LA-11496-OBES

UC-403
Issued: February 1989

LA--11496-OBES

DE89 010765

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# SELECTED DATA FROM CONTINENTAL SCIENTIFIC DRILLING CORE HOLES VC-1 AND VC-2a, VALLES CALDERA, NEW MEXICO

by

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## ABSTRACT

This report presents geochemical and isotopic data on rocks and water and wellbore geophysical data from the Continental Scientific Drilling Program core holes VC-1 and VC-2a, Valles caldera, New Mexico. These core holes were drilled as a portion of a broader program that seeks to answer fundamental questions about magma, water/rock interactions, ore deposits, and volcanology. The data in this report will assist the interpretation of the hydrothermal system in the Jemez Mountains and will stimulate further research in magmatic processes, hydrothermal alteration, ore deposits, hydrology, structural geology, and hydrothermal solution chemistry.

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## I. INTRODUCTION

VC-1 and VC-2a are the first and second core holes drilled in the Valles caldera (Figs. 1 and 2) as part of the Continental Scientific Drilling Program (CSDP), Thermal Regimes (Goff and Nielson 1986). VC-1 was planned to penetrate a hydrothermal outflow plume issuing from the caldera, to obtain stratigraphic and structural information near the intersection of the Valles caldera ring-fracture zone and the precaldera Jemez fault zone, and to core the youngest intracaldera rhyolite sequence in the Jemez Mountains (Goff et al. 1986). VC-2a was designed to penetrate the postulated vapor cap in the main spring and

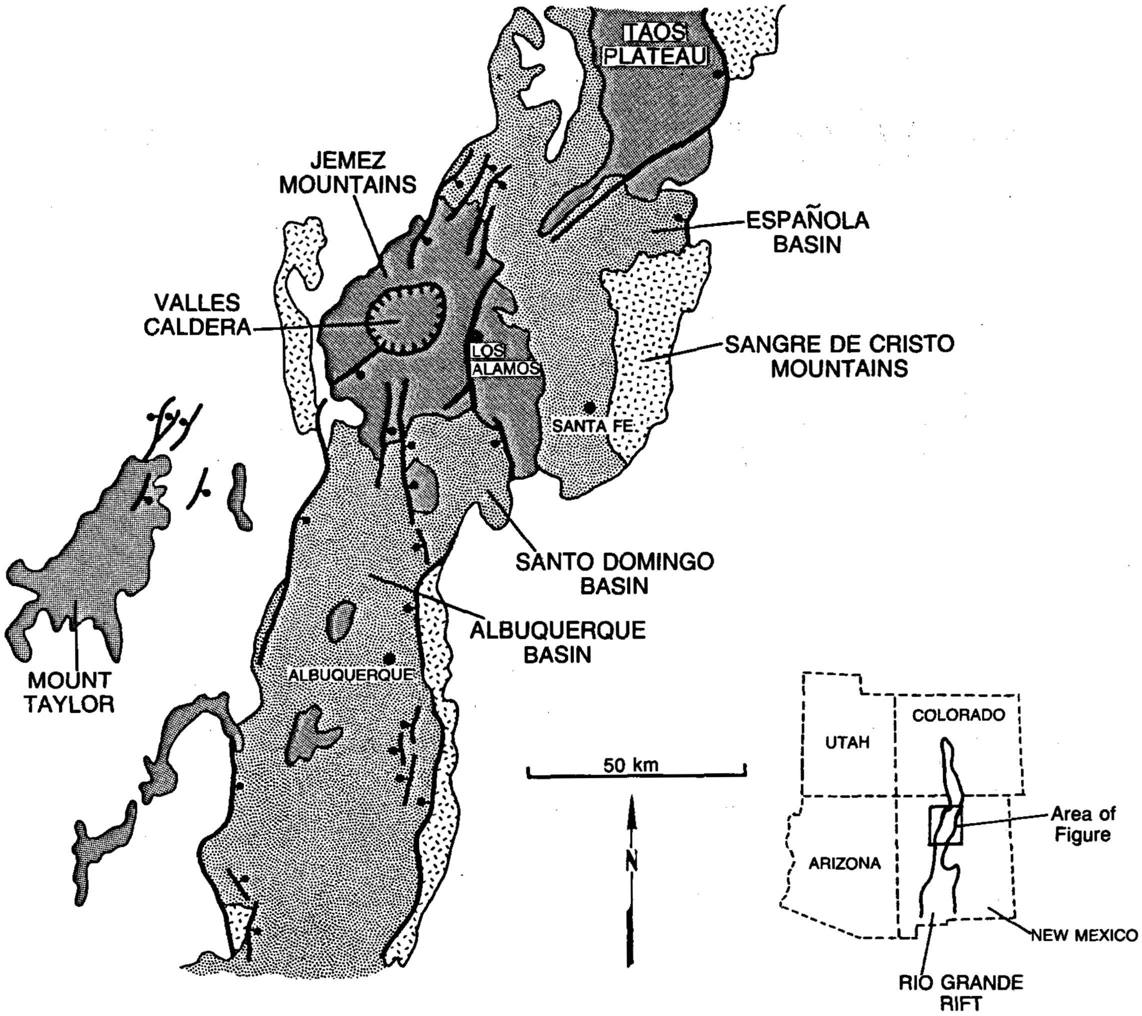


Fig. 1. Location map of the Jemez Mountains, Valles caldera (closed depression), and Rio Grande rift. Regular stipple = Tertiary-Quaternary basin-fill sediments; close-spaced stipple = Tertiary-Quaternary volcanic rocks; jackstraw = Precambrian rocks.

fumarole area of Sulphur Springs, to obtain stratigraphic and structural data near the resurgent dome, and to investigate ore deposit mechanisms in an active hydrothermal system (Goff et al. 1987; Hulen et al. 1987). Coring of the 856-m VC-1 took 35 days to complete, ending on September 3, 1984. Coring of the 528-m VC-2a took 28 days to complete, ending on September 28, 1986.

