EE0005514

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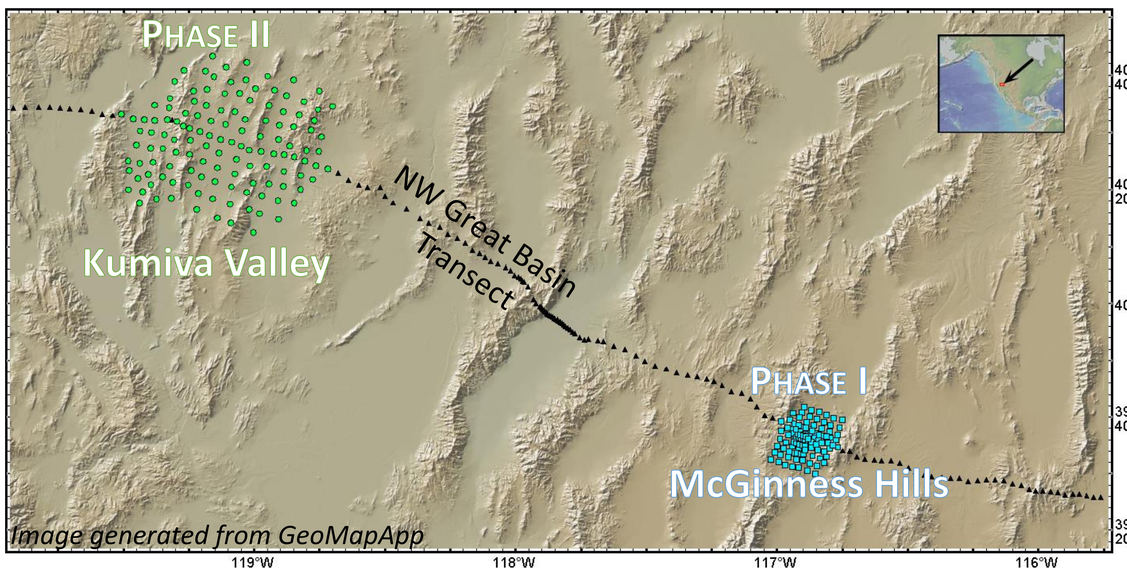
# Integrating Magnetotellurics, Soil Gas Geochemistry and Structural Analysis to Identify Hidden, High Enthalpy, Extensional Geothermal Systems

## Summary

Project is combining 3-D magnetotellurics (MT), soil gas flux and geochemistry, and structural geology into a multi-method, integrative technology for identifying blind, high temperature, high enthalpy geothermal resources. Reconnaissance MT revealed several crustal scale breaks across the Great Basin that may represent connections between high-T geothermal systems near surface and magmatic emplacement at depth. MT, magmatic $^3$He and dilatant intersecting faults at Dixie Valley constituted the initial basis for this.

