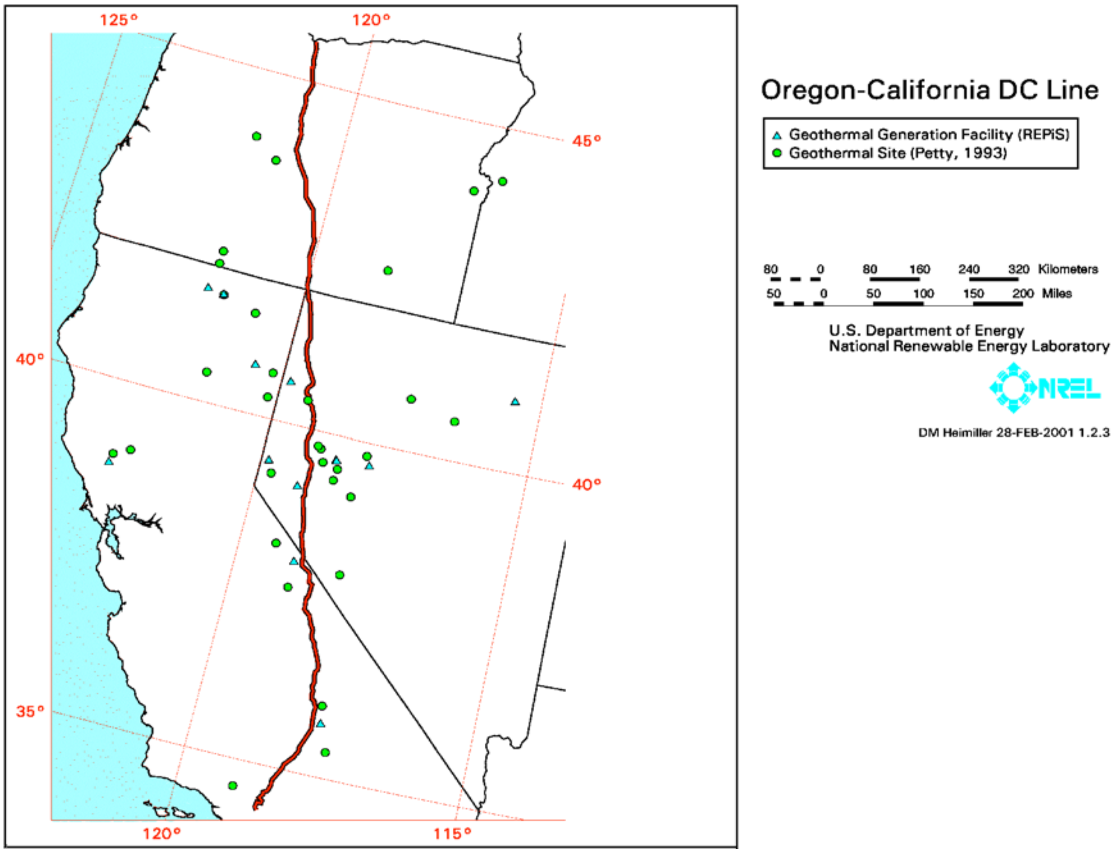
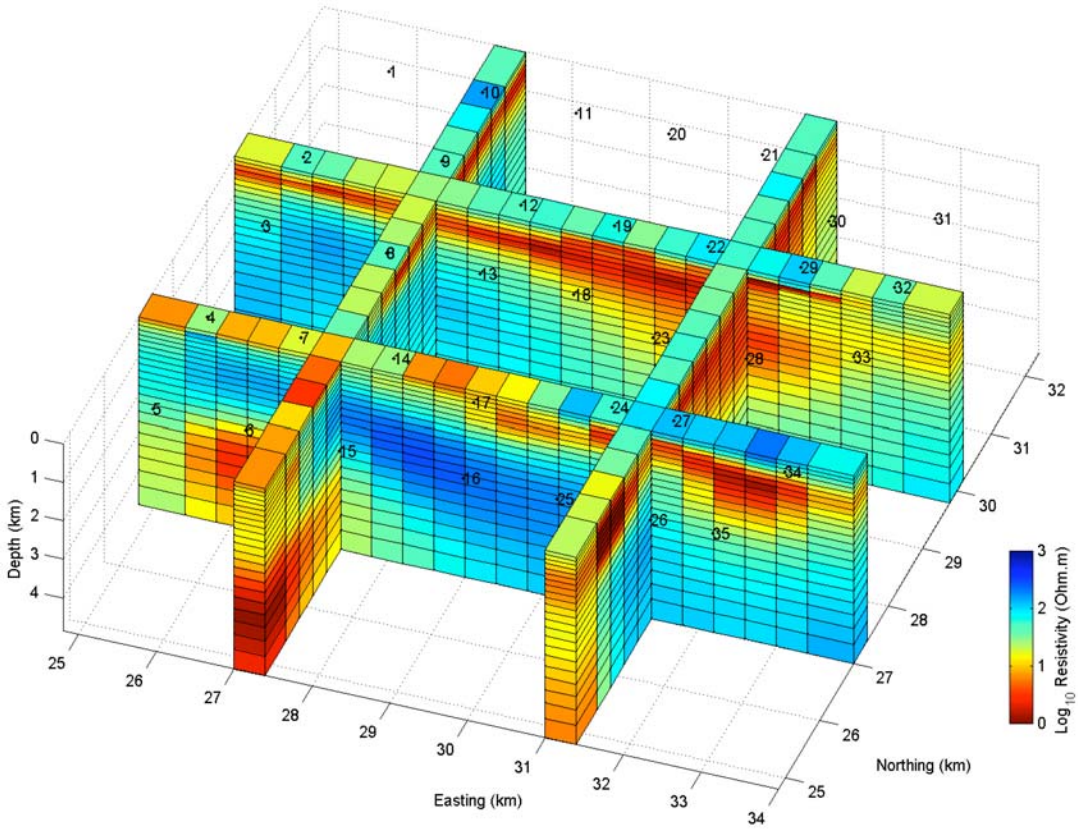
Geothermal Systems for Geoscientists (5920/6920 sec-3)

