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U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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Physical, chemical, and isotopic data for samples from the Anderson Springs area, Lake County, California, 1998–1999

By

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INTRODUCTION

The Anderson Springs area is located about 90 miles (145 kilometers) north of San Francisco, California, in the southwestern part of Lake County, Township 11 North, Range 8 West, Sections 25, 26, 35, and 36 (Figure 1). The area was first developed in the late 1800s as a health resort, which was active until the 1930s. Patrons drank a variety of cool to hot mineral waters from improved springs, swam in various baths and pools, and hiked in the rugged hills flanking Anderson Creek (Anderson, 1892; Waring 1915). In the bluffs to the south of the resort were four small mercury mines of the eastern Mayacmas quicksilver district: the Anderson (also called Schwartz after its longest tunnel), Big Chief, Big Injun, and Thorne mines. About 1,260 flasks of mercury were produced from these mines between 1909 and 1943 (Yates and Hilpert, 1946, p. 283-285). By the early 1970s, the higher ridges south and west of Anderson Springs became part of the southeast sector of the greater Geysers geothermal field. Today, several electric power plants are built on these ridges, producing energy from a vapor-dominated 240 °C reservoir.

Because of the resort, mining, and geothermal activities in the area, waters from Anderson Springs have been sampled and analyzed by many investigators during the past 110 years. The first known report was by W. Anderson (1892), who included analyses of waters from the health resort as a reference for medical practitioners. Waring (1915), in his summary of springs in California, provided temperatures and descriptions of nine of the Anderson Springs and chemical analyses of five, including the principal spring which he identifies as the Hot Spring. Only this main hot spring has maintained a recognizable identity since the 1930s. It is actually in a cluster of seeps and springs that issue (≤ 6 L/min cumulative flow) from a small fault that cuts Franciscan metagraywacke in a ravine southwest of Anderson Creek (Figure 1, site 1). Numerous investigators have reported chemical and isotopic data on the main hot spring water. They include, but are not limited to: Berkstresser (1968), Goff and others (1977), Thompson and others (1981; 1992), Goff and others (1993a; 1993b), Donnelly-Nolan and others (1993). Chemical and isotopic analyses of a gas sample collected from this spring in 1991 are reported by Goff and Janik (1993) and by Goff and others (1993a; 1993b). A partial gas analysis as well as carbon isotope data on carbon dioxide and methane issuing from the main spring in 1995 are included in a paper by Bergfeld and others (in press). Regarding other features in the area, Yates and Hilpert (1946) reported that waters of the Anderson, Big Chief, and Big Injun mines are warm and smell strongly of H_2S. White (1967) reported that these mines discharge gases and warm to hot thermal waters (a few liters per minute from each), and provided an analysis of water from the Big Injun mine. Barnes and others (1973) published a chemical analysis of water (41.5 °C) from a mine adit located in the southwest quarter of Section 26, near Anderson Springs.

CURRENT INVESTIGATIONS

Drainage from the lower adit of the Schwartz (Anderson) mine (Figure 1, site 5) enters a tributary of Anderson Creek, and rock surfaces in the tributary bed are coated with iron and aluminum oxyhydroxides. In July 1998, this drainage increased substantially over a 2-day period, resulting in the transport of a slurry of mine water and precipitates down the tributary and into Anderson Creek. Base metal and methylmercury concentrations in filtered and

unfiltered samples of the mine water were reported by Rytuba and Enderlin (1999). They also reported metal data on samples collected during the same period from the main hot spring of Anderson Springs, and recorded a temperature of 85 °C for that site.

Published records show that the maximum temperature (T_m) of the Anderson Springs cluster was 63 °C in 1889, and 42 to 52 °C from 1974 through 1991. A temperature of 77 °C was recorded for the main hot spring in 1995 (Goff and Janik, 1999). To investigate the reports of further increases in thermal activity and release of mine drainage, Janik and Goff returned to the area for additional geochemical sampling in September and December 1998. They determined that T_m of the main hot spring was 68.0 °C, but T_m of the hot spring cluster had increased dramatically to 98 °C. They also observed that a new area of boiling vents and small fumaroles (T_m = 99.3°C) had formed about 20 meters to the north of the original cluster (Figure 1, site 2). Goff and Janik returned in August 1999 to monitor any changes in these thermal manifestations and to conduct additional fluid sampling in the area. They noted that the new fumarolic area had increased in intensity, and observed that a zone of dead trees had developed on the steep bank directly west of the fumaroles.

On September 16, 1999, Janik, Sorey, and Colvard visited Anderson Springs to prepare a location map of the thermal features, make additional temperature measurements, and measure CO_2 flow through soils surrounding the springs and in the zone of tree-kill. Diffuse flow of CO_2 through the soil to the atmosphere was measured using equipment and methods described in Sorey and others (1999). The equipment includes an accumulation chamber, a gas pumping system, and an infrared gas analyzer in combination with a Global Positioning System (GPS) receiver for locating the measurement site. GPS locations were based upon continuous-mode reception from 5 satellites; horizontal errors are 6–10 meters. Coordinates obtained for the Anderson main hot spring (Figures 2 and 3) are (in NAD27 datum): Longitude 122°42'22.50" (122.70625°) and Latitude 38°46'20.47" (38.77235°). CO_2 flow rates are expressed in terms of mass flow (in grams per day) per unit area (in meters squared), $gd^{-1}m^{-2}$. Ground temperature measurements were made using a microprocessor-based handheld thermometer and a thermocouple probe at a depth of 5 cm near each CO_2 flow-measurement site (Figure. 2). Within the area where ground temperatures varied from 33 °C to 55 °C, CO_2 flow rates of 2–143 $gd^{-1}m^{-2}$ were measured (Figure 3). Two separate measurements of gas flow were also made inside an excavated area (Figures 2 and 3) that had relatively low ground temperature (28 °C). In each case, the concentration increased up to about 800 ppm and then stayed constant. The apparent gas flow rate computed from the buildup period was approximately 400 $gd^{-1}m^{-2}$. Hot spring temperatures had changed somewhat from the previous year. The main hot spring remained at 68 °C, but T_m of the original cluster had decreased to 85 °C, and T_m of the new hot spring had increased slightly to 99.5 °C (Figures 2 and 3).

On October 5, 1999, Janik, Rytuba, and Foster visited the area to conduct additional sampling of the Schwartz (Anderson) mine drainage and the new hot spring at Anderson Springs. Rytuba and Janik established consistent names for various sites at that time.