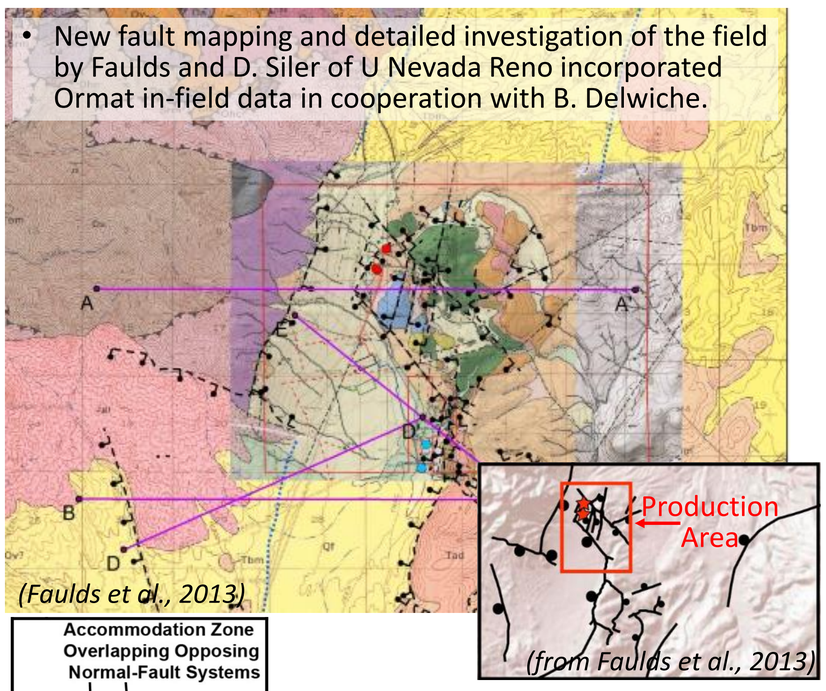
Phase I examined crustal scale structure at McGinness Hills, in cooperation with Ormat. 3D MT surveying, structural mapping, and fluid and soil gas surveying confirmed this confluence of indicators as characterizing a high-T system. Phase II moved forth to examine the Kumiva Valley area where a large, shallow anomaly also was observed in MT transect studies. A 3D MT survey was undertaken and the 3D inversion model presented here. Low-resistivity upwellings are associated with known system San Emidio, plus two favorable structural settings on the west side of the Seven Troughs Range and west side of Blue Wing Mountains. Soil gas flux and isotope investigations will take place this summer.




## Phase I : Proof of concept - McGinness Hills Field

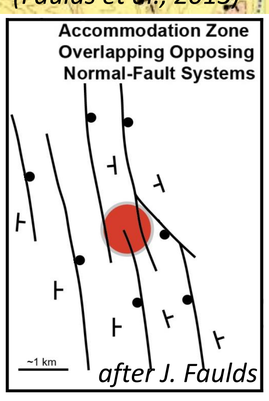
### STRUCTURAL GEOLOGY

- New fault mapping and detailed investigation of the field by Faulds and D. Siler of U Nevada Reno incorporated Ormat in-field data in cooperation with B. Delwiche.





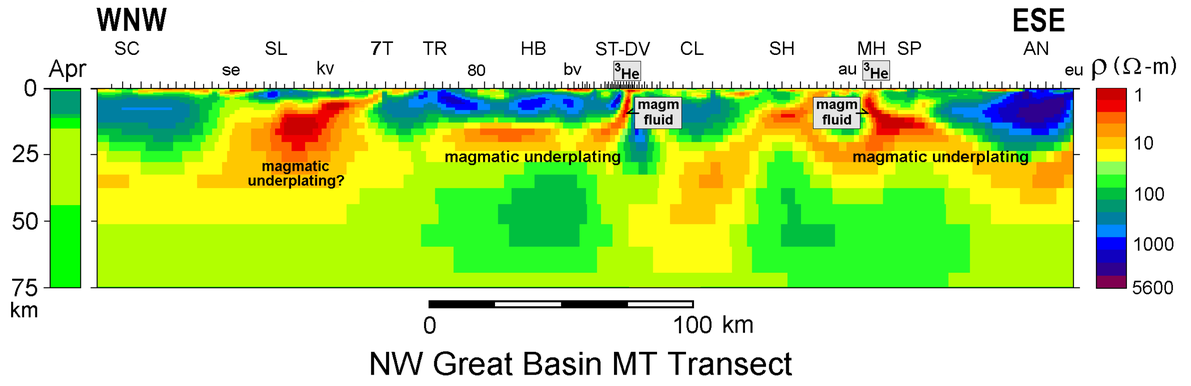




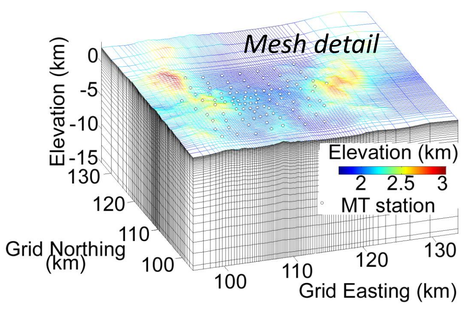

- Structural setting of the field is an accommodation zone: a left step-over utilizing NW-SE trending normal faults connecting a large W-dipping normal fault to the south with an E-dipping normal fault to the north.

