



Mocha

**Collaborative Research: Onshore-offshore MT investigation
of Cascadia margin 3D structure, segmentation and fluid
distribution**

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Mocha

Magnetotelluric Observations of Cascadia using a Huge Array

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motivation

PROJECT GOAL To greatly refine our understanding of the segmentation, structure and fluid distribution along the Cascadia margin and its relationship to the spatial pattern of ETS.

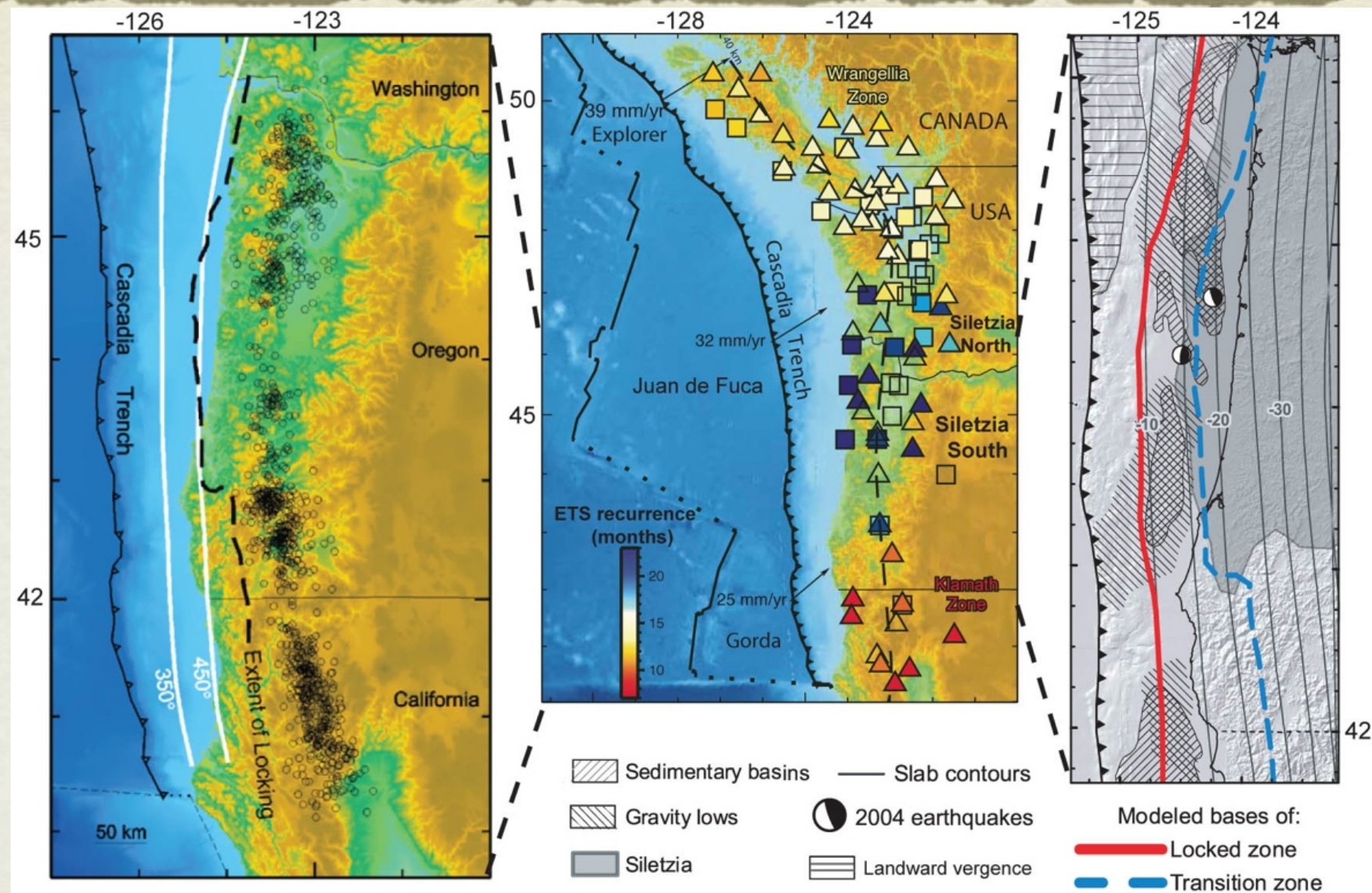
- Physical explanations for ETS usually invoke fluids - temporal patterns replicated in numerical models of sliding with rate/state dependent frictional laws require low effective confining pressures (Liu & Rice, 2005; 2007; Rubin, 2008), such as if pore pressures were elevated
- Detailed mapping of variations in bulk pore fluid content both up and down dip and orthogonally up and down segment of the slab, particularly in and surrounding the ETS source region would provide the necessary framework for better understanding the role of fluids in the space-time distribution of ETS

