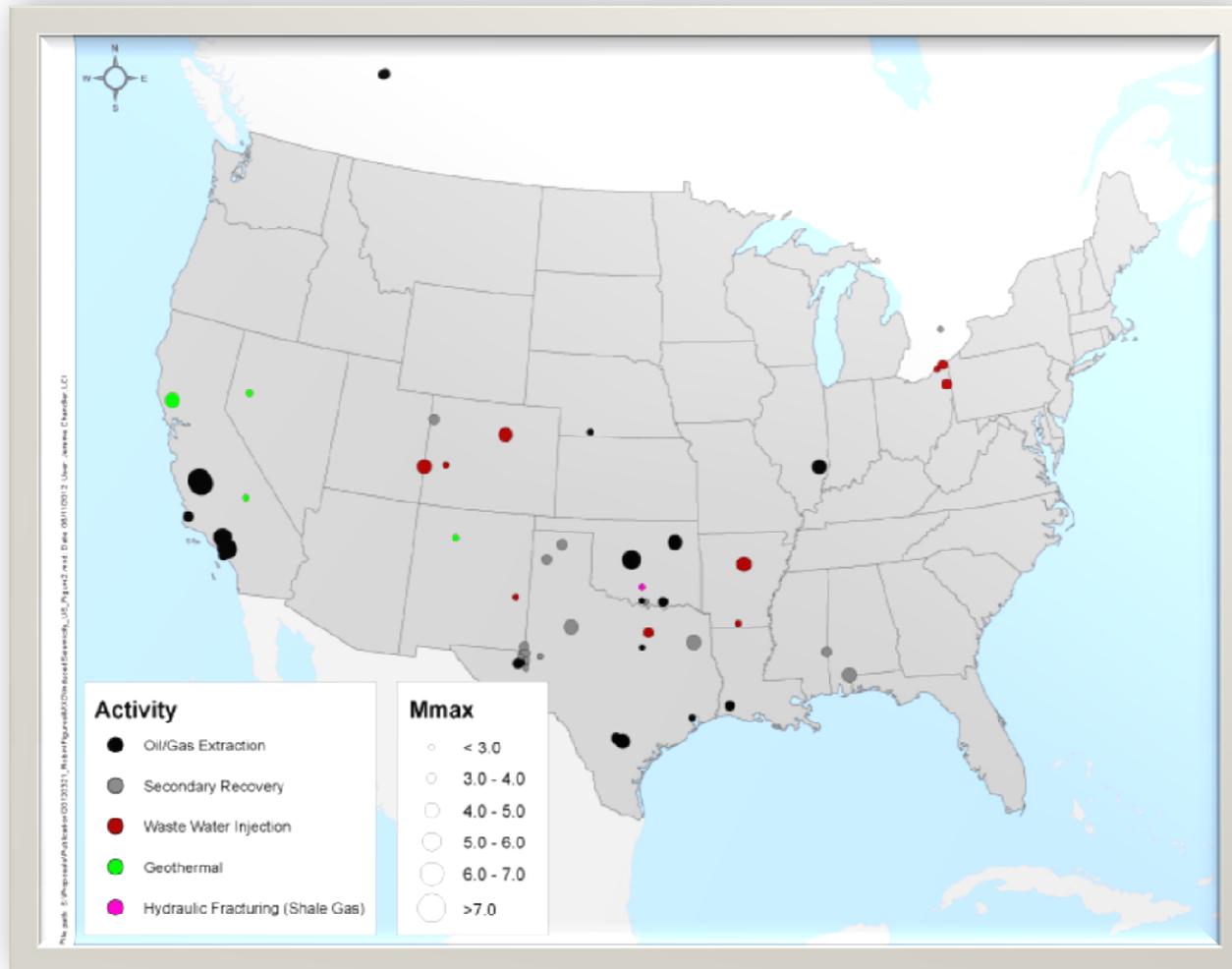
- To provide a platform for direct communication among
 - Scientists,
 - State officials,
 - Oil and Gas operators,
 - Service Companies,
 - National Laboratories,
 - Environmental Groups
 - General Public
- To highlight different challenges
 - Technical Challenges
 - Operators Challenges
 - Regulatory Challenges
- To Develop Seismic Risk
- To Develop Workflow for Safe Operation