Electrical Geophysical Methods of Geothermal Exploration (P. Wannamaker, instr.; pewanna@egi.utah.edu):

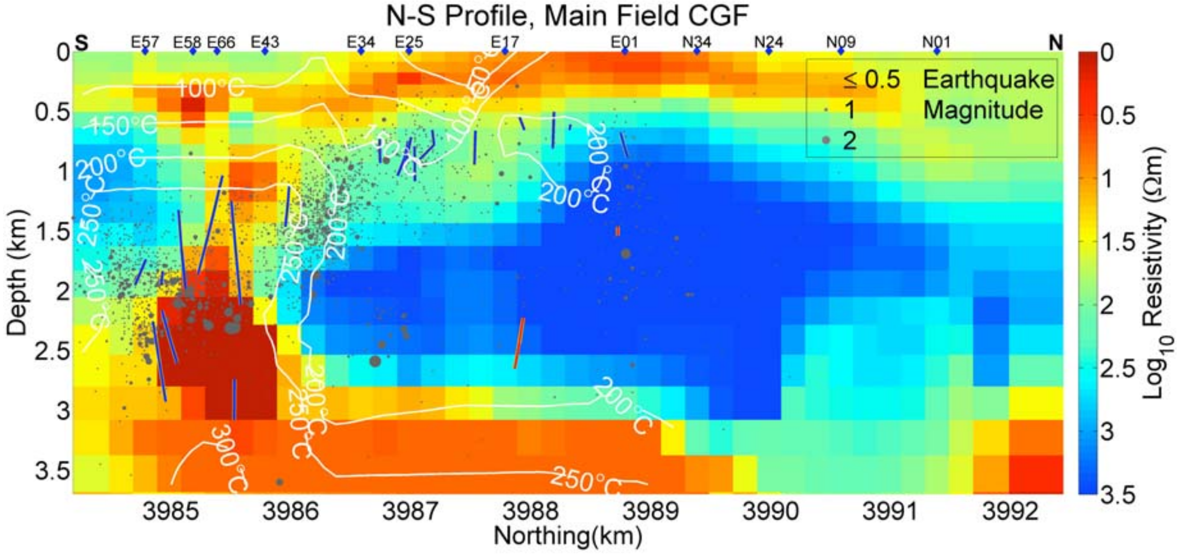
Exercises: Electrical geophysical exploration in geothermal systems.



