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Geochemical Data for 95 Thermal and Nonthermal Waters of the Valles Caldera—Southern Jemez Mountains Region, New Mexico

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DISCLAIMER

GEOCHEMICAL DATA FOR 95 THERMAL AND NONTHERMAL WATERS OF THE VALLES CALDERA--SOUTHERN JEMEZ MOUNTAINS REGION, NEW MEXICO

by

Fraser Goff, Tamsin McCormick, Pat E. Trujillo, Jr., Dale Counce, and C. O. Grigsby

ABSTRACT

This report presents field, chemical, and isotopic data for 95 thermal and nonthermal waters of the southern Jemez Mountains, New Mexico. This region includes all thermal and mineral waters associated with Valles Caldera and many of those located near the Nacimiento Uplift, near San Ysidro. Waters of the region can be categorized into five general types: (1) surface and near-surface meteoric waters; (2) acid-sulfate waters (Valles Caldera); (3) thermal meteoric waters (Valles Caldera); (4) deep geothermal and derivative waters (Valles Caldera); and (5) mineralized waters near San Ysidro. Some waters display chemical and isotopic characteristics intermediate between the types listed. The object of the data is to help interpret geothermal potential of the Jemez Mountains region and to provide background data for investigating problems in hydrology, structural geology, hydrothermal alterations, and hydrothermal solution chemistry.

I. INTRODUCTION

The Jemez Mountains consist of volcanic rocks of basaltic to rhyolitic composition that overlie Tertiary to Paleozoic sediments on the western margin of the Rio Grande rift. Volcanic activity culminated in the Pleistocene with eruption of ~500 km^3 of Bandelier tuff and with formation of the Valles Caldera, a large well-preserved silicic cauldron. The Valles region also contains a variety of hot springs having distinct geologic, chemical, and isotopic characteristics. Young, large silicic volcanic centers such as the Valles Caldera have great potential for geothermal energy because they overlie shallow magma reservoirs of batholithic proportions. A study of the chemistry of geothermal fluids can provide information on the hydrothermal systems and the geologic formations and structures through which they flow. The purpose of this paper is to present field, chemical, and isotopic data for ground water and thermal water in the Jemez Mountains area, to characterize different water types and relate them to the hydrothermal systems. These data are presented to aid the overall assessment of geothermal resources of the Jemez Mountains and to provide data for other scientific investigations.

The general geohydrology and geochemistry of waters in the Jemez Mountains have been described by Goff and Grigsby,[1] Goff et al.,[2] Goff and Sayer,[3] Trainer and Lyford,[4] Trainer,[5,6] Titus,[7] Purtymun and Johansen,[8] Purtymun et al.,[9,10] and Purtymun.[11]

II. SIMPLIFIED GEOLOGY

The geology of the Jemez Mountains has been described by Ross et al.,[12] Smith et al.,[13] Griggs,[14] Doell et al.,[15] and Bailey et al.[16] Smith, Bailey and Ross[17] published an excellent regional geologic map in 1970. The Jemez Mountains consist of an extensive pile of Tertiary and Quaternary lavas and tuffs (10 to 0.1 Myr) overlying Precambrian granite, gneiss, and schist and the Paleozoic to Mesozoic sedimentary sequence of the Colorado Plateau (Figs. 1 and 2). The main Paleozoic units include the Pennsylvanian Madera Formation, the red sandstone, siltstone, and shale of the Permian Abo and Yeso Formations and the Triassic Chinle Formation. Mesozoic rocks crop out south of the Jemez Mountains near San Ysidro. The older Mesozoic units include the Entrada Formation sandstone, Todilto Formation evaporites (mainly gypsum), and Morrison Formation shale and sandstone.

Colorado Plateau rocks of this region are down-faulted to the east into the Rio Grande rift. Unconsolidated Tertiary sediments of the Santa Fe Formation thicken eastward towards the axis of the rift. The Jemez Mountains volcanics occur at the intersection of the rift with the northeast-trending Jemez Lineament, a line of Miocene to Quaternary volcanic fields extending across the northwest portion of New Mexico.[18-20]

Volcanic activity commenced with dominantly mafic to intermediate lava flows that are partly interbedded with the Tertiary sediments. These rocks

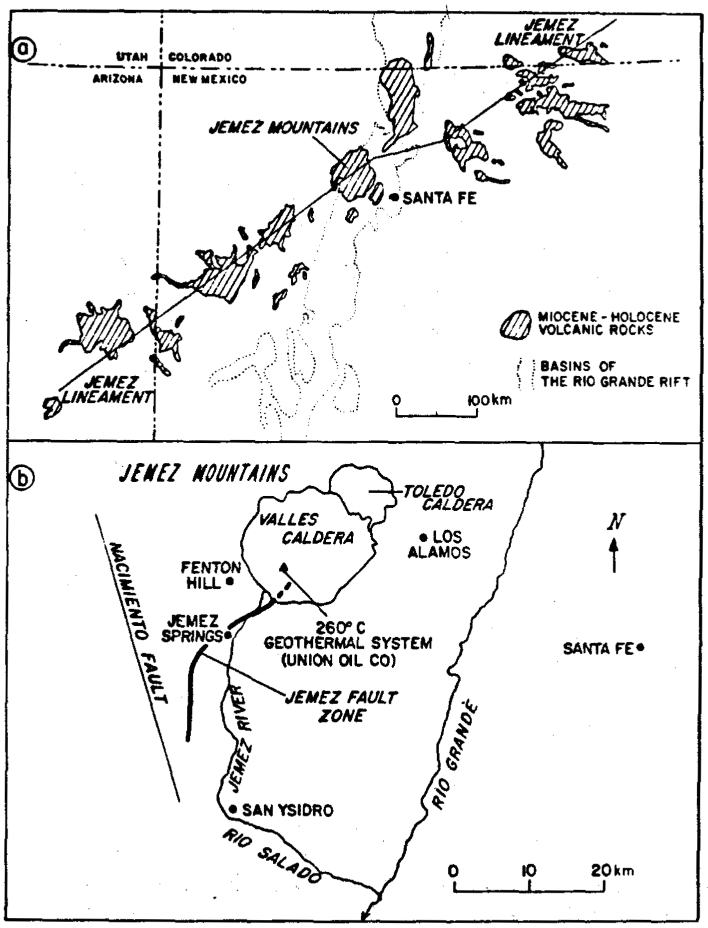


Fig. 1.
Location map showing (a) volcanic centers in relationship to the Rio Grande rift and Jemez Lineament and (b) sketch of Jemez Mountains region.

are best exposed in the areas north, northeast, and south of the Valles Caldera complex. Two major eruptions of Bandelier rhyolite tuff in the early Pleistocene resulted in the formation of the Toledo and Valles Caldera. Deposits of tuff up to 300 m thick occur to the west and east of the caldera forming the Jemez and Pajarito Plateaus, respectively. The final activity in the Jemez Mountains involved eruption of rhyolite domes, obsidian, and tuffs in the moat zone of the Valles Caldera.

III. METHODS AND PROCEDURES FOR COLLECTION AND ANALYSIS OF WATERS

Temperatures were recorded with mercury thermometers and field pH was determined using a pH meter or using sensitive limited range pH test papers (Colorfast Indicator Strips nos. 9581, 9582, and 9583). Laboratory values of pH are not considered reliable because most waters gain or lose CO_2 gas after

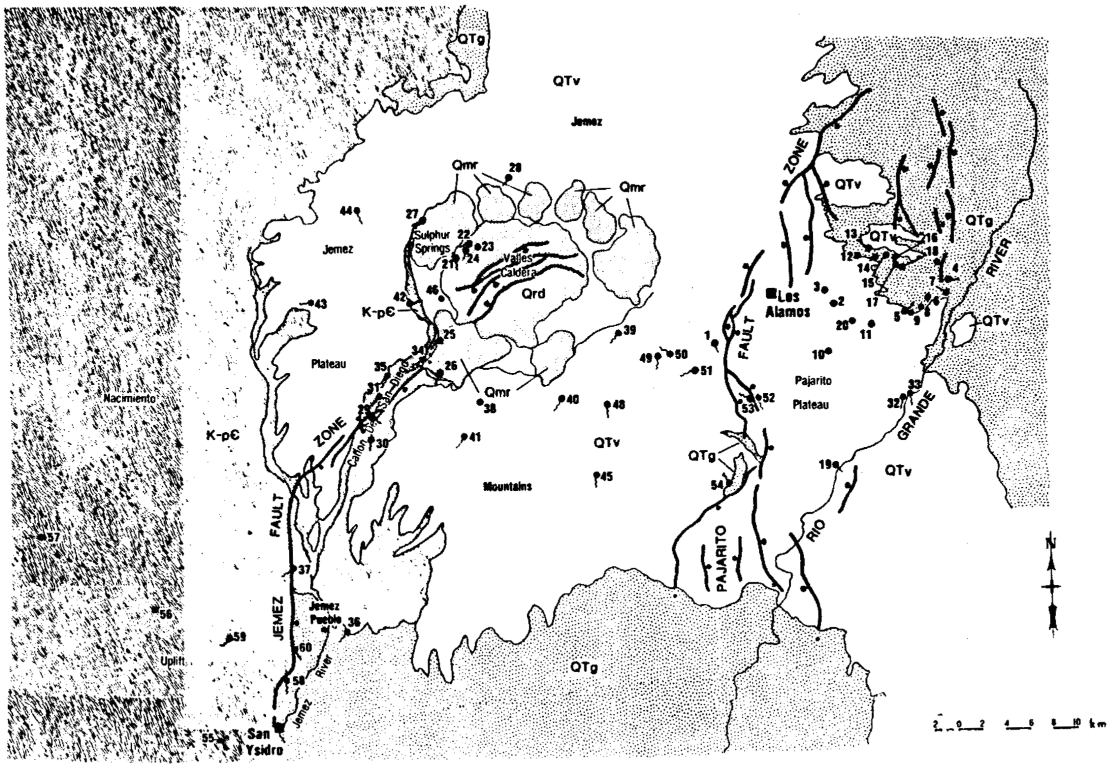


Fig. 2.
Schematic geologic map of Jemez Mountains region showing major faults. Numbers refer to spring and well locations listed in tables in Appendix B. Qrd = Resurgent Dome of Valles Caldera, Qmr = Moat Rhyolites of Valles Caldera, QTv = Quaternary-Tertiary volcanic rocks, QTg = Quaternary-Tertiary sediments, K-pЄ = Cretaceous-Precambrian bedrock.

sampling and before laboratory analysis. This alters the concentration of bicarbonate ions, which in turn changes the pH. Flow rates of springs were estimated visually; flow rates of wells were obtained from gauges on the wellhead where possible. A compilation of unusual springs of the Jemez Mountains is presented in Appendix A. Field data is recorded in Table B-I (all tables appear in Appendix B).

Samples of water for chemical analysis were filtered using a large syringe attached to a filter holder containing 0.8μ filter paper. The filtered water was squirted brimful into polyethylene bottles with Polyseal caps. Three types of samples were collected: (1) a 500-mℓ bottle of filtered unacidified water for anions, (2) a 250-mℓ bottle of filtered acidified water for cations, and (3) a 125-mℓ bottle of filtered diluted water for silica. Dilute HCl was added dropwise to the acidified sample until the pH was less than 2. The bottles used for silica analyses contained 90 mℓ of deionized water before 10 mℓ of sample were added. This dilution prevents polymerization of monomeric silica in more concentrated water samples before analysis. Samples for determination of Al were collected and analyzed according to our modified procedure of Barnes.[21] Major element analyses are presented in Table B-II.

Laboratory analyses were performed by the following methods: SiO_2 by a colorimetric method using a yellow molybdate complex; Fe, Mn, Ca, Mg, Na, K, and Li by atomic absorption spectroscopy; HCO_3 by sulfuric acid titration; SO_4 and Cl by ion chromatography; F by either selective ion electrode or ion chromatography; and B by colorimetry using azomethine-H. Because HCO_3 was not determined in the field, HCO_3 values listed in Table B-II may not be reliable for dilute (unbuffered) waters. Analyses of Ag, Ba, Cd, Cr, Cu, Mo, Ni, Pb, Sr, and Zn were performed by atomic absorption spectroscopy either by using a graphite furnace or flame excitation. These data appear in Table B-III.

Samples for D and ^{18}O analysis were collected by filling 125-mℓ glass bottles full of raw water and sealing with a Polyseal cap. Isotope variations were determined by standard methods and the data appear in Table B-IV.

IV. GEOHYDROLOGY AND GEOCHEMISTRY

The waters described in this report can be divided into several groups on the basis of field, chemical, and isotopic characteristics. In this section each group is discussed separately, but the reader should refer to Figs. 6 through 13 to observe chemical and isotopic differences and similarities among water types.

A. Surface and Near-Surface Meteoric Water - Los Alamos Area and Miscellaneous

Surface and near-surface meteoric waters are generally cold, potable, and dilute. Waters included in this group issue from water-supply and test wells in the Pajarito Plateau and from cold springs, creeks, and wells in the Valles Caldera-southern Jemez Mountains region (see Figs. 2-5 for locations). Cold meteoric waters occur in three different geologic settings; (1) within late Tertiary to Quaternary volcanic rocks of the Jemez Mountains volcanic field, (2) within late Tertiary basin-fill sediments of the Rio Grande rift, and (3) within Paleozoic to Mesozoic sediments of the Colorado Plateau. These three

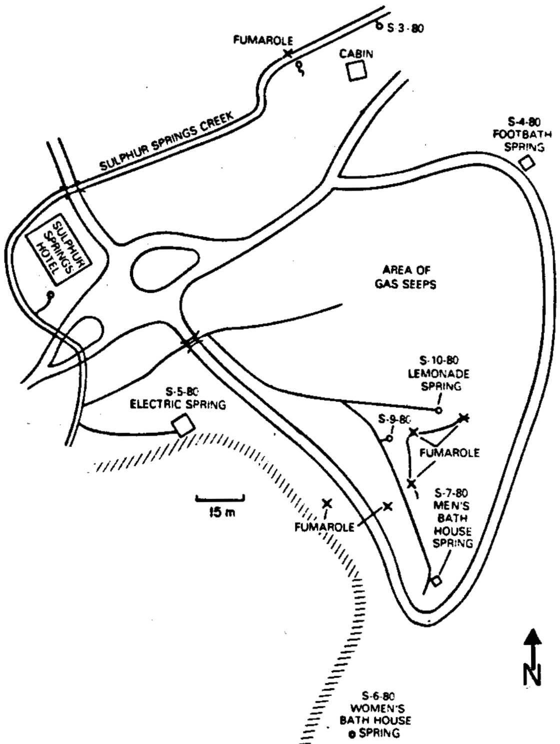


Fig. 3.
Sketch map of Sulphur Springs area (modified from Summers[24]).

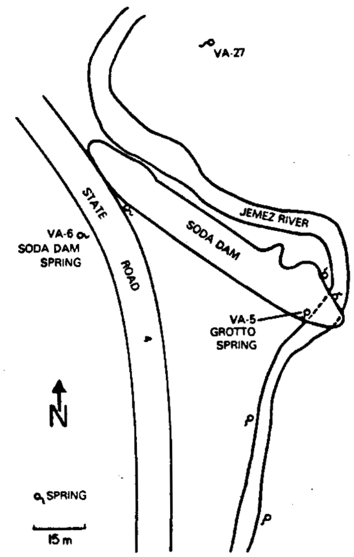
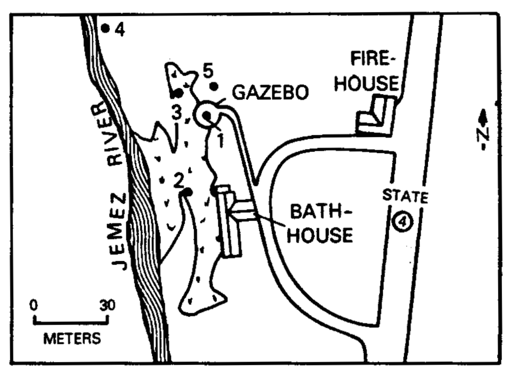


Fig. 4.
Sketch map of Soda Dam Area.

different settings produce subtle differences in the chemistry of near-surface waters.

The hydrology of the Pajarito Plateau has been described by Purtymun and Johansen[8] and the geochemistry of the waters with respect to geothermal potential has been discussed in detail by Goff and Sayer.[3] Hydrology of the southern Jemez Mountains is not known in detail although the Jemez River and tributaries drain Valles Caldera in a southerly direction.

In general, surface and near-surface waters of this category are



1. MAIN JEMEZ SPRING, VA-10
2. TRAVERTINE MOUND SPRING, VA-7
3. UNNAMED WARM SPRING, VA-12
4. BUDDHIST SPRING, VA-8
5. JEMEZ SPRINGS GEOTHERMAL WELL, VA-19

Fig. 5.
Sketch map of Jemez Springs are (modified from Summers[24]).

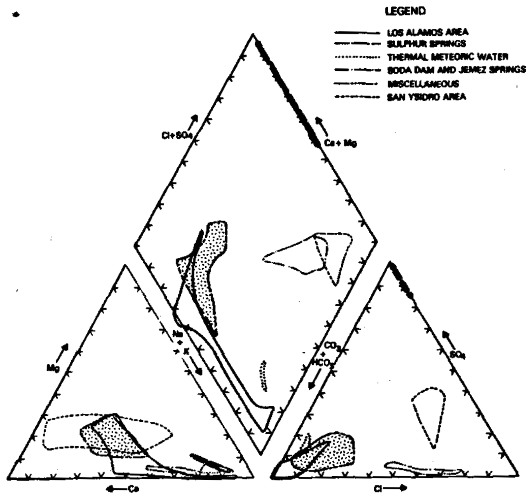


Fig. 6.
Piper diagram showing the ranges in chemical composition in equivalents of various types of water in southern Jemez Mountains, New Mexico. Patterns are added to help distinguish overlapping fields of data points.

