

DOCKETED

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Seismic Risk Assessment for Underground Gas Infrastructure

Ongoing Efforts and Research Needs

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Management Program



Together, Building
a Better California

September 17, 2017



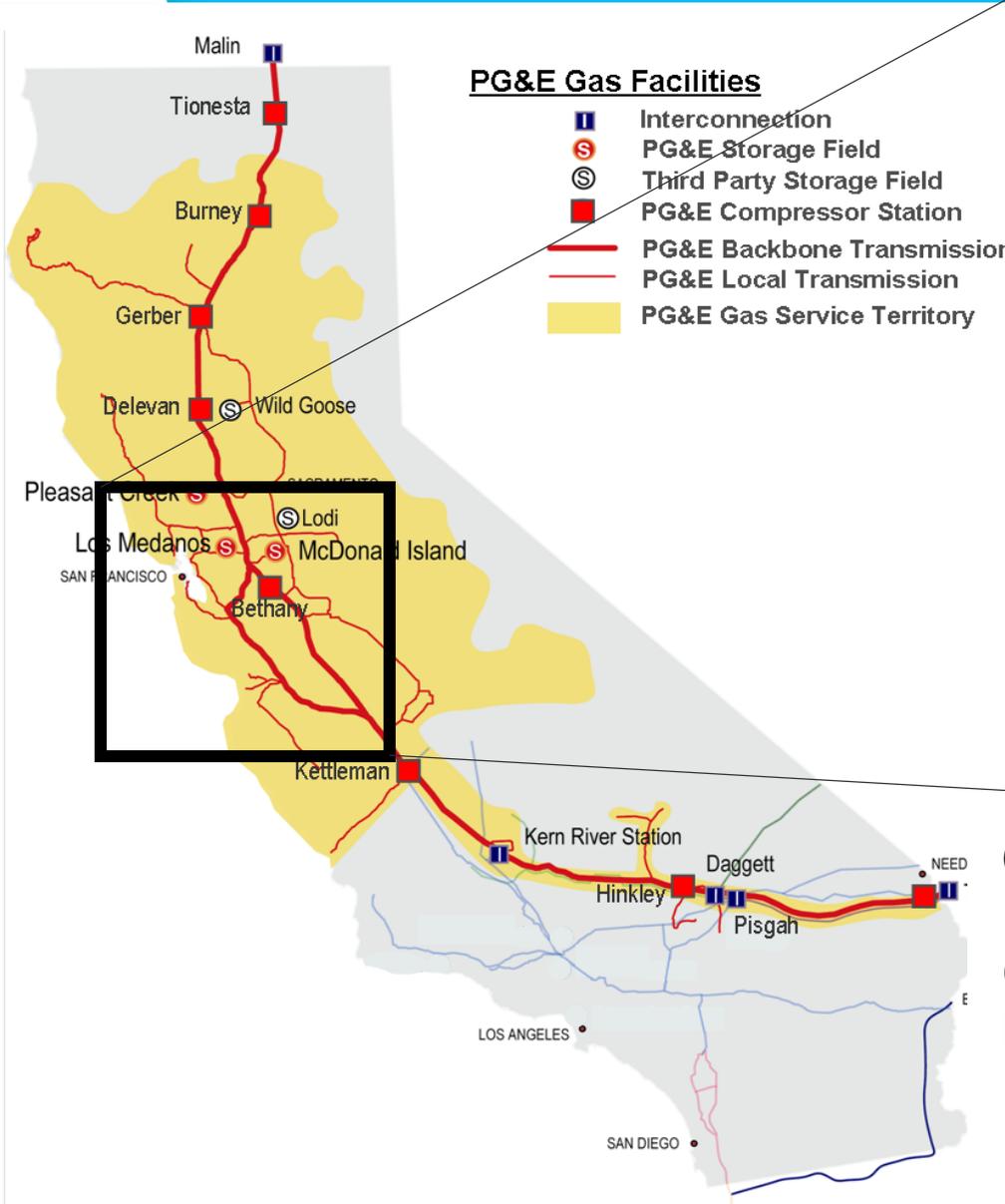
PG&E's Gas System



6700+ miles of gas transmission lines



PG&E's Gas System – Bay Area Seismic Hazard

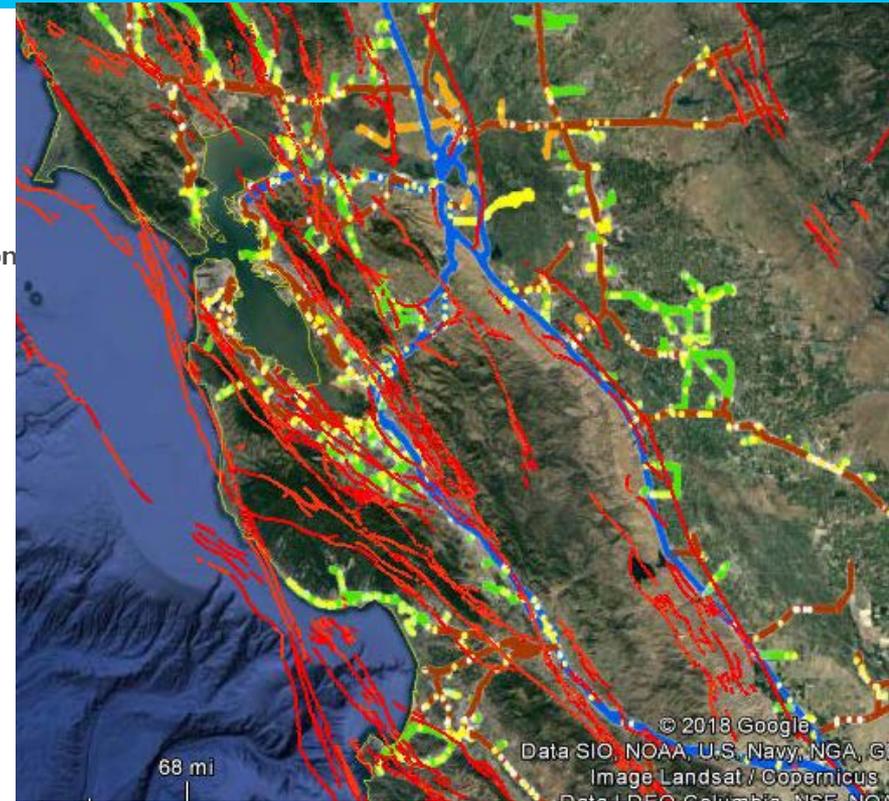
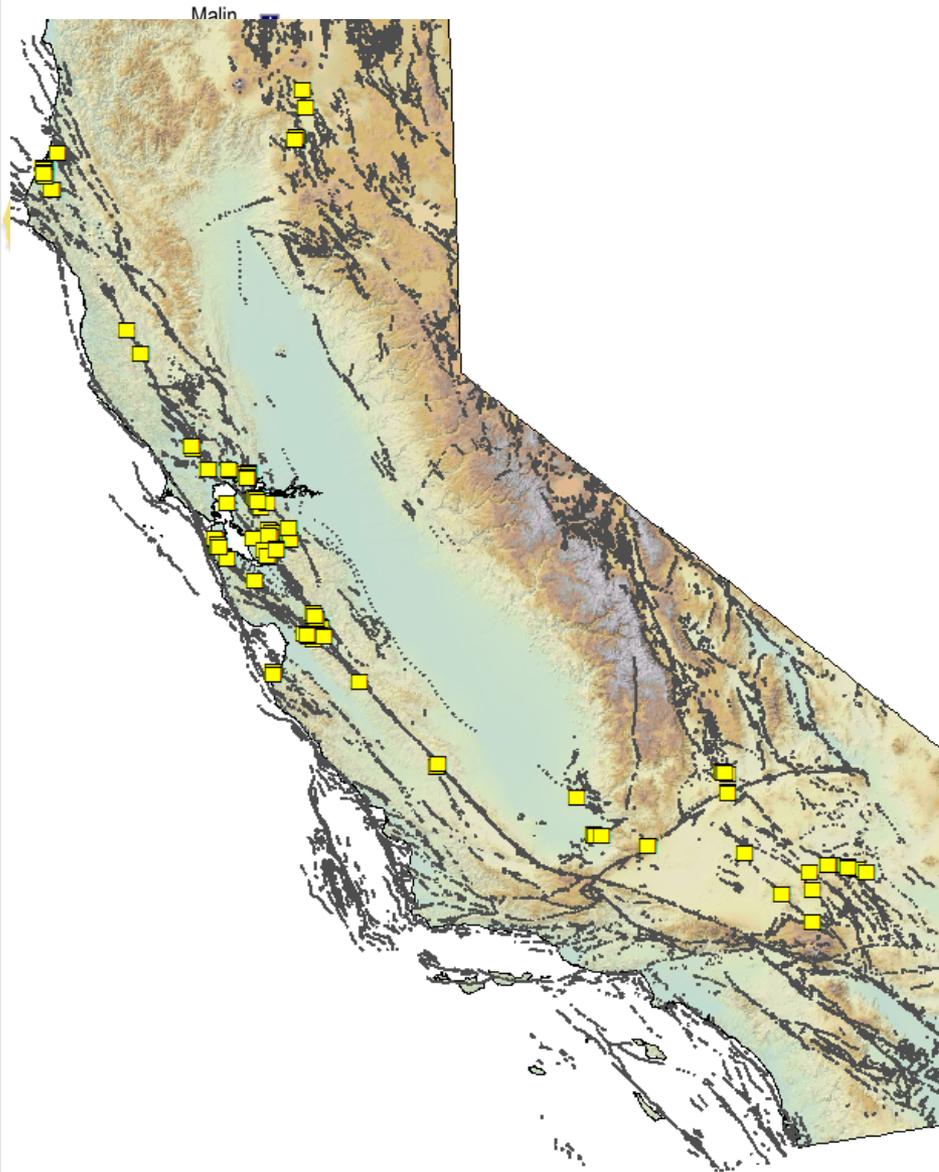