The purpose of this report is to provide physical, chemical, and isotopic data on samples collected in the vicinity of Anderson Springs in 1998 and 1999, in response to a Freedom of Information Act request. This report also corrects confusion that may have resulted from inconsistent site descriptions or errors in geographic locations reported in Rytuba and Enderlin (1999) and Goff and Janik (1999).

SAMPLING AND ANALYTICAL METHODS

Complete Chemical Analyses

Analytical methods currently used in the Earth and Environmental Sciences Division laboratory (EES-1, Geology/Geochemistry) of the Los Alamos National Laboratory (LANL), Los Alamos, New Mexico, are outlined in Table 1. A general description of methods and apparatus used by this laboratory for chemical analysis of geothermal fluids is given in Trujillo and others (1987), which includes appendices with step-by-step descriptions of the procedures used at the time the report was written. During the past 12 years, better instrumentation and development of improved methods have resulted in lower limits of detection than were reported in that reference for many of the constituents analyzed.

Results of chemical analyses on waters from the Anderson Springs area are given in Table 2. The EES-1 laboratory reports chemical concentrations in weight-per-weight units (ppm = mg/kg), whereas the analytical procedures generally involve measurements in terms of weights per unit volume of water (mg/L). The conversion to ppm assumes that a liter of the filtered water sample weighs exactly 1 kilogram. The error introduced is not significant compared to other anticipated analytical errors until the concentration of dissolved constituents exceeds about 7,000 mg/L (Hem, 1985, p. 55). A correction for solution density is recommended when computing ppm from mg/L for waters containing higher concentrations of dissolved constituents.

Trace Elements, Mercury, and Methylmercury

Sampling for analysis of trace elements in waters followed clean-hands protocol in order to avoid introduction of contaminants. Samples were collected in pre-cleaned, acid-washed (nitric acid) polyethylene bottles. Both unfiltered and filtered samples (0.45µm filter) were acidified with Ultrex nitric acid. Samples were analyzed by CHEMEX using Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

Sampling for mercury analysis followed ultra-clean sampling and handling protocols (Bloom, 1995; Gill and Fitzgerald, 1987) during the collection of field samples and analysis of samples in order to avoid introduction of mercury. Borosilicate I-CHEM™ glass with teflon-lined caps were used for water sampling. Water samples were field-preserved in a cooler at 1–4 °C until maintained under laboratory established conditions to preserve mercury retention and speciation. Transportation to the laboratory was under conditions specified to maintain mercury retention within the sample. All handling of samples in the laboratory was undertaken in a mercury-free, clean-air bench.

Analytical procedures for mercury were carried out at Frontier Geosciences. Ultra-clean mercury trace metal protocol was used including the use of rigorously cleaned and tested teflon equipment and sample bottles as well as prescreened and laboratory-purified reagents. A class-100 clean air station was used and monitored routinely for low levels of total gaseous mercury. Laboratory atmosphere and water supply were also routinely monitored for low levels of mercury. Primary standards used in the laboratory were NIST-certified or traceable to NIST-certified materials (NIST = National Institute of Standards & Technology; formerly the National Bureau of Standards, NBS). Monomethyl mercury standards were made from pure powder and calibrated for monomethyl mercury (MMHg) against NBS-3133 and cross verified by daily analysis of NRCC DORM-2. EPA Method

1631 was used. Total mercury was determined by BrCl oxidation, $SnCl_2$ reduction, and dual gold amalgamation. All mercury analysis was performed using cold vapor atomic fluorescence (CVAFS) (Bloom and others, 1988). MMHg was liberated from water through distillation using an all-teflon distillation system (Horvat and others, 1993). Distilled samples were analyzed using aqueous-phase ethylation purging onto Carbotrap, isothermal GC separation, and CVAFS (Bloom, 1989). To address accuracy and precision, all laboratory analyses followed quality assurance measures with the following minimum frequency: the collection of laboratory duplicates (one per ten samples), method blanks (three per analytical batch), filtration blank (one per ten samples), and laboratory spike recovery (one per ten samples) or standard reference material (one per ten samples).

Results of trace-element and methylmercury analyses on samples from the Anderson Springs area are listed in Table 3.

Sediment Samples

Particulate matter collected on a 0.45 µm filter membrane during filtering of about 400 mL of the water from the new hot spring at Anderson Springs was saved for chemical analysis of metals. The filter with residue was placed in a new polyethylene sample bag. A sample of the sediment (muck) from the bed of the new spring was collected by scooping up a representative mixture and placing it in a new polyethylene sample bag.

An aliquot of the muck sample was fused with $NaKCO_3$ flux, ~0.25 g sample to 2 g flux, to obtain the Br, Cl, F, and sulfur (S) values. To analyze concentrations of Au, As, Cu, Fe, Hg, Pb, Se, Sb, Tl, and Zn in the muck and filter residue, the samples were first placed in teflon vessels and microwave digested in a $HCl/HNO_3/HF$ solution. To evaluate the metal data quality, Reference Material NBS 2704 from the NIST was analyzed by D. Counce at EES-1 LANL using the same methods employed for the Anderson Springs sediment samples. Results are given in Table 4.

Gas Samples

Procedures for sampling gases from geothermal manifestations are reported in Trujillo and others (1987) and Fahlquist and Janik (1992). Gases collected from the new feature at Anderson Springs (Table 5) were analyzed by D. Counce at EES-1 LANL using methods and equipment described in Trujillo and others (1987).

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DESCRIPTION OF TABLES

Table 1. Methods of Chemical Analysis and Detection Limits, EES-1 LANL.

Constituent: The chemical symbols/formulas for the species analyzed.

Method: The method/instrumentation used to analyze the constituent listed in the adjacent row of the first column. Where more than one method of analysis is available for a particular constituent, the chemical symbol/formula is not repeated in the first column. The following acronyms are used:

    AA = Atomic Adsorption Spectroscopy

    GFAA = Graphite Furnace AA

    IC = Ion Chromatography

    ICP-AES = Inductively Coupled Plasma - Atomic Emission Spectroscopy

Det. Limit: The detection limit for the method listed in adjacent row of the second column. The values are reported in parts per million (= milligrams per kilogram).

Table 2. Chemical and Isotopic Analyses of Waters.

Sample #: Denotes an individual visit to a particular site. "CL" represents samples collected in the vicinity of Clear Lake as part of a regional investigation of The Geysers-Clear Lake area. "And" represents samples collected specifically for an investigation of the Anderson Springs area. The number following the initial letters represents the year in which the sample was collected (19XX). The final number denotes the order in which the samples were collected during that year.

Map #: The number assigned to the sampling location shown in Figure 1.