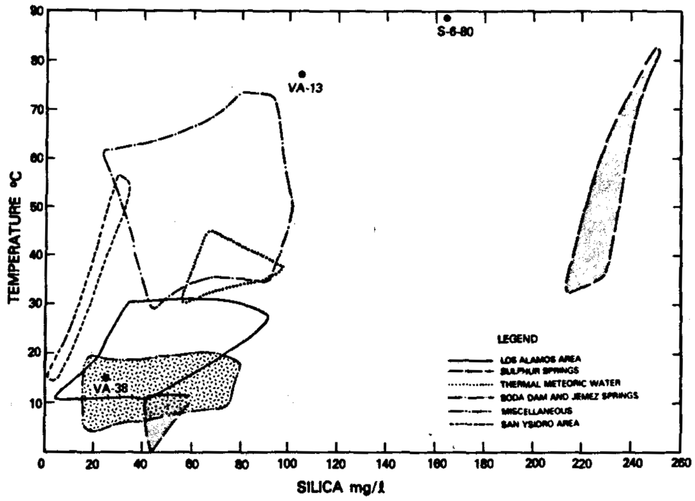


Fig. 7.
Plot of SiO_2 vs measured temperature for various types of water in southern Jemez Mountains region, New Mexico. Sample numbers refer to waters that fall outside fields of generalized water types. Note that waters from Sulphur Springs area fall into two distinct fields.

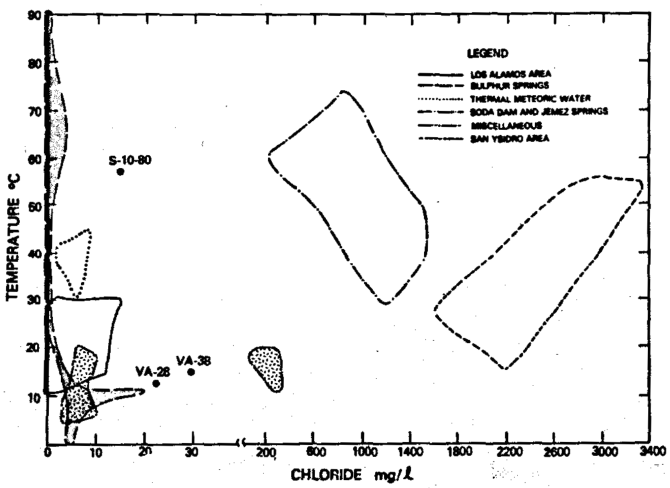


Fig. 8.
Plot of Cl vs measured temperature for various types of water in southern Jemez Mountains region, New Mexico. Sample numbers refer to waters that fall outside fields of generalized water types. Note that miscellaneous meteoric waters fall into two distinct fields. Those with high Cl issue from Paleozoic-Mesozoic rocks.

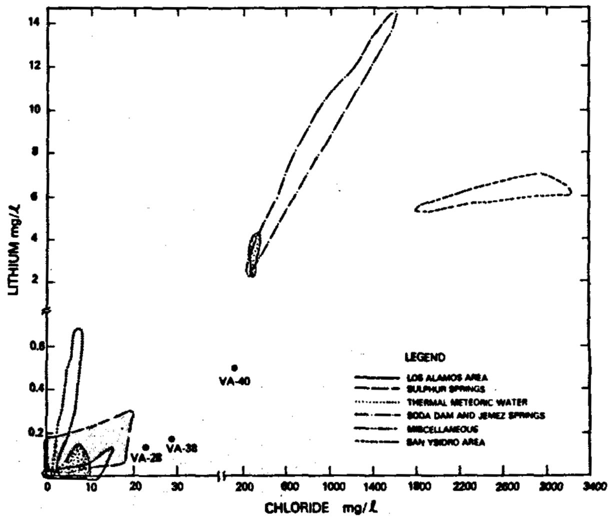


Fig. 9.
Plot of Li vs Cl for various types of water in southern Jemez Mountains region, New Mexico. Sample numbers refer to waters that fall outside fields of generalized water types. Note that miscellaneous meteoric waters fall into two distinct fields. Those with high Li issue from Paleozoic-Mesozoic rocks.

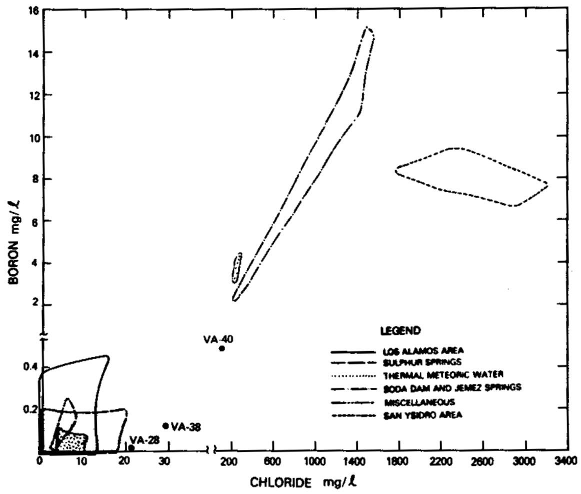


Fig. 10.
Plot of B vs Cl for various types of water in southern Jemez Mountains region, New Mexico. Sample numbers refer to waters that fall outside fields of generalized water types. Note that miscellaneous meteoric waters fall into two distinct fields. Those with high B issue from Paleozoic-Mesozoic rocks.

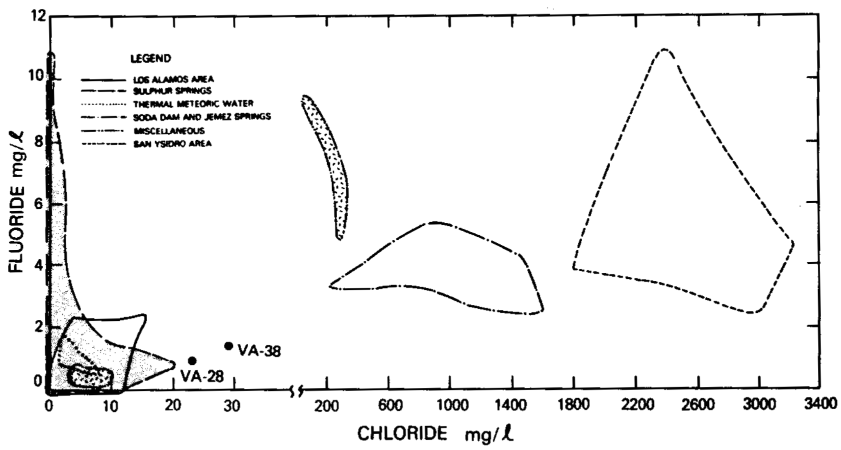


Fig. 11.
Plot of F vs Cl for various types of water in southern Jemez Mountains region, New Mexico. Sample numbers refer to waters that fall outside fields of generalized water types. Note that miscellaneous meteoric waters fall into two distinct fields. Those with high F issue from Paleozoic-Mesozoic rocks.

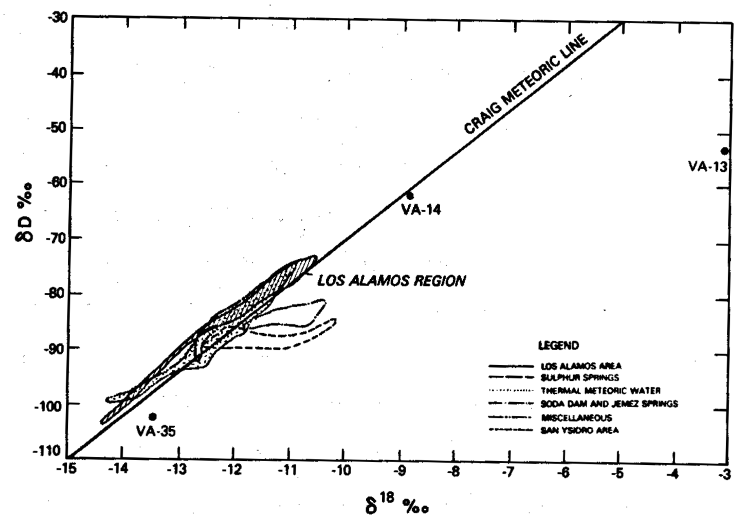


Fig. 12.
Plot of δD vs $\delta^{18}O$ for various types of water in southern Jemez Mountains region, New Mexico. Sample numbers refer to waters that fall outside fields of generalized water types. Two hot springs from Sulphur Springs (VA-13, VA-14) are plotted separately.

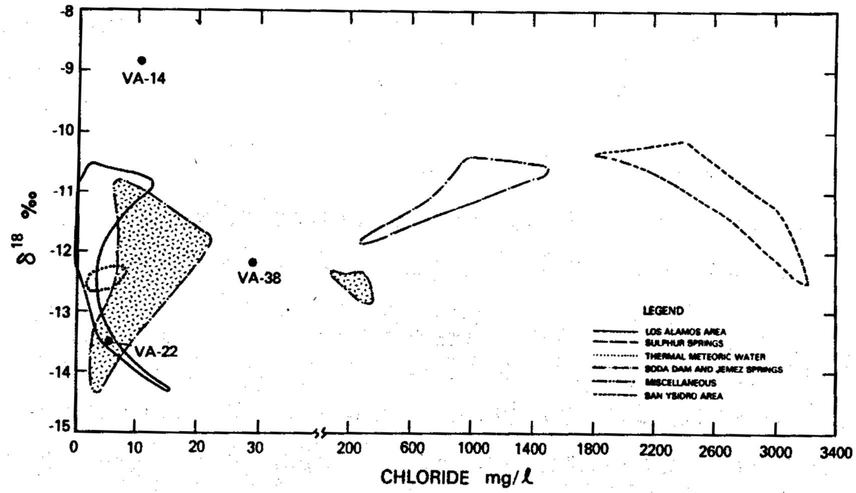


Fig. 13.
Plot of $\delta^{18}O$ vs Cl for various types of water in southern Jemez Mountains region, New Mexico. Sample numbers refer to waters that fall outside fields of generalized water types. One hot spring from Sulphur Springs (VA-14) is plotted separately. Note that miscellaneous meteoric waters fall into two distinct fields. Those with high Cl issue from Paleozoic-Mesozoic rocks.

calcium-bicarbonate waters although some of the Los Alamos water-supply wells and cold mineral springs in the Valles Caldera region are sodium-bicarbonate waters. The waters can be characterized by low conductivity (since they are relatively dilute), low temperature and pH near 7. They typically contain low concentrations of F, Cl, Li, B, and SiO_2, (Figs. 7, 8, 9, 10, and 11) indicating a low temperature, near-surface environment.[22] The Los Alamos waters show a wider range in all these constituents than most cold waters of the region, possibly due to long residence time of some waters in deep aquifers or to some mixing with deep thermal/mineral water rising along faults in the Pajarito Plateau.[3] A few springs in the Caldera region are anomalous in that they are somewhat mineralized but cold (location nos. 34, 36, 37, and to a lesser extent location 31, Fig 2; samples VA-31, VA-39, VA-40, and VA-28, Table B-II). These samples have much greater conductivity, comparatively high Na+K relative to Ca, high Cl relative to HCO_3, and relatively high F, B, and Li (see Figs. 8, 9, 10, 11, and 13). Two of the springs (location nos. 34 and 36) also have very low SiO_2. These slightly mineralized meteoric waters issue from Mesozoic-Paleozoic sediments and either leach out evaporitic minerals from them, or else contain an extremely small fraction of deep thermal water from Valles Caldera.

Trace elements of all waters in this group are fairly low (Table B-III). Sr appears to be higher in waters issuing from Madera limestone (especially location nos. 34 and 36), suggesting that Sr is dissolved out of the carbonate rocks.

The D and ^{18}O isotope ratios follow Craig's[23] line for meteoric waters (Fig. 12). The cold mineral waters described above are not isotopically distinct from other waters in this group.

B. Valles Caldera-Sulphur Springs Area

A suite of thermal and nonthermal acid-sulfate springs and mudpots and some associated dilute carbonated waters are located within the Valles Caldera near the western margin of the resurgent dome (Figs. 2 and 3). Discussion of the chemistry and origin of the Sulphur Springs has been presented by Goff and Grigsby[1] and Trainer.[5] Names used for various springs in Tables B-I, B-II, B-III, and B-IV correspond with those presented by Summers.[24] Rhyolitic flows and tuffs and caldera fill deposits in the area have been extensively altered and leached to clays, silica minerals, authigenic feldspars and sulfates.

Native sulfur, pyrite and aluminum sulfates have precipitated near fumaroles (R. Charles and D. Bish, Los Alamos National Laboratory, personal communication, 1981). The waters are characterized by a high conductivity (except for the dilute bubbling waters), and low pH, especially in the most concentrated waters. Most of the samples have moderate F and low B, Li, and Cl (Figs. 8, 9, 10, and 11). The F concentrations are highest in the Cl-free waters. SiO_2 contents vary within the suite but the waters can generally be divided into two groups: a high-temperature, high-SiO_2 group and a low-temperature, low-SiO_2 group (Fig. 7). This relationship is in part a function of the increasing solubility of SiO_2 with increasing temperature.

Trace elements Zn, Cu, Cr, Co, and Ni show relatively high concentrations in acid waters that are also rich in Fe (Table B-III), a relationship probably due to the greater solubilities of these metals in acid waters.

The D and ^{18}O isotope ratios of the bubbling seep (sample VA-23; location no. 22, Fig. 2) and unnamed acid spring (sample VA-14; location no. 21, Fig. 2) both fall on Craig's meteoric line, the unnamed spring being more enriched in ^{18}O and D (Fig. 12). In contrast, the Men's Bathhouse mudpot (sample VA-13) consists mostly of condensed steam from depth and is very enriched in ^{18}O, probably the result of extensive hot water rock interactions at depth.

The Sulphur Springs are typical of a vapor-dominated geothermal system[25] where water vapor, H_2S, and CO_2 rise from an underlying boiling water table. The known occurrence of a high temperature (260°C) hydrothermal system beneath the resurgent dome of Valles Caldera[20] indicates that such a boiling water table may exist beneath Sulphur Springs. Condensation of the steam near the surface and surface oxidation of H_2S to H_2SO_4 results in acid-sulfate water. The flowing springs mix seasonally with surface meteoric water since they show lower flow rates and higher temperatures during the dry months of the year.

C. Valles Caldera - Thermal Meteoric

Included here are a group of warm springs in the western ring fracture zone, previously described by Goff and Grigsby,[1] Goff and Sayer,[3] and Trainer.[5] The waters are typically dilute, near neutral in pH and have moderate temperature (31-45°C). They are sodium-bicarbonate waters displaying low concentrations of F, Cl, B, and Li (Figs. 8, 9, 10, and 11). The F, B, and Li contents are slightly higher than most of the surface waters in the Caldera and B and Li concentrations are both slightly enriched in samples with higher Cl. McCauley Spring differs from the others in that it contains more Ca and Mg and less alkalis. All samples show low concentrations of the trace elements analyzed (Table B-III). The D and ^{18}O isotopes fall close to Craig's meteoric line in a tight cluster (Fig. 12).

These waters can be considered to be meteoric waters that have been heated during circulation in the ring fracture zone of the Valles Caldera. All waters of this type discharge near the youngest (less than 0.5 Myr) of the moat rhyolites erupted in the Caldera. They are slightly depleted in Ca and Mg compared with surface waters in the Caldera region due to the inverse relationship between carbonate solubility and temperature. Very slight mixing with deep thermal waters may have occurred in Spence, Little Spence, and possibly, McCauley Hot Springs (location nos. 25 and 26, Fig. 2; samples VA-1, VA-2, and VA-3) because they have higher Li and Na than most of the meteoric waters in the Valles Caldera region.

D. Valles Caldera - Deep Thermal Waters and Derivatives

A number of hot springs and warm springs occur along the trace of the Jemez fault zone in Cañon de San Diego, including springs at Soda Dam (Fig. 4) and near the village of Jemez Springs (Fig. 5). The Jemez fault zone extends southwest and south from the Caldera for about 20 km. It was active before eruption of the Jemez Mountains volcanic field[2] and locally represents the western boundary of the Rio Grande rift. The hot springs occur at intersections of the Jemez River with the fault and fracture zones. Chemical composition and origin of these mineralized springs has been discussed by Goff et al.,[2] Trainer,[5] and in part by Goff and Grigsby[1] and Goff and Sayer.[3] Soda Dam, Travertine Mound Spring, and some others are actively depositing carbonate travertine.

The springs display fairly high conductivity and are neutral to slightly acid sodium-chloride to calcium-bicarbonate waters. The Cl and Ca concentrations show a slight inverse relationship suggesting a mixing of deep thermal water and surface meteoric water. They contain moderate F and high Li and B concentrations with a marked trend of increasing B and Li with increasing Cl (Figs. 9, 10, and 11).

Sr is the most noteworthy trace element in these waters, ranging from 0.4 to 2 mg/ℓ (Table B-III). There is an approximate trend of increasing Sr with increasing Ca. The waters have probably derived most of their Ca and HCO_3 by flow through fractured Paleozoic carbonate rocks and this is probably the main source of Sr.

The D and ^{18}O isotopes fall away from the meteoric line of Craig,[23] showing a distinct trend of ^{18}O enrichment (Fig. 12). Water from Travertine Mound Spring and from the well near main Jemez Spring are isotopically most similar to meteoric water and the main Jemez and Soda Dam Springs show the most relative enrichment in ^{18}O.

These thermal waters are probably derivatives of the deep geothermal fluids beneath Valles Caldera, which are almost pure NaCl waters.[2] Mixing of this hot NaCl water with calcium-bicarbonate meteoric water has cooled it down and diluted it. This mixed water dissolves $CaCO_3$ while flowing southwest through shattered Paleozoic sediments along the Jemez fault zone, giving rise to the higher Ca and HCO_3 contents observed in the springs. This mixing is supported by oxygen isotopes since the deep geothermal water from Valles Caldera is much more enriched in ^{18}O relative to meteoric water.[1]

E. San Ysidro Area

A number of warm springs and hot and cold water wells including mineral and nonmineral waters were sampled in the San Ysidro-Jemez Pueblo area. Many of the samples were collected for isotope analysis up to two years before they were collected for chemical analysis. The chemistry of the waters in this area has been discussed by Goff et al.,[2] Goff and Sayer,[3] Mariner et al.,[26] and Trainer.[5,6]

The waters are low- to moderate-temperature, near-neutral, concentrated (except for dilute surface water) sodium-chloride to sodium-sulfate waters. They contain much more SO_4, Na, and Cl than the thermal waters discharging along the Jemez fault zone (Table B-II) except for Owl Spring, which resembles the surface meteoric calcium-bicarbonate water. The concentrated waters have very high Cl and moderate to high F, B, and Li contents (Figs. 8, 9, 10, and 11). Silica contents are much lower than most other waters described in this report although concentrations of silica increase with temperature (Fig. 7).