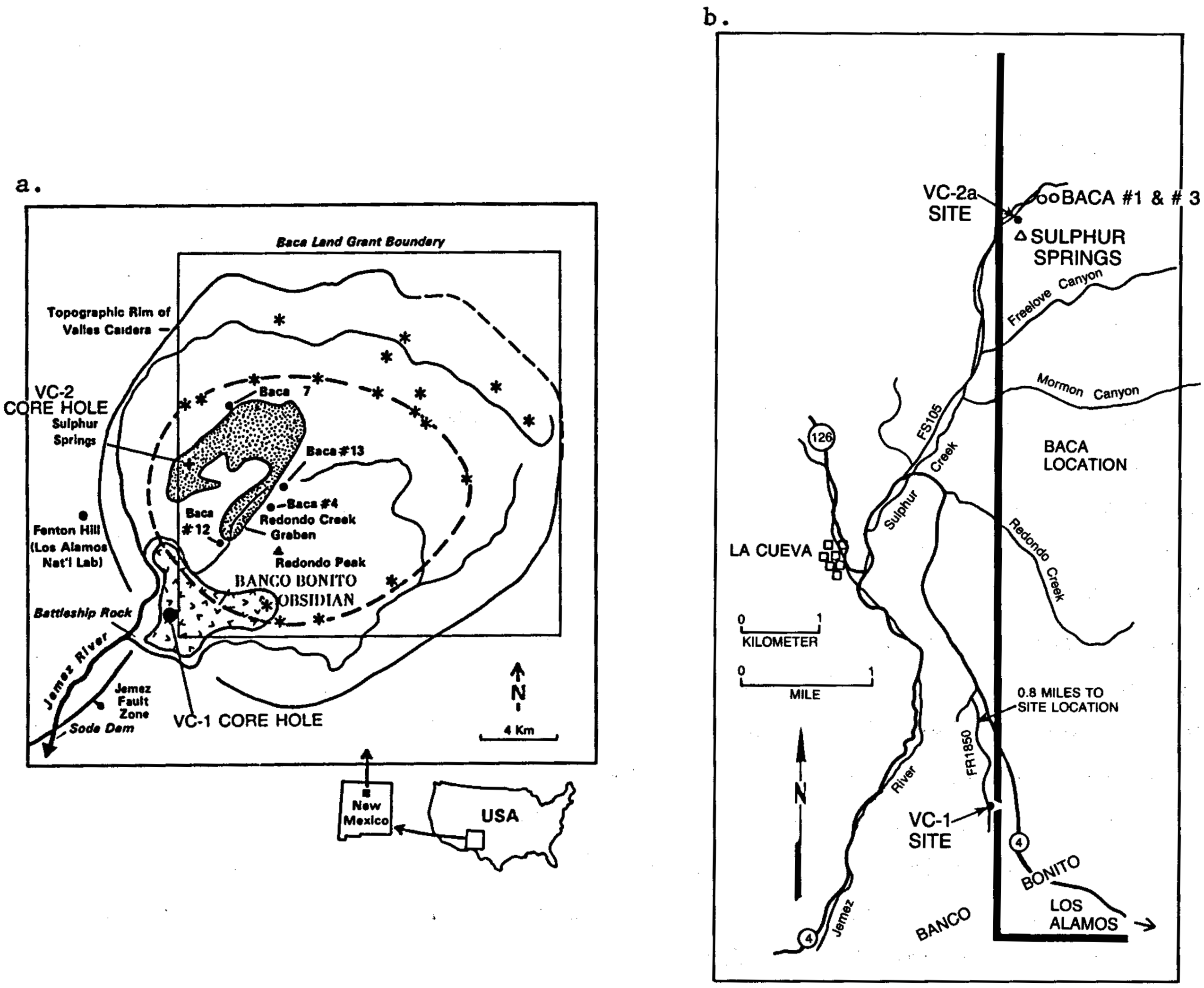


Fig. 2. a. Location map of CSDP core holes VC-1 and VC-2a in the Valles caldera. Stippled pattern is the area of intense surface hydrothermal alteration. b. Detailed location map of CSDP core holes VC-1 and VC-2a.

The purpose of this report is to provide a scientific data base on VC-1 and VC-2a to interested researchers working on caldera processes in active magma-hydrothermal systems. This data base was compiled from investigations initiated primarily at Los Alamos National Laboratory as part of the CSDP funded by the US Department of Energy, Office of Basic Energy Sciences. Detailed core lithology of VC-1 and VC-2a has been presented by Gardner et al. (1987) and Starquist (1988), respectively.

A compilation of photographs of various well site operations at VC-1 and VC-2a is presented in Appendix A. All tables appear in Appendix B.

## A. Geologic Setting

The geology of the Jemez Mountains and the Valles caldera has been described by Ross et al. (1961), Smith et al. (1961), Griggs (1964), Doell et al. (1968), Bailey et al. (1969), Laughlin (1981), Laughlin et al. (1983), Gardner and Goff (1984), Heiken and Goff (1983), Nielson and Hulen (1984), Gardner et al. (1986), Heiken et al. (1986), and Self et al. (1986).

The Jemez Mountains consist of an extensive pile of Tertiary and Quaternary lavas and tuffs that ranges in age from >13 to 0.13 Ma. Volcanic activity culminated with the eruption of greater than 600 $km^3$ of Bandelier Tuff and the development of the Toledo and Valles calderas. The caldera is actually a nested caldera complex: the Toledo caldera formed at 1.45 Ma with the eruption of the Otowi Member of the Bandelier Tuff, and the Valles caldera formed at 1.12 Ma with the eruption of the Tshirege Member of the Bandelier Tuff. The volcanic sequence overlies a section composed of Precambrian granite, schist and gneiss, and Paleozoic to Tertiary sedimentary rocks. The Paleozoic units include the Pennsylvanian Sandia and Madera Formations and the Permian Abo and Yeso Formations. Mesozoic units include the Triassic Chinle Formation and the Jurassic Entrada, Todilto, and Morrison Formations. The Mesozoic units crop out south of the Jemez Mountains. Tertiary rocks include the Abiquiu Formation and Galisteo Formations and the Santa Fe Group.

