

The Origin of Carbon-bearing Volatiles in Surprise Valley Hot Springs in the Great Basin:
Carbon Isotope and Water Chemistry Characterizations

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There are numerous hydrothermal fields within the Great Basin of North America, some of which have been exploited for geothermal resources. With methane and other carbon-bearing compounds being observed, in some cases with high concentrations, however, their origins and formation conditions remain unknown. Thus, studying hydrothermal springs in this area provides us an opportunity to expand our knowledge of subsurface (bio)chemical processes that generate organic compounds in hydrothermal systems, and aid in future development and exploration of potential energy resources as well. While isotope measurement has long been used for recognition of their origins, there are several secondary processes that may generate variations in isotopic compositions: oxidation, re-equilibration of methane and other alkanes with CO₂, mixing with compounds of other sources, etc. Therefore, in addition to isotopic analysis, other evidence, including water chemistry and rock compositions, are necessary to identify volatile compounds of different sources.

Surprise Valley Hot Springs (SVHS, 41°32'N, 120°5'W), located in a typical basin and range province valley in northeastern California, is a terrestrial hydrothermal spring system of the Great Basin. Previous geophysical studies indicated the presence of clay-rich volcanic and sedimentary rocks of Tertiary age beneath the lava flows in late Tertiary and Quaternary. Water and gas samples were collected for a variety of chemical and isotope composition analyses, including *in-situ* pH, alkalinity, conductivity, oxidation reduction potential (ORP), major and trace elements, and C and H isotope measurements. Fluids issuing from SVHS can be classified as Na-(Cl)-SO₄ type, with the major cation and anion being Na⁺ and SO₄²⁻, respectively. Thermodynamic calculation using ORP and major element data indicated that sulfate is the most dominant sulfur species, which is consistent with anion analysis results. Aquifer temperatures at depth estimated by both dissolved SiO₂ and Na-K-Ca geothermometers are in the range of 125.0 to 135.4 °C, and higher than the values measured at orifices (77.3 to 90.0 °C).

CO₂ and homologs of straight chain alkanes (C₁-C₅) were identified in gas samples. Carbon isotope values of alkanes increase with carbon numbers. The ¹³C fractionation between CO₂ and dissolved inorganic carbon suggests they are out of carbon isotope equilibrium. The hypothesis regarding the formation of carbon-bearing compounds in SVHS may involve two processes: 1) Under high heat flow conditions which are caused by regional faulting and crustal extension, original high molecular weight organic compounds (kerogens) in clay-rich rocks decomposed to generate methane and other alkane homologs. 2) The SVHS area is associated with outflow structures, and distant from the heat source. Anaerobic oxidation of methane

(AOM) with sulfate at shallow depth (< 90 °C) is suggested as being responsible for the generation of CO_2 in SVHS.