Introduction to Induced Seismicity



Documented Induced Seismicity of SFIP

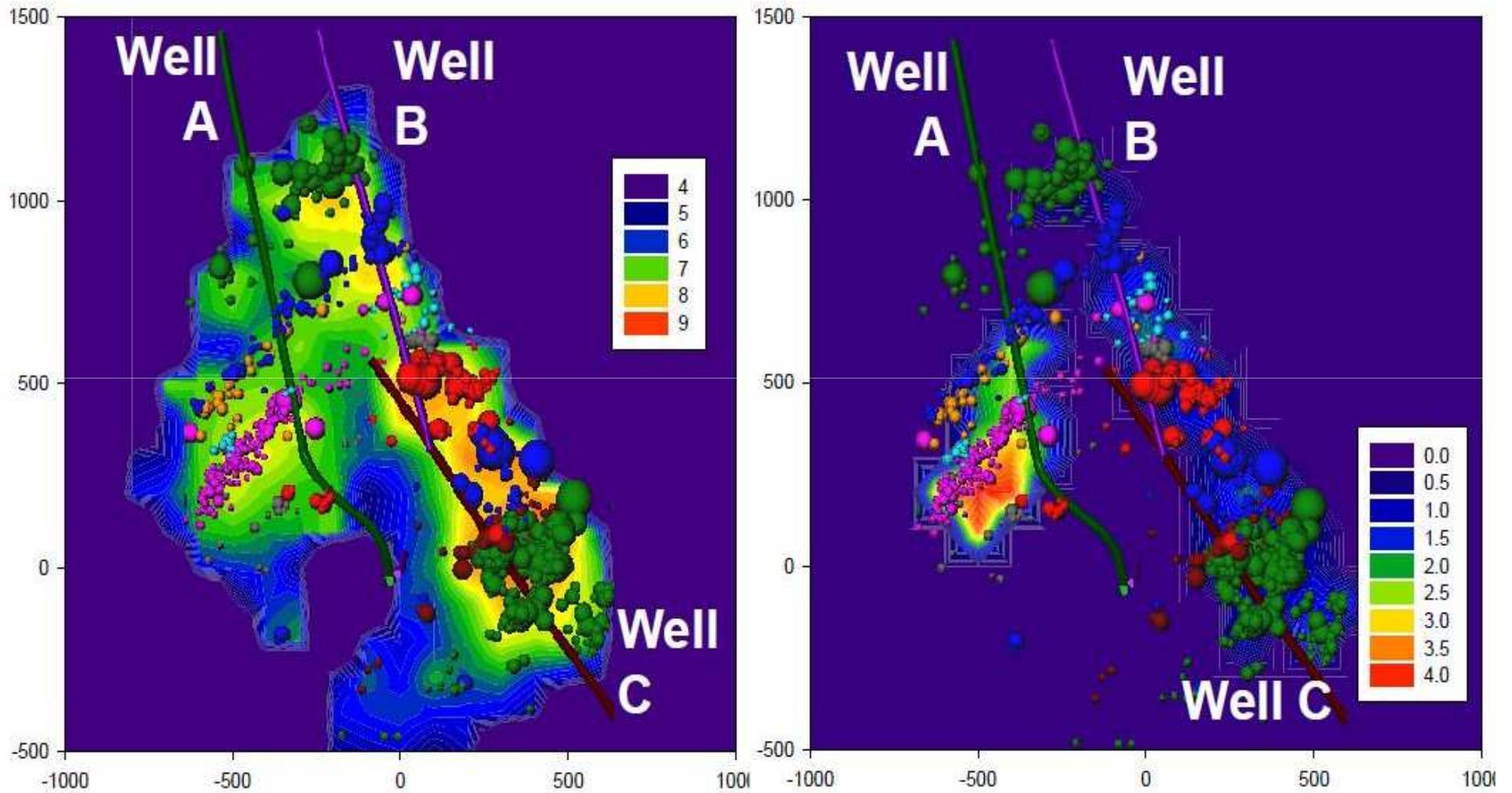
- Seismic events have been measured and felt at a limited number of Subsurface Fluid Injection (including Hydraulic Fracturing) and Production (SFIP) in the US.
- Seismic events caused by or likely related to SFIP were documented in Alabama, Arkansas, California, Colorado, Illinois, Louisiana, Mississippi, Nebraska, Nevada, New Mexico, Ohio, Oklahoma, and Texas