Rocks of the Colorado Plateau in this region are downfaulted to the east into the Rio Grande Rift. The Jemez Mountains volcanics occur at the intersection of the rift with the Jemez lineament, a northwest-trending line of Miocene to Quaternary volcanic fields extending across the northwest portion of New Mexico (Aldrich and Laughlin 1984).

Three types of natural thermal waters occur within the Valles caldera. These waters are (1) acid-sulfate, (2) thermal meteoric, and (3) deep geothermal and derivative. Each type possesses distinct geologic and structural control and unique chemical and isotopic characteristics (Goff and Grigsby 1982).

Acid-sulfate waters are restricted to the interior of the caldera where they issue from faults and fissures within the resurgent dome. Chemically, they have extremely high $SO_4$, low pH, and more K than Na (Shevenell et al. 1987). Isotope data show that the acid springs are meteoric water and condensed steam. Carbon dioxide is by far the dominant gas, although $H_2S$ and sublimed sulfur occur around the fumaroles.

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# memorandum

TO: Holders of LA-11496-OBES

DATE: April 18, 1989

FROM: John A. Musgrave

MAIL STOP/TELEPHONE:

SYMBOL:

SUBJECT: Errata for LA-11496-OBES

The title for Table B-XIII, p. 60, is incorrect. This table is a continuation of Table B-XII, p. 59, and the title should read

> TABLE B-XII (cont). WHOLE ROCK CHEMISTRY FOR SELECTED, UNALTERED ROCKS FROM THE JEMEZ REGION (oxide values in wt%; trace element values in ppm).

The corrected p. 60 is attached.

Please insert Table B-XIII (a new page, 60A, attached):

> TABLE B-XIII. INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS, VC-2A, VALLES CALDERA, NEW MEXICO (values in ppm).

TABLE B-XII (cont). WHOLE ROCK CHEMISTRY FOR SELECTED, UNALTERED ROCKS FROM THE JEMEZ REGION (oxide values in wt%; trace element values in ppm)

| Sample Number | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MnO | MgO | CaO | $K_2O$ | $Na_2O$ | $P_2O_5$ | $H_2O^+$ | $H_2O^-$ | Totals | Ba | Rb | Sr | V | Cr | Ni | Zn | Y | Zr | Nb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Welded Upper Bandelier Tuff F81-160 | 75.3 | 0.07 | 11.70 | 1.46 | 0.07 | 0.08 | 0.31 | 4.28 | 4.07 | 0.01 | | 1.99 | 99.34 | – | 250 | – | – | – | – | 70 | – | 240 | – |
| Welded Upper Bandelier Tuff F83-275 | 76.5 | 0.12 | 11.80 | 1.43 | 0.05 | 0.05 | 0.23 | 4.74 | 3.72 | 0.01 | | 1.22[a] | 99.87 | – | – | – | – | – | – | – | – | – | – |
| Upper Bandelier Tsankawi Pumice F82-94 | 72.7 | 0.08 | 12.2 | 1.47 | 0.08 | 0.05 | 0.33 | 5.36 | 3.08 | 0.005 | | 4.01[a] | 99.365 | – | 330 | – | – | – | – | 33 | – | 350 | – |
| Welded Lower Bandelier Tuff F83-45 | 77.0 | 0.08 | 12.1 | 1.48 | 0.05 | 0.06 | 0.25 | 4.39 | 4.23 | 0.01 | | 0.28[a] | 99.93 | – | 180 | 20 | 17 | – | – | 90 | – | 140 | – |
| Lower Bandelier Pumice F82-11 | 73.6 | 0.04 | 11.9 | 1.40 | 0.07 | 0.10 | 0.24 | 4.61 | 4.36 | 0.005 | | 4.26[a] | 100.585 | – | 330 | 9.9 | 16 | 5 | – | 20 | – | 190 | – |
| Lower Bandelier Guaje Pumice F83-12 | 74.2 | 0.08 | 11.8 | 1.50 | 0.05 | 0.09 | 0.30 | 5.88 | 2.86 | 0.005 | | 2.95[a] | 99.385 | – | 184 | 6.1 | – | – | – | – | – | 186 | 83 |
| Pre-Bandelier Ignimbrite "B" F82-92 | 74.4 | 0.10 | 11.8 | 1.54 | 0.06 | 0.08 | 0.33 | 4.67 | 4.00 | 0.005 | | 3.35[a] | 100.335 | – | 155 | 2.1 | – | 5 | – | 40 | – | 180 | 71 |
| Pre-Bandelier Ignimbrite "A" F82-91 | 73.0 | 0.11 | 12.0 | 1.25 | 0.06 | 0.42 | 0.45 | 4.90 | 2.90 | 0.005 | | 4.70[a] | 99.795 | – | 145 | 12 | – | – | – | – | – | – | 71 |
| Cerro Rubio Quartz Latite F83-245 | 66.9 | 0.47 | 15.2 | 3.43 | 0.05 | 1.42 | 3.32 | 3.20 | 3.60 | 0.15 | | 0.28[a] | 98.02 | 1170 | 52 | 500 | 64 | 51 | – | 73 | – | 160 | – |
| Paliza Canyon Dacite Type 1 JG81-31 | 66.48 | 0.68 | 15.75 | 3.27 | 0.07 | 0.58 | 1.91 | 3.81 | 5.49 | 0.19 | | 0.57[a] | 98.80 | 2400 | 95 | 505 | 31 | – | – | 52 | – | 454 | 39 |
| Paliza Canyon Andesite, Type 1 JG82-28 | 59.98 | 1.09 | 16.37 | 6.40 | 0.08 | 2.66 | 5.27 | 2.55 | 4.25 | 0.40 | | 0.47[a] | 99.52 | 1280 | 55 | 718 | 144 | 25 | – | 71 | – | 241 | 19.6 |

[a] Combined $H_2O/H_2O^-$.