Trace element concentrations are low except for Sr, which increases with Ca concentration (Table B-III). Sr contents are much higher than waters from the Jemez fault zone with comparable Ca.

Most of the SO_4 in these waters may be derived from massive gypsum deposits (Jurassic Todilto Formation) near San Ysidro. Most of the springs issue from pre-Jurassic sediments so the SO_4 is probably derived from both pore fluids in the rocks and from downward percolating ground water. Assuming Ca is also derived in part from gypsum, the higher Sr/Ca in these waters compared with the Jemez and Soda Dam Springs may result from greater leaching of Sr from the gypsum than from carbonate.

Several chemical features make these waters distinct from the waters derived from the deep geothermal system in the Valles Caldera.[2] The ratios of Na/Cl and B/Cl in the Jemez Springs waters are 1.3-1.9 and 0.008-0.009, respectively, whereas the same ratios in the San Ysidro waters are 0.8-1.2 and 0.002-0.005, respectively. Li/Na ratios in waters from the Jemez Springs area are in the range 0.012-0.019 compared with 0.002-0.005 for waters from the San Ysidro region. Finally the isotopic enrichment of ^{18}O in San Ysidro waters follows a parallel but different trend (Fig. 12) than deep Caldera waters. All these data indicate that the San Ysidro waters originate from a separate geothermal system near the Nacimiento fault zone rather than the one located beneath Valles Caldera.

V. SUMMARY

The geologic, chemical, and isotopic data presented here are sufficient to characterize the different thermal and nonthermal waters of the Valles Caldera-southern Jemez Mountains region. Further interpretations are beyond the scope of this report. However, the authors feel this data can be applied to the solution of other hydrologic and geochemical problems of the region. Perhaps, the most interesting problem would be to determine the age, geochemical evolution, and hydrologic balance of the high-temperature geothermal system within Valles Caldera.

ACKNOWLEDGMENTS

Many people at Los Alamos have contributed to the collection and analysis of waters listed in this report: Ron Aguilar, Kevin Ferdinand, Jamie Gardner, Kim Kariya, Tino Lucero, Dave Mann, Suzanne Sayer, Bruce Stewart, and Rosemary Vidale. L. Merlivatt, Departement de Recherche et Analyse, Saclay, France, provided the isotope analyses. J. Husler, University of New Mexico, analyzed major elements for samples VA-1 to VA-6 and LA-1 to LA-20. The previous work of Frank Trainer and Bill Purtymun is gratefully acknowledged.

APPENDIX A

UNUSUAL SPRINGS OF VALLES CALDERA AND SOUTHERN JEMEZ MOUNTAINS, NEW MEXICO

I. SULPHUR SPRINGS, VALLES CALDERA

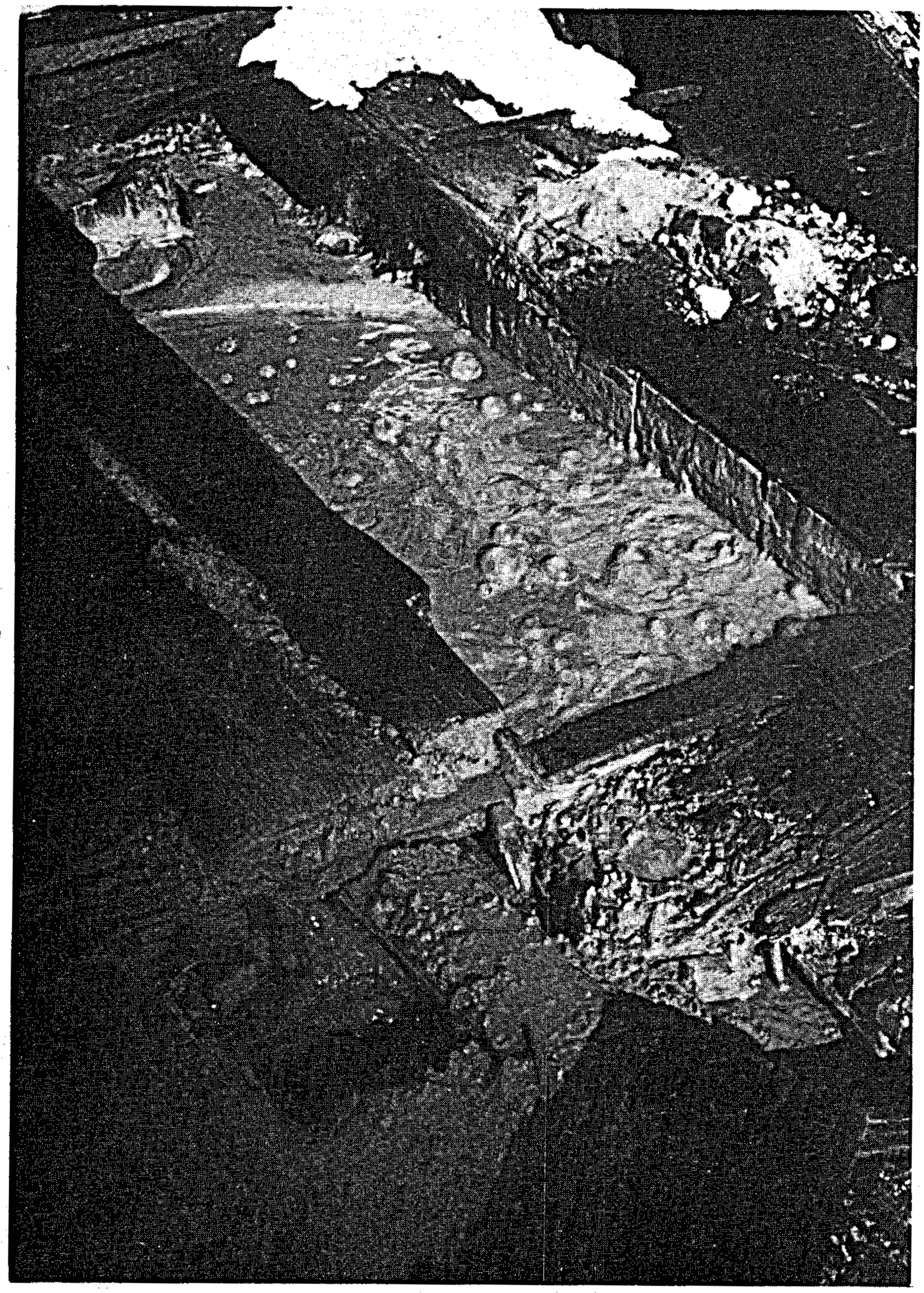


Fig. A-1.
Men's Bathhouse Mudpot in January 1979; pH ≈ 2.0, temperature ≈ 80°C. The bathhouse that is now collapsed once held several concrete pools of acid-sulfate muddy water at various temperatures suitable for bathing. The mudpot occurs on a small knoll from which several fumaroles, 93°C, discharge sulfurous gases.

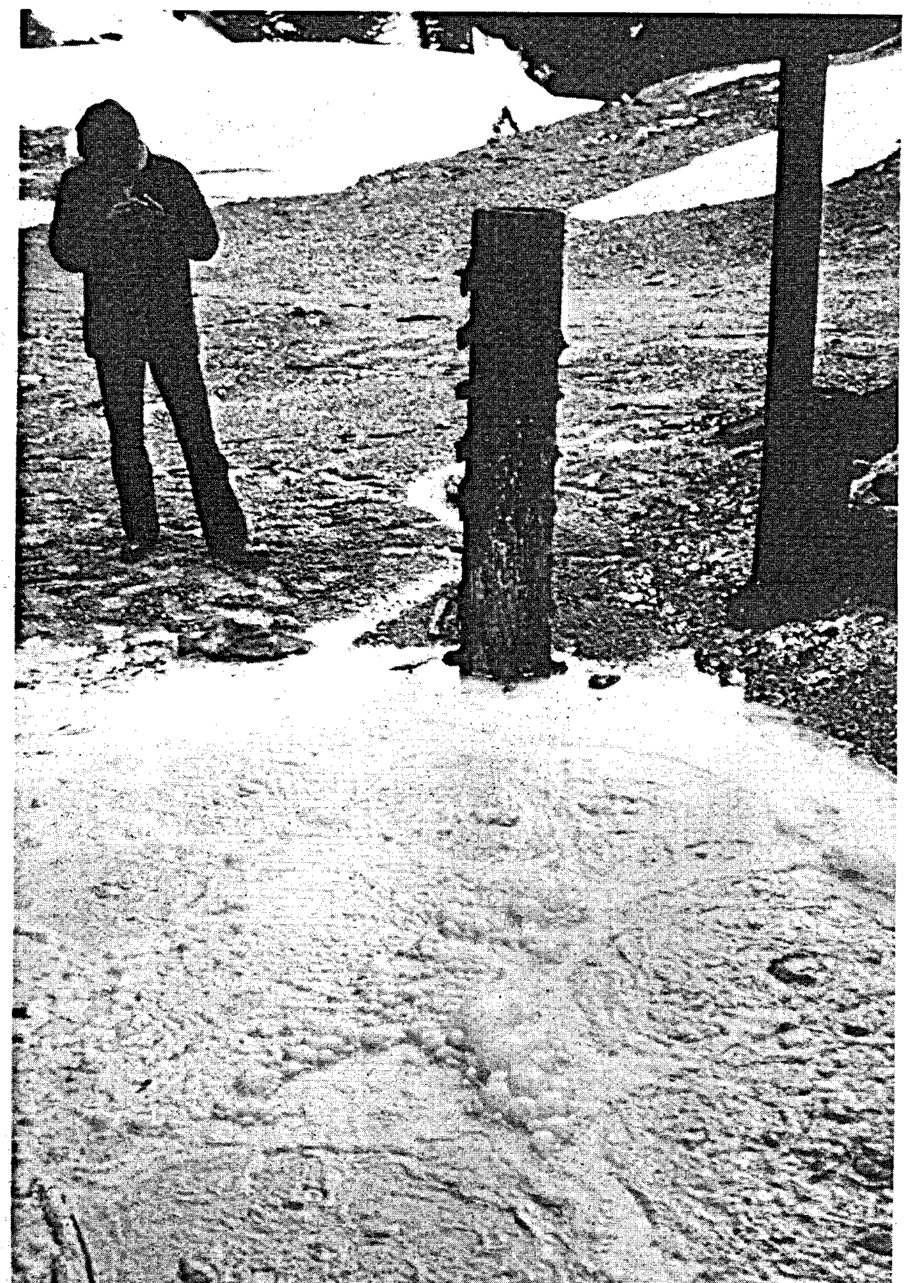


Fig. A-2.
Footbath Spring in March 1980; pH ≃ 1.0, temperature highly variable. The pale yellow color of the suspended mud is due to colloidal sulfur.

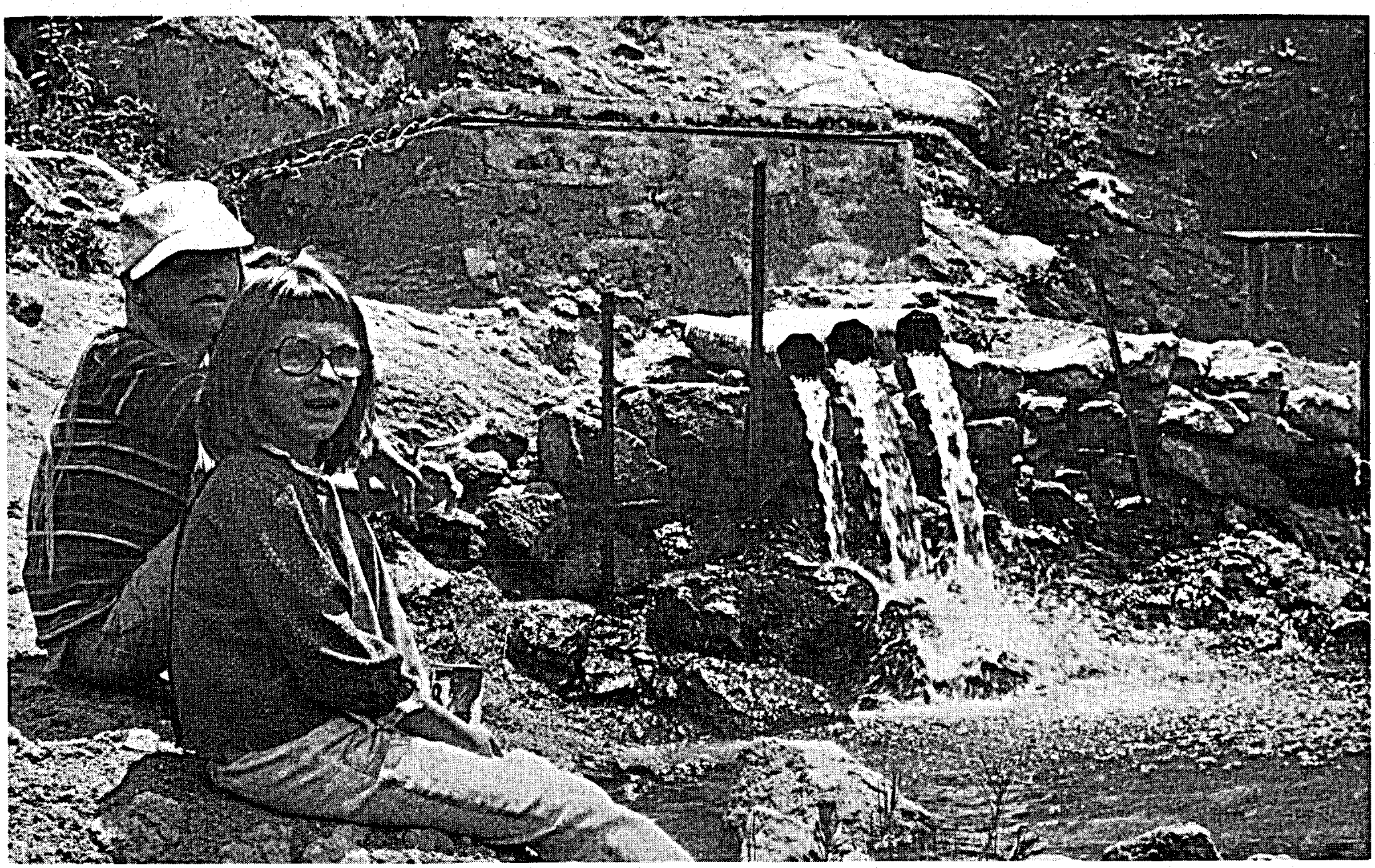


Fig. A-3
San Antonio Hot Spring in July 1978; pH ≈ 7, temperature = 42°C. Spring discharges from concrete crib on fractured rhyolite about 60 m above San Antonio Creek, a favorite destination of cross-country skiers.

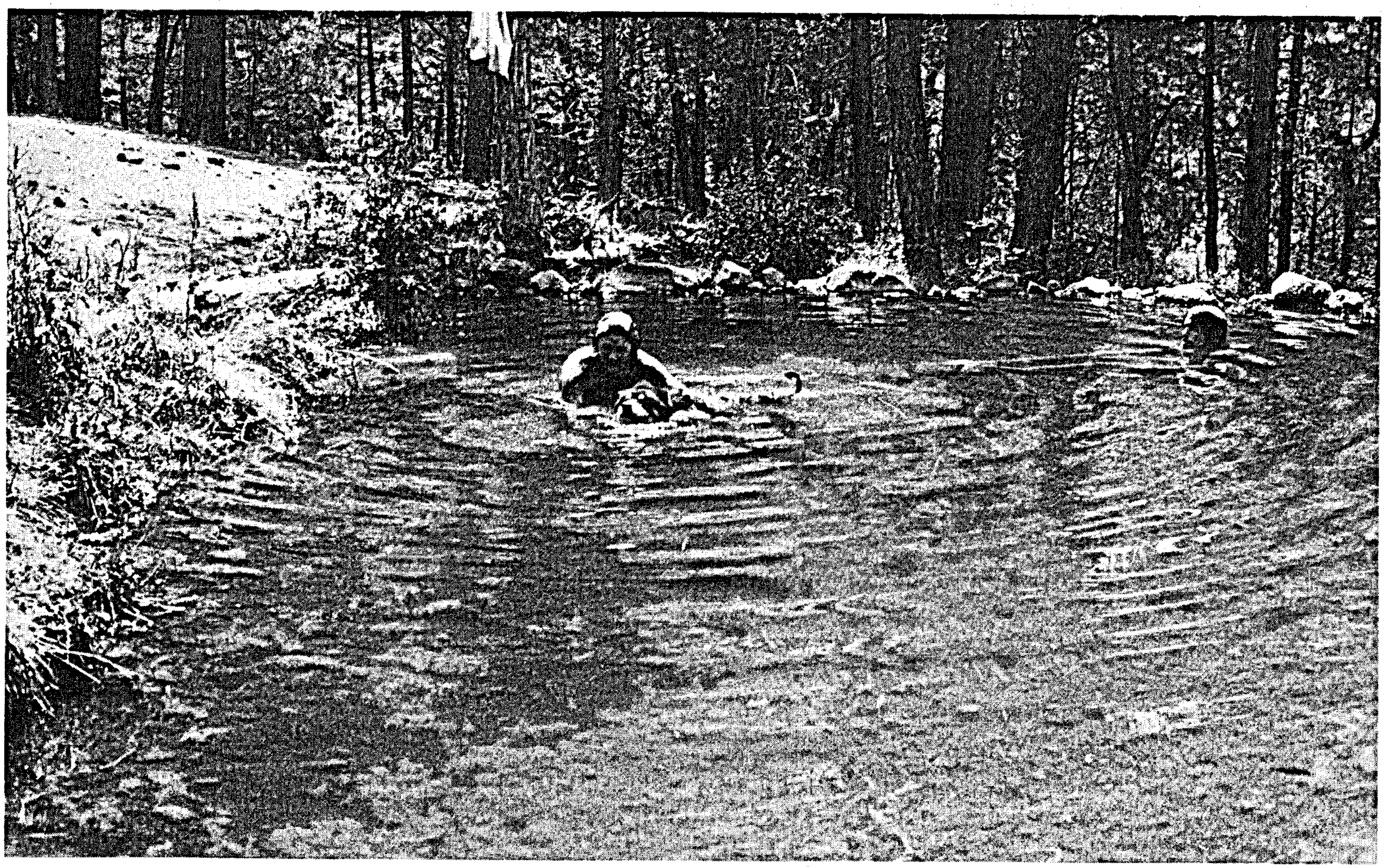


Fig. A-4.
McCauley Spring in July 1978; pH ≃ 6.5, temperature = 31°C. Visitors have built a rock swimming pool about 30 m wide and 1 m deep adjacent to the spring orifice. They have also stocked it with tropical freshwater fish.

