Use of He isotopes for Geothermal Resource Identification in the Cascades and Snake River Plain

Project Officer: Eric Hass

Total Project Funding: $100K (FY15); $100K (FY14)

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Co-I – Mack Kennedy

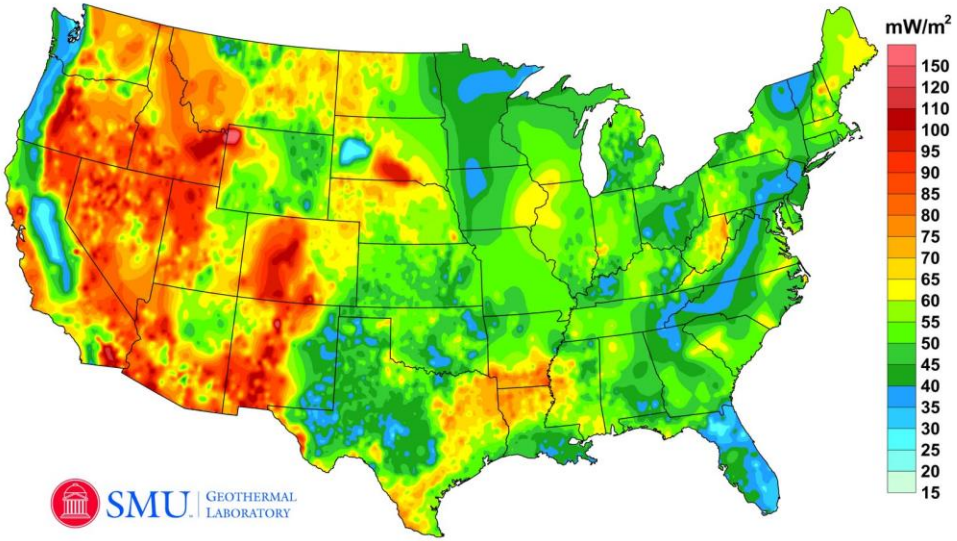
Lawrence Berkeley National Laboratory

HRC Track

Relevance/Impact of Research

Project Objectives

- Extend the use of He isotopes to conduct geothermal exploration in areas in the US (Snake River Plain and Cascades) that have high regional heat flow associated with volcanic activity, but where surface thermal features do not provide a clear indication of the presence (or absence) of potential geothermal reservoirs at depth.

