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Surprise Valley Geochemistry

Project Officer: Holly Thomas

Total Project Funding: $206,000

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Track 2, HRC: Tracers / Zonal Isolation / Geochemistry

Relevance/Impact of Research

- Project Objective
  - Evaluate the deep thermal fluid(s) temperature in Surprise Valley
  - Apply geothermometry and modeling approaches recently tested at Dixie Valley (Spycher et al., Peiffer et al., and Wanner et al., Geothermics, July 2014)
  - Integrate water geochemistry with geological, structural, and geophysical data (in collaboration with other related projects)
  - Further test/develop the multicomponent geothermometry code GeoT (http://esd.lbl.gov/research/projects/geot/)
- Challenges
  - Dilution/mixing and gas loss mask deep chemical signatures of waters
- Knowledge Gaps
  - Tectonic transition zone less studied than Cascades or Basin & Range
- Impacts
  - Provide early-phase exploration data
  - Reduce development costs
- Innovation
  - Optimized multicomponent geothermometry (development of iGeoT)
  - Integration with geochemical and reactive transport modeling

Relevance/Impact of Research

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- Meets two of the Geothermal Technologies Office's goals
  - "Accelerate Near Term Hydrothermal Growth"
  - "Systems Analysis"

  (Both goals lower risks and costs of development and exploration)

- Integration/synergies with other projects
  - Estimates of Deep Permeability project (LBNL): Drew Siler is contributing his structural geology expertise and data integration skills using GIS
  - Play/Fairway project "Analysis of Potential Geothermal Resources in NE California, NW Nevada, and Southern Oregon": UC Davis/LBNL collaborative project (includes Modoc plateau/Surprise Valley area)
  - UC Davis Surprise Valley investigations (California Geothermal Energy Collaborative): Collaborate with Prof. R. Zierenberg's students Carolyn Cantwell and Andrew Fowler – hired as Summer interns at LBNL in 2014

Completed

- Compile chemical analyses of thermal waters and groundwater from Surprise Valley
- Integrate these data into a GIS database including other exploration-relevant data such as structural, geophysical, and geological data
- Perform solute geothermometry analyses to infer deep reservoir temperatures
  - Optimized multicomponent geothermometry: use the GeoT code with iTOUGH2 to reconstruct the composition of deep fluid(s) (estimate CO_2 loss, dilution, deep Al concentration) and estimate deep temperature
  - "Classical" geothermometry with reconstructed waters
- Apply various modeling techniques to infer relationships between thermal waters, cold groundwater, and alkali lake waters
  - "Classical" graphical analyses of geochemical data
  - Reaction path geochemical modeling of evaporation to investigate alkali lake water compositions

Scientific/Technical Approach

In Progress

- Develop conceptual and numerical model(s) to help assess flow and recharge patterns towards a better understanding of the study area
  - Develop local and regional geologic/structural cross sections
  - Reactive transport simulations using TOUGHREACT (http://esd.lbl.gov/research/projects/tough/)
- Develop a stand-alone GeoT optimization package: iGeoT
  - Incorporates iTOUGH2 optimization routines directly into GeoT
  - More practical than using both codes in tandem

Project Execution

- Specific tasks/milestones were closely mapped to the technical approach (see table in next slide)
- Key Issues
  - Some milestones were delayed (competing project deadlines)
  - Addressed by hiring Summer interns (2014) and accelerating effort/burn rate in 2015

Accomplishments, Results and Progress

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Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
FY14-Q1: literature review and compilation of water chemistry data	Data compiled as planned. Submitted to the GDR April 2, 2015	Aug. 2014
FY14-Q2: review and integrate geochemical data with other data	Data integrated with geological, structural and geophysical data into an ArcInfo GIS database (Drew Siler)	Sept. 2014
FY14-Q3: integrated geothermometry/modeling analyses	Optimized multicomponent geothermometry with GeoT-iTOUGH2	Oct. 2014
FY14-Q4: complete conceptual model, conference/publications	Geologic/structural cross-sections developed; papers published	Partly completed
FY15-Q1 – Complete numerical discretization of model domain	Conceptual and numerical model currently being developed	In progress
FY15-Q2 – Finish testing and release of iGeoT V1.0	iTOUGH2 optimization routines were incorporated into GeoT; The new iGeoT is functional and being tested	In progress, release by Summer 2015

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
FY15-Q3 – Development of alternative conceptual models	Started in Q3	Expected June 2015
FY15-Q4 – Complete reactive transport modeling analyses of the Surprise Valley area	Started in Q3	Expected September 2015