TABLE B-XIII. INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS, VC-2A, VALLES CALDERA, NEW MEXICO (values in ppm)

| Element | VC2A105.5 | VC2A119 | VC2A129.5 | VC2A340 | VC2A425 | VC2A440 | VC2A553 | VC2A653.3 | VC2A752 | VC2A857 | VC2A954.4 | VC2A1051.8 | VC2A1142 | VC2A1254 | VC2A1357 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Na | 118 | 420 | 490 | 920 | 142 | 116 | 1080 | 24200 | 980 | 12300 | 9100 | 16100 | 22900 | 1620 | 940 |
| Mg | <1000 | <1100 | <1000 | 1300 | 3100 | <900 | <1600 | <3000 | 4000 | <1800 | <2000 | 4700 | <1700 | <1400 | 2100 |
| Al | 65000 | 59000 | 59000 | 52000 | 53000 | 51000 | 64000 | 61000 | 53000 | 58000 | 60000 | 56000 | 58000 | 61000 | 64000 |
| Cl | <30 | <40 | <30 | <30 | <40 | <30 | <60 | <130 | <50 | <120 | <130 | <130 | <110 | <240 | <760 |
| K | 32000 | 57000 | 55000 | 62000 | 22600 | 21200 | 71000 | 38000 | 56000 | 41000 | 55000 | 44000 | 42000 | 63000 | 30300 |
| Ca | <1100 | <900 | 680 | <500 | <800 | <800 | <1100 | 3200 | 7500 | 8600 | 8200 | 7400 | 4500 | 6600 | <1400 |
| Sc | 2.63 | 2.31 | 2.40 | 1.03 | 1.92 | 1.62 | 1.16 | 1.11 | 0.90 | 1.18 | 0.79 | 0.78 | 0.74 | 1.89 | 4.5 |
| Ti | 1310 | 1170 | 1270 | 440 | 490 | 580 | 470 | <3000 | <3000 | <4000 | <4000 | <4000 | <3000 | 800 | 820 |
| V | 14 | 8.6 | 5.4 | <3 | <4 | <4 | <7 | <6 | <4 | <7 | <8 | <7 | <5 | <6 | 11 |
| Cr | 7.8 | 6.9 | 9.5 | 2.7 | 3.6 | 2.4 | 7.4 | 3.7 | 3.2 | 4.4 | <1.4 | 3.8 | 3.2 | 2.1 | 9.3 |
| Mn | 250 | 60 | 65 | 137 | 211 | 90 | 175 | 380 | 900 | 690 | 640 | 940 | 780 | 640 | 154 |
| Fe | 13600 | 13000 | 13300 | 10800 | 10800 | 10900 | 8300 | 10400 | 8000 | 11200 | 9800 | 11000 | 10500 | 10500 | 13700 |
| Co | 18.2 | 14.2 | 18.9 | 53 | 15.6 | 24.4 | 47 | 34.5 | 28.6 | 50 | 73 | 79 | 27.4 | 73 | 60 |
| Cu | <150 | <140 | <120 | <100 | <140 | <130 | <200 | <300 | <150 | <300 | <300 | <300 | <200 | <200 | <200 |
| Zn | 83 | 94 | 320 | 60 | 910 | 24 | 160 | 180 | 61 | 102 | 180 | 260 | 79 | 49 | 850 |
| Ga | 23 | 15 | 21 | 21 | 21 | 18 | 28 | 17 | 21 | 24 | 20 | 20 | 19 | 22 | 17 |
| As | 75 | 59 | 60 | 68 | 74 | 94 | 54 | <2 | 10.1 | 3.4 | 3.8 | 6.2 | <1.6 | 18.5 | 25 |
| Se | 1.9 | 0.7 | <1.3 | 0.6 | 1.6 | 1.2 | <3 | 0.9 | 0.8 | 1.4 | 1.5 | <1.7 | <1.4 | <2 | <3 |
| Br | <1.4 | <1.3 | <1.3 | <1.1 | <1.4 | <1.4 | <2 | <4 | <1.0 | <3 | <3 | <3 | <2 | <2 | <1.5 |
| Rb | 121 | 214 | 235 | 278 | 146 | 129 | 338 | 189 | 320 | 286 | 337 | 276 | 275 | 270 | 175 |
| Sr | <170 | <110 | <100 | <100 | <140 | <130 | <200 | <200 | <200 | <300 | <300 | <300 | <200 | <300 | <170 |
| Zr | 290 | 260 | 350 | 330 | 230 | 230 | 160 | 230 | 300 | 260 | 210 | 240 | 400 | 300 | 170 |
| Mo | 31 | 60 | 333 | 192 | 103 | 442 | <60 | <180 | 7 | <80 | <70 | <180 | 18 | <70 | <40 |
| Ag | <3 | <1.4 | <1.5 | <1.4 | <1.7 | 4.2 | <2 | <1.6 | <1.3 | <3 | <2 | <1.9 | <1.2 | <3 | 4.8 |
| In | <0.12 | <0.11 | 0.10 | <0.09 | <0.11 | 1.7 | <0.16 | <0.2 | <0.14 | <0.2 | <0.2 | <0.2 | <0.18 | <0.19 | 0.98 |
| Sb | 4.3 | 2.53 | 2.61 | 3.54 | 5.6 | 8.7 | 1.60 | <0.4 | <0.37 | <0.4 | <0.3 | 0.69 | 0.54 | 0.89 | 1.89 |
| I | <12 | <6 | <7 | <8 | <11 | <9 | <11 | <19 | <15 | <20 | <18 | <20 | <17 | <20 | <9 |
| Cs | 1.64 | 2.14 | 2.14 | 3.3 | 4.2 | 2.36 | 7.8 | 5.7 | 6.1 | 7.6 | 5.0 | 4.2 | 4.0 | 4.0 | 6.6 |
| Ba-131 | 250 | 570 | 410 | 230 | 60 | 40 | 180 | 130 | 100 | 160 | <200 | 50 | 80 | 200 | <300 |
| Ba-139 | <1900 | 500 | 450 | 190 | <2000 | <1400 | <3000 | <4000 | <3000 | <3000 | <5000 | <5000 | <3000 | <3000 | <2000 |
| La | 70 | 61 | 59 | 53 | 59 | 45 | 66 | 58 | 47 | 53 | 50 | 49 | 54 | 61 | 47 |
| Ce | 135 | 121 | 116 | 104 | 124 | 110 | 139 | 124 | 100 | 112 | 113 | 113 | 116 | 105 | 105 |
| Nd | 41 | 33 | 47 | 41 | 65 | 57 | 49 | 50 | 41 | 41 | 30 | 60 | 39 | 30 | 24 |
| Sm | 9.1 | 8.0 | 6.9 | 8.5 | 11.4 | 12.4 | 10.8 | 9.8 | 9.8 | 10.8 | 10.4 | 10.2 | 10.4 | 7.1 | 8.0 |
| Eu | 0.50 | 0.44 | 0.40 | 0.23 | 0.30 | 0.25 | 0.16 | 0.21 | 0.11 | 0.26 | 0.20 | 0.076 | 0.070 | 0.30 | 0.43 |
| Tb | 1.18 | 0.90 | 0.97 | 1.36 | 1.77 | 1.82 | 1.59 | 1.75 | 1.85 | 1.81 | 1.93 | 2.3 | 2.26 | 0.91 | 1.52 |
| Dy | 7.2 | 6.0 | 6.1 | 9.9 | 12.6 | 13.2 | 10.9 | 11.6 | 12.1 | 12.5 | 14.2 | 14.8 | 15.1 | 5.8 | 9.7 |
| Yb | 4.7 | 3.4 | 3.4 | 5.6 | 6.7 | 7.4 | 6.8 | 6.2 | 9.2 | 9.1 | 9.1 | 9.8 | 10.3 | 3.6 | 5.9 |
| Lu | 0.59 | 0.51 | 0.49 | 0.74 | 0.87 | 0.85 | 0.94 | 0.91 | 1.27 | 1.01 | 1.24 | 1.48 | 1.49 | 0.45 | 0.84 |
| Hf | 8.7 | 8.7 | 8.0 | 7.9 | 8.2 | 8.3 | 9.7 | 9.2 | 9.6 | 9.6 | 12.4 | 12.3 | 13.2 | 7.1 | 8.4 |
| Ta | 2.85 | 2.5 | 2.68 | 4.0 | 4.6 | 4.1 | 4.9 | 5.7 | 6.1 | 6.5 | 8.4 | 9.5 | 9.4 | 3.3 | 5.2 |
| W | 170 | 121 | 190 | 430 | 170 | 400 | 460 | 420 | 260 | 480 | 520 | 680 | 340 | 630 | 123 |
| Au | 0.015 | 0.018 | 0.033 | 0.019 | 0.023 | 0.022 | <0.009 | <0.015 | <0.006 | <0.017 | <0.011 | <0.014 | <0.011 | <0.014 | <0.006 |
| Hg | <0.6 | <0.3 | <0.3 | <0.3 | <0.3 | <0.5 | <0.4 | <0.3 | <0.3 | <0.7 | <0.4 | <0.4 | <0.3 | <0.6 | <0.4 |
| Th | 14.7 | 11.7 | 11.6 | 16.2 | 17.5 | 17.8 | 20.6 | 21.5 | 21.5 | 24.5 | 29.0 | 30.3 | 30.1 | 15.4 | 20.1 |
| U | 9.9 | 11.3 | 13.3 | 16.5 | 9.1 | 13.0 | 6.2 | 6.4 | 6.8 | 7.6 | 10.3 | 9.7 | 11.2 | 5.0 | 8.1 |