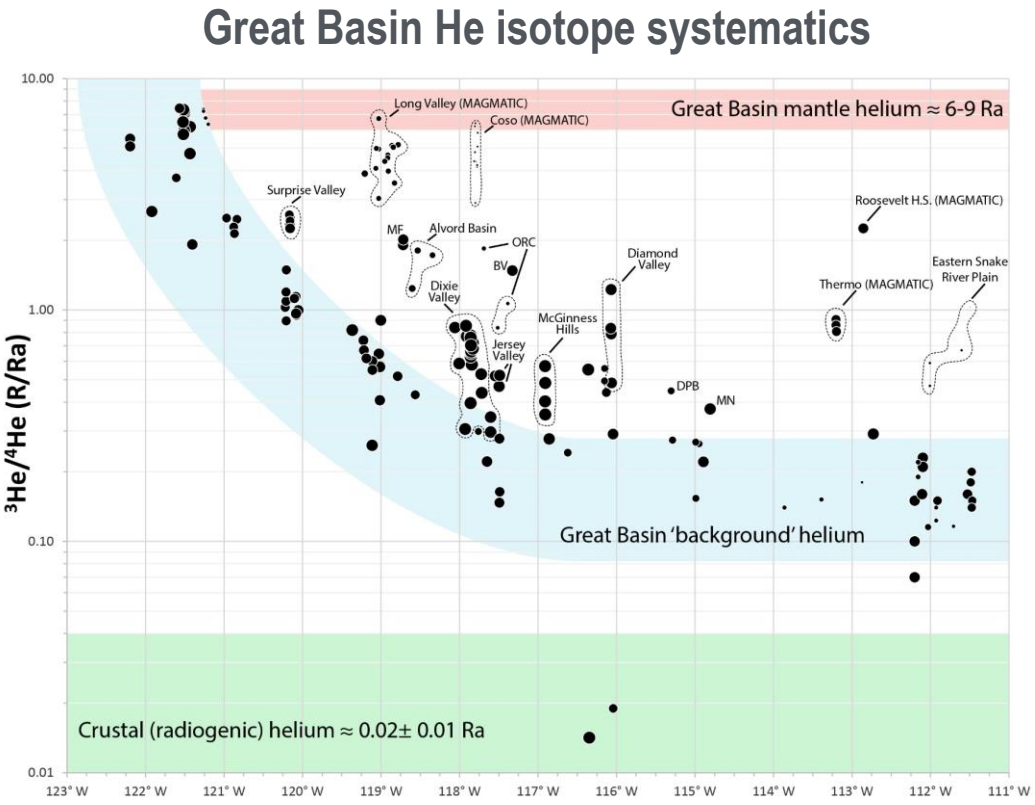


Project Goal

- Demonstrate the utility of He isotopes as a means for identifying hidden geothermal resources at depth

Scientific/Technical Approach

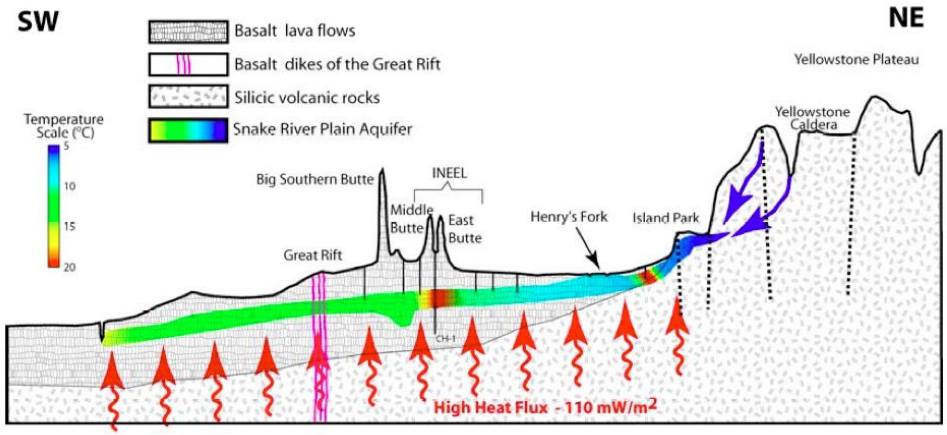
- Three main reservoirs of He: mantle, crust, and atmosphere
  - $^{3}He/^{4}He$ of air is 1.4×10^{-6} (Ra)
  - Mantle (magmatic) He values typically 6-9 Ra (Yellowstone hotspot with values up to 16 Ra)
  - ^{4}He produced by radiogenic decay of Th, U, with crustal He ratios typically ~ 0.02 Ra
- He sampled as a gas phase or as a dissolved gas phase in water



Kennedy and van Soest (2007), as modified by Siler et al. (2014)