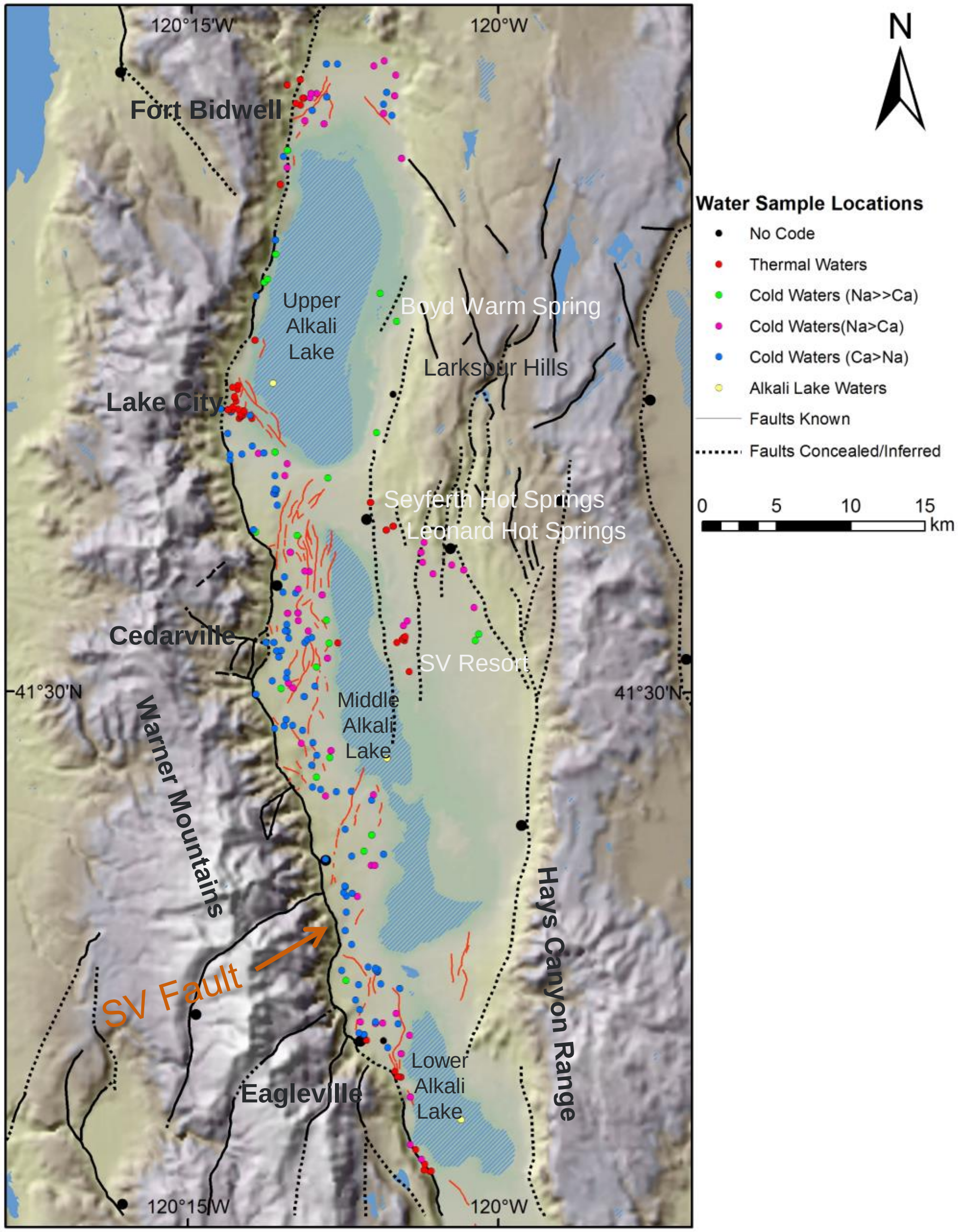
Publications (FY14-FY15)

Fowler, A., Cantwell, C., Spycher, N., Siler, D., Dobson, P., Kennedy, B.M., Zierenberg, R., 2015. Integrated Geochemical Investigations of Surprise Valley Thermal Springs and Cold Well Waters. PROCEEDINGS, 40th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, SGP-TR-204