6700+ miles of gas transmission lines

Cross major faults: San Andreas, Hayward, Calaveras



PG&E's Gas System – Statewide Seismic Hazard



6700+ miles of gas transmission lines

Cross major faults: San Andreas, Hayward, Calaveras

Hundreds of crossings throughout the state (yellow dots)



REGULATIONS

- **Code of Federal Regulations (CFR) Title 49, Transportation, Part 192**—Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards
- **ASME B31.8S, Appendix A9 (as reference by code)** – Risk assessment and mitigation for Weather Related and Outside Forces Threat (including Earth Movement, Heavy Rains, Floods, Cold Weather, Lightning)

GUIDANCE DOCUMENTS AND RELEVANT REGULATIONS

- **Pipeline Research Council International (2004; 2017)**
- **Alquist-Priolo Act, Seismic Hazard Mapping Act**



PG&E's Mission, Vision, Culture

Our Mission

To safely and reliably deliver affordable and clean energy to our customers and communities every single day, while building the energy network of tomorrow.

Our Vision

With a sustainable energy future as our North Star, we will meet the challenge of climate change while providing affordable energy for all customers.

Our Culture

We put safety first.

We are accountable. We act with integrity, transparency and humility.

We are here to serve our customers.

We embrace change, innovation and continuous improvement.

We value diversity and inclusion. We speak up, listen up and follow up.

We succeed through collaboration and partnership. We are one team.