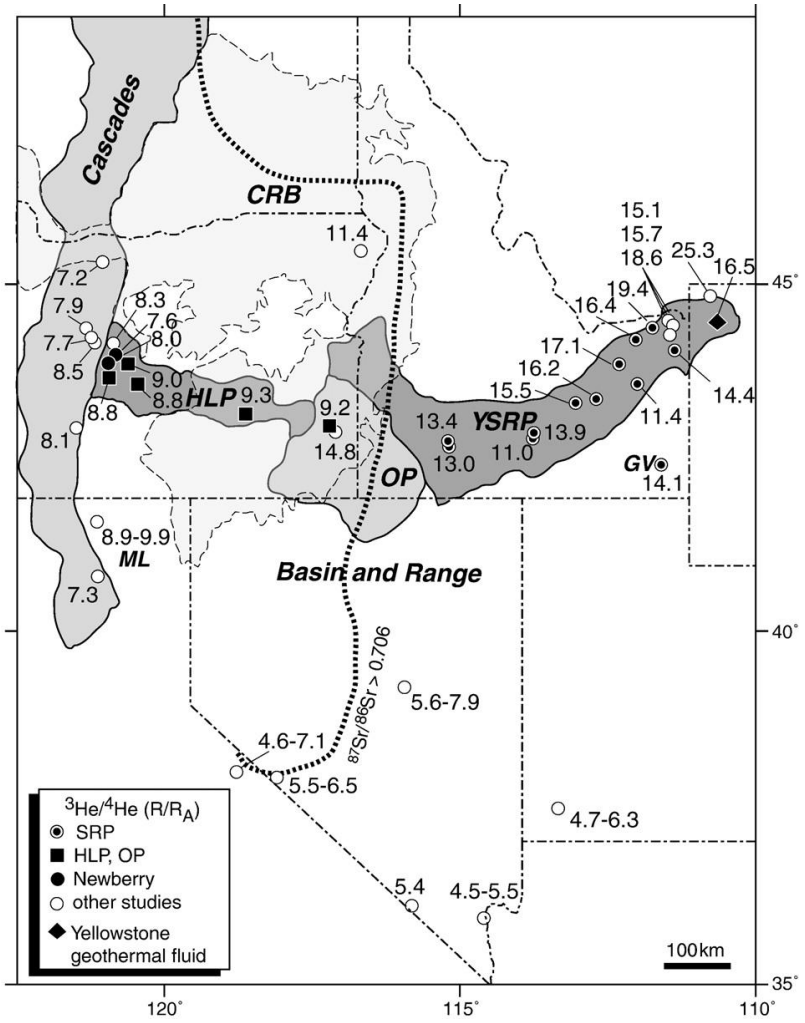
Scientific/Technical Approach

- Extensive volcanism in Snake River Plain associated with mantle plume
- Thick cold water aquifer in E. Snake River Plain obscures underlying thermal activity



Smith, 2004

He isotope values in Quaternary basalts



Graham et al. (2009)

Scientific/Technical Approach

- Compiled existing He data for Cascades and Snake River Plain regions
- Created GIS maps depicting results of existing data and locations of wells and thermal features to identify potential data gaps and areas of interest
- Conducted sampling campaigns **in conjunction with LBNL-INL-U Idaho collaborators** in Snake River Plain
- Analyzed new samples and interpret results in context of location of young volcanism and elevated heat flow
- Identify additional locations for new sampling campaign planned for summer of 2015 (*in progress*)
- Develop integrated interpretation of He isotope data for the Snake River Plain region based on heat flow data, location of young volcanism, and results of multicomponent geothermometry

Collaborations with other DOE-funded geothermal projects

- Geothermometry Mapping of Deep Hydrothermal Reservoirs in Southeastern Idaho (INL-LBNL-Univ. Idaho)
- Geothermal Play Fairway Analysis, Snake River Plain, Idaho (Utah State Univ., Boise State, DOSSEC, USGS, LBNL, Leidos, NREL)

Sampling of 1000 Springs well with INL-LBNL-Univ. Idaho team

Modifications/Changes to Original Research Plan

- Focus on Snake River Plain after initial data review
  - More data gaps identified for Snake River Plain
  - Budget would not permit extensive field surveys in both areas
- Developed collaboration with INL-LBNL-Univ. Idaho project "Geothermometry Mapping of Deep Hydrothermal Reservoirs in Southeastern Idaho"
  - Logistical/budgetary/safety benefits
    - Gained access to thermal features on private land
    - Had field partners required for safety
    - Logistics of field work covered by INL-U. Idaho partners
  - Scientific benefits
    - Obtained wealth of additional geochemical data to provide better context to interpret He isotope data
    - Provided more integrated approach to resource evaluation