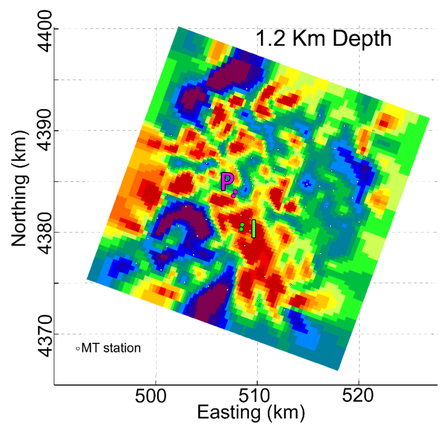
### MT

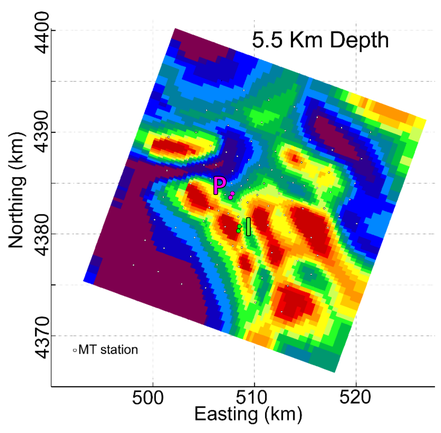
- Reconnaisance transect MT identified several possible magmatic emplacement and fluid release zones. One under the Humboldt Range (HB) connects through a steep fluidized fault-zone feeder to the Dixie Valley geothermal system. Others were seen projecting upward into McGinness Hills (MH) and the Kumiva-Seven Troughs (kv-7T) district.

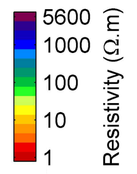



- 3D MT survey utilizing new deformable finite element inversion algorithm (Kordy et al., 2015a,b) confirms reconnaissance 2D survey. At production depth (~1.2 km), production (P, red dots) and injection (I, green dots) lie in pronounced NW-SE conductive zone. This orientation persists to the deep crust, suggestion large-scale controls on the accommodation zone faults that constitute permeability of the producing reservoir.



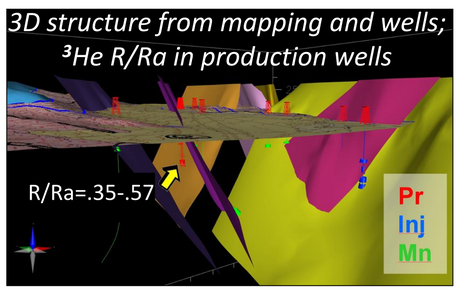



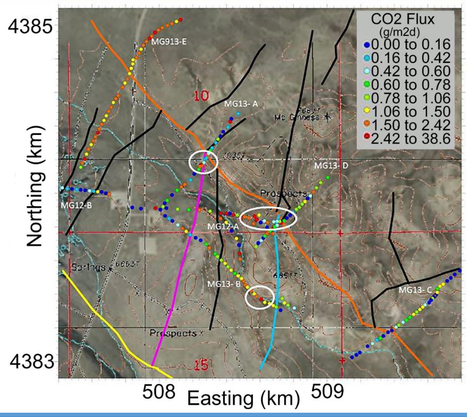

### SOIL GAS FLUX & GEOCHEMISTRY

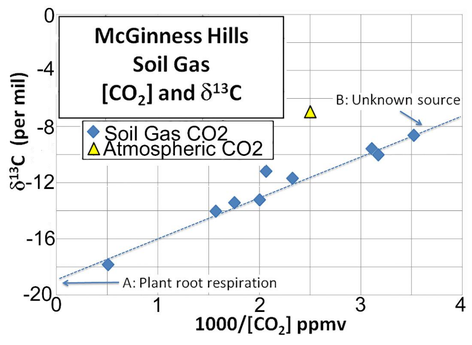
- $^3$He samples indicate that ~5-10% of McGinness Hills fluid is magmatic. This confirms low-resistivity upwellings are carriers of mantle input. This is not a large fraction of produced fluid; we interpret that such geophysical structures reveal abnormally vigorous deformational events that create large-scale permeability exploited by geothermal systems.