Description: The formal or informal name of the feature sampled, or a brief explanation of the location relative to a named feature.

Date: The date of sampling in month/day/year notation.

Temp.: The temperature (in degrees Celsius) measured at the time of sampling using a microprocessor-based handheld thermometer and a thermocouple probe. The accuracy at 23 °C is ±0.1% of reading ±0.2 °C. For hot spring waters, the maximum measured temperature is recorded.

pH (F): The pH of water as measured at the sampling site using non-bleeding, three-color pH indicator strips. Reproducibility is ±0.2 units.

pH (L): The pH of water as measured by D. Counce at EES-1, LANL.

Cond. (L): The specific electrical conductance of the water (in micromhos) as measured by D. Counce at EES-1, LANL.

CO_3, HCO_3, Ag, and other chemical constituents listed in alphabetical order: Concentrations reported in parts per million as determined at EES-1, LANL by D. Counce using methods listed in Table 1. The electric charge of positive and negative ions is not shown. Boron is reported as elemental B, without attempting to define the species present in solution. Dissolved silica (SiO_2) concentration is calculated by multiplying the Si value by the formula-weight fraction of SiO_2/Si.

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Std.D.: Where determined, the standard deviation from the mean value is listed immediately following the species analyzed. This root-mean square deviation (± 1 sigma) is given in parts per million.

TDS: "Total dissolved solids", which is the sum of all constituents (concentrations in parts per million) analyzed in the filtered aliquot.

Cation Sum: The sum of the positively charged ions in milligram-equivalents (meq) per kilogram (or liter) of sample. Concentrations in ppm are converted to meq by dividing by the formula weight (in mg) of the constituent and multiplying by the ionic charge.

Anion Sum: The sum of the negatively charged ions in meq per kilogram (or liter) of sample.

Balance: If all ion concentrations have been correctly determined, the total meq of cations is equal to the total meq of anions in solution. As a measure of analytical quality, an ion balance (Bal) is calculated: $Bal = 2(\Sigma\ Cations - \Sigma\ Anions)/(\Sigma\ Cations + \Sigma\ Anions)$. The error is generally expected to be ≤ 0.05.

$\delta D, \delta^{18}O$: The hydrogen and oxygen isotope composition of water in units of parts per thousand (permil, ‰) relative to Vienna Standard Mean Ocean Water (VSMOW), where:

$$\delta_{sample} = (\ (R_{sample} - R_{VSMOW})/R_{VSMOW}\ )\ x\ 10^3$$

and $R = (^2H/^1H)$ or $(^{18}O/^{16}O)$. ^2H is called deuterium (D). Samples were prepared for hydrogen isotope analysis by M. Huebner in the USGS laboratory of C. Janik. Mass-spectrometric measurements were performed by L. D. White in the USGS laboratory of C. Kendall in Menlo Park, CA. Analytical precision is 1 ‰ for δD and 0.2 ‰ for $\delta^{18}O$.

^3H: The tritium concentration in water expressed in Tritium Units (TU), where 1 TU indicates a $^3H/^1H$ ratio of 10^{-18}. The values refer to the new tritium scale of U.S. NIST (formerly NBS), based on their tritium water standard #4926 and age–corrected with the new half-life of 12.43 years. In this scale, 1 TU = 3.193 pCi/kg H_2O. TU values were calculated for the date of sample collection. Measurements were conducted in the University of Miami, Rosenstiel School of Marine and Atmospheric Science, Tritium Laboratory, Miami, FL.

Table 3. Trace Element Analyses of Waters.

Sample #: Denotes an individual sample from a particular site. The first number represents the year in which the sample was collected (19XX). The letters following the initial number represent the name given to the location at which the sample was collected: SM = Schwartz (Anderson) Mine adit, HS = the main hot spring at Anderson Springs, NAS = the new hot spring at Anderson Springs. 1W = an individual water sample. UF indicates that the sample was unfiltered. F indicates that the water was filtered through a membrane having a 0.45 micron pore diameter.

Map #: The number assigned to the sampling location shown in Figure 1.

Date: The date of sampling in month/day/year notation.

Al, As, Ba, and other trace constituents listed in alphabetical order: Total concentrations of trace elements and methylmercury in solution, reported in milli- (10^{-3}), micro- (10^{-6}), or nano- (10^{-9}) grams per liter of sample, as indicated: mg/L, µg/L, or ng/L, respectively.

Table 4. Chemical Analyses of Sediment Samples.

Sample #: Denotes an individual visit to a particular site. "CL" represents samples collected in the vicinity of Clear Lake as part of a regional investigation of The Geysers-Clear Lake area. The number following the initial letters represents the year in which the sample was collected (19XX). The final number denotes the order in which the site was sampled that year. During the site visit CL98-2, multiple samples were collected, including water samples for chemical and isotopic analyses (Table 2). To avoid confusion, the mineral sample designator includes an identification term.

Map #: The number assigned to the sampling location shown in Figure 1.

Description: Further explanation of the type of sample collected at CL98-2. For NBS 2704, the name of the standard is given. "Target Values" denotes the known chemical composition of the standard as provided by NIST.

Date: The date of sampling in month/day/year notation. The date given for NBS 2704 indicates the month during which the sediment analyses were conducted.

Au, As, Br, and other constituents: Concentrations of metals and other constituents reported in parts per million as determined at EES-1 LANL by D. Counce using methods listed in Table 1. Total Fe_2O_3 is calculated from the Fe analyses, and reported in weight percent of the sample.

Table 5. Chemical Composition of Gases.

Sample #: Denotes an individual visit to a particular site. "And" represents samples collected specifically for an investigation of the Anderson Springs area. The number following the initial letters represents the year in which the sample was collected (19XX). The final number and letter denote the order in which the samples were collected during that year.

Map #: The number assigned to the sampling location shown in Figure 1.

Description: The informal name of the feature sampled.

Date: The date of sampling in month/day/year notation.

Temp.: The maximum temperature (in degrees Celsius) measured at the time of sampling using a microprocessor-based handheld thermometer and a thermocouple probe. The accuracy at 23 °C is ±0.1% of reading ±0.2 °C.

Moles of Steam Collected: The amount (in number of moles) of condensed water vapor (H_2O) collected in the bulk sample.

Total Moles of DRY Gas: The total moles of non-condensable gases ($CO_2+H_2S+H_2+…+Hg$) in the bulk sample; i.e. without H_2O.

Total Moles of WET Gas: The total number of moles of condensed steam plus non-condensable gases in the bulk sample.