Accomplishments, Results and Progress

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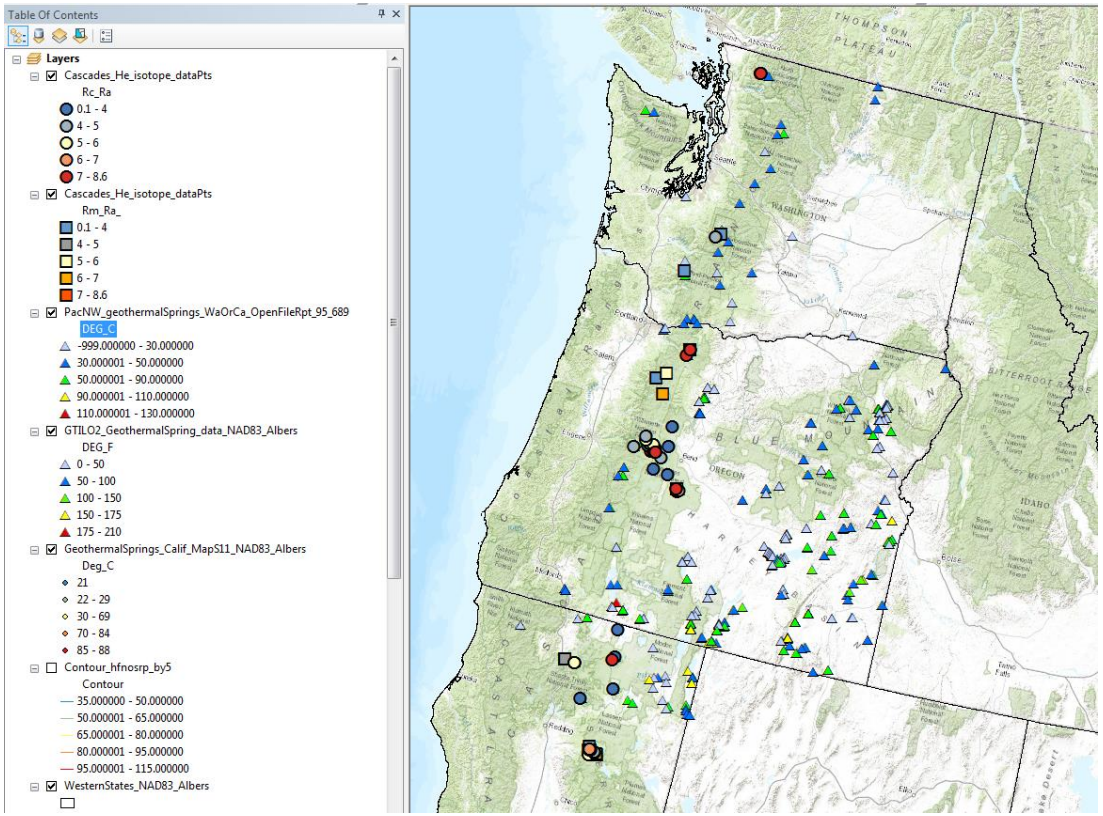
Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Compile He isotope data for Cascades and Snake River Plain	Compilations completed	1/14
Develop initial interpretation of existing He isotope data and identify data gaps	Initial interpretation developed and new sites for sampling identified	4/14
Conduct field sampling of thermal features identified in data gap analysis (SRP only) and analyze samples in lab	Two field campaigns conducted with INL-U. Idaho-LBNL team	4/14 to 8/14
Submit paper to Stanford Geothermal Workshop	Paper submitted and presented	1/15
Integrate He data with results of LBNL-INL-University of Idaho geothermometry study	Obtained RTEst geothermometry results from INL-U. Idaho team and started analysis	4/15