III. JEMEZ FAULT ZONE, 10 km SOUTHWEST OF VALLES CALDERA

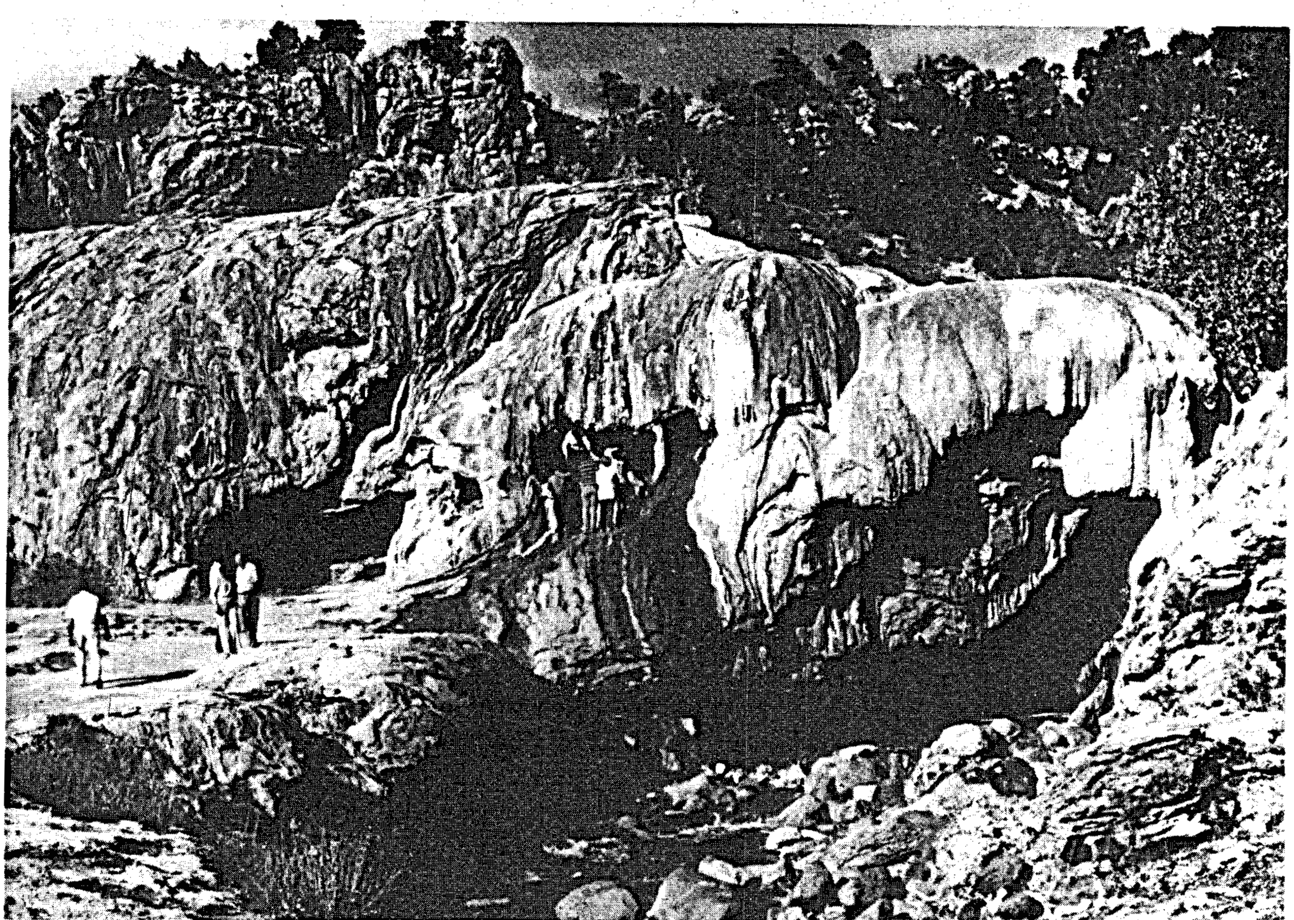


Fig. A-5.
Soda Dam looking north, April 1980. The dam is built of carbonate travertine deposited by bicarbonated hot springs, but construction of the present highway (just to left of photo) ruined the spring system. The existing dam is now disintegrating. Jemez River has undercut dam on right of photo. Sightseers are standing at the entrance to Grotto Spring.

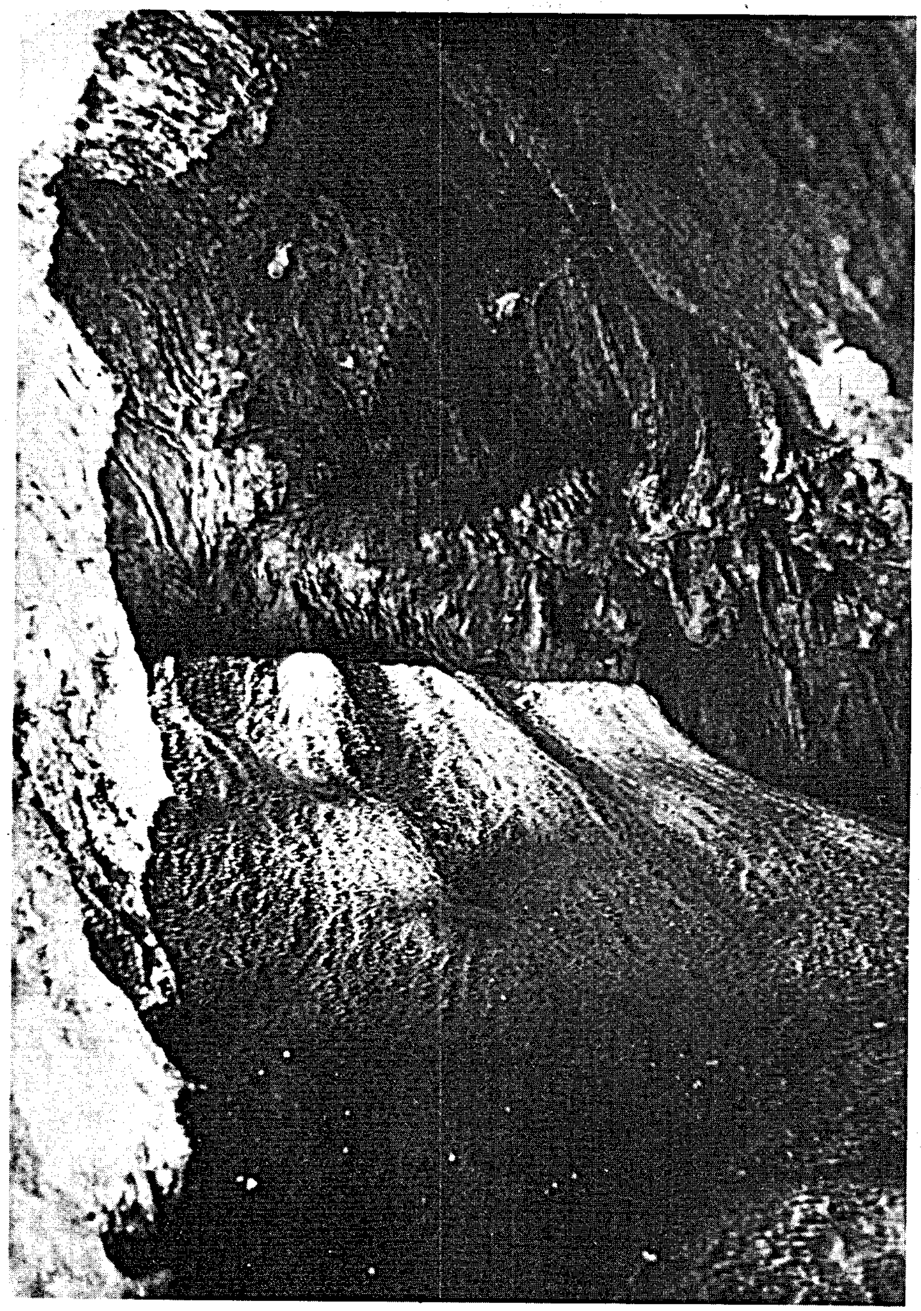


Fig. A-6.
Grotto Spring in October 1980; pH ≈ 7, temperature = 38°C. This spring discharges from cave in Soda Dam shown on previous page. Although cooler in temperature, Grotto Spring has identical chemistry to Soda Dam Spring.

Fig. A-7.
Soda Dam Spring in October 1980; pH ≈ 6.3, temperature = 47°C. Spring issues from shear zone separating granite from vertically faulted sandstone along edge of State Highway 4.

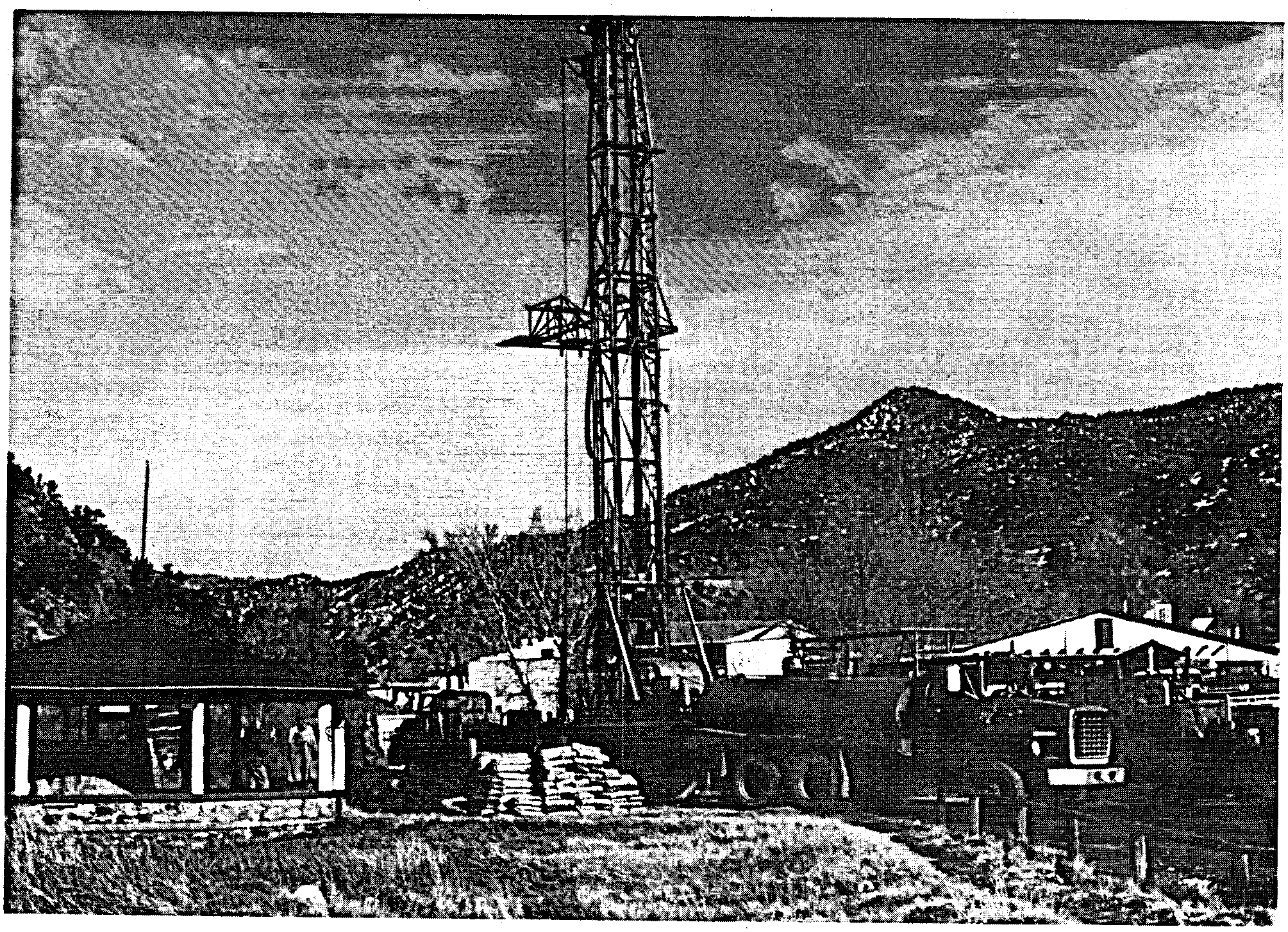


Fig. A-8.
Main Jemez Spring during drilling of Jemez Springs Geothermal Well, January, 1979. The gazebo covers the main spring, really an old shallow well, that supplies water to the bathhouse (behind photographer). The geothermal well struck hottest water, 72°C, at 25-m depth although total depth attained 255 m.

Fig. A-9.
Travertine Mound Spring in January 1979; pH ≈ 6.4, temperature = 72°C. This spring, which discharges between the bathhouse and Jemez River, contains an extremely rare species of algae.

IV. SAN YSIDRO AREA

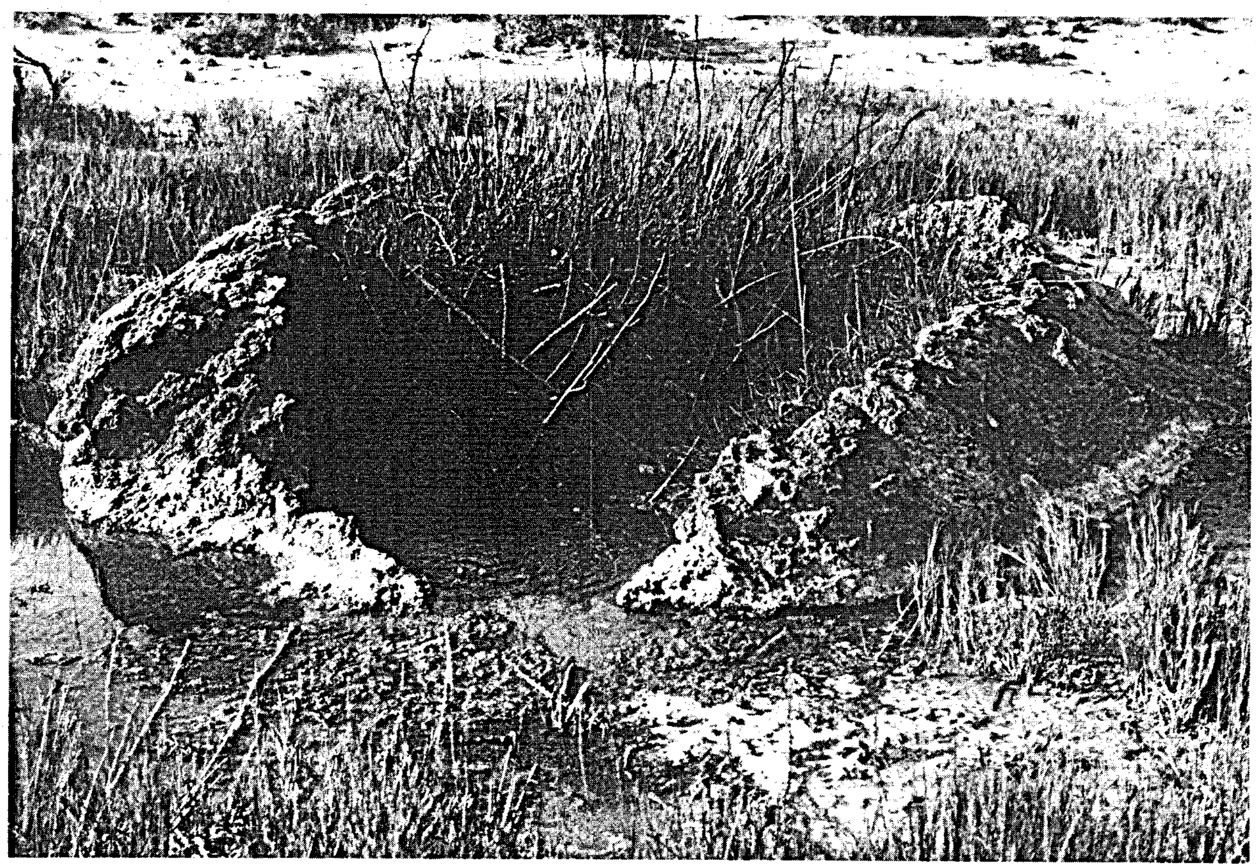


Fig. A-10.
Unnamed Mineral Spring in August 1979; pH ≈ 6.5, temperature ≈ 25°C. Spring discharges about 20 m north of state highway and resembles 4 or 5 others within 200 m. Water is rich in dissolved sulfate that is probably leached from gypsum-bearing rocks nearby.