CO_2, H_2S, H_2, and other non-condensable gases: Concentrations in mole percent (= volume %) of the non-condensable portion of the sampled fluid (without H_2O).

Table 1. Methods of Chemical Analysis and Detection Limits for Constituents in Water and Sediment Samples Analyzed by the EES-1 Laboratory, LANL.

Constituent	Method	Det. Limit (ppm)
Ag	GFAA	0.0005
	ICP-AES	0.002
Al	GFAA	0.002
	ICP-AES	0.01
As	Hydride-AA	0.0002
	GFAA	0.002
	ICP-AES	0.05
Au	GFAA	0.002
	ICP-AES	0.02
B	ICP-AES	0.002
Ba	ICP-AES	0.002
Be	ICP-AES	0.002
Br	IC	0.005
Ca	ICP-AES	0.002
Cd	GFAA	0.0002
	ICP-AES	0.005
Cl	IC	0.01
CN	Electrode	0.02
	IC	0.01
Co	GFAA	0.002
	ICP-AES	0.01
$CO_3/HCO_3/OH$	Titration	0.5
Conductivity	Electrode	0.5
Cr	GFAA	0.002
	ICP-AES	0.01
Cs	GFAA	0.002
	AA	0.02
Cu	GFAA	0.002
	ICP-AES	0.01
F	IC	0.01
	Electrode	0.01
Fe	ICP-AES	0.01
Hg	Cold Vapor AA	0.00002
I	IC	0.01
K	AA	0.01
	ICP-AES	0.2
Li	ICP-AES	0.005
Mg	ICP-AES	0.002
Mn	ICP-AES	0.002

Table 1, continued.

Constituent	Method	Det. Limit (ppm)
Mo	GFAA	0.002
	ICP-AES	0.02
Na	AA	0.01
	ICP-AES	0.05
NH_4	Electrode	0.02
Ni	GFAA	0.002
	ICP-AES	0.01
NO_2	IC	0.01
NO_3	IC	0.01
Pb	GFAA	0.002
	ICP-AES	0.05
Pd	GFAA	0.005
	ICP-AES	0.02
pH	Electrode	0.01
PO_4	IC	0.02
Rb	GFAA	0.002
	AA	0.01
Sb	Hydride AA	0.0002
	GFAA	0.002
	ICP-AES	0.05
Se	Hydride AA	0.0002
	GFAA	0.002
	ICP-AES	0.1
Si	ICP-AES	0.02
S	Electrode	0.02
	IC	0.01
SO_3	IC	0.01
SO_4	IC	0.02
S_2O_3	IC	0.01
Sr	ICP-AES	0.005
Ti	ICP-AES	0.002
Tl	GFAA	0.002
V	ICP-AES	0.002
Zn	ICP-AES	0.005

Table 2. Chemical and Isotopic Analyses of Waters from the Anderson Springs Area.

Sample #	Map #	Description	Date mm/dd/yy	Temp. °C	pH (F)	pH (L)	Cond.(L) µmho/cm	CO_3 ppm	HCO_3 ppm	Ag ppm
CL98-3	1	Main Hot Spring, Anderson Springs	09/10/98	68.0	6.0	7.13	920	0	332	<0.001
CL98-5	1	Main Hot Spring, Anderson Springs	12/04/98	50.4	6.2	6.94	654	0	224	<0.001
And99-2	1	Main Hot Spring, Anderson Springs	08/19/99	69.5	6.0	7.13	920	0	348	<0.001
CL98-2	2	New Hot Spring, Anderson Springs	09/10/98	90.4	6.0	7.58	558	0	101	<0.001
And99-4	2	New Hot Spring, Anderson Springs	08/20/99	98.4	5.5	8.36	492	16.6	3.8	<0.001
And99-3	3	Fe-rich Spring	08/19/99	21.1	6.0	6.27	851	0	31.8	<0.001
And99-5	4	Creek below Unnamed Adit and Map #1,2,3	08/20/99	20.5	6.0	5.90	530	0	0.8	<0.001
CL98-4	5	Schwartz (Anderson) Mine Adit	12/04/98	22.0	6.0	6.15	1012	0	62.0	<0.001
And99-6	5	Schwartz (Anderson) Mine Adit	08/20/99	18.8	5.5	6.67	1159	0	175	<0.001
And99-7	6	Drainage from 99-6, just above road	08/20/99	12.4	4.5	6.54	848	0	7.4	<0.001

Chemical analyses by D. Counce, Los Alamos National Laboratory, Los Alamos, New Mexico.
Stable isotope analyses by M. Huebner and L. D. White, U. S. Geological Survey,
    Menlo Park, California.
Tritium analyses by University of Miami, Rosenstiel School of Marine and Atmospheric Science,
    Tritium Laboratory, Miami, Florida.

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Sample #	Map #	Al ppm	Std.D. +/-	As ppm	B ppm	Std.D. +/-	Be ppm	Ba ppm	Std.D. +/-	Br ppm	Ca ppm	Std.D. +/-	Cd ppm	Cl ppm	Co ppm	Std.D. +/-
CL98-3	1	0.04	0.02	<0.0001	0.45	0.01	<0.002	0.10	0.01	0.01	75.8	1.5	<0.001	1.98	<0.002	
CL98-5	1	0.09	0.01	0.0002	0.33	0.01	<0.002	0.069	0.001	0.08	52.0	0.1	<0.001	2.76	0.002	0.002
And99-2	1	<0.02		0.0010	0.52	0.01	<0.002	0.096	0.001	<0.02	72.3	0.7	<0.001	1.97	<0.002	
CL98-2	2	0.03	0.01	0.0103	0.43	0.01	<0.002	0.26	0.01	0.03	29.9	0.1	<0.001	1.77	<0.002	
And99-4	2	0.13	0.01	0.019	0.52	0.01	<0.002	0.062	0.001	0.08	17.1	0.1	<0.001	1.49	<0.002	
And99-3	3	<0.02		<0.0002	0.05	0.01	<0.002	0.028	0.001	<0.02	82.7	0.1	<0.001	2.11	0.003	0.002
And99-5	4	<0.02		0.0002	0.21	0.01	<0.002	0.098	0.001	0.03	39.9	0.1	<0.001	2.40	0.009	0.002
CL98-4	5	0.88	0.01	0.0014	0.088	0.002	<0.002	0.020	0.001	<0.02	108	1	<0.001	1.89	0.020	0.002
And99-6	5	<0.02		0.0008	0.10	0.01	<0.002	0.019	0.001	<0.02	128	2	<0.001	1.63	0.015	0.002
And99-7	6	<0.02		<0.0002	0.16	0.01	<0.002	0.047	0.001	<0.02	92.4	0.2	<0.001	1.69	0.008	0.002