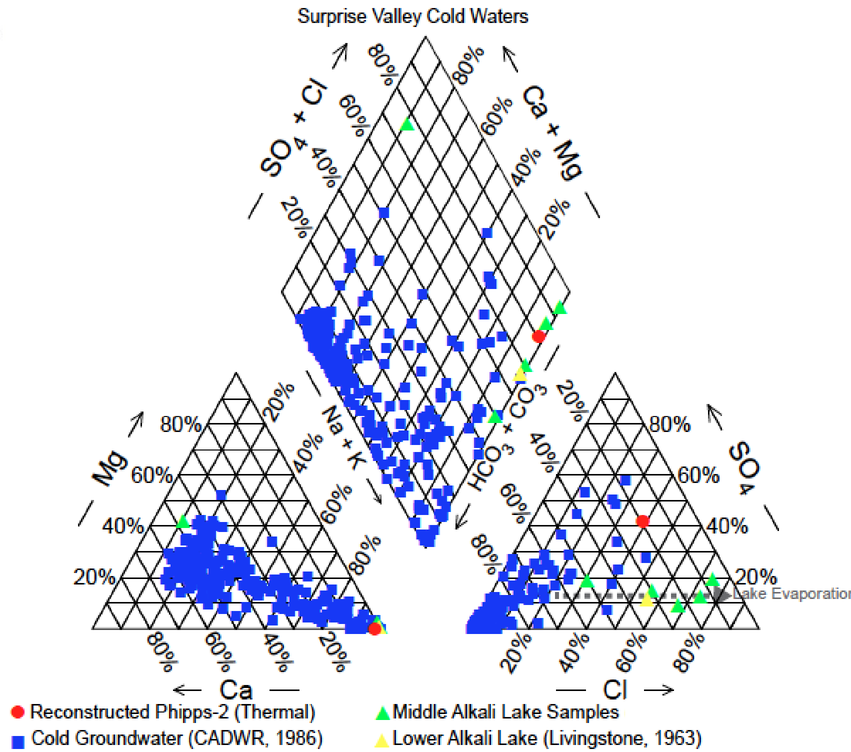
Spycher, N., Peiffer, L., Saldi, G., Sonnenthal, E., Reed, M.H., Kennedy, B.M., 2014. Integrated multicomponent solute geothermometry. *Geothermics*, 51, 113–123.

Peiffer, L., Wanner, C., Spycher, N., Sonnenthal, E.L., Kennedy, B.M., Iovenitti,J., 2014. Multicomponent vs. classical geothermometry: insights from modeling studies at the Dixie Valley geothermal area. Geothermics 51, 154–169.

Wanner, C., Peiffer, L., Sonnenthal, E., Spycher, N., Iovenitti, J., Kennedy,B.M., 2014. Reactive transport modeling of the Dixie Valley geothermal area: insights on flow and geothermometry. *Geothermics* 51,130–141.



- Most of the data are from the western part of the valley
  - Thermal waters (hot springs and wells)
  - Many groundwater wells
  - Alkali Lake waters
- Build on previous work by Cantwell & Fowler (2014, Stanford Geoth. W.)

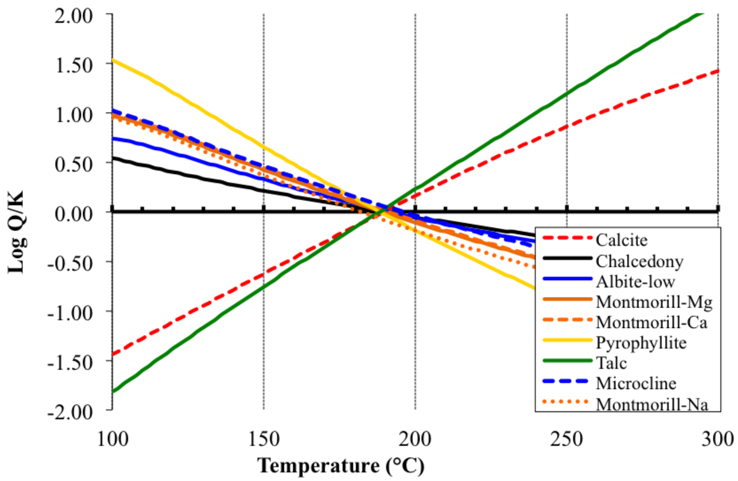


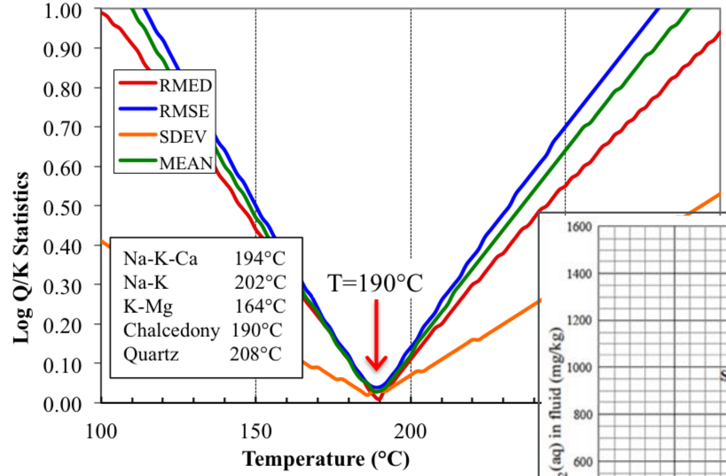
Reconstruction of Deep Thermal Component