Thermal meteoric waters are found in the moat region of the caldera, where they discharge from fractures and along lithologic contacts between the rhyolite and the underlying volcanic and Paleozoic rocks. These waters are simply near-surface groundwater heated as a result of the high thermal gradient of the area. They are chemically dilute and near-neutral pH and, isotopically, are meteoric water (Shevenell et al. 1987).

Deep geothermal fluids are localized along faults and fractures of the medial graben of the resurgent dome in silicified ignimbrite (Dondanville 1978). The deep fluid is chemically distinct, having approximately 7000 mg/ℓ total dissolved solids (TDS) with significant amounts of Na, Cl, and B. Isotopic data show this water is enriched in $^{18}O$ due to rock-water interaction in a high-temperature environment.

Derivative geothermal fluids containing surface meteoric water discharge along the Jemez fault zone at Soda Dam and Jemez Springs (Fig. 2) (Goff and Grigsby 1982). These waters are chemically similar in the ratios of B/Cl, Br/Cl, and Li/Cl to the deep fluids. The deep fluids migrate out of the principal reservoir inside the caldera, along the Jemez fault zone, and mix with near-surface bicarbonate-rich waters before discharging (Trainer 1975; Goff et al. 1981). The deep fluids may dissolve Paleozoic limestone during the traverse along the Jemez fault zone, and mixed thermal and nonthermal fluids deposit voluminous amounts of travertine at Soda Dam (Goff and Shevenell 1987).