fluids and conductivity

The electrical conductivity of crustal and upper mantle rocks is extremely sensitive to the presence and interconnectivity of fluids (both magmatic and aqueous)

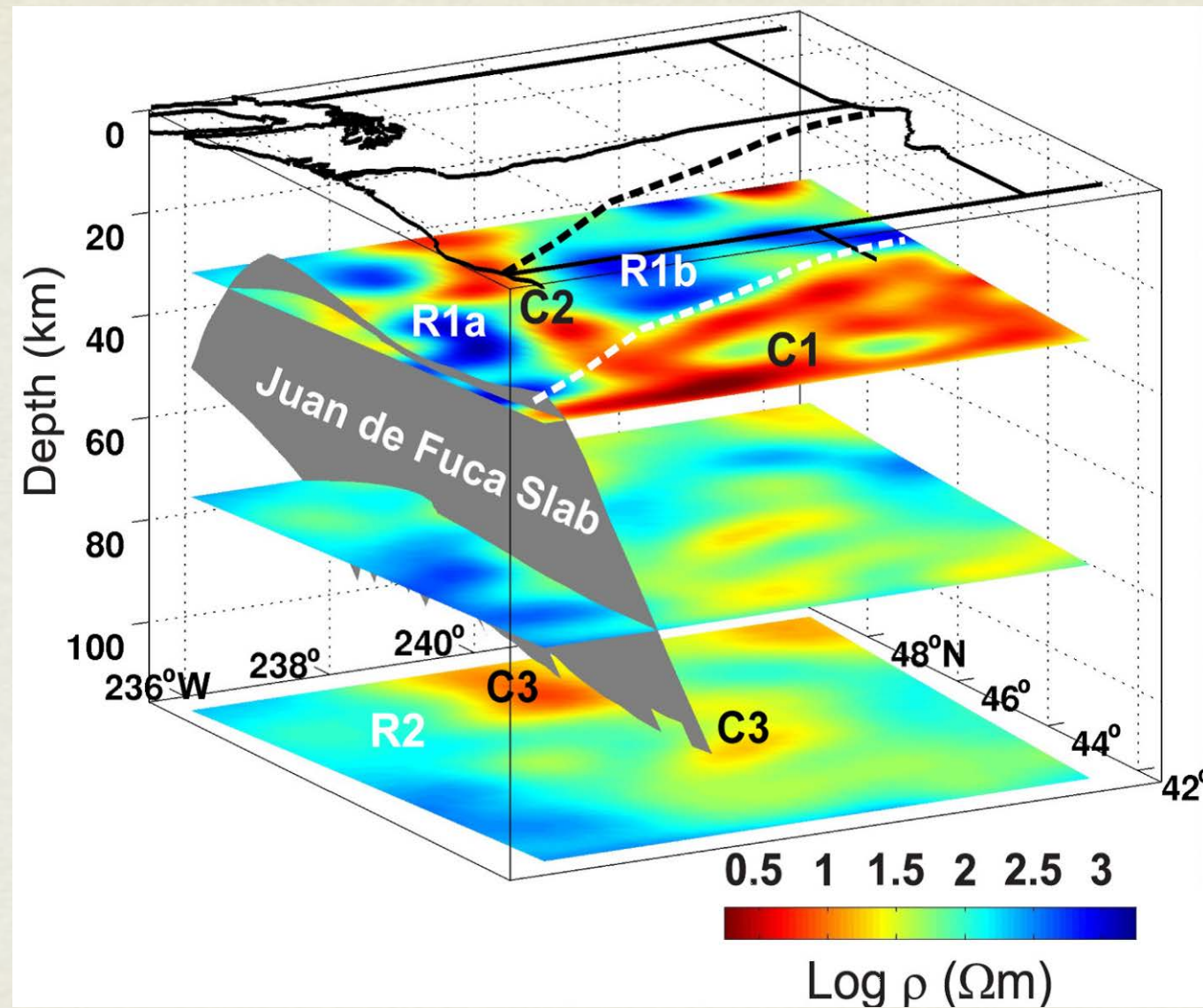
- The interconnection of fluids within pores, cracks and along grain boundaries depends on the porosity as well as the geometry of voids within the bulk matrix. Changes in the stress field result in changes in strain, hence hydrofracturing and dilatancy strengthening can have a first order impact on conductivity
- While it might be possible to image temporal changes in fluid content using electromagnetic methods, even a static image of the 3D variation of conductivity at and just above the slab interface may play a critical role in understanding the impact of fluids on the factors governing stress propagation along the margin