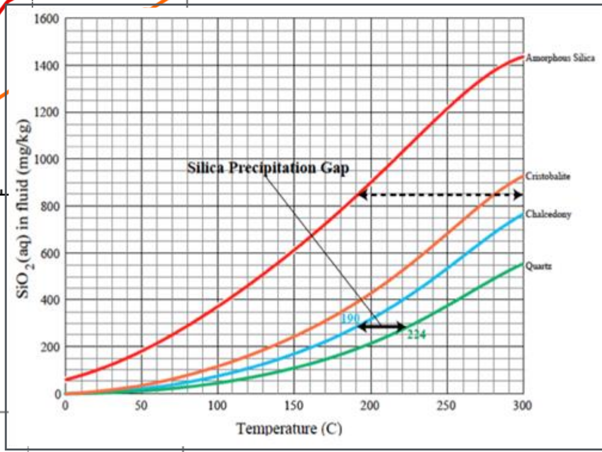
- Started with a fluid analysis from the Phipps #2 well (near Lake City) (Sladek et al., 2004, GRC)
- Deepest (~1500 m) and hottest (~170ºC) well drilled to date
- Significant reported boiling fraction (~11%)
- Optimized multicomponent geothermometry
  - Use GeoT coupled with iTOUGH2 optimization software (Finsterle & Zhang, 2011, Env. Mod.& Softw.)
  - Solve for amount of CO_2 loss from sample, as well as unknown Al and Mg concentrations (following Peiffer et al., 2014)
- Geothermometry method relies on alteration mineral assemblage
  - Use core alteration mineralogy (Benoit et al., 2005, GRC)
  - Calcite, albite, microcline; quartz or chalcedony (silica polymorphs); pyrophyllite (sericite analog); and talc and montmorillonite (clay analogs)
- Consider two cases: result in different temperatures (190 and 228ºC)
  - Calcite-quartz equilibrium constraint
  - Calcite-chalcedony equilibrium constraint