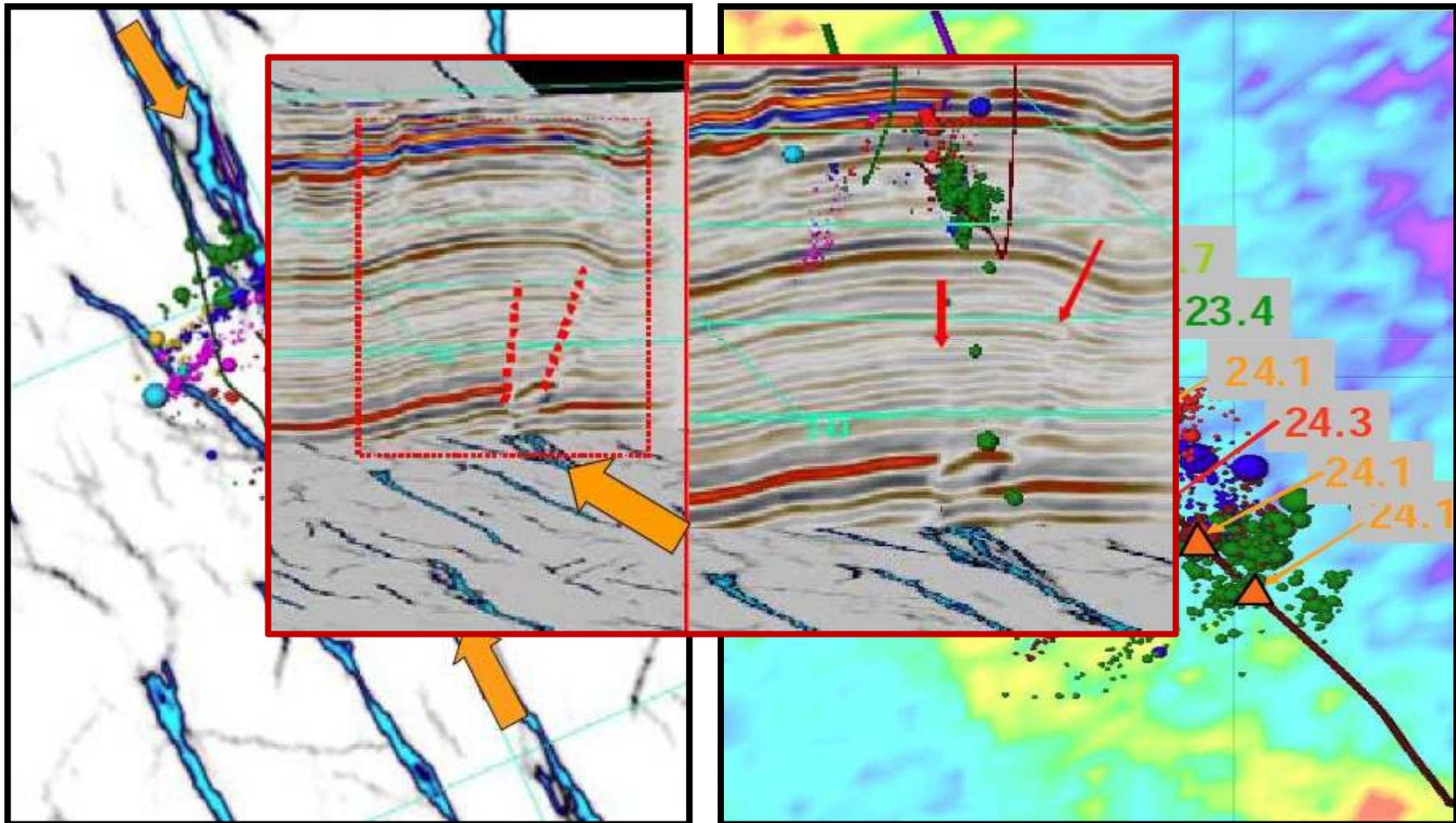
What Are the Key Factors for Induced Seismicity