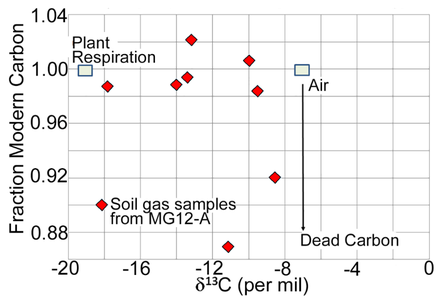




- Soil gas transects sought $CO_2$ flux anomalies associated with the controlling accommodation faults. Anomalies (white circles) are not strong, but considered associated with a deep source given the crustal column of quartzites and granite. Followup pipette sampling indicates $CO_2$ is a mixture of plant respiration plus an unknown source B. Further sample analyses showed two samples with depleted 14C content, implying an older, deeper carbon $CO_2$ flux.



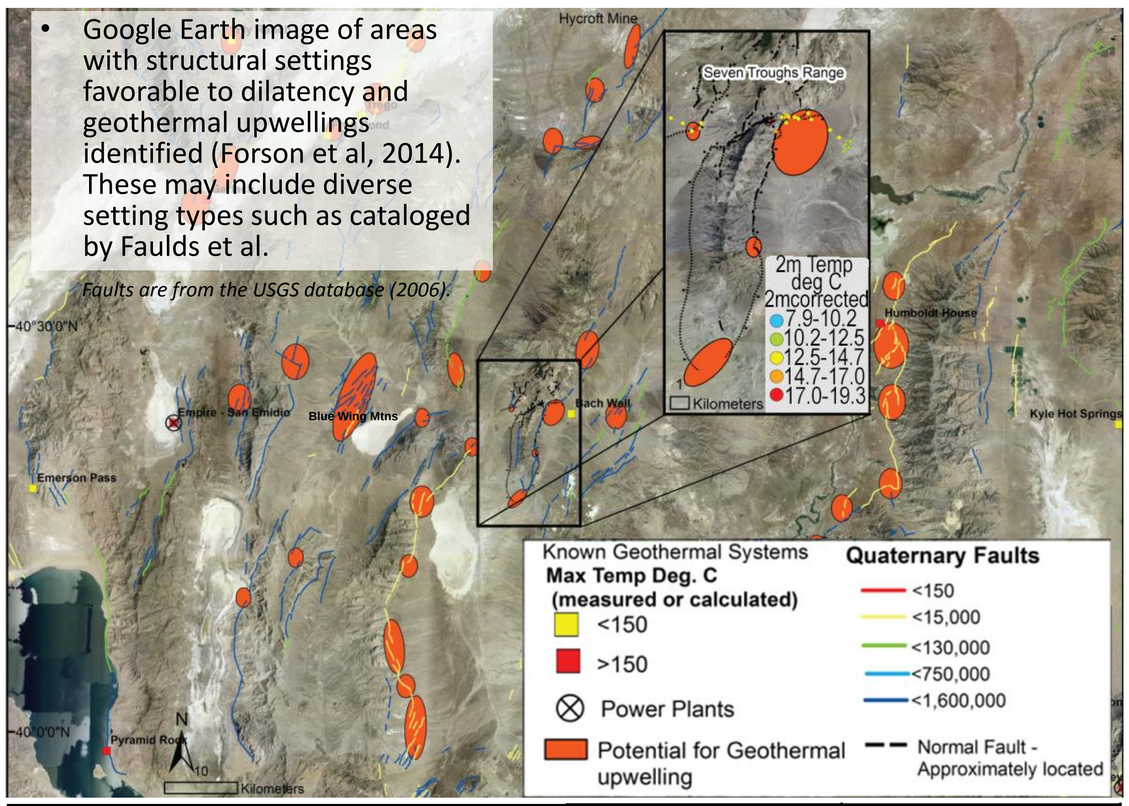



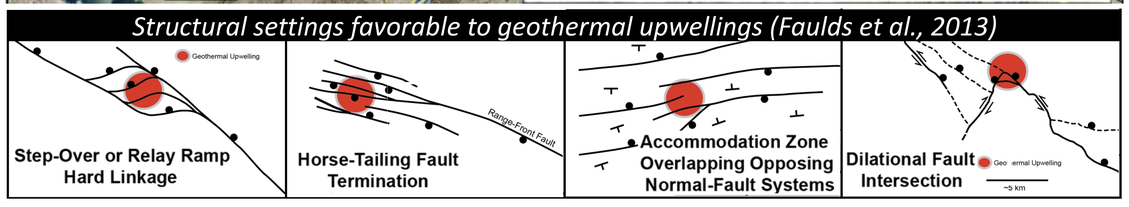

## Phase II : Validation – Kumiva Valley Area

### STRUCTURAL GEOLOGY

- Google Earth image of areas with structural settings favorable to dilatency and geothermal upwellings identified (Forson et al, 2014). These may include diverse setting types such as cataloged by Faulds et al.

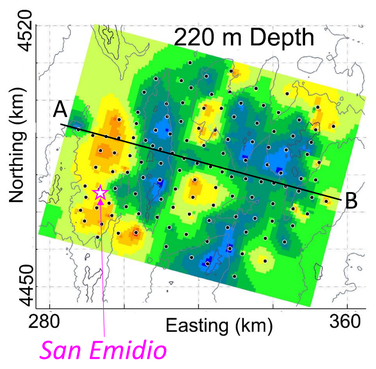
*Faults are from the USGS database (2006).*