Accomplishments, Results and Progress

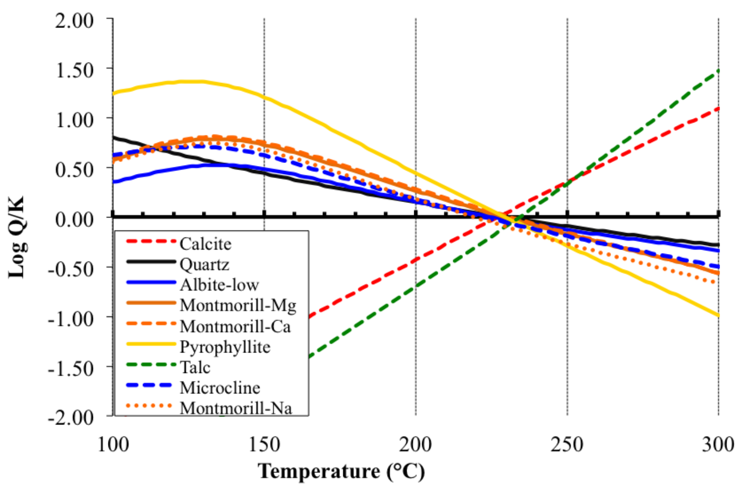
Chalcedony Case

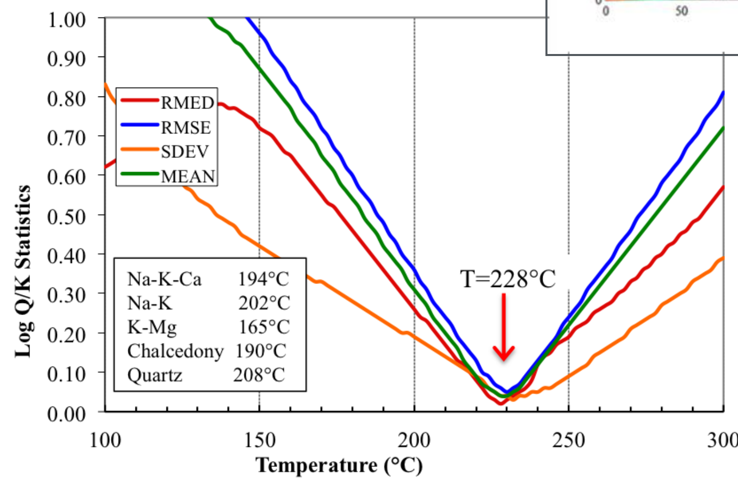






Quartz Case

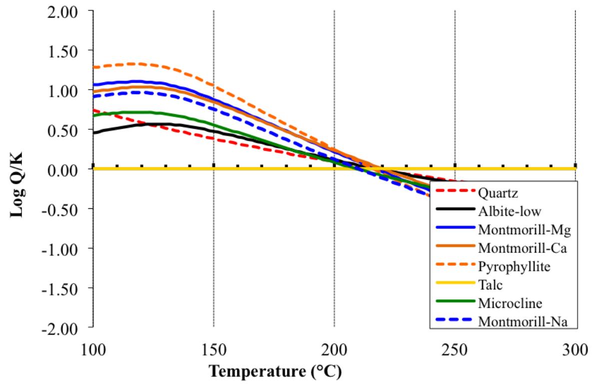


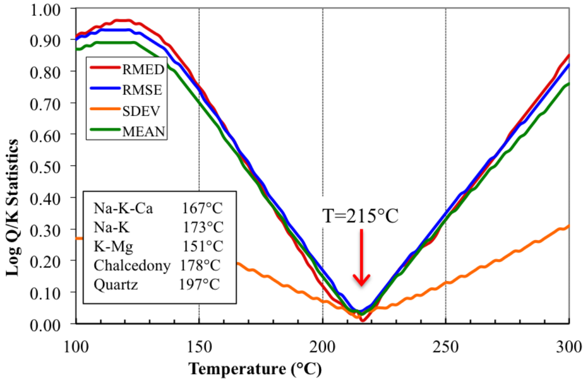


- Quartz case is favored

Integrated Hot Spring Geothermometry

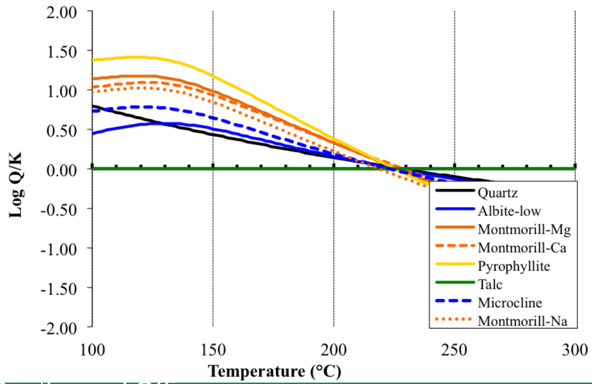
- Apply similar methods, process data from multiple springs simultaneously when possible, also optimize for dilution factor in addition to CO_2, Al and Mg
- Quartz case yields the most consistent results
- Lake City (208-215ºC, using samples from 3 springs)

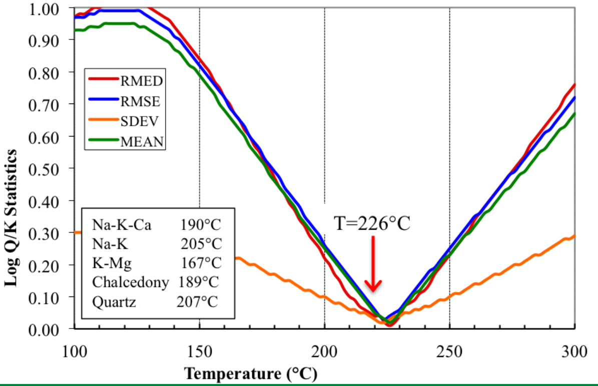




- Dilution factor 1.1–1.2

- Similar results at Fort Bidwell (226ºC)