- Stress field
- Pressure
- Temperature
- Formation Depth
- Fluid Saturation
- Formation Thickness
- Faulting / Fracture Network
- Geology and Rock Type
- Injection Rate
- Injection Volume

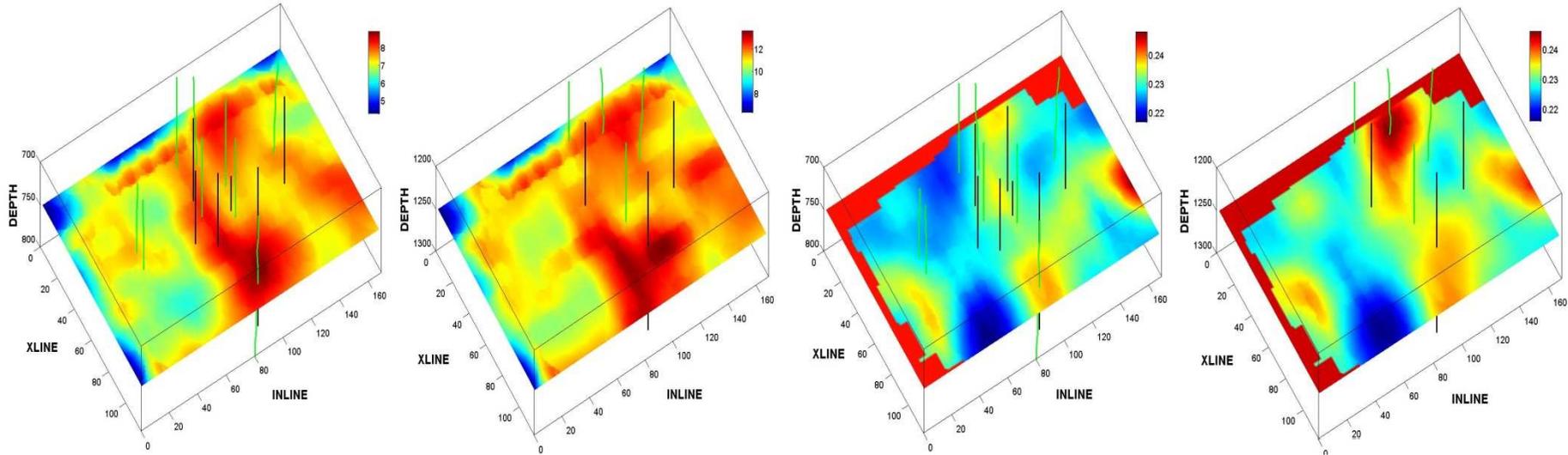
Seismic moment density and b-value for microearthquake characterization



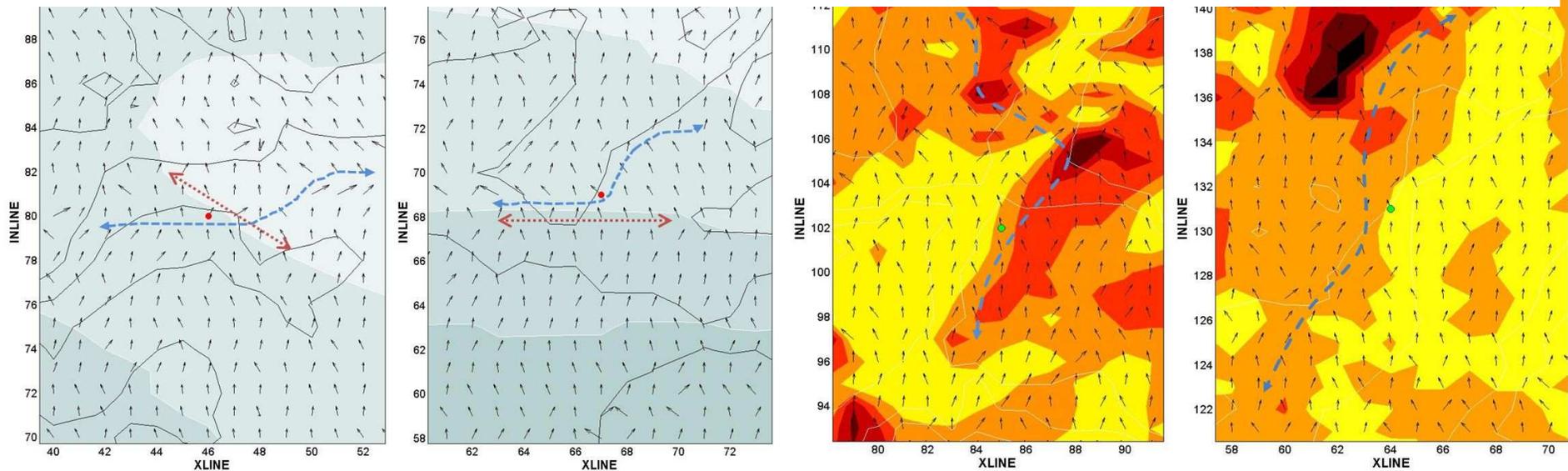
Microseismic (event locations) integrated with seismic derived attributes/ properties