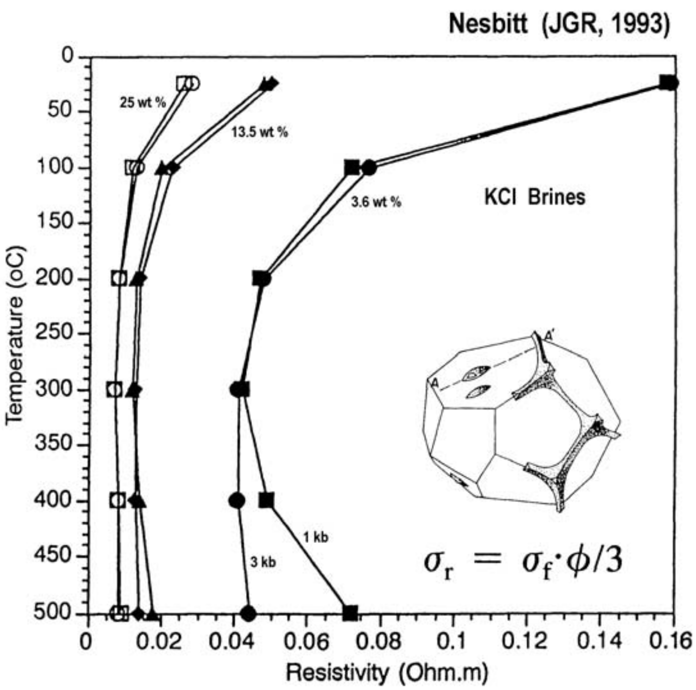
Question 1: A major "noisy" electrical transmission line passes near your geothermal prospect area, where you would like to do MT surveying to image resistivity structure. The average resistivity of the rocks in the region is 100 ohm-m. The e-folding or "skin" depth relationship in kilometers is $\delta = 0.5\mathrm{sqrt}(\rho/\mathrm{freq})$, where ρ is that resistivity. The wave length of the EM fields in earth materials is $\lambda = 2\pi\delta$, over which the attenuation of the noise fields is essentially complete and would represent a good distance to place a remote reference for cancelling the powerline interference. To achieve good quality referenced MT data down to freq = 0.1 Hz, how far away (λ) should the remote reference be placed in 100 ohm-m average resistivity? How far away should the remote reference be placed in 1000 ohm-m average resistivity?



Question 2: Above is a fence diagram display of electrical resistivity imaged using MT in an andesitic geothermal system from Indonesia. Identify the smectite dominated alteration volumes. Identify the higher-temperature propyllitic (clay depleted) volume. Sketch in and label the temperature isotherm representing the transition between the two types of mineralogy. Where seems to be most prospective for drilling based just on this geophysics (normally we will have other info too like surface faulting and hot springs). Is a deep magmatic source suggested by this figure?



Earthquakes from: 427.9225 - 428.1225 km Easting   Wells within: 427.7225 - 428.3225 km Easting



Question 3: Above is a resistivity cross section through the Coso high-temperature system in eastern California. Shown also are temperature contours from various wells, plus high-temperature fluid entries (blue line segments). Identify the smectite dominated alteration zone. Identify the tight, non-productive crystalline rock host volume. Identify the high-temperature fluid upwelling zone. State the range of resistivity observed in the upwelling zone.

Assume the porosity in the productive upwelling zone is dominated by ideal planar fractures. The formula for bulk conductivity σ_b (inverse of resistivity ρ_b) for a fracture network is $\sigma_b = 1/\rho_b = 2\sigma_f X/3$, where X is porosity (0 to 1 range) and $\sigma_f = 1/\rho_f$ is fluid conductivity. Assuming the fluids are 3.6 wt % KCl brines (similar to NaCl actually) with resistivity a function of temperature as in the Nesbitt diagram at left, estimate the inferred fracture porosity in the upwelling zone. Ignore pressure effects (minor).

References:

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Simpson, F., and K. Bahr, Practical magnetotellurics, Cambridge Univ. Press, 254 pp., 2005.

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Proceedings of the Workshop of Geothermal Reservoir Engineering, Stanford University, Stanford, CA (yearly), pangea.stanford.edu/ERE/research/geoth/conference/workshop.html.

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