Cascadia ETS' spatial relationship to inferred slip along the plate interface



- (left) tremor locations from late 2005 to late 2007 (circles), down-dip limit of inferred transition zone (black lines, Burgette et al, 2008) and the thermally defined transition zone (white lines), from Boyarko & Brudzinski (2009). (center) segmentation of ETS recurrence intervals; Brudzinski & Allen (2007), modified to show segmentation of Siletzia into N and S segments. (right) map of central part of Cascadia subduction zone showing lower limit of locked and transition zones (red and blue lines). Deflections of these boundaries between 45 and 46 N correspond ~ to boundary between Siletzia sub-segments in center panel. Mechanisms and locations of two recent low-angle thrust EQs up-dip of ETC zone (M 4.8, 4.9; Trehu et al, 2008) also shown.

EMScope - 2008 3D Cascadia MT image



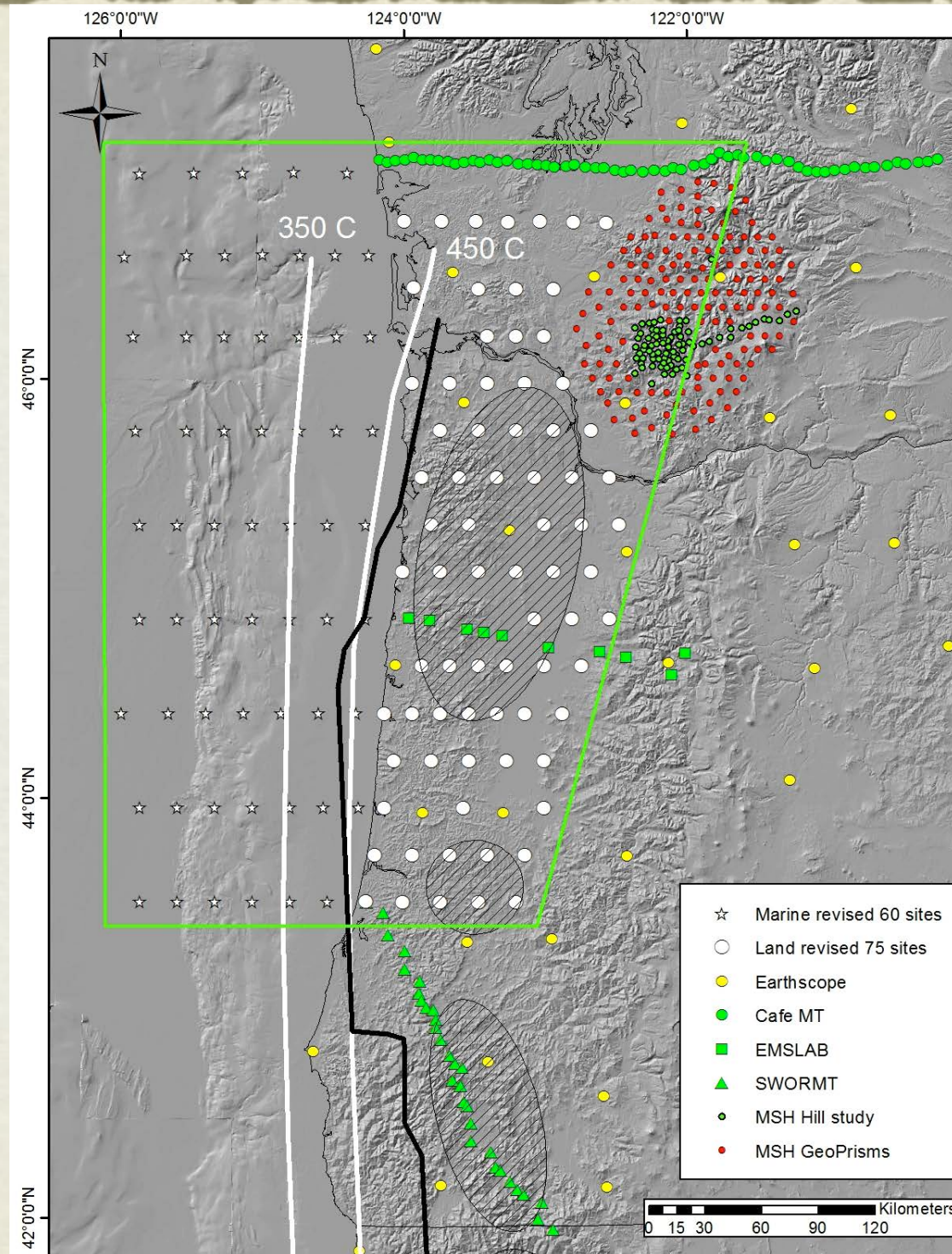
- EarthScope/USArray 3D MT model of Washington, Oregon and W. Idaho (Patro & Egbert, 2008).