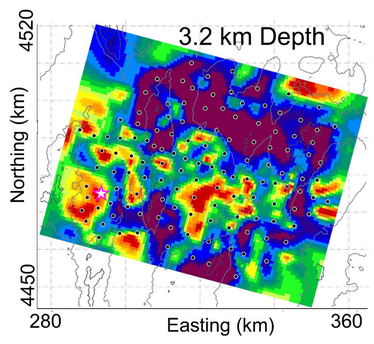


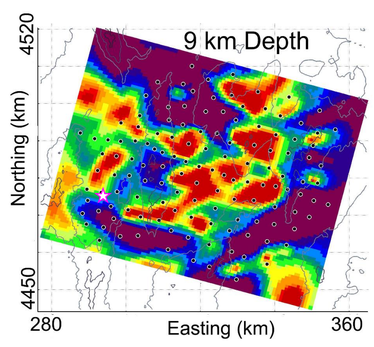



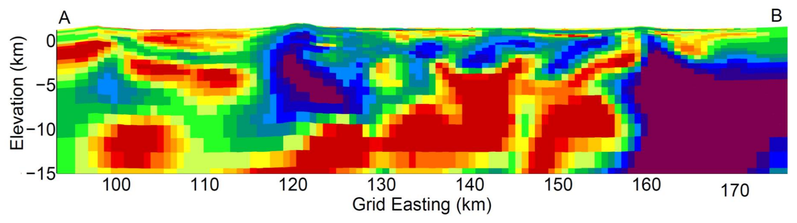

### MT

- 3D inversion of the Kumiva Valley area MT data set shows several interesting characteristics. Valley alluvium and shallow outcrop give way to low resistivity upwellings under known San Emidio, under west side of Blue Wing Mtns and under west side of Seven Troughs Range. These will be double-checked against mapped structures and prioritized for followup soil gas surveying summer of 2015. In lowermost model section, 3D structure compares favorably with original 2D transect section.




### SOIL GAS FLUX & GEOCHEMISTRY

- Soil gas geochemistry will be undertaken for indications of deep abiotic gas components. These will be performed at areas where upwelling MT anomalies and zones of structure favorable to dilatency are observed.

## References

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