The Valles caldera hydrothermal system resides in caldera-fill ignimbrites at depths of 600 to 2500 m and temperatures of 220° to 300°C (Dondanville 1978; Nielson and Hulen 1984). The Valles hydrothermal system contains two drilled reservoirs or subsystems, the Redondo Creek reservoir (Truesdell and Janik 1986; Smith and Kennedy 1985) and the Sulphur Springs reservoir (Goff et al. 1988). One of the main objectives of VC-1 was to penetrate and verify the thermal outflow plume at a point southwest of the Redondo Creek reservoir (Goff et al. 1986; Rowley et al. 1987). VC-1 verified the existence of the Valles hydrothermal outflow plume through hydrogeochemical data from the aquifers sampled (Goff et al. 1988). One of the main objectives of VC-2a was to penetrate the vapor-dominated cap, pass through the boiling interface, and drill into the liquid-dominated, neutral chloride fluids. Representative samples of the 210°C neutral-chloride fluids at 490 m will be described later in this report (Tables B-I, B-II, and B-III).

## II. METHODS, PROCEDURES, AND ANALYSIS OF SAMPLES

### A. Rock Sampling Procedures and Analysis

VC-2a core was sampled every 16 m over the entire length of the hole. The core was cut lengthwise with one half returned to the core box and the other half crushed and pulverized for x-ray fluorescence (XRF) (Valentine 1983) spectroscopy and instrumental neutron activation analysis (INAA) (Minor and Garcia 1983). A full-diameter by 2-cm cut was made for the preparation of thin sections. The whole rock isotope samples were taken from the split core used for the XRF analysis. Vein quartz and carbonate samples for isotopic analysis were hand-picked from vein material.

Chemical analyses were performed by the following methods: $SiO_2$, $TiO_2$, $Al_2O_3$, $Fe_2O_3$, MnO, MgO, CaO, $K_2O$, $Na_2O$, $P_2O_5$, Ba, Sr, Rb, V, Cr, Ni, Zn, Y, Zr, and Nb by XRF. The INAA technique was used on the following elements: Ag, Al, As, Au, Ba, Br, Ca, Ce, Cl, Co, Cr, Cs, Cu, Dy, Eu, Fe, Ga, Hf, Hg, I, In, K, Lu, Mg, Mn, Mo, Na, Nd, Rb, Sb, Sc, Se, Sm, Sr, Ta, Tb, Th, Ti, U, V, W, Yb, Zn, and Zr. The above analyses were performed at Los Alamos. The selected gold analyses were also performed by fire assay/atomic absorption (AA) spectroscopy. Cold-vapor AA was used to determine Hg. Inductively coupled plasma (ICP) spectroscopy also was used for the determination of Cu, Pb, Zn, Mo, Ag, Co, Ni, Cr, Mn, W, Bi, As, and Sb. Stable isotopic analyses on whole rocks and vein minerals were performed by Geochron Laboratories, Cambridge, Massachusetts. The fire assay/AA and the ICP analyses were performed by Bondar-Clegg, Inc., Lakewood, Colorado.

### B. Water

Seven types of water samples were collected from the two core holes for chemical analyses: (1) a 125-mℓ filtered unacidified water for anions; (2) a 125-mℓ filtered acidified water for cations; (3) a 500-mℓ glass bottle of unfiltered water for tritium analysis; (4) a 30-mℓ glass bottle of unfiltered water for stable isotope analysis; (5) a 60-mℓ bottle of filtered diluted (1:5) water for silica; (6) a 250-mℓ bottle of unfiltered water with 10 mℓ $NH_4OH$ saturated with $SrCl_2$ added for determination of $^{13}C$-$HCO_3$; and (7) a 250-mℓ bottle of unfiltered water with 5 mℓ of formaldehyde added for the determination of $^{18}O$-$SO_4$. Cation samples were acidified in the field to

$pH < 2$. Samples were filtered using a hand-operated vacuum pump with a filter funnel containing 0.45-$\mu$m filter paper.

Chemical analyses were performed by the following methods: $SiO_2$ by colorimetry using ammonium molybdate; Al, As, Ba, Ca, Fe, K, Li, Mg, Mn, Mo, Na, Si, Sr, and Zn by ICP; Ag, $Al^{3+}$, Cd, Co, Cr, Cu, Ni, Pb, and Rb by AA spectroscopy using a graphite furnace; Br, Cl, $NO_3$, $PO_4$, and $SO_4$ by ion chromatography; B by colorimetry using azomethine-H or by ICP; F, $S^{2-}$, $NH_4$, and $O_2$ (dissolved) by ion selective electrode; low-level Na, K, Li by flame AA; and $HCO_3$ and $CO_3$ by titration with $H_2SO_4$ (Trujillo et al. 1987). All of the above chemical analyses were performed at the Fenton Hill laboratory (Los Alamos National Laboratory), and the data appear in Tables B-I and B-II.

Deuterium and $^{18}O$ isotope analyses were performed by Jim Borthwick at the Stable Isotope Laboratory, Southern Methodist University, Dallas, Texas, and the tritium analyses were performed by H. Gote Ostlund at the Tritium Laboratory, University of Miami, Florida, and the data appear in Table B-III.

## C. Well Locations

VC-1 is located 1.3 km off State Road 4 on Fire Road 1850 (Fig. 2) at an elevation of 2492.37 m on Forest Service land. The site is moderately forested, mostly with Ponderosa pine and minor scrub oak. For details on all aspects of the coring operations of VC-1, consult Rowley et al. (1987).

VC-2a is located 4 km off State Road 4 on Forest Service Road 105 (Fig. 2) at an elevation of 2545 m. It is within the Baca Location, but is on two 20-acre patented mining claims at Sulphur Springs owned by John Corbin and partners. Vegetation in the area consists mostly of spruce and fir, minor scrub oak, and along Sulphur Creek willow.