Sample #	Map #	Cr ppm	Cs ppm	Std.D. +/-	Cu ppm	Std.D. +/-	F ppm	Fe ppm	Std.D. +/-	Hg ppm	I ppm	K ppm	Std.D. +/-	Li ppm	Std.D. +/-	Mg ppm	Std.D. +/-
CL98-3	1	<0.002	0.36	0.02	0.002	0.002	0.33	0.70	0.01	0.0002	<0.01	8.02	0.06	0.28	0.01	32.2	0.4
CL98-5	1	<0.002	0.21	0.01	<0.002		0.28	0.96	0.02	<0.0001	<0.01	5.31	0.02	0.16	0.01	23.0	0.1
And99-2	1	<0.002	0.50	0.01	<0.002		0.37	0.38	0.01	<0.00005	<0.01	9.17	0.09	0.25	0.01	28.5	0.1
CL98-2	2	<0.002	0.52	0.02	0.006	0.002	0.29	0.18	0.01	0.0009	<0.01	4.46	0.04	0.04	0.01	11.1	0.1
And99-4	2	<0.002	0.16	0.01	<0.002		0.24	0.02	0.01	0.00055	<0.01	4.70	0.01	0.05	0.01	3.93	0.01
And99-3	3	<0.002	0.031	0.002	<0.002		0.04	1.41	0.01	<0.00005	<0.01	1.25	0.01	0.05	0.01	51.2	0.1
And99-5	4	<0.002	0.049	0.002	<0.002		0.04	7.12	0.05	<0.00005	<0.01	4.76	0.04	0.03	0.01	24.6	0.2
CL98-4	5	<0.002	0.33	0.01	<0.002		0.75	8.23	0.02	<0.0001	<0.01	6.74	0.02	0.15	0.01	54.3	0.1
And99-6	5	<0.002	0.54	0.02	<0.002		0.54	6.51	0.04	<0.00005	<0.01	9.04	0.08	0.18	0.01	60.3	0.4
And99-7	6	<0.002	0.47	0.01	<0.002		0.31	0.02	0.01	<0.00005	<0.01	6.89	0.06	0.13	0.01	44.7	0.1

Sample #	Map #	Mn ppm	Std.D. +/-	Mo ppm	Na ppm	Std.D. +/-	NH_4 ppm	Ni ppm	Std.D. +/-	NO_2 ppm	NO_3 ppm	Pb ppm	PO_4 ppm	Rb ppm	Std.D. +/-
CL98-3	1	4.83	0.01	<0.002	52.6	0.2	20.0	<0.002		<0.02	0.06	<0.002	0.09	0.082	0.004
CL98-5	1	4.33	0.03	<0.002	33.4	0.1	11.1	<0.002		<0.02	<0.02	<0.002	<0.05	0.052	0.004
And99-2	1	3.83	0.09	<0.002	51.0	0.1	23.2	<0.002		<0.02	<0.02	<0.002	<0.05	0.10	0.01
CL98-2	2	0.82	0.01	<0.002	35.9	0.4	28.5	0.003	0.002	<0.02	0.03	<0.002	0.92	0.035	0.002
And99-4	2	0.29	0.01	<0.002	37.8	0.5	24.9	<0.002		<0.02	0.04	<0.002	0.49	0.049	0.002
And99-3	3	3.54	0.01	<0.002	18.2	0.1	0.54	0.017	0.002	<0.02	0.15	<0.002	<0.05	0.007	0.002
And99-5	4	1.78	0.01	<0.002	14.4	0.1	2.13	0.14	0.01	<0.02	4.29	<0.002	<0.05	0.034	0.002
CL98-4	5	4.77	0.03	<0.002	11.4	0.1	10.2	0.16	0.01	0.03	3.23	<0.002	<0.05	0.07	0.01
And99-6	5	4.48	0.01	<0.002	13.4	0.2	14.1	0.11	0.01	<0.02	3.86	<0.002	<0.05	0.14	0.01
And99-7	6	2.88	0.02	<0.002	12.8	0.1	0.80	0.14	0.01	<0.02	28.4	<0.002	<0.05	0.11	0.01

Table 2, continued.

Sample #	Map #	S ppm	Sb ppm	Se ppm	Si ppm	Std.D. +/-	SiO$_2$ calc ppm	Sn ppm	SO$_3$ ppm	SO$_4$ ppm	S$_2$O$_3$ ppm	Sr ppm	Std.D. +/-	Ti ppm
CL98-3	1	---	0.0008	<0.0001	34.2	0.1	73.2	<0.005	<0.02	228	<0.01	0.69	0.01	<0.002
CL98-5	1	---	0.0003	<0.0001	24.0	0.2	51.4	<0.005	<0.02	150	<0.01	0.42	0.02	<0.002
And99-2	1	---	0.0004	<0.0001	35.0	0.1	74.9	---	<0.05	206	<0.01	0.58	0.01	<0.002
CL98-2	2	---	0.092	<0.0001	30.9	0.1	66.1	<0.005	<0.02	165	2.24	0.26	0.01	<0.002
And99-4	2	---	0.058	<0.0001	35.1	0.1	75.1	---	<0.05	179	1.86	0.12	0.01	<0.002
And99-3	3	---	<0.0001	<0.0001	18.0	0.1	38.5	---	<0.05	445	<0.01	0.48	0.01	<0.002
And99-5	4	---	0.0004	<0.0001	19.2	0.1	41.1	---	<0.05	261	<0.01	0.32	0.01	<0.002
CL98-4	5	---	0.0004	<0.0001	32.0	0.2	68.5	<0.005	<0.02	508	<0.01	0.12	0.01	<0.002
And99-6	5	0.91	0.0006	<0.0001	32.0	0.1	68.5	---	<0.05	520	<0.01	0.54	0.01	<0.002
And99-7	6	---	0.0004	<0.0001	20.4	0.1	43.7	---	<0.05	443	<0.01	0.41	0.01	<0.002