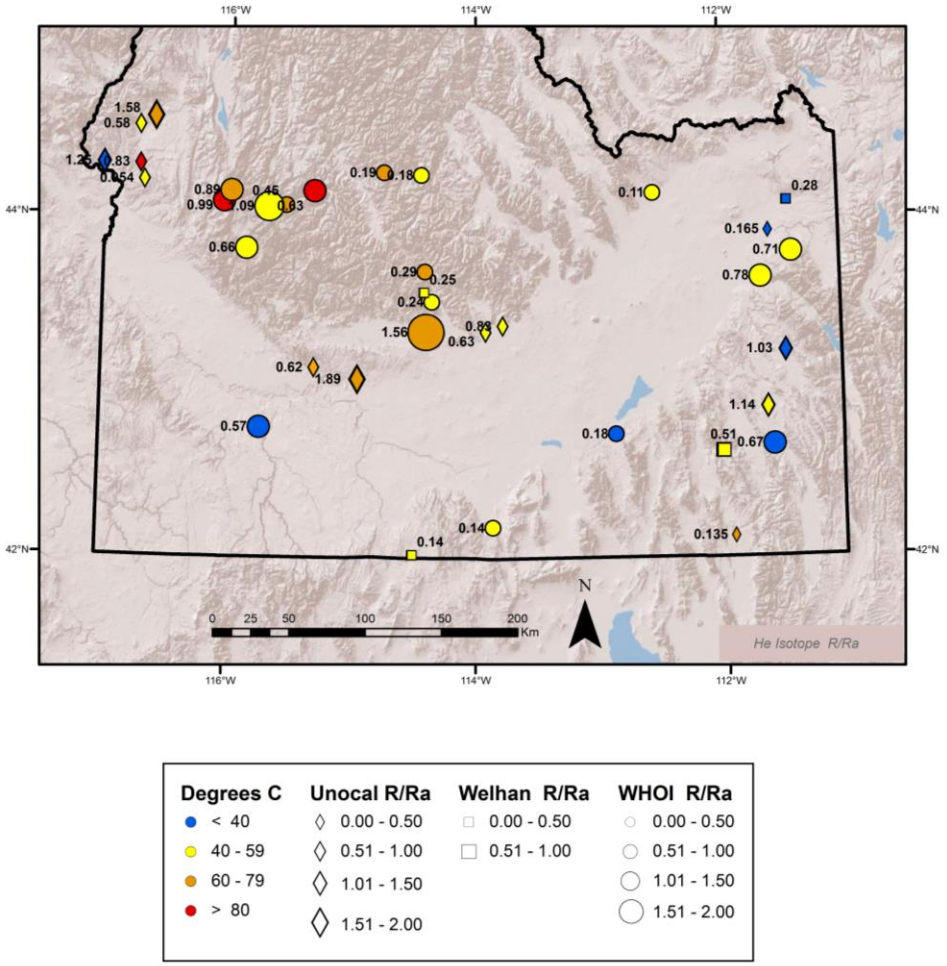
Cascades

- Completed extensive compilation of published and unpublished He isotope data for Cascades region
- Created GIS map of He isotope data and locations of additional thermal features