Reservoir Property estimation: Integrating microseismic, seismic & logs



Extensional stress maps & tangential weakness maps with well tracks for reference



Discontinuity gradient, extensional stress & edge maps

Discontinuity gradient, ANN derived FZI & edge maps

Induced Seismicity Consortium (ISC)

“To better understand, limit, and respond to induced seismic events, work is needed to build robust prediction models, to assess potential hazards, and to help relevant agencies coordinate to address them.” NRC2012

ISC will focus on the risk assessment of induced seismicity in connection with SFIP. It will attempt to build predictive tools and models. The goal is to develop IS hazard probability and deliver an effective science-based roadmap for best operational practices, policy decisions, regulatory processes, as well as public education and communication on induced seismicity in energy related activities worldwide.



Induced Seismicity Consortium (ISC)

A Proposal

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Behnam Jafarpour CO- PI, Petroleum Engineering Program

Charles Sammis, and Meghan Miller, CO-PI

Department of Earth Sciences and Southern California Earthquake Center

Lucio Soibelman, and Roger Ghanem, CO-PI,

Department of Civil and Environmental Engineering

Advisory Board

TBD

Why ISC at USC?

- Southern California Earthquake Center (SCEC),
- Petroleum Engineering Program
- Department of Civil and Environmental Engineering (CEE),
- Price School of Public Policy
- Annenberg School of Communication
- Marshal School of Business