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Sample #	Map #	Tl ppm	Std.D. +/-	V ppm	Zn ppm	Std.D. +/-	TDS ppm	Cation Sum	Anion Sum	Balance	δD per mil	$\delta^{18}O$ per mil	^3H T.U.	Std.D. +/-
CL98-3	1	<0.002		<0.002	<0.01		832	10.305	10.275	0.0029	-47.2	-7.48	NC	
CL98-5	1	<0.002		<0.002	0.01	0.01	560	6.943	6.899	0.0065	-46.2	-7.42	NC	
And99-2	1	<0.002		<0.002	<0.01		822	9.900	10.083	-0.0183	-47.7	-7.56	2.45	0.13
CL98-2	2	<0.002		<0.002	<0.01		450	5.721	5.229	0.0900	-48.3	-7.57	NC	
And99-4	2	<0.002		<0.002	<0.01		348	4.359	4.461	-0.0231	-46.7	-7.40	NC	
And99-3	3	<0.002		<0.002	<0.01		677	9.411	9.837	-0.0443	-47.2	-7.44	2.20	0.11
And99-5	4	<0.002		<0.002	0.04	0.01	405	5.342	5.589	-0.0452	NC	NC	NC	
CL98-4	5	<0.002		<0.002	0.04	0.01	850	11.825	11.723	0.0086	-47.2	-7.64	NC	
And99-6	5	<0.002		<0.002	<0.01		1008	13.489	13.841	-0.0257	-48.9	-7.84	2.55	0.13
And99-7	6	0.003	0.002	<0.002	0.07	0.01	686	9.202	9.858	-0.0688	NC	NC	NC	

NC = Sample not collected for analysis.

Table 3. Trace Elements and Methylmercury in Waters from Anderson Springs and Schwartz (Anderson) Mine.

Sample #	Map #	Date	Al	As	Ba	Ca	Co	Cr	Cu	Fe	Hg	Methyl Hg
		mm/dd/yy	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L	ng/L	ng/L
98SM-1W UF	5	08/07/98	13.6	<.2	19	138	31	<.1	7.9	15.8	19.2	0.037
98SM-1W F	5	08/07/98	0.11	<.2	90	93	32	<.1	<.1	7.8	0.24	0.015
99SM-1W UF	5	10/05/99	0.61	<10	30	151.5	8.2	<5.0	5	5.5	9.7	0.21
99SM-1W F	5	10/05/99	0.19	<10	23	146.5	10.4	<5.0	4	4.5	na	na
98HS-1W UF	1	08/07/98	0.09	<.2	18	89	0.9	<.1	<.1	2.1	215	0.056
98HS-1W F	1	08/07/98	0.08	<.2	93	93	0.8	<.1	<.1	2.1	0.73	0.017
99NAS-1W UF	2	10/05/99	0.654	11	72.9	13.55	0.9	3	1.9	0.8	5700	0.17
99NAS-1W F	2	10/05/99	0.066	10	64.4	13.5	0.04	<0.5	0.1	<0.01	na	na

na = not available
Concentration of the following elements were below noted detection limit in µg/L (except as noted):
 B < 0.1 mg/L , Ag <0.5, Be <0.5, Bi <0.5, Cd <1.0, Pb < 20, Se <10, Sn <5.0, Tl <0.5, U<0.5,

Table 3, continued.

Sample #	K mg/L	Mg mg/L	Mn µg/L	Mo µg/L	Na mg/L	Ni µg/L	P mg/L	Sb µg/L	Sr µg/L	Ti µg/L	V µg/L	Zn µg/L
98SM-1W UF	9.8	80.3	6500	<.05	16.7	256	na	<.2	480	37	2.7	240
98SM-1W F	10.7	88.8	6900	<.05	18.3	251	na	<.2	505	34	0.5	39
99SM-1W UF	11.5	73.7	3800	<1.0	18	60	<1.0	<0.50	713	10	<10	45
99SM-1W F	11	71.1	3760	<1.0	17	64	<1.0	<0.50	674	10	<10	25
98HS-1W UF	10.3	42.7	4900	<.05	64.7	35	na	0.21	580	33	<.05	47
98HS-1W F	10.8	45.5	5100	<.05	68.8	35	na	0.5	590	33	<.05	25
99NAS-1W UF	4.3	3.33	278	0.5	39	3.4	0.6	26.4	106	41	3	5
99NAS-1W F	4.35	2.94	256	0.4	39.3	0.2	<2.0	9.7	106.5	4	<1	2

na = not available

Table 4. Chemical Analyses of Sediment Samples from a New Hot Spring at Anderson Springs, with analysis of Reference Standard NBS 2704 for comparison.

Sample #	Map #	Description	Date	Au	As	Br	Cl	Cu
			mm/dd/yy	ppm	ppm	ppm	ppm	ppm
CL98-2 Residue	2	Residue on 0.45 micron filter membrane after filtering approx. 400 mL sample	09/10/98	<2	88.4	---	---	349
CL98-2 Muck	2	Sediment/Muck from bed of New Hot Spring	09/10/98	<0.04	13.6	<4	3.9	45.3
Standard NBS 2704*		SRM River Sediment, Given Target Values	---	---	23.4	---	---	98.6
NBS 2704		SRM River Sediment, D. Counce	02/--/99	<0.04	22.6	---	---	98.7

Analyses by D. Counce, Los Alamos National Laboratory, Los Alamos, New Mexico

Table 4, continued.

Sample #	F ppm	Fe ppm	Hg ppm	Pb ppm	P_2O_5 ppm	Sb ppm	Se ppm	S ppm	Tl ppm	Zn ppm	Fe_2O_3 Total %
CL98-2 Residue	---	139,535	523	465	---	395	<3	---	23.3	349	19.9
CL98-2 Muck	3.9	64,472	30.4	11.8	990	22.7	0.51	20,738	0.79	80.8	9.22
Standard NBS 2704*	---	41,127	1.47	161	---	3.79	1.12	3,970	1.06	438	5.88
NBS 2704	---	40,913	1.52	156	---	0.78	1.07	---	0.62	428	5.85

Table 5. Chemical Composition of Gases from a New Hot Spring in the Anderson Springs Area.

Sample #	Map #	Description	Date mm/dd/yy	Temp °C	Moles of Steam Collected	Total Moles of DRY Gas	Total Moles of WET Gas	CO_2 mole %	H_2S mole %	H_2 mole %	CH_4 mole %
And99-1a	2	New Hot Spring	08/19/99	98.4	1.9076	0.0122	1.9198	64.5	4.85	5.50	1.15
And99-1b	2	New Hot Spring	08/19/99	98.4	2.1436	0.0188	2.1624	49.4	3.71	4.31	0.802

Analyses by D. Counce, Los Alamos National Laboratory, Los Alamos, New Mexico

Table 5, continued.