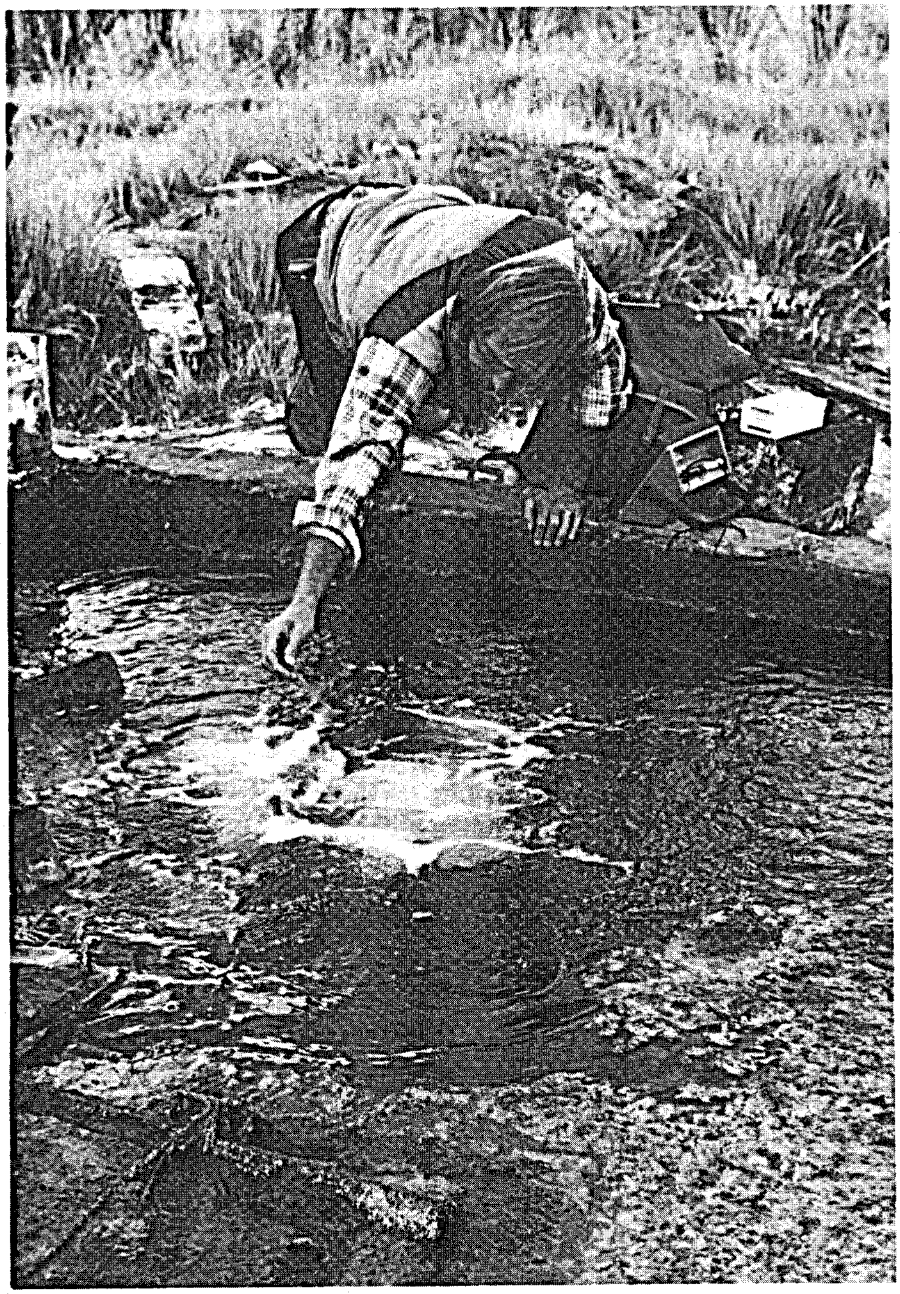


Fig. A-11.
Zia Hot Well (Kaseman #2 Oil Test Well) in April 1980; pH ≈6.5, temperature ≈ 54°C. Well was drilled in 1926 as oil test but struck hot water instead. A hotel which was built adjacent to the well burned down in the 1950's. Now unused, this well could supply substantial geothermal space heat.

APPENDIX B

TABLES OF FIELD, CHEMICAL, AND ISOTOPIC DATA

TABLE B-I
LOCATION, FIELD DATA, AND REFERENCES FOR WATERS IN THE JEMEZ MOUNTAINS REGION, NEW MEXICO

Map No.[a]	Name	Field No.	Date	Location	Water Type[b]	Temp (°C)	Field pH	Flow Rate, ℓ/min	Comments	Reference[c]
Los Alamos Area, Pajarito Plateau										
1	Gallery Spring	LA-1	8/78	SW-1/4, Sec 25, T19N, R5E	m	11	5.6	160	Spring issues from concrete gallery built in fractured Bandelier Tuff.	G-S; G *et al.*; P79; T78 (R5)
2	T-3 Well	LA-2	8/78	SW-1/4, Sec 13, T19N, R6E	m	13	6.5	0-12	Observation Well ~50 m deep, iron casing; in alluvium and Puye(?)Fm.	G-S
3	T-2 Well	LA-3	8/78	NE-1/4, Sec 14, T19N, R6E	m	11	5.7	0-8	Observation Well ~50 m deep, iron casing; in alluvium and Puye(?)Fm.	G-S
4	Sacred Spring	LA-4	8/78	Center, Sec 12, T19N, R7E	m	14	5.7	Seep	Seep discharges from Santa Fe Fm.	G-S; G *et al.*; T78 (T6)
5	Basalt Spring	LA-5	8/78	NW-1/4, Sec 22, T19N, R7E	m	15	5.8	4	Spring flows from near contact of Cerros del Rio basalt and Puye Fm.	G-S; G *et al.*
6	L-6 Well	LA-6	9/78	W-1/2, Sec 14, T19N, R7E	m	27	6.8	0-2160	Water-supply well drilled 625 m into Santa Fe Fm; steel casing.	G-S; Gr; P77; P79
7	L-1B Well	LA-7	9/78	NW-1/4, Sec 13, T19N, R7E	m	30	7.2	0-2180	Water-supply well drilled 694 m into Santa Fe Fm; steel casing.	G-S; P77; P79; P-C
8	L-5 Well	LA-8	9/78	SE-1/4, Sec 15, T19N, R7E	m	26.5	6.5	0-1880	Water-supply well drilled 623 m into Santa Fe Fm; steel casing.	G-S; Gr; P77; P79; P-C
9	L-4 Well	LA-9	9/78	NW-1/4, Sec 22, T19N, R7E	m	28	6.5	0-1560	Water-supply well drilled 622 m into Santa Fe Fm; steel casing.	G-S; Gr; P77; P79
10	PM-2 Well	LA-10	9/78	NW-1/4, Sec 36, T19N, R6E	m	23.5	6.5	0-5520	Well drilled 800 m into Santa Fe Fm; steel casing.	G-S; P79
11	PM-1 Well	LA-11	9/78	SW-1/4, Sec 20, T19N, R7E	m	28	6.5	0-2320	Well drilled 770 m into Santa Fe Fm; steel casing.	G-S; P79
12	G-6 Well	LA-12	9/78	NE-1/4, Sec 6, T19N, R7E	m	30.5	6.5	0-1100	Water-supply well drilled 617 m into Santa Fe Fm; steel casing.	G-S; P79
13	G-5 Well	LA-13	9/78	NW-1/4, Sec 5, T19N, R7E	m	26.5	6.5	0-2100	Water-supply well drilled 614 m into Santa Fe Fm; steel casing.	G-S; Gr; P79; P-C
14	G-4 Well	LA-14	9/78	Center, Sec 5, T19N, R7E	m	26	6.5	0-1260	Water-supply well drilled 616 m into Santa Fe Fm; steel casing.	G-S; Gr; P79
15	G-3 Well	LA-15	9/78	NW-1/4, Sec 4, T19N, R7E	m	29	6.5	0-1620	Water-supply well drilled 614 m into Santa Fe Fm; steel casing.	G-S; Gr; P79

TABLE B-I (cont)

Map No.[a]	Name	Field No.	Date	Location	Water Type[b]	Temp (°C)	Field pH	Flow Rate, ℓ/min	Comments	Reference[c]
16	G-2 Well	LA-16	9/78	Center Sec 4, T19N,R7E	m	30	6.5	0-1820	Water-supply well drilled 617 m into Santa Fe Fm; steel casing.	G-S; Gr; P79
17	G-1A Well	LA-17	9/78	SE-1/4 Sec 4, T19N, R7E	m	28	6.5	0-2060	Water-supply well drilled 637 m into Santa Fe Fm; steel casing.	G-S; P79
18	G-1 Well	LA-18	9/78	SE-1/4, Sec 4, T19N, R7E	m	26	6.5	0-1340	Water-supply well drilled 646 m into Santa Fe Fm; steel casing.	G-S; Gr; P79; P-C
19	Spring, White Rock Canyon	LA-19	9/78	NE-1/4, Sec 36, T18N, R6E	m	19	6.5	6	Spring issues from Santa Fe Fm; covered by volcanic colluvium.	G-S; G <u>et al</u>.; T78 (K10)
20	PM-3 Well	LA-20	9/78	W-1/2, Sec 19, T19N, R7E	m	27.5	6.5	0-5600	Well drilled 786 m into Santa Fe Fm; steel casing.	G-S; P79
<u>Valles Caldera, Sulphur Springs Area</u>										
21	Mudpot, Men's Bathhouse	VA-13	1/79	Lat. 35°54', Long.106°37' (Fig. 3)	a	78	2.52	0	Mudpot in concrete crib in collapsed bathhouse; from landslide in rhyolite; $CO_2\uparrow$, $H_2S\uparrow$.	G-G; S; R; T78 (P2)
21	Mudpot, Men's Bathhouse	S-7-80	9/80	Lat. 35°54', Long. 106°37' (Fig. 3)	a	82	2.0	0	Mudpot in concrete crib in collapsed bathhouse; from landslide in rhyolite; $CO_2\uparrow$, $H_2S\uparrow$.	
21	Unnamed Hot Spring	VA-14	1/79	Lat. 35°54', Long.106°37' (Fig. 3)	a	63	2.38	2	Spring issues from alluvium; $CO_2\uparrow$, $H_2S\uparrow$.	G-G
21	Unnamed Hot Spring	S-9-80	9/80	Lat. 35°34' Long. 106°37' (Fig. 3)	a	--	2.03	1	Spring issues from alluvium; $CO_2\uparrow$, $H_2S\uparrow$.	
21	Lemonade Spring	S-10-80	9/80	Lat. 35°54', Long.106°37' (Fig. 3)	a	58	2.3	1/2	Spring issues from alluvium; $CO_2\uparrow$, $H_2S\uparrow$.	S, T78 (P1)
21	Unnamed Spring	S-3-80	9/80	Lat. 35°54', Long.106°37' (Fig. 3)	cm	11	3.6	1/4	Spring discharges into Sulphur Creek; $CO_2\uparrow$, $H_2S\uparrow$.	
21	Footbath Spring	S-4-80	9/80	Lat. 35°54', Long.106°37' (Fig. 3)	a	33	1.1	0	Large bubbling pool with colloidal sulfer; $CO_2\uparrow$, $H_2S\uparrow$.	S
21	Electric Spring	S-5-80	9/80	Lat. 35°54', Long.106°37' (Fig. 3)	a	36	1.5	1/2	Spring flows from alluvium; $CO_2\uparrow$, $H_2S\uparrow$.	S

TABLE B-I (cont)

Map No.[a]	Name	Field No.	Date	Location	Water Type[b]	Temp (°C)	Field pH	Flow Rate, ℓ/min	Comments	Reference[c]
21	Women's Bathhouse	S-6-80	9/80	Lat. 35°54', Long.106°37' (Fig. 3)	a	90	1.4	1/4	Spring issues from landslide; CO_2↑, H_2S↑.	S; T78 (P3)
22	Spring, Alamo Canyon	S-1-80	9/80	Lat. 35°55', Long. 106°36'	cm	11	4.2	0	Gaseous springs in alluvium and creek bed; CO_2↑, H_2S↑.	S
22	Creek, Alamo Canyon	S-2-80	9/80	Lat. 35°55', Long. 106°36'	cm	11	3.1	4	Creek sampled 5 m upstream of S-1-80.	
23	Bubbling Pool	VA-22	3/79	Lat. 35°55', Long. 106°35.5'	cm	0.5	4.5	8	Large bubbling pond 1/2 km east of S-1-80; CO_2↑, H_2S↑.	G-G; T78 (P19)
22	Bubbling Seep	VA-23	3/79	Lat. 35°55', Long. 106°35.5'	cm	7	5.2	1	Bubbling seep 30 m north of S-1-80; from alluvium; CO_2↑, H_2S↑.	G-G
24	Spring, Short Canyon	S-8-80	9/80	Lat. 35°54.5', Long. 106°36'	cm	8	4.1	1	Gaseous spring issues from alluvium; CO_2↑, H_2S↑.	
Valles Caldera, Thermal Meteoric (Ring Fracture Zone)										
25	Spence Hot Spring	VA-1	7/78	W-1/2, Sec 28, T19N, R3E	tm	45	6.7	60	Spring issues from rhyolite talus near contact with Abo Formation.	G-G; G-S; P-W-A; S; T74; T75; T78 (H42)
25	Little Spence Hot Spring	VA-2	7/78	W-1/2, Sec 28, T19N, R3E	tm	34	6.7	20	Spring issues from rhyolite talus near contact with Abo Formation.	G-S
26	McCauley Spring	VA-3	7/78	W-1/2, Sec 4, T18N, R3E	tm	31	6.2	140	Spring flows from contact of rhyolite and Abo Formation.	G-S; P-W-A; S; T78 (H39)
27	San Antonio Hot Spring	VA-4	7/78	NW-1/4, Sec 29, T20N, R3E	tm	42	6.8	150	Spring discharges from concrete crib on fractured rhyolite.	G-G; G-S; P-W-A; S; T75; T78 (P12)
28	Bathhouse Spring	VA-20	2/79	Lat. 35°58', Long. 106°33.5'	tm	38	6.1	12	Spring issues from south base of small rhyolite dome; covered by wood bathhouse.	T78 (P9)
Valles Caldera, Soda Dam and Jemez Springs (Jemez Fault Zone)										
29	Soda Dam Spring	VA-6	7/78	Lat. 35°47.5', Long. 106°41' (Fig. 4)	d	47	6.2	60	Main Spring; discharges from faulted Paleozoic sediments in Jemez fault zone; CO_2↑, H_2S↑.	G-G; G *et al.*; G-S; P-W-A; S; T74; T75; T-78 (H6)

TABLE B-I (cont)

Map No.[a]	Name	Field No.	Date	Location	Water Type[b]	Temp (°C)	Field pH	Flow Rate, ℓ/min	Comments	Reference[c]
29	Soda Dam Spring	VA-9	1/79	Lat. 35°47.5', Long. 106°41' (Fig. 4)	d	48	6.40	60	Main Spring; discharges from faulted Paleozoic sediments in Jemez fault zone; $CO_2\uparrow$, $H_2S\uparrow$.	
29	Soda Dam Spring	VA-64	12/80	Lat. 35°47.5', Long. 106°41' (Fig. 4)	d	47	6.28	60	Main Spring; discharges from faulted Paleozoic sediments in Jemez fault zone; $CO_2\uparrow$, $H_2S\uparrow$.	
29	Soda Dam Spring	VA-26	5/79	Lat. 35°47.5', Long. 106°41' (Fig. 4)	d	47	6.52	60	Main Spring; discharges from faulted Paleozoic sediments in Jemez fault zone; $CO_2\uparrow$, $H_2S\uparrow$.	
29	Soda Dam Spring	VA-51	4/80	Lat. 35°47.5', Long. 106°41' (Fig. 4)	d	47	6.35	60	Main Spring; discharges from faulted Paleozoic sediments in Jemez fault zone; $CO_2\uparrow$, $H_2S\uparrow$.	
29	Grotto Spring	VA-5	7/78	Lat. 35°47.5', Long. 106°41' (Fig. 4)	d	38	6.8	12	Spring flows from cave on east side Soda Dam.	G-S
29	Outfall of Soda Dam Spring	VA-65	12/80	Lat. 35°47.5', Long. 106°41' (Fig. 4)	d	17	8.13	60	Sampled at point where water of Soda Dam Spring enters Jemez River.	
29	Unnamed Spring	VA-27	5/79	Lat. 35°47.5', Long. 106°41' (Fig. 4)	d	29	6.28	2	Spring issues from alluvium east side Jemez River.	
30	Main Jemez Spring	VA-10	1/79	Lat. 35°46.5', Long. 106°41' (Fig. 5)	d	55	7.01	20	Spring discharges from concrete tank under gazebo; $CO_2\uparrow$.	G-G; G *et al.*; T75; T78 (H15)
30	Main Jemez Spring	VA-18	1/79	Lat. 35°46.5', Long. 106°41' (Fig. 5)	d	36	7.51	0	Spring discharges from concrete tank under gazebo; $CO_2\uparrow$.	G *et al.*
30	Travertine Mound Spring	VA-7	1/79	Lat. 35°46.5', Long. 106°41' (Fig. 5)	d	70	6.28	4	Spring issues from travertine mound west of bathhouse; $CO_2\uparrow$.	G *et al.*; T74; T78 (H14)
30	Travertine Mound Spring	VA-66	12/80	Lat. 35°46.5', Long. 106°41' (Fig. 5)	d	72	6.23	4	Spring issues from travertine mound west of bathhouse; $CO_2\uparrow$.	G *et al.*
30	Travertine Mound Spring	VA-17	1/79	Lat. 35°46.5', Long. 106°41' (Fig. 5)	d	72	6.66	4	Spring issues from travertine mound west of bathhouse; $CO_2\uparrow$.	G *et al.*
30	Buddhist Spring	VA-8	1/79	Lat. 35°46.5', Long. 106°41' (Fig. 5)	d	49	6.38	4	Spring flows from man-made pool by Jemez River; $CO_2\uparrow$.	G *et al.*

TABLE B-I (cont)