- Dilution factor 3–4

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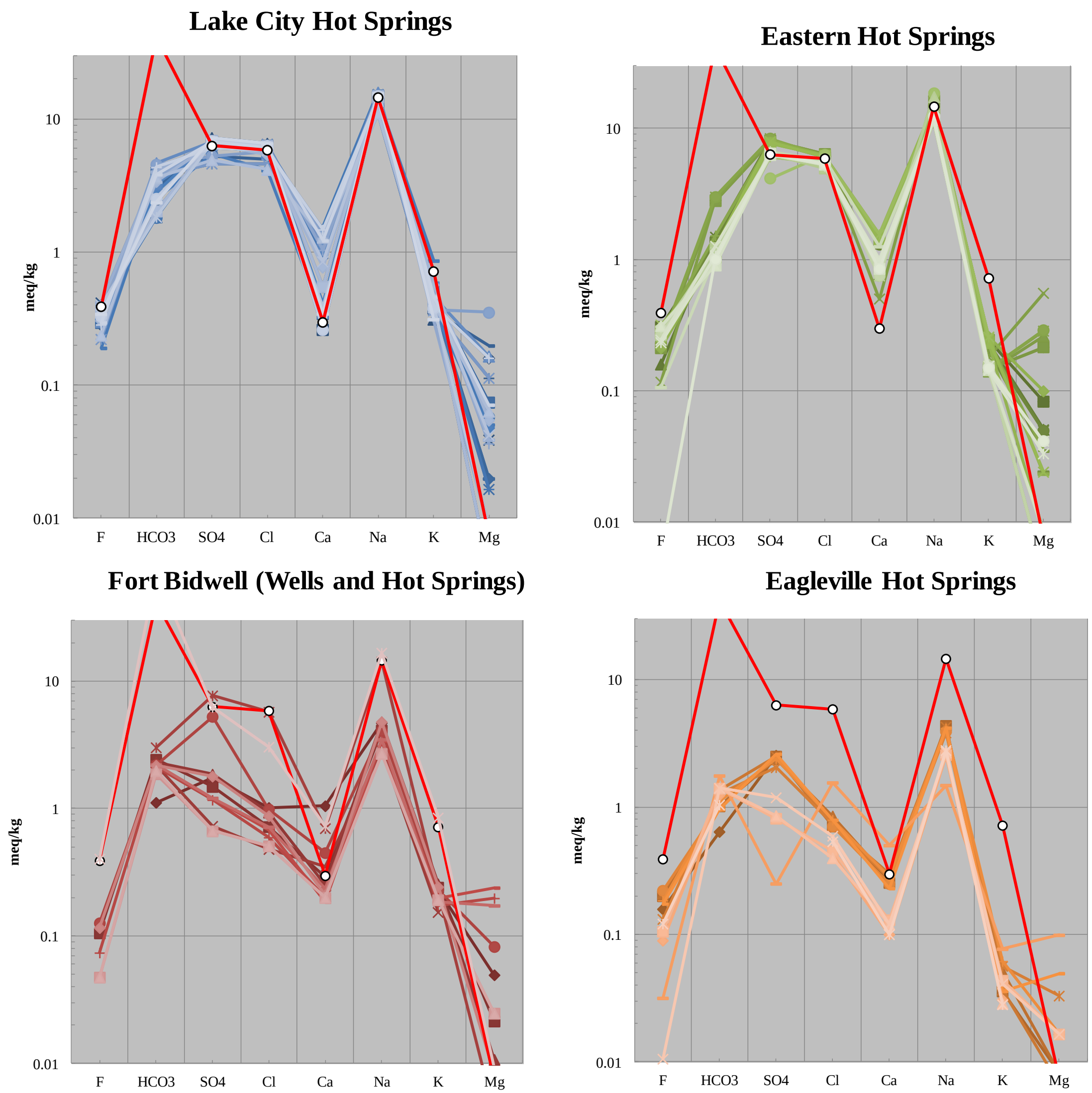
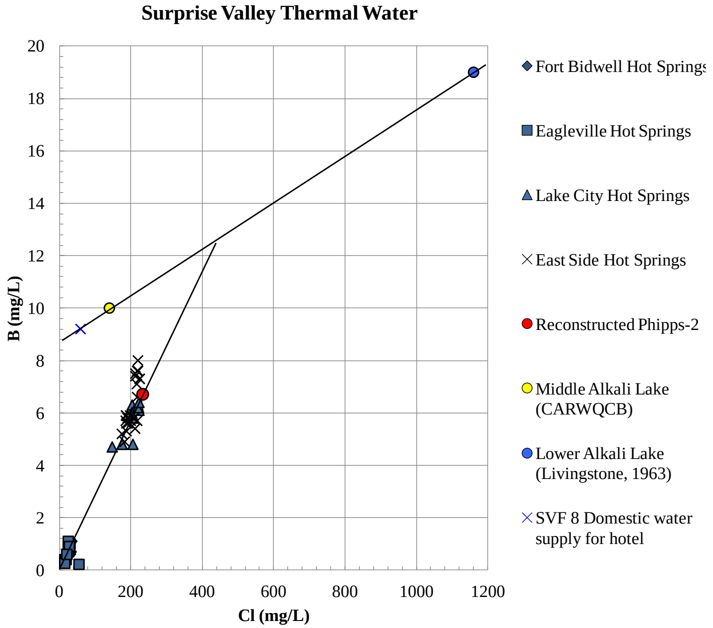
Fingerprinting Thermal Waters