The MOCHA Array Deployment 2013 (sea & land) & 2014 (land)

The white circles represent the terrestrial MT sites, and the stars are the ocean bottom MT sites.

The small yellow circles are completed EarthScope MT stations, which are spaced on a quasi-regular 70 km grid.

The terrestrial MOCHA sites are spaced roughly every 20 km from east-to-west and 25 km from north-to-south. The marine MT stations have similar east-west spacing, with approximately double the north-south spacing.



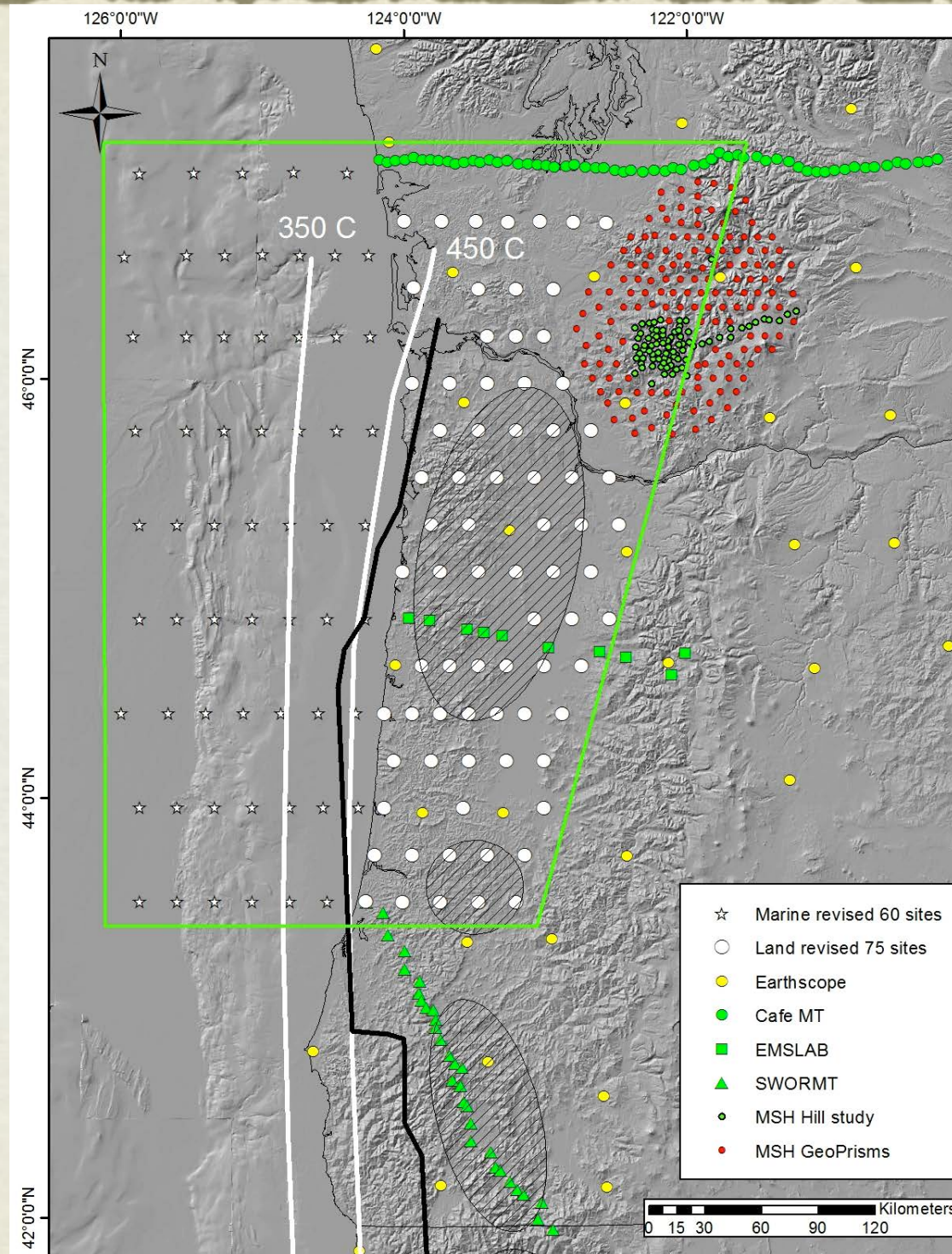
The hatched areas are ETS clusters which appear to be related to the northern and southern Siletzia segment, and to the Klamath segment of the Cascadia Margin.