Map No.[a]	Name	Field No.	Date	Location	Water Type[b]	Temp (°C)	Field pH	Flow Rate, ℓ/min	Comments	Reference[c]
30	Buddhist Spring	VA-16	1/79	Lat. 35°46.5', Long. 106°41'	d	50	6.59	4	Spring flows from man-made pool by Jemez River; CO_2↑.	
30	Unnamed Spring	VA-12	1/79	Lat. 35°46.5', Long. 106°41'	d	49	6.35	4	Spring discharged from marsh 15 m NW of main Jemez Spring; CO_2↑ (now destroyed).	
30	80 ft Aquifer	VA-19	1/79	Lat. 35°46.5', Long. 106°41'	d	68	6.64	120	Well drilled N of main Jemez Spring	G *et al.*
30	80 ft Aquifer	VA-25	5/79	Lat. 35°46.5', Long. 106°41'	d	73.3	6.55	8	Well drilled N of main Jemez Spring	
30	500 ft Aquifer	VA-15	1/79	Lat. 35°46.5', Long. 106°41'	d	60.5	6.69	80	Well drilled N of main Jemez Spring	G *et al.*
30	500 ft Aquifer	VA-21	2/79	Lat. 35°46.5', Long. 106°41'	d	61	6.55	20	Well drilled N of main Jemez Spring	
Valles Caldera Region, Miscellaneous										
28	San Antonio Creek	VA-24	2/79	Lat. 35°58', Long. 106°33.5'	m	2	--	>250	Creek sampled 5 m upstream of VA-20, Bathhouse Spring.	
31	Panorama Spring	VA-28	5/79	Lat. 35°48', Long. 106°41'	m	13	7.67	4	Spring issues from travertine and Madera limestone, 100 m above canyon-floor.	
32	Pajarito Spring	VA-29	7/79	SE-1/4, Sec 9, T18N, R7E	m	20	5.9	>300	Spring issues from landslide in basalt; spring 4A of Purtymun.	P-P-O; T78 (K4)
33	Spring, White Rock Canyon	VA-30	7/79	W-1/2, Sec 10, T18N, R7E	m	18	6.0	1	Spring issues from alluvium west of Rio Grande; spring 4 of Purtymun.	P-P-O; T78 (K5)
34	Cold Mineral Seep	VA-31	8/79	SW-1/4, Sec 32, T19N, R3E	m	19	8.37	1	Seep about 1/4 km WNW of Battleship Rock and just W highway 4; from Madera limestone.	
35	Sino Spring	VA-32	8/79	Lat. 35°49', Long. 106°41'	m	21	7.45	15	Spring flows from contact of andesite and Abo Formation.	P-W-A; T78 (H1)
35	Sino Spring	VA-63	12/80	Lat. 35°49', Long. 106°41'	m	18	7.10	80	Spring flows from contact of andesite and Abo Formation.	
36[d]	Unnamed Spring	VA-39	3/81	SE-1/4, Sec 10, T16N, R2E	c	11	6.91	seep	Spring discharges from Chinle Fm. near contact w/overlying Zia SS; tastes salty.	T78 (E1)

TABLE B-I (cont)

Map No.[a]	Name	Field No.	Date	Location	Water Type[b]	Temp (°C)	Field pH	Flow Rate, ℓ/min	Comments	Reference[c]
37[d]	Canon Spring	VA-40	4/81	Lat. 35°40.5', Long. 106°45.5'	m	18	7.58	1	Spring issues from fault in Precambrian granite.	T78 (D6)
38[d]	Indian Valley Well	VA-41	10/79	SE-1/4, Sec 11, T18N, R3E	m	17.5	6.81	0	Well drilled 60+ m in alluvium and pumice; iron casing.	
39[d]	Unnamed Cold Spring	VA-42	10/79	Lat. 35°51.5', Long. 106°27'	m	15	7.20	30	Spring issues from rhyolite colluvium; elev. = 8606 ft.	
40[d]	Unnamed Cold Spring	VA-43	10/79	SW-1/4, Sec 10, T18N, R4E	m	15	6.68	8	Spring flows from dacite colluvium; elev. = 9100 ft.	
41[d]	Unnamed Cold Spring	VA-44	10/79	E-1/2, Sec 22, T18N, R3E	m	8	6.91	2	Spring discharges from rock crib on andesite alluvium by dirt road.	T78 (J2)
42[d]	Horseshoe Spring	VA-45	10/79	E-1/2, Sec 18, T19N, R3E	m	12	6.89	12	Spring issues from rhyolite alluvium.	P-W-A; T78 (N15)
43[d]	Unnamed Cold Spring	VA-46	10/79	Lat. 35°52.5', Long. 106°44.5'	m	10	6.42	40	Spring flows from contact of Bandelier Tuff and Abo Formation; sampled from iron pipe.	T78 (N6)
44[d]	Unnamed Cold Spring	VA-47	10/79	NE-1/4, Sec 27, T20N, R2E	m	10	6.48	60	Spring discharges from fractured Bandelier Tuff.	T78 (N10)
45	Unnamed Cold Spring	VA-48	6/80	Lat. 35°45', Long. 106°28'	m	9	5.6	12	Spring issues from gully 1/2 km east of Albemarle ruins; from hypabyssal volcanics.	
46	Eddy's Well	VA-49	6/80	Center, Sec 16, T19N, R3E	m	15	7.24	0-20	Well 40+ m deep in alluvium and pumice.	
34	Cold Mineral Seep	VA-50	4/80	SW-1/4, Sec 32, T19N, R3E	m	11	7.92	1	Seep about 1/4 km WNW Battleship Rock and just W Highway 4; from Madera limestone.	
29	Jemez River	VA-52	4/80	Lat. 35°47.5', Long. 106°41'	m	5	5.30	>>500	River sampled 10 m upstream of Soda Dam travertine deposit; high water.	P-W-A; T78
48	Unnamed Cold Spring	VA-54	6/80	N-1/2, Sec 13, T18N, R4E	m	11	5.4	20	Spring issues from alluvium in Canon del Norte.	
49	Unnamed Cold Spring	VA-55	6/80	Lat. 35°51', Long. 106°25.5'	m	8.5	5.4	20	Spring issues from contact of latite and Bandelier Tuff.	
50	Unnamed Cold Spring	VA-56	6/80	Lat. 35°50', Long. 106°24.5'	m	6.5	5.4	24	Spring discharges from contact of latite and Bandelier Tuff.	

TABLE B-I (cont)

Map No.[a]	Name	Field No.	Date	Location	Water Type[b]	Temp (°C)	Field pH	Flow Rate, ℓ/min	Comments	Reference[c]
51	Apache Spring	VA-57	7/80	Lat. 35°49', Long. 106°23.5'	m	9	5.3	15	Spring discharges from contact of latite and Bandelier Tuff.	
52	Unnamed Cold Spring	VA-58	7/80	Lat. 35°48', Long. 106°20'	m	15	5.4	12	Spring flows from fractured Bandelier Tuff.	
53	Unnamed Cold Spring	VA-59	7/80	Lat. 35°48', Long. 106°20'	m	17	5.6	24	Spring issues from fractured Bandelier Tuff.	
54	Turkey Springs	VA-60	7/80	Lat. 35°44.5', Long. 106°21.5'	m	18	5.5	60	Spring flows from volcanic alluvium.	
46	Henson's Well	VA-61	12/80	Center Sec 16, T19N, R3E	m	19	6.82	0-40	Well drilled 65 m into caldera fill; plastic pipe.	
<u>San Ysidro - Jemez Pueblo Area, Miscellaneous</u>										
55	Warm Mineral Spring	VA-33	8/79	NW-1/4, Sec 10, T15N, R1E	c	27	6.57	1	Spring seeps from travertine mound N of highway 44; Chinle Fm; CO_2↑.	T74 ( ); T78 ( ); M
56	Zia Hot Well	VA-34	8/79	Lat. 35°39', Long. 106°53'	c	56	6.29	40	Artesian well flows from concrete crib E of highway 44; Chinle Fm; CO_2↑.	T74; T78 (C3)
56	Zia Hot Well	VA-52	4/80	Lat. 35°39', Long. 106°53'	c	54	6.53	40	Artesian well flows from concrete crib E of highway 44; Chinle Fm; CO_2↑.	
56	Zia Hot Well	VA-67	3/81	Lat. 35°39', Long. 106°53'	c	53	6.72	40	Artesian well flows from concrete crib E of highway 44; Chinle Fm CO_2↑.	
57[d]	Unnamed Well	VA-35	8/79	Lat. 35°42.5', Long. 106°59.5'	m	21	--	1/2	Well drains into cattle trough above San Luis Tank; Morrison Fm(?).	
58[d]	Salt Spring	VA-36	3/81	SW-1/4, Sec 20, T16N, R2E	c	15.5	7.90	1/2	Spring seeps from Chinle Fm and Tertiary gravels.	T78 (A10)
59[d]	Log Spring	VA-37	8/79	E-1/2, Sec 5, T16N, R1E	m	28.5	--	<1	Spring seeps from fault zone near contact of limestone and granite.	T78 (D4)
60[d]	Owl Spring	VA-38	3/81	SE-1/4, Sec 7, T16N, R2E	m	16	7.22	25	Spring flows from Madera limestone.	P-W-A; T78 (A8)

a Location no. on Fig. 2.

TABLE B-I (cont)

b m surface meteoric
cm carbonated meteoric
a acid-sulphate
tm thermal meteoric
d deep geothermal + derivative
c connate

c G-G: Goff and Grigsby[1]
G *et al.*: Goff *et al.*[2]
G-S: Goff and Sayer[3]
Gr: Griggs[14]
M: Mariner *et al.*[26]
P77: Purtymun[11]
P79: Purtymun[27]
P-C: Purtymun and Cooper[28]
P-P-O: Purtymun *et al.*[10]
P-W-A: Purtymun *et al.*[9]
S: Summers[24]
T-74: Trainer[5]
T-75: Trainer[6]
T-78: Trainer[29]; Trainer's sample no. given in parentheses.

d Water samples collected for isotopes and for chemical analysis at different times.

TABLE B-II
MAJOR ELEMENT ANALYSES FOR WATERS IN THE JEMEZ MOUNTAINS REGION, NEW MEXICO (VALUES IN mg/ℓ)

Map No.	Name	Field No.	Temp. °C	Field pH	Conductivity μmhos/cm	SiO_2	Al	Fe	Mn	Ca	Mg	Na	K	Li	HCO_3	SO_4	Cl	F	B
Los Alamos Area, Pajarito Plateau																			
1	Gallery Spring	LA-1	11	5.6	--	43	--	<0.04	<0.02	7.0	3.3	5.8	1.4	0.02	52	<5	<1	0.12	<0.05
2	T-3 Well	LA-2	13	6.5	--	15	--	0.53	0.11	14.0	5.0	11.0	1.9	0.03	102	5	4	0.26	<0.05
3	T-2 Well	LA-3	11	5.7	--	5	--	<0.04	<0.02	11.0	2.7	8.8	0.88	0.03	78	5	2	0.46	<0.05
4	Sacred Spring	LA-4	14	5.7	--	34	--	<0.04	<0.02	22	0.45	20	2.5	0.04	114	7	2	0.46	<0.05
5	Basalt Spring	LA-5	15	5.8	--	44	--	<0.04	<0.02	26	7.6	12	3.1	0.03	98	18	12	0.32	<0.05
6	L-6 Well	LA-6	27	6.8	--	33	--	<0.04	<0.02	2.8	0.15	72	0.8	0.04	170	6	4	2.2	<0.05
7	L-1B Well	LA-7	30	7.2	--	36	--	<0.04	<0.02	6.5	0.30	138	2.0	0.11	326	32	15	2.3	0.45
8	L-5 Well	LA-8	26.5	6.5	--	40	--	<0.04	<0.02	7.2	0.13	52	1.3	0.04	143	6	3	0.98	<0.05
9	L-4 Well	LA-9	28	6.5	--	39	--	<0.04	<0.02	10	0.22	21	1.7	0.03	85	5	4	0.33	0.38
10	PM-2 Well	LA-10	23.5	6.5	--	83	--	<0.04	<0.02	8.8	3.0	9.6	1.7	0.02	65	<5	3	0.19	0.25
11	PM-1 Well	LA-11	28	6.5	--	82	--	<0.04	<0.02	26	6.8	18	3.6	0.03	146	6	6	0.26	0.25
12	G-6 Well	LA-12	30.5	6.5	--	55	--	<0.04	<0.02	15	2.3	15	2.0	<0.02	94	5	2	0.27	<0.05
13	G-5 Well	LA-13	26.5	6.5	--	59	--	<0.04	<0.02	17	3.9	11	1.8	<0.02	93	5	2	0.25	0.12
14	G-4 Well	LA-14	26	6.5	--	53	--	<0.04	<0.02	16	2.5	14	1.8	<0.02	92	5	2	0.27	0.12
15	G-3 Well	LA-15	29	6.5	--	59	--	<0.04	<0.02	11	1.2	22	1.6	<0.02	93	5	2	0.45	<0.05
16	G-2 Well	LA-16	30	6.5	--	77	--	<0.04	<0.02	11	0.61	33	2.5	0.02	122	5	4	1.0	0.12
17	G-1A Well	LA-17	28	6.5	--	78	--	<0.04	<0.02	11	0.58	24	2.8	<0.02	100	5	1	0.55	<0.05
18	G-1 Well	LA-18	26	6.5	--	84	--	<0.04	<0.02	13	0.68	22	3.1	<0.02	97	5	1	0.50	<0.05
19	Spring, White Rock Canyon	LA-19	19	6.5	--	71	--	<0.04	<0.02	12	3.1	11	1.4	0.03	74	<5	<1	0.45	<0.05
20	PM-3 Well	LA-20	27.5	6.5	--	91	--	<0.04	<0.02	26	8.7	16	3.3	0.04	146	6	12	0.28	0.18

TABLE B-II (cont)

Map No.	Name	Field No.	Temp. °C	Field pH	Conductivity μmhos/cm	SiO_2	Al	Fe	Mn	Ca	Mg	Na	K	Li	HCO_3	SO_4	Cl	F	B
Valles Caldera, Sulphur Springs Area																			
21	Mudpot, Men's Bathhouse	VA-13	78	2.52	4050	103	--	13	0.01	2.1	1.25	2.1	8.2	0.02	0	786	2.48	6.36	<0.1
21	Mudpot, Men's Bathhouse	S-7-80	82	2.00	10300	246	--	37	0.64	10	6.5	6.0	35	0.04	0	2500	<1	<0.20	0.1
21	Unnamed Hot Spg.	VA-14	63	2.38	5800	230	3.17	18.1	11.7	90.8	16.2	14.6	18.7	0.05	0	2110	3.72	0.61	<0.1
21	Unnamed Hot Spg.	S-9-80	--	2.03	5700	243	--	38	3.20	165	40.0	16.4	6.4	0.09	0	1750	8.3	1.75	<0.03
21	Lemonade Spring	S-10-80	58	2.30	--	238	--	38	3.76	168	42	7.7	5.6	0.14	0	2740	17	0.52	0.03
21	Unnamed Spring	S-3-80	11	3.60	1910	59	--	16.2	2.84	280	33	25	27	0.29	0	1500	20	0.70	0.2
21	Footbath Spring	S-4-80	33	1.10	30200	214	--	468	4.65	56	26.5	10.8	94	0.10	0	7900	<1	10.6	0.2
21	Electric Spring	S-5-80	36	1.50	12800	228	--	127	2.40	114	23.0	8.5	66	0.06	0	4100	<1	5.2	<0.1
21	Women's Bathhouse	S-6-80	90	1.40	13400	168	--	190	8.10	131	50.0	18.9	72	0.17	0	6400	<1	5.2	0.2
22	Spring, Alamo Canyon	S-1-80	11	4.20	430	53	--	16.3	0.44	15.2	2.49	13.0	6.2	0.06	0	113	11	0.52	<0.1
22	Creek, Alamo Canyon	S-2-80	11	3.10	340	41	--	1.1	0.35	12.8	2.29	14.1	6.3	0.06	0	101	13	<0.20	<0.1
23	Bubbling Pool	VA-22	0.5	4.5	280	44	--	1.37	0.30	14.1	2.75	5.8	4.5	0.4	0	109	4.9	0.23	<0.1
22	Bubbling Seep	VA-23	7	5.2	730	51	--	0.28	0.96	83.5	12.0	32.8	7.9	0.08	178	254	7.2	0.23	<0.1
24	Spring, Short Canyon	S-8-80	8	4.10	500	55	--	5.5	0.54	43	5.9	7.8	7.3	0.02	0	199	5.9	<0.20	<0.1
Valles Caldera, Thermal Meteoric (Ring Fracture Zone)																			
25	Spence Hot Spring	VA-1	45	6.7	--	66	--	<0.04	<0.02	5.5	1.9	50	1.3	0.66	144	16	8	0.55	0.15
25	Little Spence Hot Spring	VA-2	34	6.7	--	67	--	<0.04	<0.02	8.8	1.9	56	1.5	0.66	152	25	7	0.70	0.13
26	McCauley Spring	VA-3	31	6.2	--	56	--	<0.04	<0.02	8.5	4.9	18	0.8	0.24	86	7	6	0.85	0.24
27	San Antonio Hot Spring	VA-4	42	6.8	--	79	--	<0.04	0.02	2.3	0.30	21	1.7	<0.02	56	7	2	0.80	<0.05
28	Bathhouse Spring	VA-20	38	6.1	163	96	0.041	<0.08	<0.04	4.98	0.40	24.5	3.7	0.06	71	15	2.4	1.6	<0.1

TABLE B-II (cont)