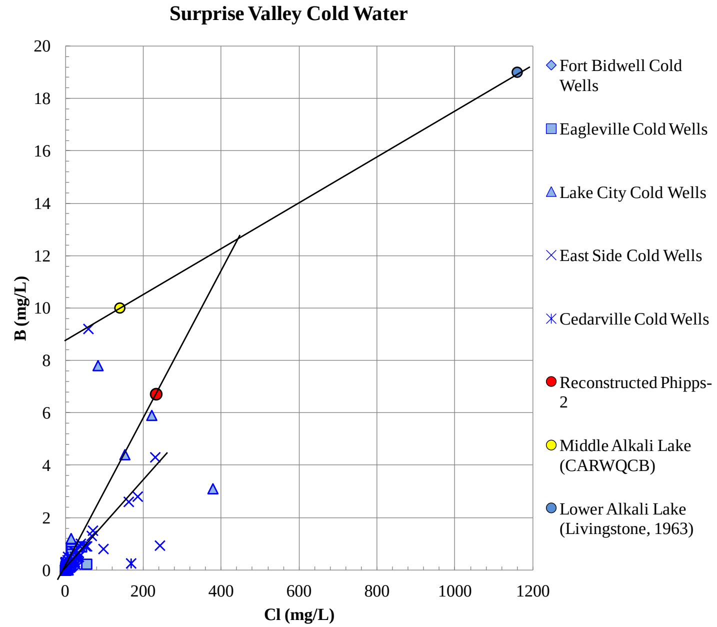


- Remarkably similar compositions across the valley
- Dilution at Ft. Bidwell and Eagleville
- Mg strongly affected by temperature

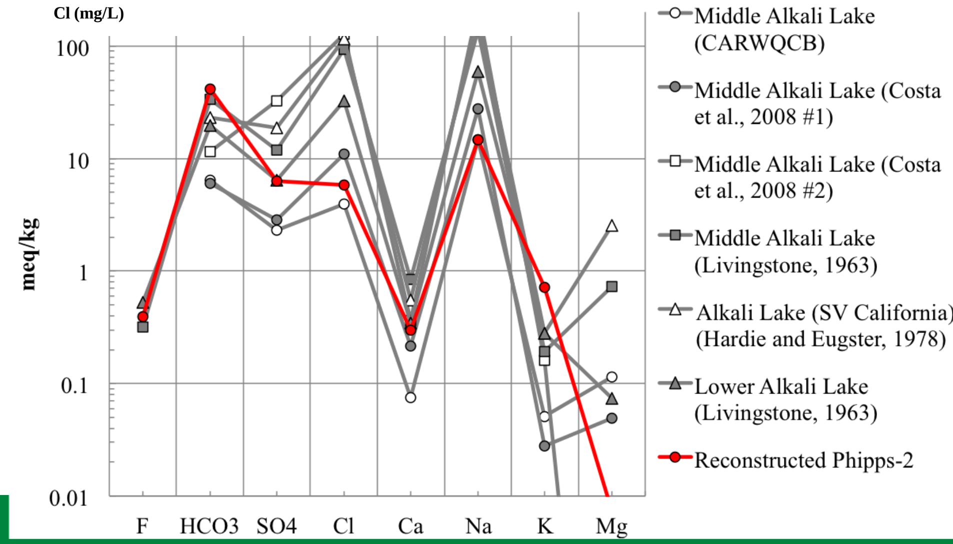
Reconstructed deep thermal component is shown in red