Seismic Hazard – Coseismic Fault Displacement

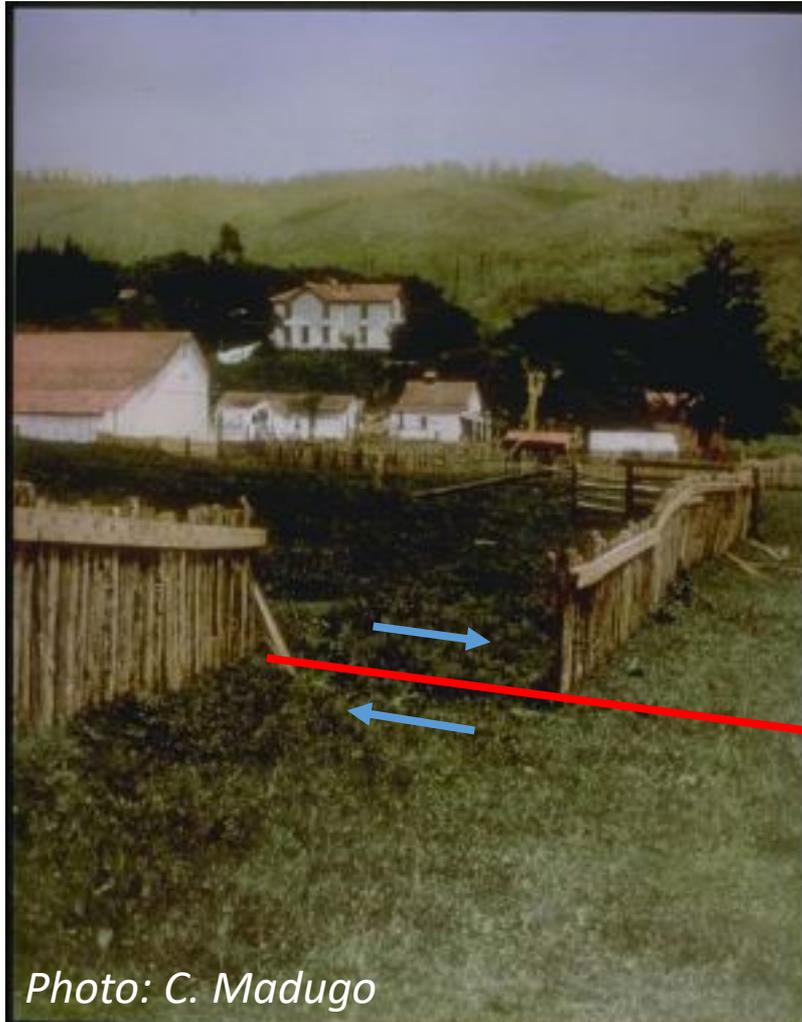


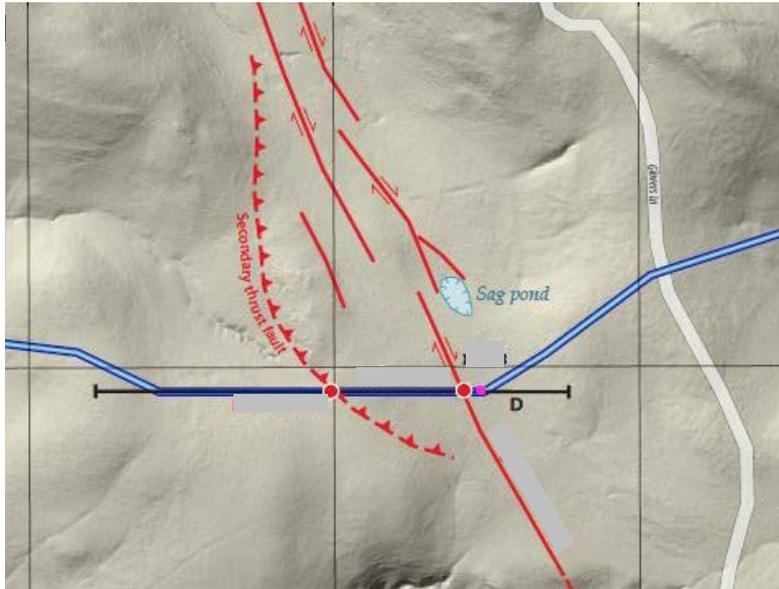
Photo: C. Madugo

**1906 San Andreas Fault Earthquake
Large displacement**



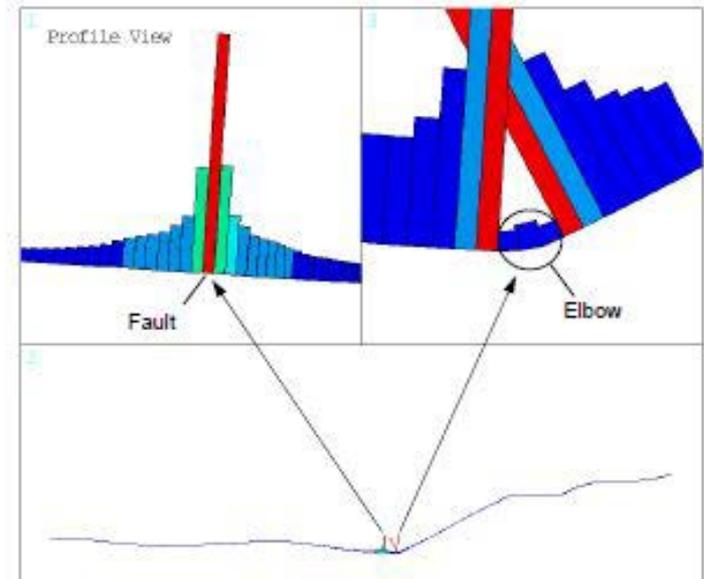
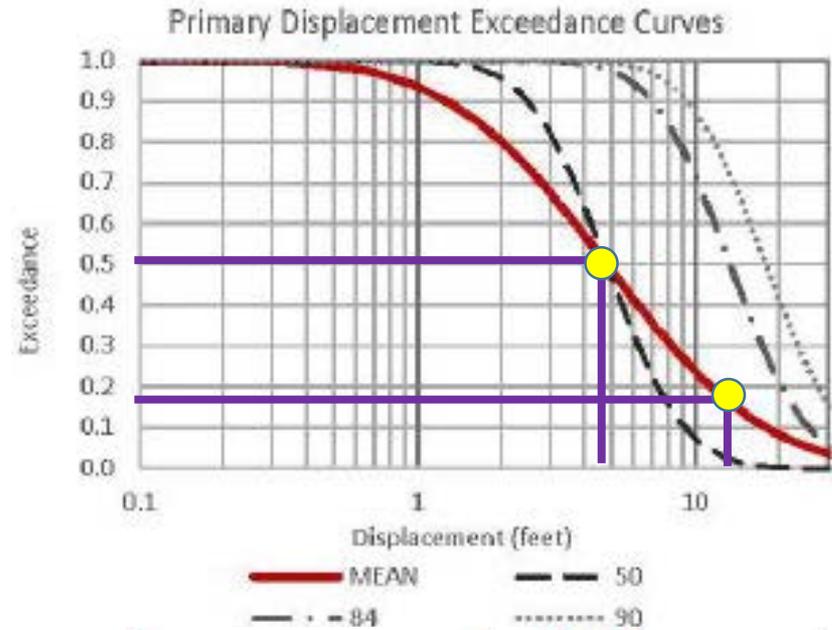
Photo: G.K. Gilbert

**2014 Napa Earthquake
Small displacement**



FAULT CROSSING ASSESSMENT

1. Characterize fault parameters at pipeline crossing
2. Estimate fault displacement during future earthquake
3. Model pipeline response



Accepted Manuscript



Eleventh U.S. National Conference on Earthquake Engineering
Integrating Science, Engineering & Policy
June 25-29, 2018
Los Angeles, California