Map No.	Name	Field No.	Temp. °C	Field pH	Conductivity µmhos/cm	SiO_2	Al	Fe	Mn	Ca	Mg	Na	K	Li	HCO_3	SO_4	Cl	F	B
Valles Caldera, Soda Dam and Jemez Springs (Jemez Fault Zone)																			
29	Soda Dam Spring	VA-6	47	6.2	--	43	--	0.11	0.55	328	26	1010	174	13.2	886	37	1480	4.1	11.5
29	Soda Dam Spring	VA-9	48	6.40	7050	50	0.036	0.14	0.47	340	24.4	938	183	13.2	1510	38.4	1500	3.67	13.8
29	Soda Dam Spring	VA-64	47	6.28	5600	44	--	0.07	0.43	300	25	825	120	13.7	1250	36.1	1560	2.8	13.9
29	Soda Dam Spring	VA-26	47	6.52	6600	46	0.025	0.08	0.54	429	21.4	920	177	13.6	1490	49.4	1460	3.57	12.8
29	Soda Dam Spring	VA-51	47	6.35	5900	46	--	--	--	314	24	990	183	13.5	1000	39.1	1520	3.55	15.0
29	Grotto Spring	VA-5	38	6.8	--	38	--	0.11	0.50	324	27	1000	174	13.2	834	41	1480	4.0	11.6
29	Outfall of Soda Dam Spring	VA-65	17	8.13	6000	36	--	0.03	0.03	138	26	943	160	14.3	610	40.5	1590	2.5	14.6
29	Unnamed Spring	VA-27	29	6.28	5700	44	0.007	0.50	0.56	376	18.8	720	141	10.8	1400	69.1	1195	2.71	10.6
30	Main Jemez Spring	VA-10	55	7.01	4200	93	0.015	0.20	0.17	152	5.40	656	74.2	10.1	711	40.9	904	5.19	7.9
30	Main Jemez Spring	VA-18	35.5	7.51	4250	85	0.014	0.02	0.10	115	4.52	690	74.0	9.00	699	45.4	968	5.19	8.0
30	Travertine Mound Spring	VA-7	70	6.28	4200	93	--	0.15	0.18	182	4.56	614	75.2	8.20	723	36.1	829	5.21	7.8
30	Travertine Mound Spring	VA-66	72	6.23	3400	92	--	0.05	0.23	122	5.4	558	62	9.0	436	42.4	910	4.0	7.0
30	Travertine Mound Spring	VA-17	72	6.66	4100	83	0.016	0.15	0.11	114	4.48	612	70.3	8.46	714	43.2	936	5.05	7.9
30	Buddhist Spring	VA-8	49	6.38	3300	81	--	0.18	0.24	154	9.57	458	53.0	7.56	697	37.6	653	3.86	5.7
30	Buddhist Spring	VA-16	50	6.59	3300	72	0.013	0.16	0.19	128	7.50	494	57.8	6.06	708	40.6	653	3.76	5.7
30	Unnamed Spring	VA-12	49	6.35	4100	100	--	0.99	0.49	129	7.82	609	70.0	8.18	738	41.8	903	4.56	7.5
30	80 ft Aquifer	VA-19	68	6.64	3300	70	0.013	0.39	0.11	122	5.76	546	61.6	6.96	642	45.0	705	4.42	6.1
30	80 ft Aquifer	VA-25	73.3	6.55	3500	79	0.030	0.21	0.22	180	4.60	610	68.0	8.4	705	53.0	836	3.52	6.8
30	500 ft Aquifer	VA-15	60.5	6.69	1700	24	0.018	0.39	0.02	120	9.31	185	29.9	2.27	479	38.0	243	3.30	2.2
30	500 ft Aquifer	VA-21	61	6.55	1830	36	--	1.72	0.07	122	9.25	193	35.4	3.60	492	49.9	281	3.50	2.5

TABLE B-II (cont)

Map No.	Name	Field No.	Temp. °C	Field pH	Conductivity µmhos/cm	SiO_2	Al	Fe	Mn	Ca	Mg	Na	K	Li	HCO_3	SO_4	Cl	F	B
Valles Caldera Region, Miscellaneous																			
28	San Antonio Creek	VA-24	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
31	Panorama Spring	VA-28	13	7.67	920	62	0.0013	0.016	0.003	101	22.9	114	5.3	0.16	519	56.7	21.7	0.97	<0.1
32	Pajarito Spring	VA-29	20	5.9	210	67	--	0.044	0.002	19.6	5.3	11.8	2.08	0.08	100	7.5	6.4	0.46	0.05
33	Spring, White Rock Canyon	VA-30	18	6.0	--	63	--	0.140	0.009	29.3	6.9	14.4	2.4	0.07	--	8.8	9.8	0.48	0.07
34	Cold Mineral Seep	VA-31	19	8.37	4200	18	0.096	0.005	<0.001	10.2	71.0	613	42.0	3.22	1745	373	284	4.95	4.15
35	Sino Spring	VA-32	21	7.45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
35	Sino Spring	VA-63	18	7.10	163	78	0.001	<0.001	<0.001	11.2	3.6	14	0.2	0.12	82	5.0	6.0	0.32	0.01
36	Unnamed Spring	VA-39	11	6.91	2500	16	0.021	0.272	0.144	49	10.3	447	34	2.2	848	193	267	7.2	3.16
37	Canon Spring	VA-40	18	7.58	1090	47	0.006	0.81	0.148	36	5.2	161	7.6	0.5	367	127	71	9.3	0.41
38	Indian Valley Well	VA-41	17.5	6.81	280	77	--	0.42	0.024	23.5	6.2	22.0	4.78	0.044	137	6.2	7.3	0.17	<0.003
39	Unnamed Cold Spring	VA-42	15	7.20	88	52	--	0.006	<0.001	6.4	1.66	1.7	8.0	0.030	34	2.6	9.1	0.39	<0.01
40	Unnamed Cold Spring	VA-43	15	6.68	65	45	--	0.014	0.006	5.3	1.03	3.8	3.8	0.007	11	13.1	6.9	0.33	<0.01
41	Unnamed Cold Spring	VA-44	8	6.91	210	48	--	0.025	0.002	19.0	5.0	10.6	9.08	0.002	90	17.4	7.4	0.11	<0.003
42	Horseshoe Spring	VA-45	12	6.89	240	46	--	<0.004	<0.001	19.0	3.4	30.7	3.00	0.088	145	6.2	6.1	0.21	0.003
43	Unnamed Cold Spring	VA-46	10	6.42	126	74	--	0.004	<0.001	10.7	1.50	11.6	2.53	0.040	57	4.4	3.5	0.44	<0.003
44	Unnamed Cold Spring	VA-47	10	6.48	115	41	--	0.036	0.001	12.3	1.54	7.23	2.10	0.018	49	8.7	3.6	0.21	<0.003
45	Unnamed Cold Spring	VA-48	9	5.6	280	22	--	0.036	<0.001	33	8.7	5.9	2.1	0.003	59	78	6.2	0.28	<0.01
46	Eddy's Well	VA-49	15	7.24	550	64	--	0.029	<0.001	56	13.8	18	9.6	0.098	332	28.6	8.0	0.52	<0.01
34	Cold Mineral Seep	VA-50	11	7.92	4200	17	--	0.004	<0.001	35	46	940	47	4.0	1980	290	323	5.75	4.47

TABLE B-II (cont)

Map No.	Name	Field No.	Temp. °C	Field pH	Conductivity µmhos/cm	SiO_2	Al	Fe	Mn	Ca	Mg	Na	K	Li	HCO_3	SO_4	Cl	F	B
29	Jemez River	VA-52	5	5.30	100	17	--	0.360	0.014	11	1.4	5.6	2.0	0.040	52	9.0	4.0	0.56	0.09
48	Unnamed Cold Spring	VA-54	11	5.4	99	30	--	0.360	0.009	10.0	2.0	3.5	2.9	0.002	40	9.9	5.4	0.22	<0.01
49	Unnamed Cold Spring	VA-55	8.5	5.4	55	34	--	1.18	0.012	5.0	1.4	2.7	1.8	0.005	24	6.0	5.5	0.21	<0.01
50	Unnamed Cold Spring	VA-56	6.5	5.4	105	38	--	0.60	0.007	8.7	3.0	5.0	2.9	0.004	39	6.7	9.8	0.20	<0.01
51	Apache Spring	VA-57	9	5.3	137	58	--	0.42	0.003	10.8	4.6	6.7	3.5	0.006	57	8.3	8.0	0.27	<0.01
52	Unnamed Cold Spring	VA-58	15	5.4	130	65	--	0.15	0.002	10.6	3.4	9.4	3.1	0.024	75	3.4	7.1	0.30	<0.01
53	Unnamed Cold Spring	VA-59	17	5.6	130	69	--	1.19	0.135	10.4	3.4	9.0	3.2	0.024	73	2.4	7.5	0.35	<0.01
54	Turkey Springs	VA-60	18	5.5	193	61	--	0.012	0.001	20	5.5	10.1	1.7	0.010	103	4.2	8.0	0.38	0.03
46	Henson's Well	VA-61	19	6.82	560	62	--	<0.02	0.003	59	8.4	36	4.6	0.136	305	20.5	7.7	0.38	0.01
San Ysidro-Jemez Pueblo Region, Miscellaneous																			
55	Warm Mineral Spring	VA-33	27	6.57	11550	14	0.014	3.40	1.80	375	128	1710	75.3	5.30	1860	2330	1820	3.95	8.32
56	Zia Hot Well	VA-34	56	6.29	16600	30	0.052	1.40	0.10	302	90	2650	66.7	6.70	1440	3740	3000	2.40	6.52
56	Zia Hot Well	VA-53	54	6.53	16000	33	--	0.240?	0.022	321	61	3440	77	6.0	1068	3430	3210	4.51	7.41
56	Zia Hot Well	VA-67	53	6.72	15800	35	0.022	1.46	0.040	320	71.5	3180	64	6.3	1400	3280	2930	3.8	6.60
57	Unnamed Well	VA-35	21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
58	Salt Spring	VA-36	15.5	7.90	10500	1	0.005	0.030	0.024	89	26.4	1950	94	7.4	1870	702	2380	10.8	9.2
59	Log Spring	VA-37	28.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
60	Owl Spring	VA-38	16	7.22	620	22	0.001	<0.001	<0.001	73	10.4	34	2.1	0.176	311	33.8	27.8	1.4	0.12

TABLE B-III
TRACE ELEMENT ANALYSES FOR WATERS IN THE JEMEZ MOUNTAINS REGION, NEW MEXICO (VALUES IN mg/ℓ)

Map No.	Name	Field No.	Ag	Ba	Cd	Co	Cr	Cu	Mo	Ni	Pb	Sr	Zn
Los Alamos Area, Pajarito Plateau													
1	Gallery Spring	LA-1	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.05	<0.01
2	T-3 Well	LA-2	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.05	0.01
3	T-2 Well	LA-3	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.03	0.18
4	Sacred Spring	LA-4	0.06	<0.12	0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.42	0.02
5	Basalt Spring	LA-5	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.12	<0.01
6	L-6 Well	LA-6	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.05	<0.01
7	L-1B Well	LA-7	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.14	<0.01
8	L-5 Well	LA-8	<.05	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.10	<0.01
9	L-4 Well	LA-9	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.07	<0.01
10	PM-2 Well	LA-10	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.04	<0.01
11	PM-1 Well	LA-11	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.14	<0.01
12	G-6 Well	LA-12	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.06	<0.01
13	G-5 Well	LA-13	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.08	<0.01
14	G-4 Well	LA-14	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.07	<0.01
15	G-3 Well	LA-15	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.06	<0.01
16	G-2 Well	LA-16	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.08	<0.01
17	G-1A Well	LA-17	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.08	<0.01
18	G-1 Well	LA-18	0.06	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.08	<0.01
19	Spring, White Rock Canyon	LA-19	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.05	<0.01
20	PM-3 Well	LA-20	0.06	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.12	0.02
Valles Caldera, Sulphur Springs Area													
21	Mudpot, Men's Bathhouse	VA-13	<0.03	<0.12	<0.03	<0.06	<0.03	0.63	<0.10	<0.05	<0.14	0.03	0.16
21	Mudpot, Men's Bathhouse	S-7-80	<0.03	0.083	<0.001	0.059	---	0.030	0.010	---	---	0.113	---

TABLE B-III (cont)

Map No.	Name	Field No.	Ag	Ba	Cd	Co	Cr	Cu	Mo	Ni	Pb	Sr	Zn
21	Unnamed Hot Spring	VA-14	<0.03	<0.12	0.03	0.07	0.06	<0.04	<0.10	<0.05	<0.14	0.22	0.08
21	Unnamed Hot Spring	S-9-80	<0.03	0.037	<0.001	0.017	0.063	---	<0.002	0.042	0.120	0.027	---
21	Lemonade Spring	S-10-80	<0.03	0.055	<0.001	0.010	0.056	<0.001	<0.002	0.016	0.004	0.060	0.440
21	Unnamed Spring	S-3-80	<0.03	0.010	<0.001	0.024	0.052	<0.002	<0.002	0.039	0.032	0.610	---
21	Footbath Spring	S-4-80	<0.03	0.030	0.004	0.460	---	---	0.005	---	---	0.098	---
21	Electric Spring	S-5-80	<0.03	0.035	<0.001	0.100	0.360	0.080	0.004	0.220	0.080	0.140	0.640
21	Women's Bathhouse	S-6-80	<0.03	0.053	0.001	0.245	---	---	0.010	---	---	0.065	---
22	Spring, Alamo Canyon	S-1-80	<0.03	0.050	<0.001	<0.001	0.019	0.001	<0.002	0.008	0.004	0.180	0.880
22	Creek, Alamo Canyon	S-2-80	<0.03	0.042	<0.001	0.002	0.005	0.008	<0.002	0.003	0.004	0.140	0.560
23	Bubbling Pool	VA-22	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.40	<0.01
23	Bubbling Seep	VA-23	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.68	<0.01
24	Spring, Short Canyon	S-8-80	<0.03	0.109	<0.001	0.005	0.010	0.007	<0.002	0.001	<0.004	0.340	0.160
Valles Caldera, Thermal Meteoric (Ring Fracture Zone)													
25	Spence Hot Spring	VA-1	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.03	0.02
25	Little Spence Hot Spring	VA-2	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.04	0.02
26	McCauley Spring	VA-3	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.02	<0.01
27	San Antonio Hot Spring	VA-4	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	<0.02	<0.01
28	Bathhouse Spring	VA-20	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.02	<0.01
Valles Caldera, Soda Dam and Jemez Springs (Jemez Fault Zone)													
29	Soda Dam Spring	VA-6	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	1.38	0.02
29	Soda Dam Spring	VA-9	<0.03	<0.12	0.06	<0.06	<0.03	<0.04	<0.10	0.05	<0.14	1.50	0.04

TABLE B-III (cont)

Map No.	Name	Field No.	Ag	Ba	Cd	Co	Cr	Cu	Mo	Ni	Pb	Sr	Zn
29	Soda Dam Spring	VA-64	<0.001	0.430	<0.001	<0.002	<0.001	<0.001	<0.002	<0.006	<0.004	1.48	<0.002
29	Soda Dam Spring	VA-26	0.002	0.396	0.002	<0.06	0.062	0.004	<0.10	<0.05	0.014	2.02	<0.01
29	Soda Dam Spring	VA-51	<0.03	0.206	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	0.044	0.890	<0.002
29	Grotto Spring	VA-5	<0.03	<0.12	<0.03	0.09	<0.03	<0.04	<0.10	<0.05	<0.14	1.40	0.01
29	Outfall from Soda Dam Spring	VA-65	<0.001	0.360	<0.001	<0.002	<0.001	<0.001	<0.002	<0.001	<0.004	1.27	<0.002
29	Unnamed Spring	VA-27	0.002	0.206	0.002	0.002	0.098	0.006	<0.10	<0.05	0.006	1.90	<0.01
30	Main Jemez Spring	VA-10	<0.03	<0.12	0.03	<0.06	<0.03	<0.04	<0.10	0.10	<0.14	0.56	0.03
30	Main Jemez Spring	VA-18	<0.03	0.24	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.60	<0.01
30	Travertine Mound Spring	VA-7	<0.03	<0.12	0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.60	0.03
30	Travertine Mound Spring	VA-66	<0.001	0.232	<0.001	<0.002	0.001	<0.001	<0.002	0.002	<0.004	0.59	<0.002
30	Travertine Mound Spring	VA-17	<0.03	0.20	<0.03	0.06	<0.03	<0.04	<0.10	0.10	<0.14	0.54	0.02
30	Buddhist Spring	VA-8	<0.03	0.60	0.03	<0.06	<0.03	<0.04	<0.10	0.10	<0.14	0.56	0.02
30	Buddhist Spring	VA-16	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	0.10	<0.14	0.52	0.04
30	Unnamed Spring	VA-12	<0.03	0.35	0.06	0.12	<0.03	<0.04	<0.10	0.10	<0.14	0.64	0.02
30	80 ft Aquifer	VA-19	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.54	<0.01
30	80 ft Aquifer	VA-25	0.002	0.202	<0.03	0.002	0.082	0.002	<0.10	<0.05	0.006	0.86	<0.01
30	500 ft Aquifer	VA-15	<0.03	<0.12	<0.03	0.10	<0.03	<0.04	<0.10	0.10	<0.14	0.40	<0.02
30	500 ft Aquifer	VA-21	<0.03	<0.12	<0.03	<0.06	<0.03	<0.04	<0.10	<0.05	<0.14	0.40	<0.01
	Valles Caldera Region, Miscellaneous												
28	San Antonio Creek	VA-24	--	--	--	--	--	--	--	--	--	--	--
31	Panorama Spring	VA-28	0.002	0.176	<0.03	<0.06	0.018	0.002	<0.10	0.002	0.002	0.720	<0.01
32	Pajarito Spring	VA-29	<0.03	0.010	<0.03	<0.06	0.018	<0.04	<0.10	<0.05	<0.14	0.132	0.001
33	Spring, White Rock Canyon	VA-30	<0.03	0.014	<0.03	<0.06	0.006	0.004	<0.10	0.004	<0.14	0.225	0.003

TABLE B-III (cont)