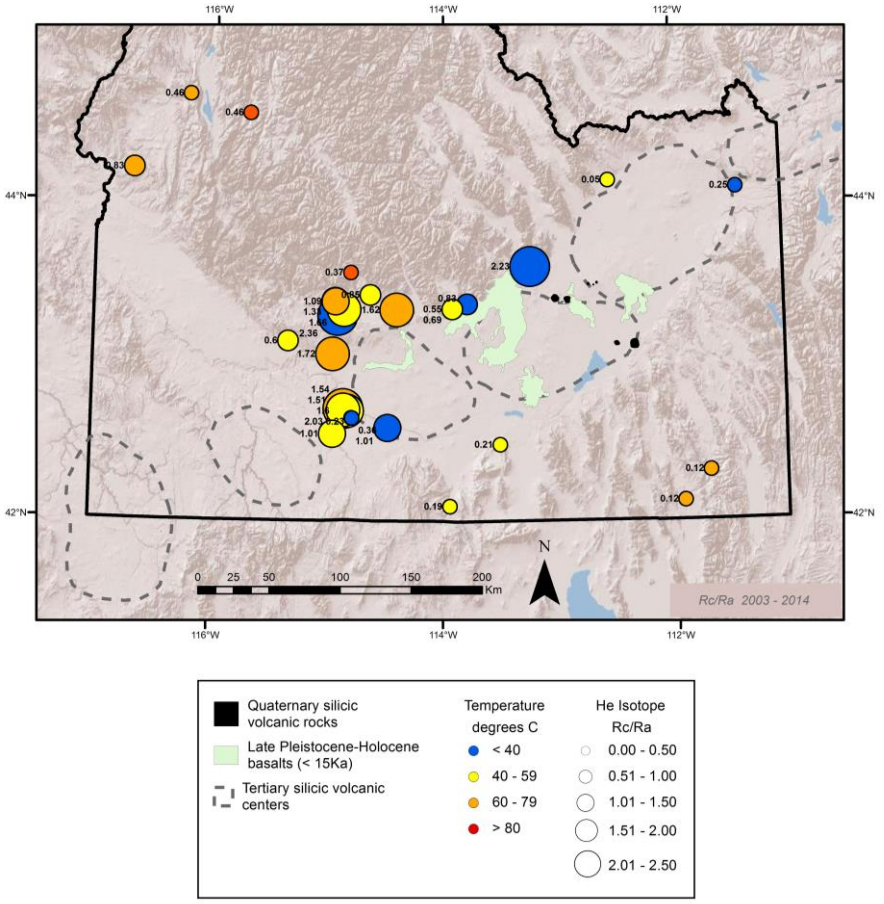
Snake River Plain

- Completed compilation of published (Welhan et al., 1989) and unpublished (Unocal, WHOI) He isotope data for SRP region
- Created GIS map of He isotope data and locations of additional thermal features