When originally envisioned, the MOCHA array was larger in all dimensions, with more than twice the total number of stations, and was shifted southward covering the northern Siletzia through Klamath margin segments.

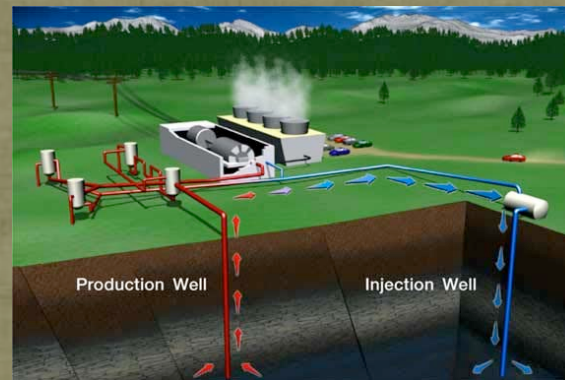
While funding levels could not support an array of that extent, the recent EarthScope/GeoPRISMS Programs decision to fund the Mt. St Helens seismic and MT arrays (red dots in this figure; see separate poster) has led us to move the **MOCHA** array slightly north so it is contiguous with that array, and bounded on the north by the already completed EarthScope CAFÉ-MT array, also seen in the figure.

The MOCHA Array Deployment 2013 (sea & land) & 2014 (land)

The aperture of the array extends from the seafloor, allowing us to constrain fluid inputs to the subduction system (and the electrical connection to the ocean—critical for interpretation even of the land data).



• This array configuration will allow us to: image the crust and upper mantle of the subduction system in 3D, from the incoming plate to the edge of the magmatic arc (and with the GeoPRISMS array to the NE, in very high resolution through the arc), and map the distribution of fluids in the subduction system in unprecedented detail, constraining both the fluid input to the system from offshore and the distribution of fluids released from the down-going slab, including along the transitional zone where Episodic Tremor and Slip (ETS) occurs.