Map No.	Name	Field No.	Ag	Ba	Cd	Co	Cr	Cu	Mo	Ni	Pb	Sr	Zn
34	Cold Mineral Seep	VA-31	0.005	0.062	0.002	<0.06	<0.03	<0.04	0.002	<0.05	<0.14	0.146	<0.01
35	Sino Spring	VA-32	--	--	--	--	--	--	--	--	--	--	--
35	Sino Spring	VA-63	<0.001	0.017	<0.001	<0.002	<0.001	<0.001	<0.002	<0.001	<0.004	0.06	0.007
36	Unnamed Spring	VA-39	<0.001	0.044	<0.001	<0.002	<0.001	<0.001	0.014	<0.001	<0.004	0.95	<0.002
37	Canon Spring	VA-40	<0.001	0.082	<0.001	<0.002	<0.05	<0.05	0.048	<0.03	<0.004	0.49	0.016
38	Indian Valley Well	VA-41	<0.03	0.053	<0.03	0.001	0.002	<0.04	0.002	<0.05	<0.14	0.160	0.002
39	Unnamed Cold Spring	VA-42	<0.03	0.010	<0.001	<0.001	0.002	<0.002	<0.002	<0.002	<0.004	0.030	0.025
40	Unnamed Cold Spring	VA-43	<0.03	0.031	<0.001	<0.001	<0.001	0.020	<0.002	<0.002	<0.004	0.038	0.060
41	Unnamed Cold Spring	VA-44	<0.03	0.129	<0.03	<0.06	0.001	<0.04	<0.10	<0.05	<0.14	0.120	0.006
42	Horseshoe Spring	VA-45	<0.03	0.119	<0.03	0.001	0.008	<0.04	0.001	<0.05	<0.14	0.088	<0.01
43	Unnamed Cold Spring	VA-46	<0.03	0.047	<0.03	<0.06	0.001	<0.04	0.001	<0.05	<0.14	0.072	0.008
44	Unnamed Cold Spring	VA-47	<0.03	0.036	<0.03	<0.06	0.001	<0.04	0.001	<0.05	<0.14	0.071	<0.01
45	Unnamed Cold Spring	VA-48	<0.03	0.068	<0.001	<0.001	0.001	0.007	<0.002	<0.002	<0.004	0.150	0.300
46	Eddy's Well	VA-49	<0.03	0.113	<0.001	<0.001	<0.001	0.021	0.117	<0.002	<0.004	0.288	0.040
34	Cold Mineral Seep	VA-50	<0.03	0.022	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	0.016	0.810	<0.002
29	Jemez River	VA-52	<0.03	0.021	<0.001	<0.001	0.001	0.016	<0.002	<0.002	<0.004	0.038	0.036
48	Unnamed Cold Spring	VA-54	<0.03	0.065	<0.001	<0.001	0.002	<0.001	<0.002	<0.002	<0.004	0.064	0.007
49	Unnamed Cold Spring	VA-55	<0.03	0.074	<0.001	<0.001	0.005	<0.001	<0.002	<0.002	<0.004	0.043	0.015
50	Unnamed Cold Spring	VA-56	<0.03	0.018	<0.001	<0.001	0.002	<0.001	<0.002	<0.002	<0.004	0.067	0.018
51	Apache Spring	VA-57	<0.03	0.066	<0.001	<0.001	0.002	<0.001	<0.002	<0.002	<0.004	0.064	0.020
52	Unnamed Cold Spring	VA-58	<0.03	0.016	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	<0.004	0.049	0.024
53	Unnamed Cold Spring	VA-59	<0.03	0.022	<0.001	<0.001	0.004	<0.001	<0.002	<0.002	<0.004	0.051	0.008
54	Turkey Springs	VA-60	<0.03	0.056	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	<0.004	0.066	0.080
46	Henson's Well	VA-61	<0.001	0.134	<0.001	<0.002	<0.001	0.088	0.015	<0.001	<0.004	0.28	0.015

TABLE B-III (cont)

Map No.	Name	Field No.	Ag	Ba	Cd	Co	Cr	Cu	Mo	Ni	Pb	Sr	Zn
<u>San Ysidro-Jemez Pueblo Area, Miscellaneous</u>													
55	Warm Mineral Spring	VA-33	0.006	0.044	0.006	0.016	0.008	0.009	<0.10	0.002	<0.14	7.70	0.001
56	Zia Hot Well	VA-34	0.015	0.120	0.013	0.063	0.026	0.027	<0.10	0.009	0.002	9.00	<0.01
56	Zia Hot Well	VA-53	0.006	0.028	<0.001	0.004	0.004	0.020	<0.002	<0.002	0.360	4.75	0.007
56	Zia Hot Well	VA-67	<0.001	0.028	<0.001	0.006	0.020	<0.001	<0.002	<0.001	0.012	9.55	<0.002
57	Unnamed Well	VA-35	--	--	--	--	--	--	--	--	--	--	--
58	Salt Spring	VA-36	<0.001	0.032	<0.001	<0.002	0.004	0.016	<0.002	<0.001	0.008	4.82	<0.002
59	Log Spring	VA-37	--	--	--	--	--	--	--	--	--	--	--
60	Owl Spring	VA-38	<0.001	0.106	<0.001	<0.002	<0.001	<0.001	0.003	<0.001	<0.004	0.43	0.007

TABLE B-IV
OXYGEN AND HYDROGEN ISOTOPE ANALYSES OF WATERS IN THE
JEMEZ MOUNTAINS REGION, NEW MEXICO

Map No.	Name	Field No.	Date Collected	Temp °C	δD°/oo	$\delta^{18}O$°/oo
Los Alamos Area , Pajarito Plateau						
1	Gallery Spring	LA-1	8/78	11	-84.3	12.20
2	T-3 Well	LA-2	8/78	13	-73.8	-10.65
3	T-2 Well	LA-3	8/78	11	-73.5	-10.60
4	Sacred Well	LA-4	8/78	14	-81.8	-11.80
5	Basalt Spring	LA-5	8/78	15	-76.5	-10.85
6	L-6 Well	LA-6	9/78	27	-94.7	-13.45
7	L-1B Well	LA-7	9/78	30	-103.0	-14.30
8	L-5 Well	LA-8	9/78	26.5	--	--
9	L-4 Well	LA-9	9/78	28	--	--
10	PM-2 Well	LA-10	9/78	23.5	-77.5	-11.40
11	PM-1 Well	LA-11	9/78	28	-74.1	-10.95
12	G-6 Well	LA-12	9/78	30.5	-76.0	-11.25
13	G-5 Well	LA-13	9/78	26.5	--	--
14	G-4 Well	LA-14	9/78	26	-76.3	-11.10
15	G-3 Well	LA-15	9/78	29	--	--
16	G-2 Well	LA-16	9/78	30	-83.1	-11.95
17	G-1A Well	LA-17	9/78	28	-82.5	-11.80
18	G-1 Well	LA-18	9/78	29	-81.0	-11.65
19	Spring, White Rock Canyon	LA-19	9/78	19	-76.8	-11.00
20	PM-3 Well	LA-20	9/78	27.5	--	--

TABLE B-IV (cont)

Map No.	Name	Field No.	Date Collected	Temp °C	δD °/oo	$\delta^{18}O$ °/oo
Valles Caldera, Sulphur Springs Area						
21	Mudpot, Men's Bathhouse	VA-13	1/79	78	-50.2	-3.25
21	Mudpot, Men's Bathhouse	S-7-80	9/80	82	--	--
21	Unnamed Hot Spring	VA-14	1/79	63	-60.7	-8.80
21	Unnamed Hot Spring	S-9-80	9/80	--	--	--
21	Lemonade Spring	S-10-80	9/80	58	--	--
21	Unnamed Spring	S-3-80	9/80	11	--	--
21	Footbath Spring	S-4-80	9/80	33	--	--
21	Electric Spring	S-5-80	9/80	36	--	--
21	Women's Bath-house	S-6-80	9/80	90	--	--
22	Spring, Alamo Canyon	S-1-80	9/80	11	--	--
22	Creek, Alamo Canyon	S-2-80	9/80	11	--	--
23	Bubbling Pool	VA-22	3/79	0.5	-97.3	-13.45
23	Bubbling Seep	VA-23	3/79	7	--	--
24	Spring, Short Canyon	S-8-80	9/80	8	--	--
Valles Caldera, Thermal Meteoric (Ring Fracture Zone)						
25	Spence Hot Spring	VA-1	7/78	45	-86.4	-12.35
25	Little Spence Hot Spring	VA-2	7/78	34	--	--
26	McCauley Spring	VA-3	7/78	31	-88.4	-12.60

TABLE B-IV (cont)

Map No.	Name	Field No.	Date Collected	Temp °C	δD °/oo	$\delta^{18}O$ °/oo
27	San Antonio Hot Spring	VA-4	7/78	42	-92.0	-12.65
28	Bathhouse Spring	VA-20	2/79	38	-86.4	-12.40
<u>Valles Caldera, Soda Dam and Jemez Springs (Jemez Fault Zone)</u>						
29	Soda Dam Spring	VA-6	7/78	47	-84.9	-10.60
29	Soda Dam Spring	VA-9	1/79	48	--	--
29	Soda Dam Spring	VA-64	12/80	47	-85.2	-10.60
29	Soda Dam Spring	VA-26	5/79	47	--	--
29	Soda Dam Spring	VA-51	4/80	47	-85.4	-10.70
29	Grotto Spring	VA-5	7/78	38	-84.6	-10.65
29	Outfall of Soda Dam Spring	VA-65	12/80	17	--	--
29	Unnamed Spring	VA-27	5/79	29	-84.9	-10.95
30	Main Jemez Spring	VA-10	1/79	55	-82.3	-10.6
30	Main Jemez Spring	VA-18	1/79	36	-81.4	-10.4
30	Travertine Mound Spring	VA-7	1/79	70	-83.6	-11.30
30	Travertine Mound Spring	VA-66	12/80	72	-83.1	-11.35
30	Travertine Mound Spring	VA-17	1/79	72	--	--
30	Buddhist Spring	VA-8	1/79	49	--	--
30	Buddhist Spring	VA-16	1/79	50	--	--
30	Unnamed Spring	VA-12	1/79	49	--	--
30	80 Ft Aquifer	VA-19	1/79	68	-84.0	-11.3
30	80 Ft Aquifer	VA-25	5/79	73.3	--	--

TABLE B-IV (cont)

Map No.	Name	Field No.	Date Collected	Temp °C	$\delta D °/_{oo}$	$\delta^{18}O °/_{oo}$
30	500 Ft Aquifer	VA-15	1/79	60.5	-85.9	-11.8
30	500 Ft Aquifer	VA-21	2/79	61	--	--
Valles Caldera Region, Miscellaneous						
28	San Antonio Creek	VA-24	5/79	2	-92.9	-12.85
31	Panorama Spring	VA-28	5/79	13	-86.9	-11.80
32	Pajarito Spring	VA-29	7/79	20	-74.5	-10.90
33	Spring, White Rock Canyon	VA-30	7/79	18	--	--
34	Cold Mineral Seep	VA-31	8/79	19	-92.9	-12.50
35	Sino Spring	VA-32	8/79	21	-88.0	-12.30
35	Sino Spring	VA-63	12/80	18	--	--
36	Unnamed Spring	VA-39	8/79	16.8	-84.6	-12.35
37	Canon Spring	VA-40	8/79	20.2	-86.6	-12.35
38	Indian Valley Well	VA-41	8/79 10/79	-- 17.5	-87.1 -91.1	-12.30 -12.75
39	Unnamed Cold Spring	VA-42	8/79	15	-85.0	-12.40
40	Unnamed Cold Spring	VA-43	8/79	14.8	-78.2	-11.40
41	Unnamed Cold Spring	VA-44	8/79	9.8	-98.2	-13.75
42	Horseshoe Spring	VA-45	8/79	14	-90.2	-12.65
43	Unnamed Cold Spring	VA-46	8/79	13.3	-96.5	-13.60
44	Unnamed Cold Spring	VA-47	8/79	12	-99.1	-14.25
45	Unnamed Cold Spring	VA-48	6/80	9	--	--
46	Eddy's Well	VA-49	6/80	15	--	--
34	Cold Mineral Seep	VA-50	4/80	11	-92.7	-12.80

TABLE B-IV (cont)

Map No.	Name	Field No.	Date Collected	Temp °C	δD°/°°	$\delta^{18}O$°/°°
29	Jemez River	VA-52	4/80	5	-94.4	-13.20
48	Unnamed Cold Spring	VA-54	6/80	11	-88.6	-12.60
49	Unnamed Cold Spring	VA-55	6/80	8.5	-90.5	-12.75
50	Unnamed Cold Spring	VA-56	6/80	6.5	-87.6	-12.55
51	Apache Spring	VA-57	7/80	9	-85.1	-12.25
52	Unnamed Cold Spring	VA-58	7/80	15	-80.5	-11.55
53	Unnamed Cold Spring	VA-59	7/80	17	-80.1	-11.60
54	Turkey Springs	VA-60	7/80	18	-76.0	-11.00
46	Henson's Well	VA-61	12/80	19	-81.2	-11.30
San Ysidro - Jemez Pueblo Area, Miscellaneous						
55	Warm Mineral Spring	VA-33	8/79	27	-86.6	-10.40
56	Zia Hot Well	VA-34	8/79	56	-89.8	-11.25
56	Zia Hot Well	VA-53	4/80	54	-89.0	-12.55
56	Zia Hot Well	VA-67	3/81	53	--	--
57	Unnamed Well	VA-35	8/79	21	-101.4	-13.65
58	Salt Spring	VA-36	8/79	29.2	-84.9	-10.20
59	Log Spring	VA-37	8/79	28.5	-87.7	-12.25
60	Owl Spring	VA-38	8/79	17.6	-86.2	-12.15

REFERENCES

1. F. E. Goff and C. O. Grigsby, "Valles Caldera Geothermal Systems, New Mexico, USA," J. Hydrol., in press (1982).

2. F. E. Goff, C. O. Grigsby, P. E. Trujillo, Jr., D. Counce, and A. Kron, "Geology, Water Geochemistry and Geothermal Potential of the Jemez Springs Area, Cañon de San Diego, New Mexico," J. Volc. Geotherm. Res. 10, 227-244 (1981).

3. F. E. Goff and S. Sayer, "A Geothermal Investigation of Spring and Well Waters of the Los Alamos Region, New Mexico," Los Alamos Scientific Laboratory report LA-8326-MS, 21 pp. (April 1980).

4. F. W. Trainer and F. P. Lyford, "Geothermal Hydrology in the Rio Grande Rift, North Central New Mexico," New Mexico Geol. Soc., 30th Field Conf. Guidebook, 299-306 (1979).

5. F. W. Trainer, "Ground-Water in the Southwestern part of the Jemez Mountains Volcanic Region, New Mexico," New Mexico Geol. Soc., 25th Field Conf. Guidebook, 337-345 (1974).

6. F. W. Trainer, "Mixing of Thermal and Nonthermal Waters in the Margin of the Rio Grande Rift, Jemez Mountains, New Mexico," New Mexico Geol. Soc., 26th Field Conf. Guidebook, 213-218 (1975).

7. F. B. Titus, Jr., "Ground-Water Geology of the Rio Grande Trough in North-Central New Mexico, with Sections on the Jemez Caldera and the Lucero Uplift," New Mexico Geol. Soc., 12th Field Conf. Guidebook, 186-192 (1961).

8. W. D. Purtymun and S. Johansen, "General Geohydrology of the Pajarito Plateau," New Mexico Geol. Soc., 25th Field Conf. Guidebook, Ghost Ranch, 347-349 (1974).

9. W. D. Purtymun, F. G. West, and W. H. Adams, "Preliminary Study of the Quality of Water in the Drainage Area of the Jemez River and Rio Guadalupe," Los Alamos Scientific Laboratory report LA-5595-MS, 26 pp. (April 1974).

10. W. D. Purtymun, R. J. Peters, and J. W. Owens, "Geohydrology of White Rock Canyon of the Rio Grande from Otowi to Frijoles Canyon," Los Alamos Scientific Laboratory report LA-8635-MS, 15 pp. (December 1980).

11. W. D. Purtymun, "Hydrologic Characteristics of the Los Alamos Well Field, With Reference to the Occurrence of Arsenic in Well L-6," Los Alamos Scientific Laboratory report LA-7012-MS, 63 pp. (November 1977).

12. C. S. Ross, R. L. Smith, and R. A. Bailey, "Outline of the Geology of the Jemez Mountains, New Mexico," New Mexico Geol. Soc., 12th Field Conf. Guidebook, 139-143 (1961).

13. R. L. Smith, R. A. Bailey, and C. S. Ross, "Structural Evolution of the Valles Caldera, New Mexico, and Its Bearings on the Emplacement of Ring-Dikes," U.S. Geol. Surv., Prof. Paper 424-D, D145-D149 (1961).

14. R. L. Griggs, "Geology and Ground-Water Resources of the Los Alamos Area, New Mexico," U.S. Geol. Surv. Water-Supply Paper 1753, 107 pp.

15. R. R. Doell, G. B. Dalrymple, R. L. Smith, and R. A. Bailey, "Paleomagnetism, Potassium-Argon Ages, and Geology of Rhyolites and Associated Rocks of the Valles Caldera, New Mexico," Geol. Soc. Am., Mem. 116, 211-248 (1968).

16. R. A. Bailey, R. L. Smith, and C. S. Ross, "Stratigraphic Nomenclature of Volcanic Rocks in the Jemez Mountains, New Mexico," U.S. Geol. Surv. Bull. 1274-P, 19 pp. (1969).

17. R. L. Smith, R. A. Bailey, and C. S. Ross, "Geologic Map of the Jemez Mountains, New Mexico," U.S. Geol. Surv. Misc Geol. Investig. Map I-571 (1970).

18. E. B. Mayo, "Lineament tectonics and some ore districts of the Southwest," Trans. AIME, 211, 1169-1175 (1958).

19. A. W. Laughlin, D. G. Brookins, and P. E. Damon, "Late-Cenozoic Basaltic Volcanism Along the Jemez Zone of New Mexico and Arizona," Geol. Soc. Am. Abst. w/Programs, 8, 598 (1976).

20. A. W. Laughlin, "The Geothermal System of the Jemez Mountains and Its Exploration," in Geothermal Systems - Principles and Case Histories, L. Rybach and L. J. P. Muffler, Eds. (John Wiley and sons, Inc., 1981) pp. 295-320.

21. R. A. Barnes, "The Determination of Specific Forms of Aluminium in Natural Water," Chem. Geol. 15, 177-191 (1975).

22. D. E. White, "Magmatic, Connate, and Metamorphic Waters," Geol. Soc. Am. Bull., 68, 1659-1682 (1957).

23. P. H. Craig, "Isotopic Variations in Meteoric Waters," Science, 133, 1702-1703 (1961).

24. W. K. Summers, "Catalog of Thermal Waters in New Mexico," New Mexico Bur. Mines. Miner. Resour. Hydrol. Rep., 4, 80 pp. (1976).

25. D. E. White, L. P. J. Muffler, and A. H. Truesdell, "Vapor-Dominated Hydrothermal Systems Compared With Hot-Water Systems," Econ. Geol., 66, 75-97 (1971).

26. R. H. Mariner, T. S. Presser, and W. C. Evans, "Chemical, Isotopic, and Gas Compositions of Selected Thermal Springs in Arizona, New Mexico and Utah," U.S. Geol. Surv., Open file report 77-654, 42 pp. (1977).

27. W. D. Purtymun, "Water Supply at Los Alamos During 1978," Los Alamos Scientific Laboratory progress report LA-8074-PR, 46 pp. (October 1979).

28. W. D. Purtymun and J. B. Cooper, "Development of Ground-water Supplies on the Pajarito Plateau," U.S. Geol. Surv., Prof. Paper 650-B, B149-B153 (1969).

29. F. W. Trainer, "Geohydrologic Data From the Jemez Mountains and Vicinity, North-Central New Mexico," U.S. Geol. Surv., Water-Resour. Invest., 77-131 146 pp. (1978).

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