Signatures of Thermal and Alkali Lake Waters in Groundwater



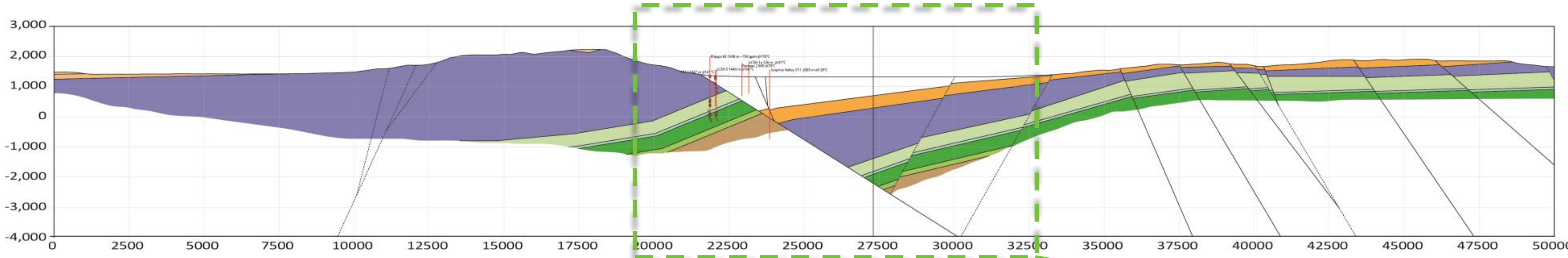


- Distinguishing signatures of deep thermal and alkali lake components not always straightforward

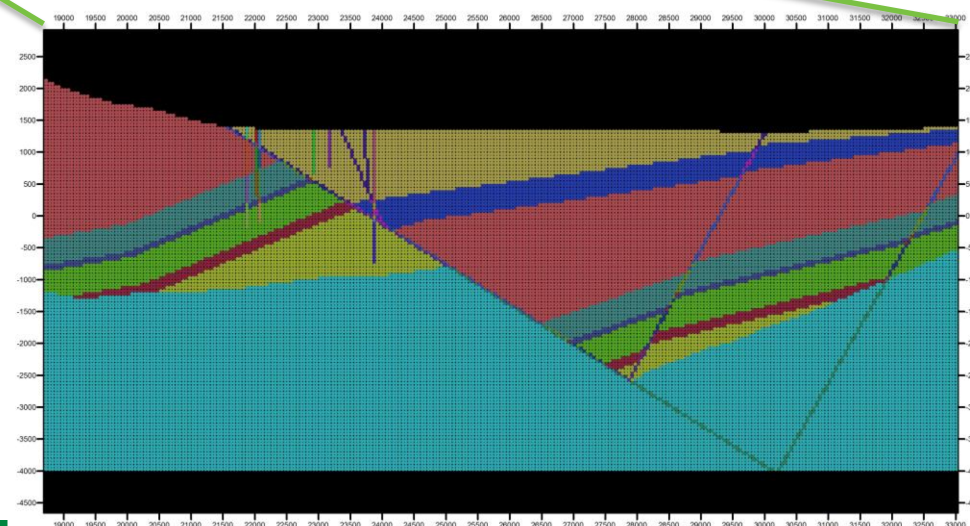


Reactive Transport Modeling

- Develop/test conceptual model(s) of the Lake City area
- Effort started in Q3, along E-W cross section cutting through Lake City area



- Investigate recharge/circulation patterns (mixing/boiling/dilution, upflow, outflow scenarios)
- Use TOUGHREACT V3 (Sonnenthal et al., 2014)
- Eventually extend the modeling to East side of the valley



Future Directions

- Apply similar exploration approach at various other locations within Surprise Valley and/or further North in the Southern Cascades to estimate deep reservoir temperatures in these areas
- Conduct additional water sampling and analyses as needed to fill any identified data gaps
- Integration of our results with the ongoing UC Davis/LBNL Play/Fairway project covering the study area

Milestone or Go/No-Go	Status & Expected Completion Date
Have high-temperature zones been identified to target exploration wells?	Current results suggest elevated temperatures at Lake City and Fort Bidwell, still evaluating other locations. Completion by Sept. 2015
How well does the RT model capture observed water chemistries and help develop the conceptual/exploration model ?	Modeling effort has just started. Completion by Sept. 2015

Mandatory Summary Slide

- A database of Surprise Valley thermal and groundwater chemical compositions was completed and integrated into a GIS database with geological, structural and geophysical data
- The geochemical variability of Surprise Valley thermal waters and cold groundwater was explored
- Optimized multicomponent geothermometry was performed to reconstruct the deep fluid composition and assess deep temperatures
- Deep reservoir temperatures may reach up to 230ºC in the Lake City and Fort Bidwell areas
- Hot spring water compositions exhibit quite similar characteristics across the valley
- Some thermal springs may be impacted by alkali lake waters
- The GeoT code continues to be upgraded; a release of iGEOT is planned for release by Summer 2015
- A reactive transport modeling effort was started to help assess recharge, mixing and deep flow patterns in the study area

Assessing the Alkali Lake Component

- Evaporation simulations using CHILLER/CHIM-XPT (Reed, 2006)
  - Composition varies following evaporative cycles
  - Compositional variations upon evaporation provides bounds for mixing scenarios
  - Observed trends can be reproduced by suppressing calcite (allowing supersaturation on grounds of slow kinetics in this environment)