	C_2H_6 mole %	NH_3 mole %	O_2 mole %	N_2 mole %	Ar mole %	He mole %	CO mole %	As mole %	HBr mole %	HCl mole %	HF mole %	Hg mole %
And99-1a	0.0121	0.286	0.780	22.5	0.305	<0.003	<0.003	0.00021	<0.0003	0.024	0.121	0.00043
And99-1b	0.0092	0.717	5.12	35.8	0.452	<0.005	<0.005	0.00019	<0.0004	<0.05	0.056	0.00031

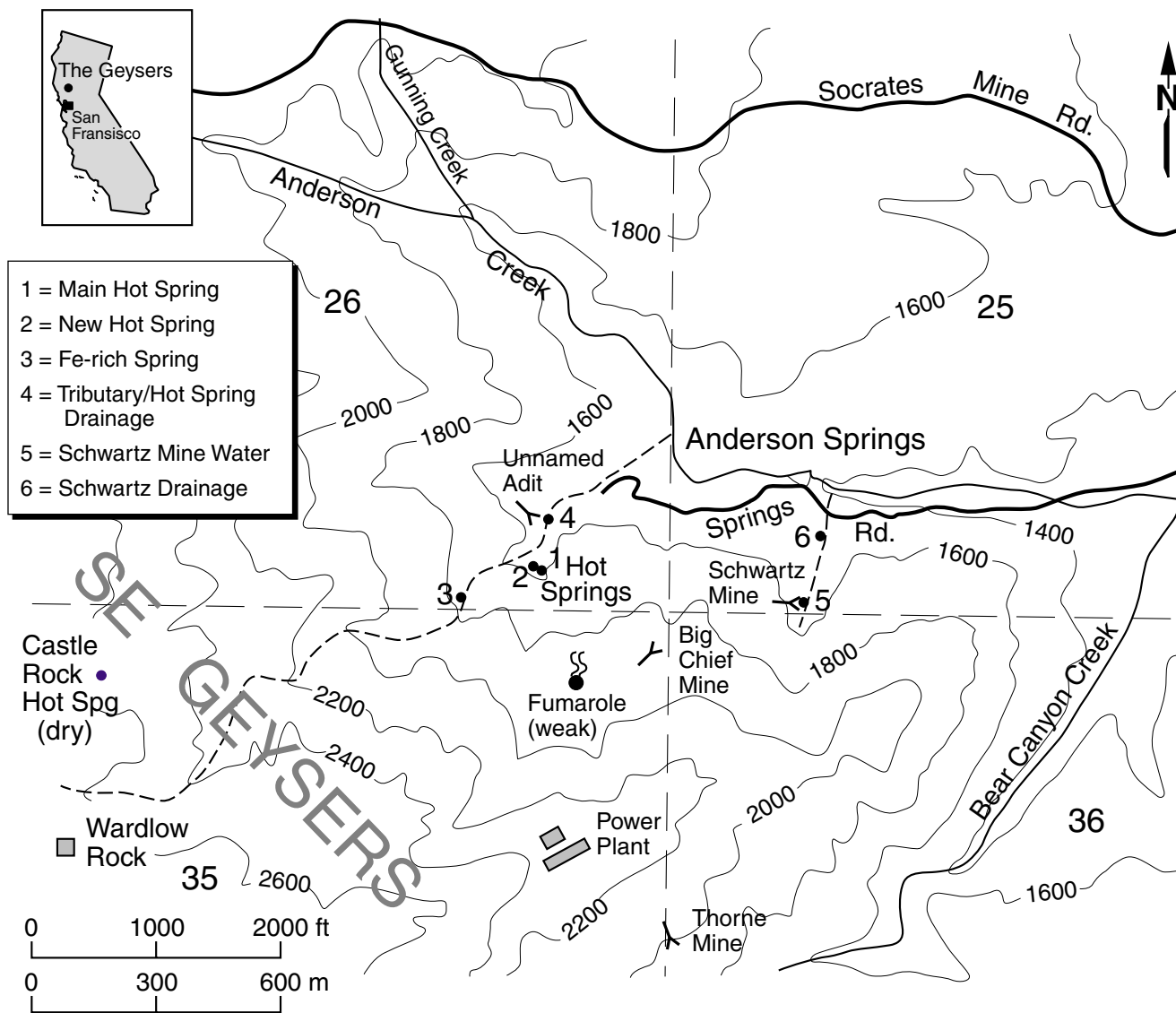Topographic map of Anderson Springs area; contours in feet.