Technical Challenges

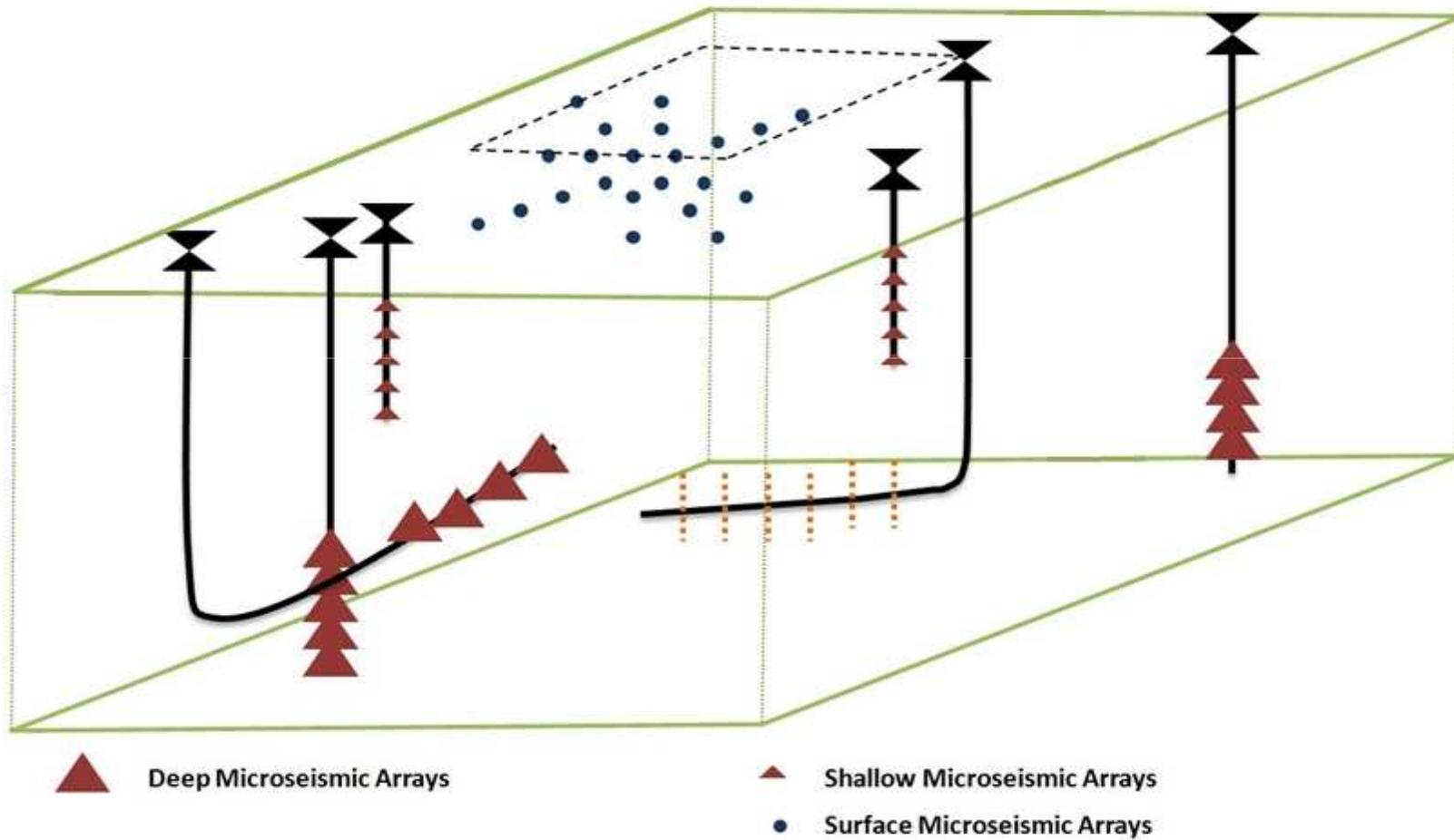
- **Risk Modeling / Monitoring:** The need for the development of science and engineering based predictive models of induced seismic hazard risks.
- **Geological information:** Improved regional geological information and characteristics (faulting, state of stress, permeability effects, etc.) for major tectonically active shale basins. Detailed extensions of this information to the trend and play scale to enable predictive models in 1.
- **Drilling and operations:** Understanding the opportunities for risk identification and mitigation from evolution of well engineering, fracturing, and completion technologies. Understanding the “many-well” effects associated with the scale, areal extent, and numbers of wells involved in shale resource development and operations,
- **Possible Long Term Impact Factors:** high-density drilling and production operations; state of stress in subsurface formations; surface impacts on land use, water management, community infrastructure, etc.

Updated Tasks

- **Characterizing Fracture Network using microseismic data**
- **Establishing correlations between induced seismic events and microseismic attributes**
- **Developing a hierarchical probabilistic model for understanding the relationship between operational parameters, subsurface stress and observed seismicity**
- **Designing a system to mitigate the seismic hazards associated with SFIP**
 - **Simultaneous MEQ survey design with borehole and surface measurements (GTI)**
- **Creating a science-based framework for input to regulatory and government entities**
 - **Economic Impact Studies (WSPA)**
- **Introducing educational and communication programs for the professional community and the general public**