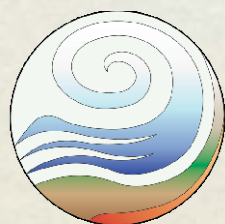
Photos: Lauren Boyd

.Newberry Volcano - Novel use of 4D monitoring techniques to improve reservoir longevity and productivity in Enhanced Geothermal Systems

OSU/Adam Schultz, Paul Vincent

DOE/NETL/Kelly Rose, Alexandra Hakala, Christina Lopano, Karl Schroeder

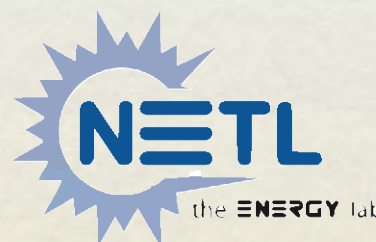
Zonge Int'l, Inc./Scott Urquhart, Jennifer Hare, Les Beard



College of Earth, Ocean and Atmospheric Sciences
Oregon State University



National Geoelectromagnetic Facility

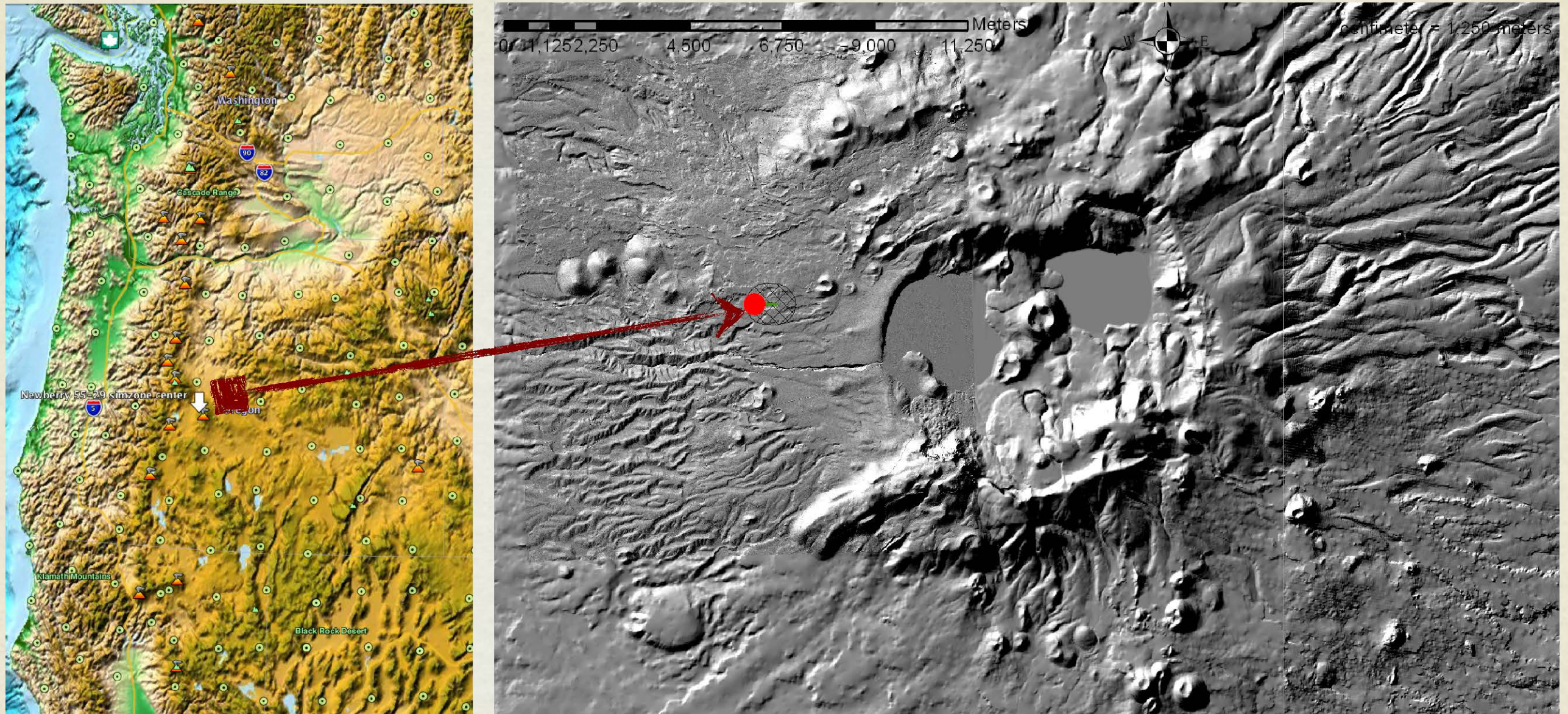


National Energy Technology Laboratory
US Department of Energy



Zonge International, Inc.