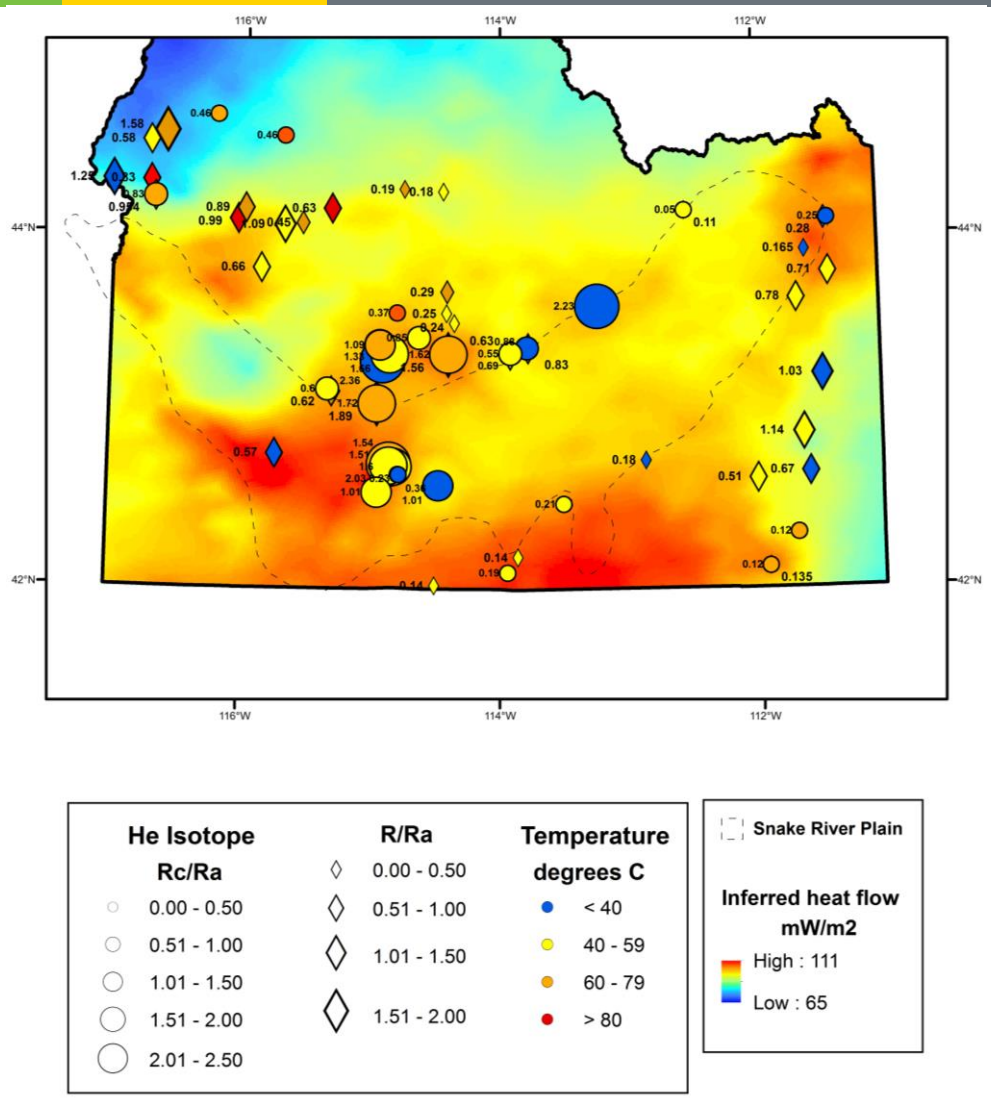
Snake River Plain

- Collect new samples in conjunction with INL-LBNL Snake River Plain geothermometry project
- Compare results to locations of recent volcanism, high heat flow, and estimated elevated subsurface temperatures from multicomponent geothermometry



Snake River Plain

- Highest $^{3}He/^{4}He$ value ever recorded for SRP thermal waters (2.36 Rc/Ra)
- Three areas with (Rc/Ra) values >1.5
  - Camas Prairie
  - Butte City/Arco
  - Miracle/Banbury/1000 springs area
- Higher $^{3}He/^{4}He$ values correlate with areas with elevated heat flow



Heat flow from Williams and DeAngelo (2011)

Comparison of He isotopes with estimated subsurface temperatures

Feature Name	Surface Temp. C	RTEst Temp. C	$^{3}He/^{4}He$ (Rc/Ra)
Butte City/Arco area			
Greenhouse well	36.3	56 ± 1	2.23
Camas Prairie area			
Barron's well	38	119 ± 3	2.36
Magic H.S. Landing well	74.2	116 ± 19	1.62
Wardrop H.S.	66	110 ± 3	1.33
Banbury/Miracle H.S. area			
Miracle H.S. well	58.4	172 ± 19	1.66
1000 Springs well	72	120 ± 0.1	2.03
Banbury H.S.	58.5	159 ± 9	1.60
Banbury H.S. well	58.8	159 ± 10	1.54

Future Directions

- USGS He data set from INL wells to be incorporated into data compilation
- Key areas for 2015 sampling campaign include:
  - Mountain Home area (secured permission from Roy Mink to sample wells in this area) – this is site of a hidden 150˚C geothermal system (Shervais et al., 2013; Nielson and Shervais, 2014)
  - Additional sampling near Butte City/Arco area
- Integrate results of multicomponent and isotope geochemistry geothermometry into interpretation of He isotope results

Milestone or Go/No-Go	Status & Expected Completion Date
Identify key sites for 2015 sampling campaign	In progress – to be completed April 2015
Collect and analyze additional samples	Sampling trip planned for June 2015; laboratory analysis by August 2015
Write and submit journal article summarizing key results of study	Submit manuscript September 2015

Mandatory Summary Slide

- New He isotope data (over 20 analyses) from Snake River Plain thermal springs and wells
- Detected significant mantle He component (7 samples with Rc/Ra > 1.5) in three zones – all are located in areas with higher heat flow, and all but one associated with elevated (110-172˚ C) predicted subsurface temperatures
- Preliminary results were presented at Stanford Geothermal Workshop
- Planned 2015 sampling will focus on confirming these results and test potential to detect presence of hidden geothermal system at Mountain Home