Complementary Projects

Integrated microseismic survey designs with multiple (downhole & surface) arrays

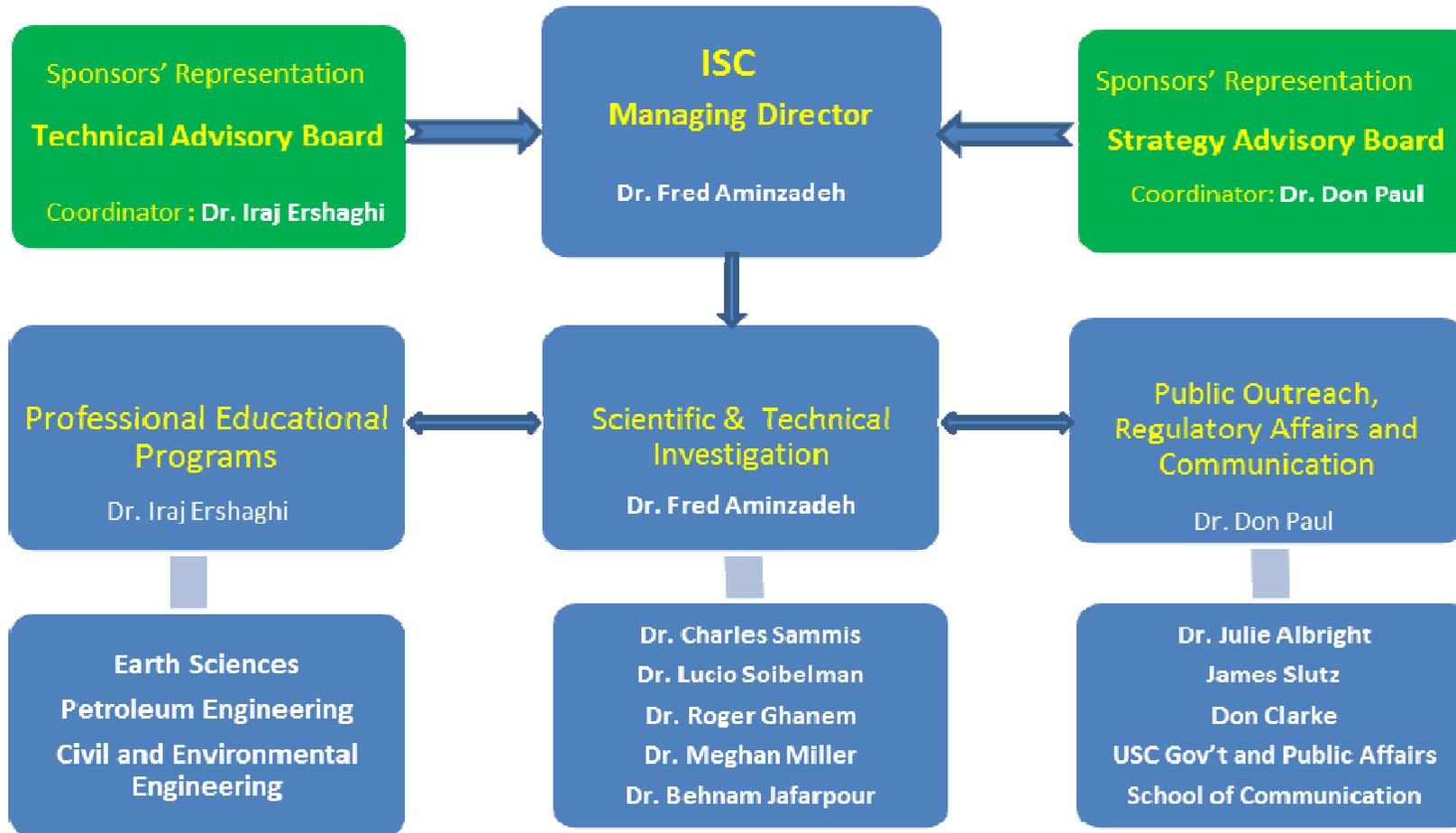


Support Status

- Aera Energy
- Gas Technology Institute (GTI)
- Occidental Petroleum
- Research Partnership for Secure Energy in America (RPSEA)
- SR2020
- Western States Petroleum Association
- California State Lands Commission, Mineral Resources Management (O)
- California State Mining Geology Board (O)
- The Center for Strategic and International Studies, CSIS.ORG (O)
- Environmental Defense Fund (O)

Observer (O)

Management Structure & Formation of Advisory Boards



Preliminary Conclusions

- The energy level which is released is **large enough to be recorded**, but too low to **directly** create major seismic events. The source volume defined by the migration distance of the fluid in the HF process is too small to generate a large damaging event,
- **Real time monitoring** of MEQ and real time analysis such as b-value, fractal, and stress can help mitigate or reduce the risk of triggering large damaging earthquakes during or after the SFIP,
- More modeling, statistical analysis and research needed to substantiate some of the preliminary conclusions: **We will start with a test beds, in San Joaquin Valley.**
- Similar to the “Earthquake Hazard Maps”, **IS hazard maps** can alleviate the concerns for IS risk of SFIP in the majority of cases.
- We are not an Advocacy Group, Science should help: **Vincit Veritas**