## D. VC-1 Rock Data

A stratigraphic column for VC-1 is presented in Fig. 3. A variety of physical and chemical analyses were performed on VC-1 core samples. Physical properties on selected core samples were analyzed to assess regional and local geologic stresses (Table B-IV) (Dey and Kranz, in press). The concentration of divalent metal cations in shales and limestones of the Madera Formation (Table B-V) was determined as a service for A. F. White (US Geological Survey) in his investigation of the Valles hydrothermal system (White et al., in prep.).

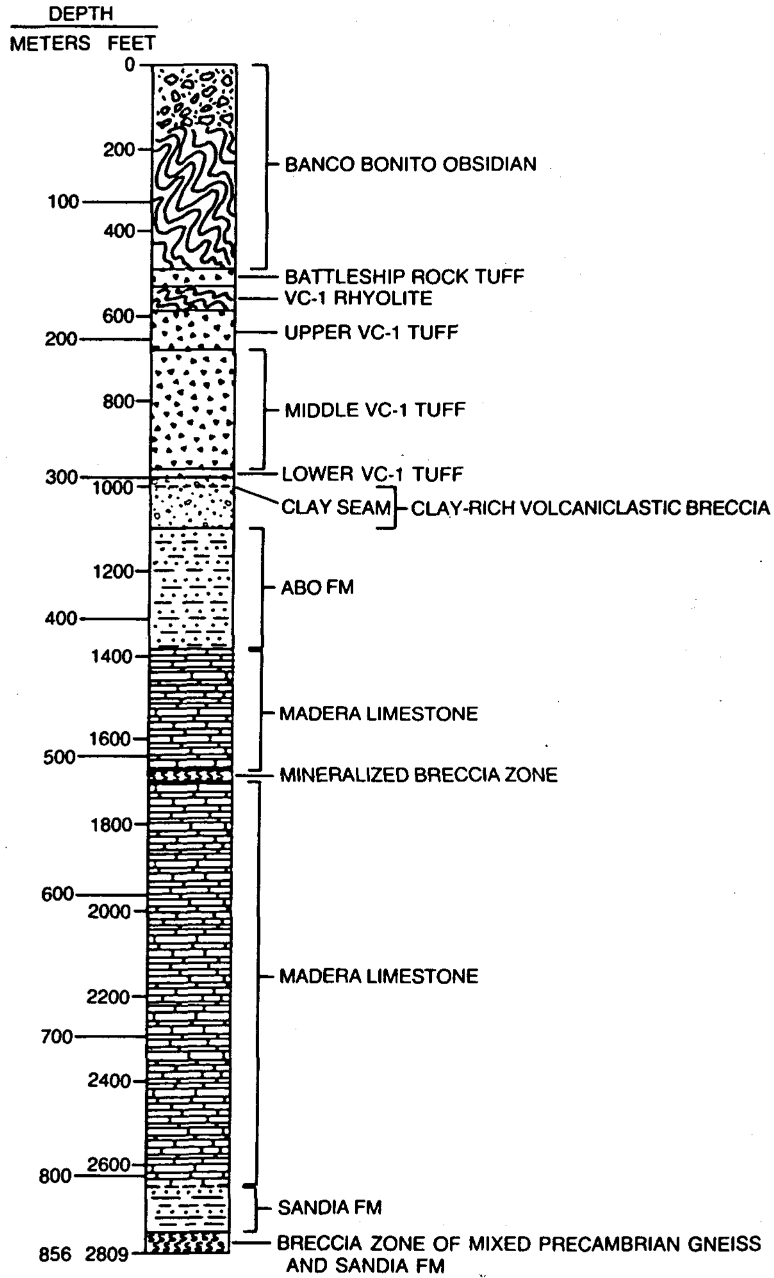



Fig. 3. Stratigraphic section of core hole VC-1.

The concentration of selected metals from a sample of hydrothermally altered and mineralized breccia near the bottom of VC-1 (Table B-VI) was determined to see what other ore elements were associated with the molybdenum in the core hole. The isotopic variation of $\delta^{18}C$ and $\delta^{18}O$ with depth in the shales, sandstones, and limestones of the Madera Formation (Table B-VII and Fig. 4)