FAULT DISPLACEMENT HAZARD ANALYSIS METHODS AND STRATEGIES FOR PIPELINES

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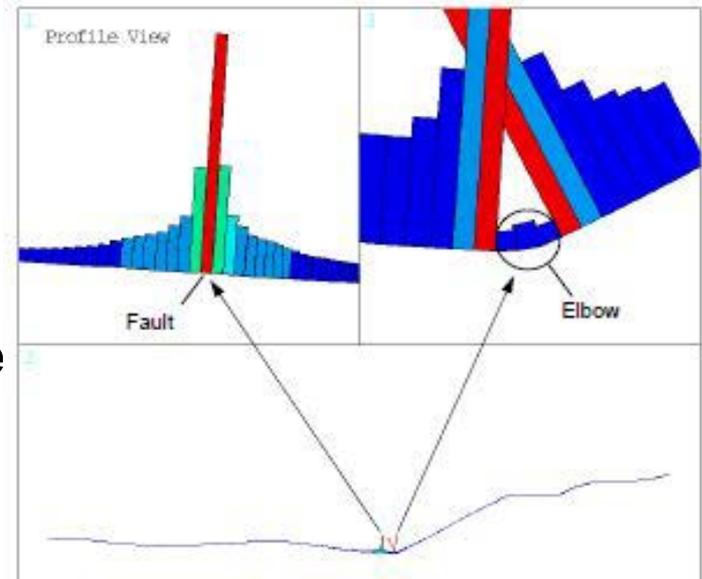
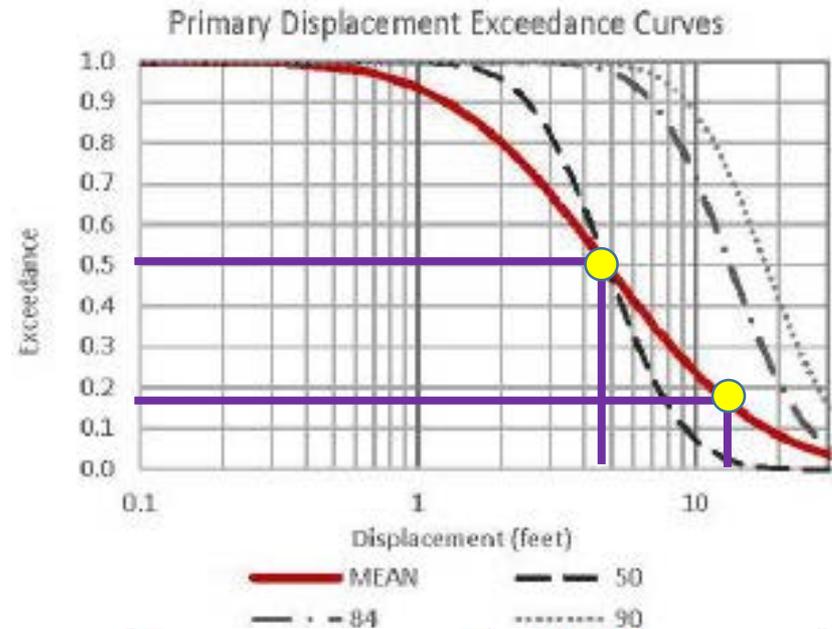
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COMMUNITY RESEARCH NEEDS

- Reduce uncertainty in displacement estimates
- Better understand pipeline response

PG&E RESEARCH ACTIVITIES

- Support UCLA fault displacement hazard initiative
- Laboratory and field testing of pipe





PG&E CREEP ASSESSMENT AND MONITORING

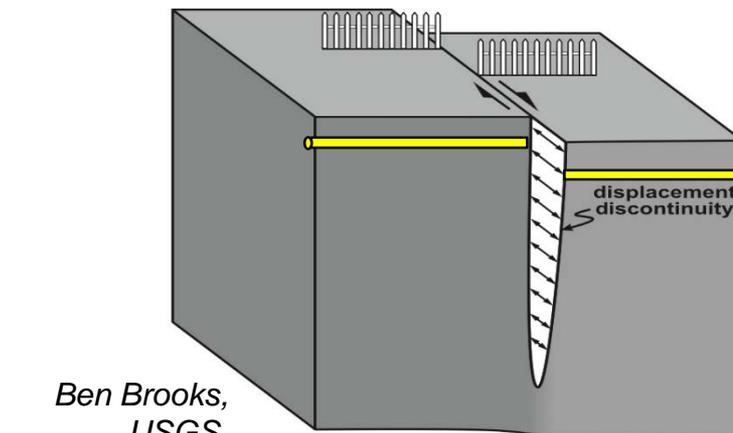
- Assess creep rate and pipeline creep capacity under fault crossing program
- Creep monitoring
 - *Marker balls*
 - *Strain gauges*
 - *LiDAR (USGS)*