Figure 1. Topographic map of Anderson Springs area; contours in feet. Numbered sites indicate sampling locations (see legend), and correspond to map numbers listed in Tables 2-5. Big Injun mine (see text) is located at 2400 ft. elevation to the south of the map, about 1 km southwest of Big Chief mine.
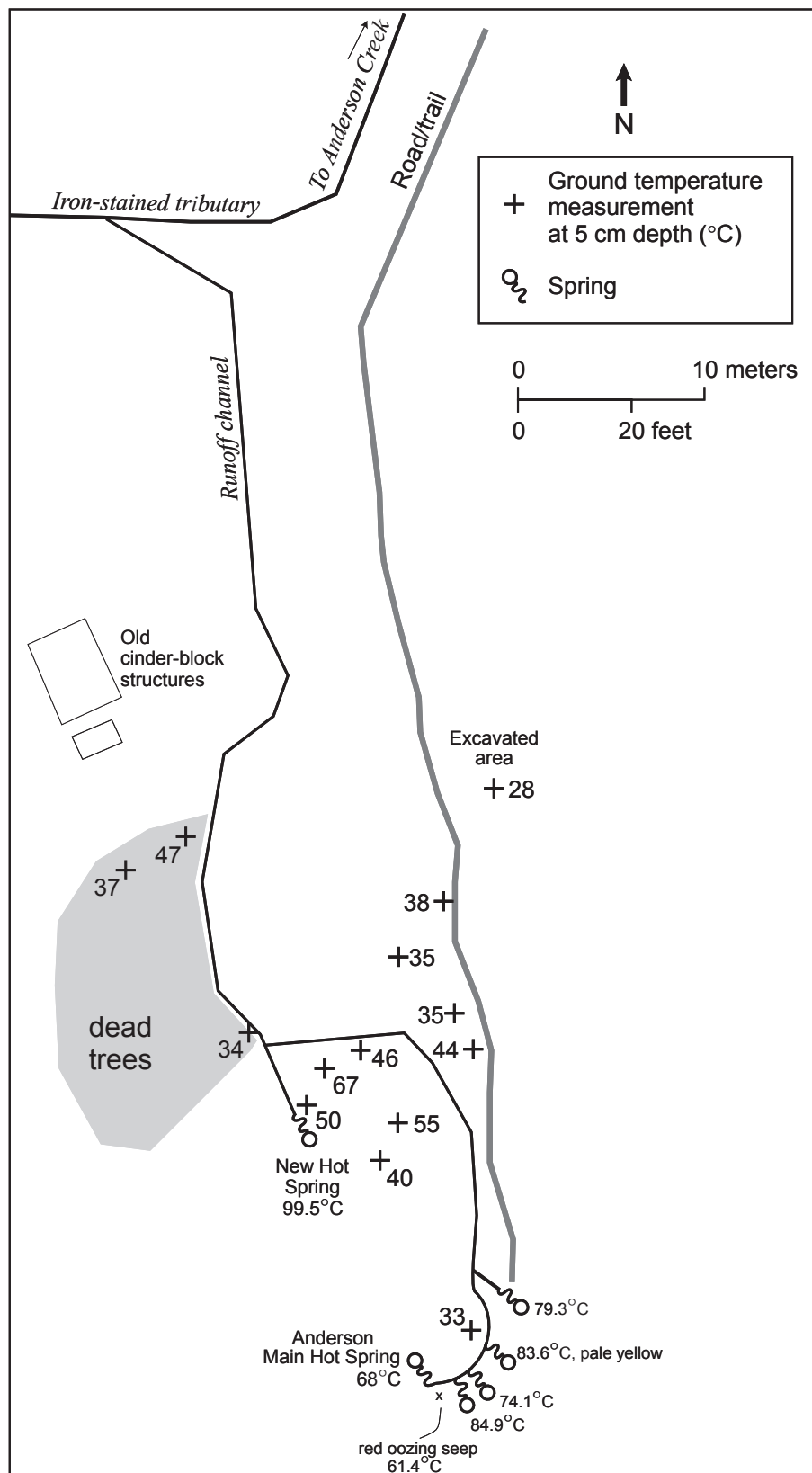
Figure 2. Schematic diagram of the Anderson Hot Springs showing measured temperatures (in °C, on 9/16/99) of the springs and the ground in the vicinity of the springs. Shaded area on the west bank of the spring-discharge channel indicates the approximate size of a dead-tree zone near the new hot spring. Within the original cluster of hot springs, the pale yellow color is attributed to filamentous bacteria, and the red color is characteristic of red algae and iron oxyhydroxides. Coordinates (NAD27 datum) for the main hot spring are Longitude 122 42'22.50", Latitude 38 46'20.47", with a horizontal error of 6–10 m.
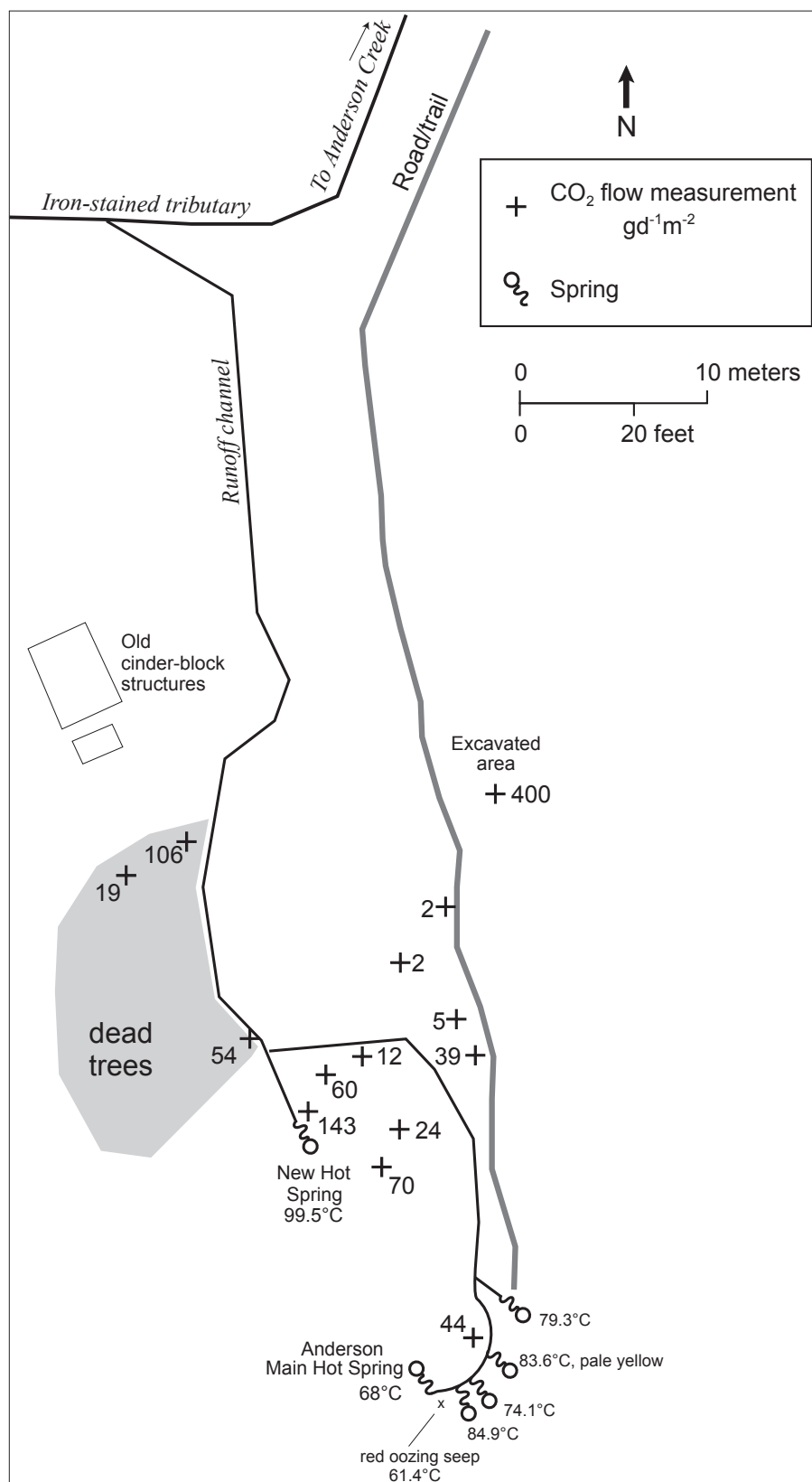
Figure 3. Schematic diagram of the Anderson Hot Springs showing diffuse flow of CO2 (in gd-1m-2) through soil in the vicinity of the hot springs. CO2 flow measurements were made on 9/16/99 near each site where ground temperatures were measured (Figure 2).