Newberry EGS Site



(left) Newberry Volcano EGS Stimulation Zone indicated by white arrow. Newberry lies just east of the central Oregon Cascades volcanic arc. (right) Hatchured area is estimated hydroshearing zone, red dot is location of stimulation well. This area lies immediately west of Newberry National Monument and Paulina Lake. (Newberry EGS GIS data courtesy of AltaRock Energy, Inc.)

Hydroshearing/well stimulation: August 2012. OSU/NETL/Zonge Project: 4D MT/CSAMT (75+6), interferometric radar, gravity (400), chemistry

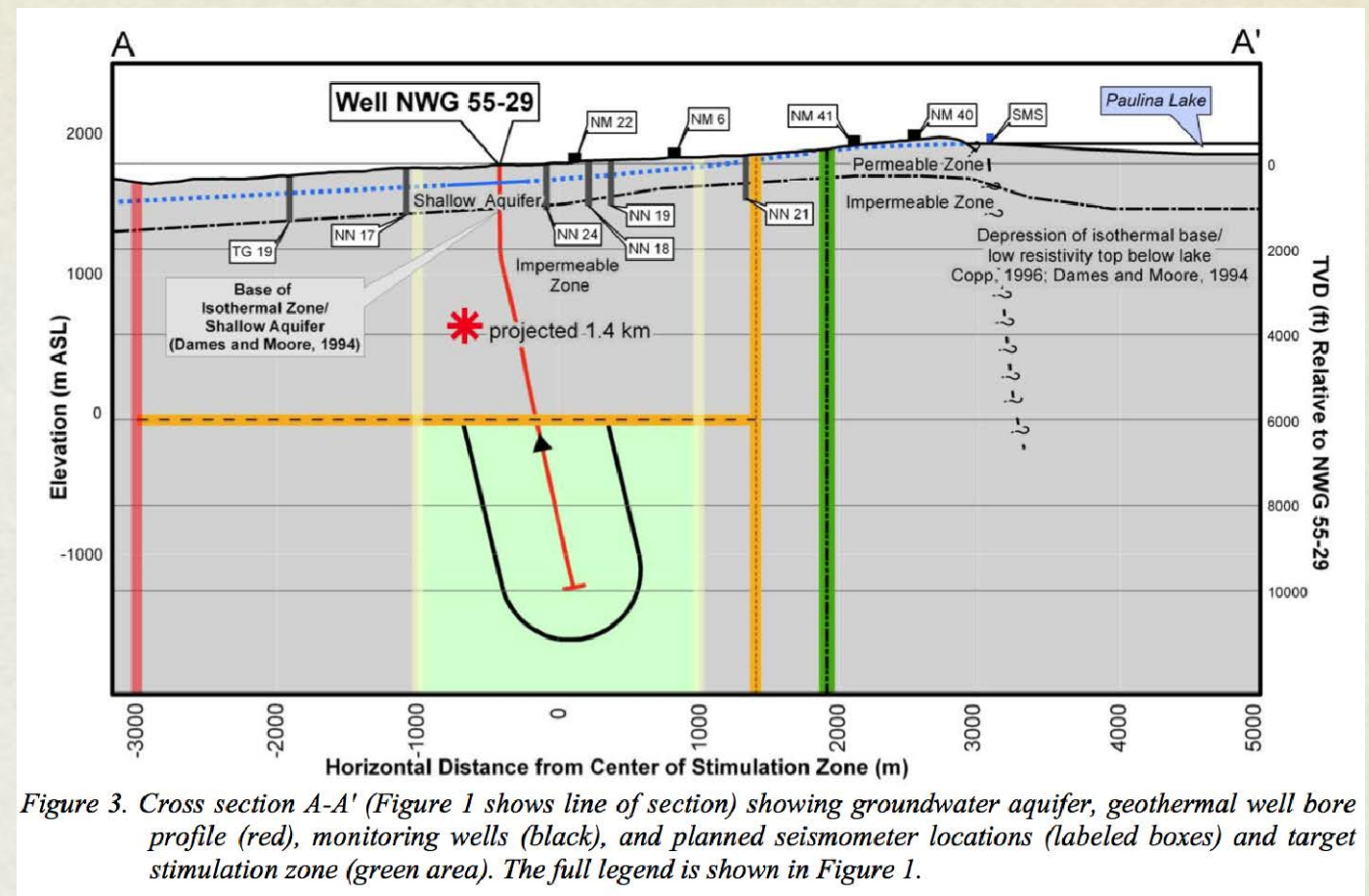
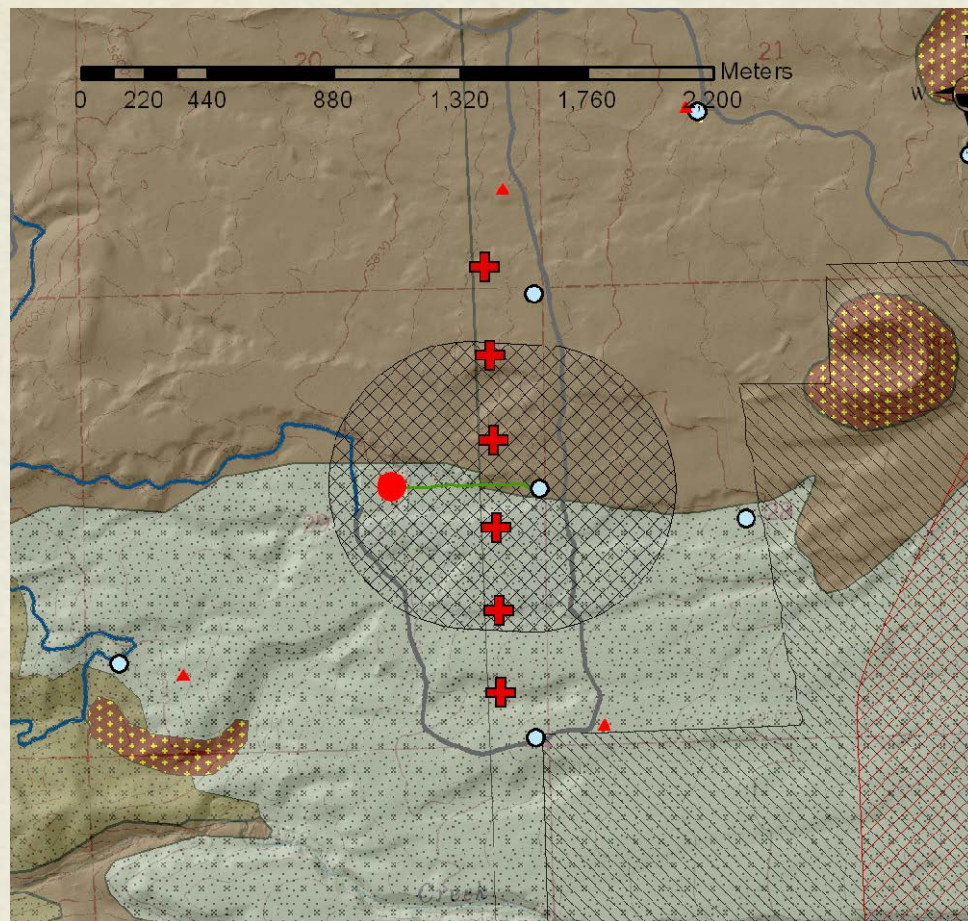


Figure 3. Cross section A-A' (Figure 1 shows line of section) showing groundwater aquifer, geothermal well bore profile (red), monitoring wells (black), and planned seismometer locations (labeled boxes) and target stimulation zone (green area). The full legend is shown in Figure 1.

- (left) Map view of approximately 3 km x 3 km monitoring zone. Hatchured zone is estimated lateral footprint of region hydrofractured during EGS stimulation. Red dot is location of stimulation well and green line is directional drill path to center of stimulation zone. Red crosses are locations of continuously monitoring MT/CSAMT sites. Not shown: 75 MT/CSAMT and 400 gravity stations distributed on uniform grid location within this area. Each of these stations is occupied three times (pre-, syn- and post-stimulation). (GIS data courtesy of AltaRock Energy, Inc.)
- (right) Cross-section of Newberry flank showing anticipated vertical section through the hydroshearing zone. (source: Newberry Volcano EGS Demonstration - Phase I Results, Cladouhos, T.T., et al, PROCEEDINGS, Thirty-Seventh Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, January 30 - February 1, 2012 SGP-TR-194.)