Hayward Fault (Hayward)

COMMUNITY RESEARCH NEEDS

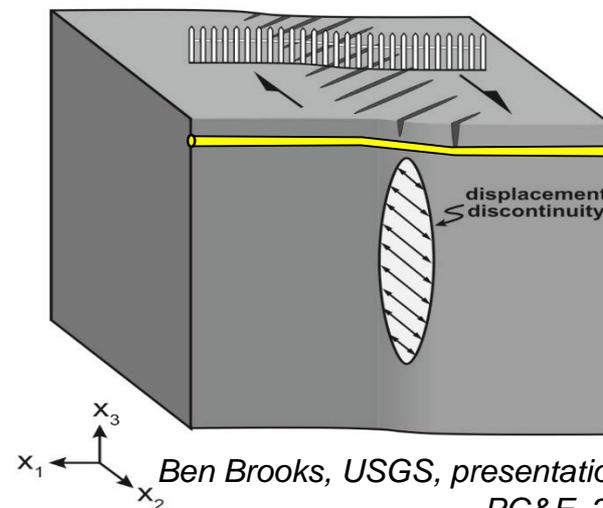
- Better understand vertical and horizontal distribution of creep at a site
- How to characterize creep at pipeline depth



Ben Brooks, USGS, presentation to PG&E, 2016

PG&E RESEARCH ACTIVITIES

- Work with USGS to improve understanding of creep displacement fields
- Improve creep monitoring methods



Ben Brooks, USGS, presentation to PG&E, 2016

Seismically Induced Landslides



Photo: GEER

2016 New Zealand Kaikoura Earthquake

Liquefaction and Lateral Spread



Photo: GEER

2011 New Zealand Christchurch Earthquake

TIMP Geohazards program maps and assesses landslides, other hazards; yearly updates

LiDAR landslide mapping, site visits for entire transmission system; Lidar change detection in process



Short Term Research Goals

IMPROVE ESTIMATES OF FAULT DISPLACEMENT HAZARD: UCLA FAULT DISPLACEMENT HAZARD INITIATIVE

- **Development of non-ergodic (regional and local) displacement models:** Parsing observational data by local tectonic regime, crustal thickness, and sense of faulting will reduce variation in displacement estimates.
- **Site effects:** Systematically quantifying how deformation relates to site conditions will produce more robust displacement estimates for discrete faults and deformation zones.
- **Distributed ruptures and distributed deformation:** Incorporating data from recent earthquakes ruptures documented with new ultra high-resolution data collection techniques will improve estimates of distributed and off fault displacement.



IMPROVE ESTIMATES OF FAULT DISPLACEMENT HAZARD: UCLA FAULT DISPLACEMENT HAZARD INITIATIVE (CONT)

- **Physical constraints from analytical models:** Analytical models will provide constraints on the PFDHA models in order to cap unreasonable displacement values that result from the extrapolation of models at long return periods.
- **Statistical methods and assumptions:** Advanced statistical methods need to be developed and applied to address these features of fault rupture data so that the resulting empirical model is unbiased for estimating the fault rupture hazard in future earthquakes.



Short Term Research Goals

UNDERSTAND HAZARD FROM POTENTIALLY ACTIVE FAULTS

- **Pilot studies of the Contra Costa Shear Zone and southern extension of the Serra Fault**
- **Convene geology board to review potentially active fault assessment methodology and risk to PG&E gas infrastructure**

IMPROVE PROBABILISTIC METHODOLOGY TO CHARACTERIZE HAZARD FROM SEISMICALLY INDUCED LANDSLIDES

- **Build on recent advances in developing regional seismically induced landslide hazard assessments**



Long Term Research Goals

MOVE TOWARD FULLY QUANTITATIVE METHODOLOGY TO ASSESS PIPELINE RISK FROM SEISMIC AND OTHER HAZARDS/THREATS

- **Reduce hazard uncertainty for all seismic hazards (fault displacement, landslide, liquefaction)**
- **Reduce uncertainty for pipeline fragility models**