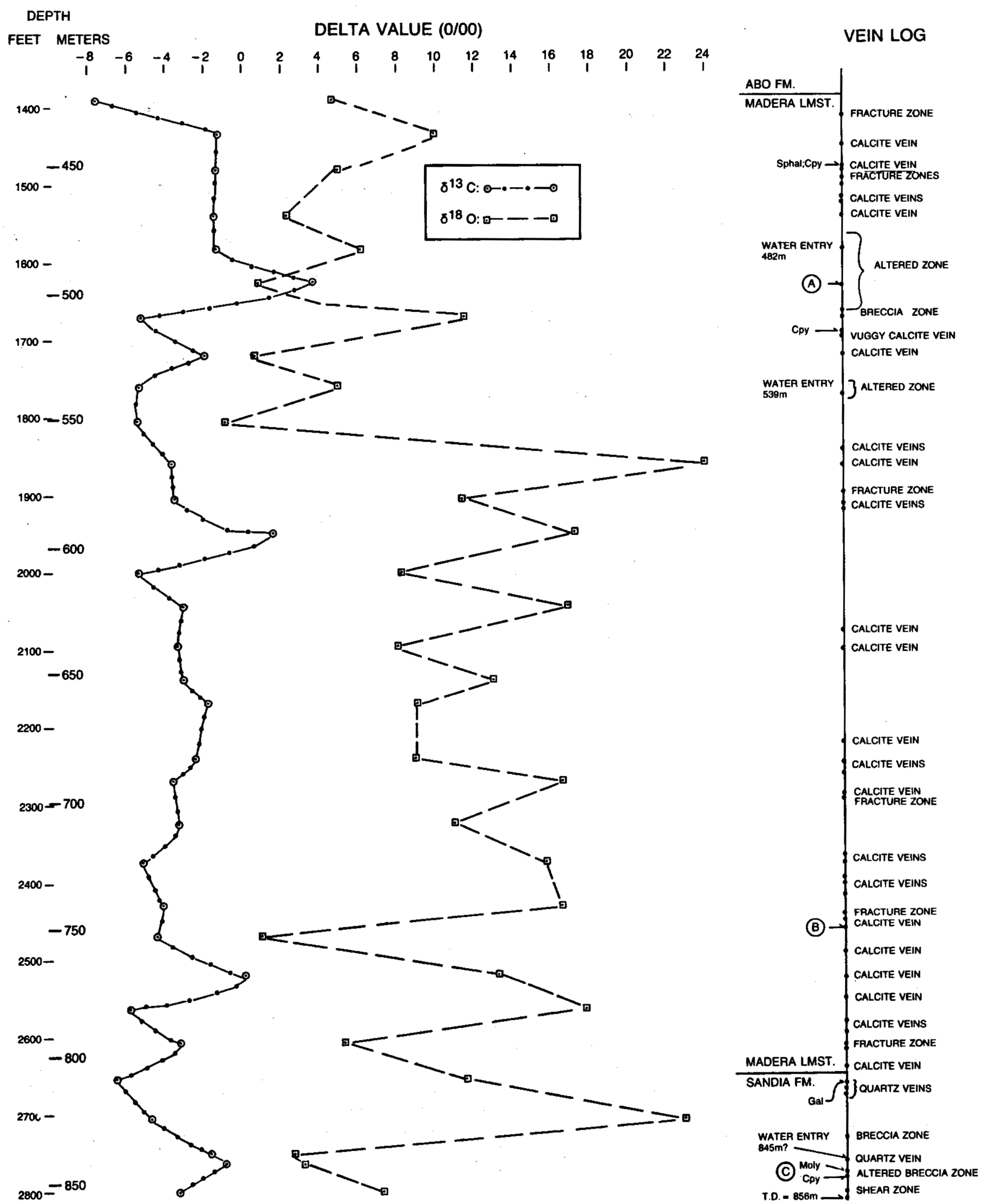



Fig. 4. $\delta^{13}C$ and $\delta^{18}O$ variations in the limestone, shale, and sandstone of the Madera Limestone.

enabled us to measure qualitatively the amount of hydrothermal alteration that has taken place in the Paleozoic section of the core hole (Goff et al. 1986).

## E. VC-1 Geophysical Data

A level line survey was performed on October 3, 1985, by J. Gardner, L. Maassen, and F. Goff for the seismic survey conducted at VC-1 (Table B-VIII). For detailed thermal conductivity measurements on 55 core samples, see Munroe and Sass (1987). Geophysical logs of VC-1 are presented in Goff et al. (1986), Rowley et al. (1987), and Sass and Morgan (in press). Temperature logs taken by Sandia National Laboratories are presented in Fig. 5, and seismic reflections of the Banco Bonito seismic experiment obtained by Los Alamos National Laboratory are presented in Fig. 6.

## F. VC-1 Water Data

One of the main objectives of VC-1 was to demonstrate that thermal fluid discharges from the caldera in a lateral outflow plume. To do this, hydrothermal inflow zones were identified on temperature logs, selected zones were perforated, and the zones were sampled with *in situ* tools and by swabbing.

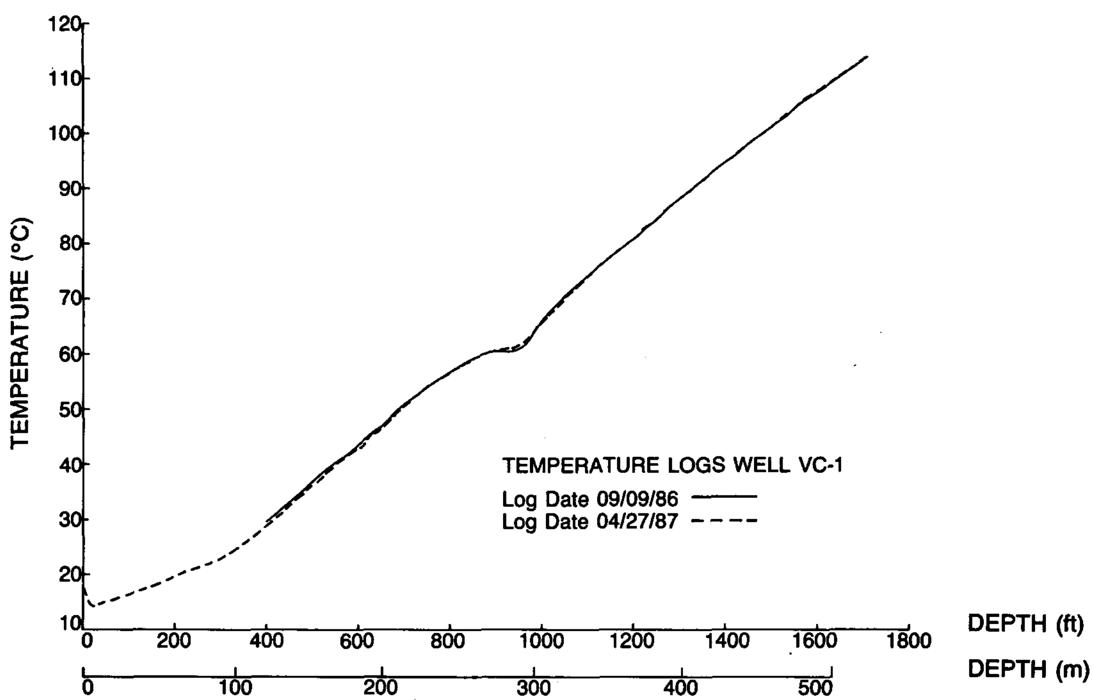



Fig. 5. Temperature log of VC-1. (Data obtained by Sandia National Laboratories.)

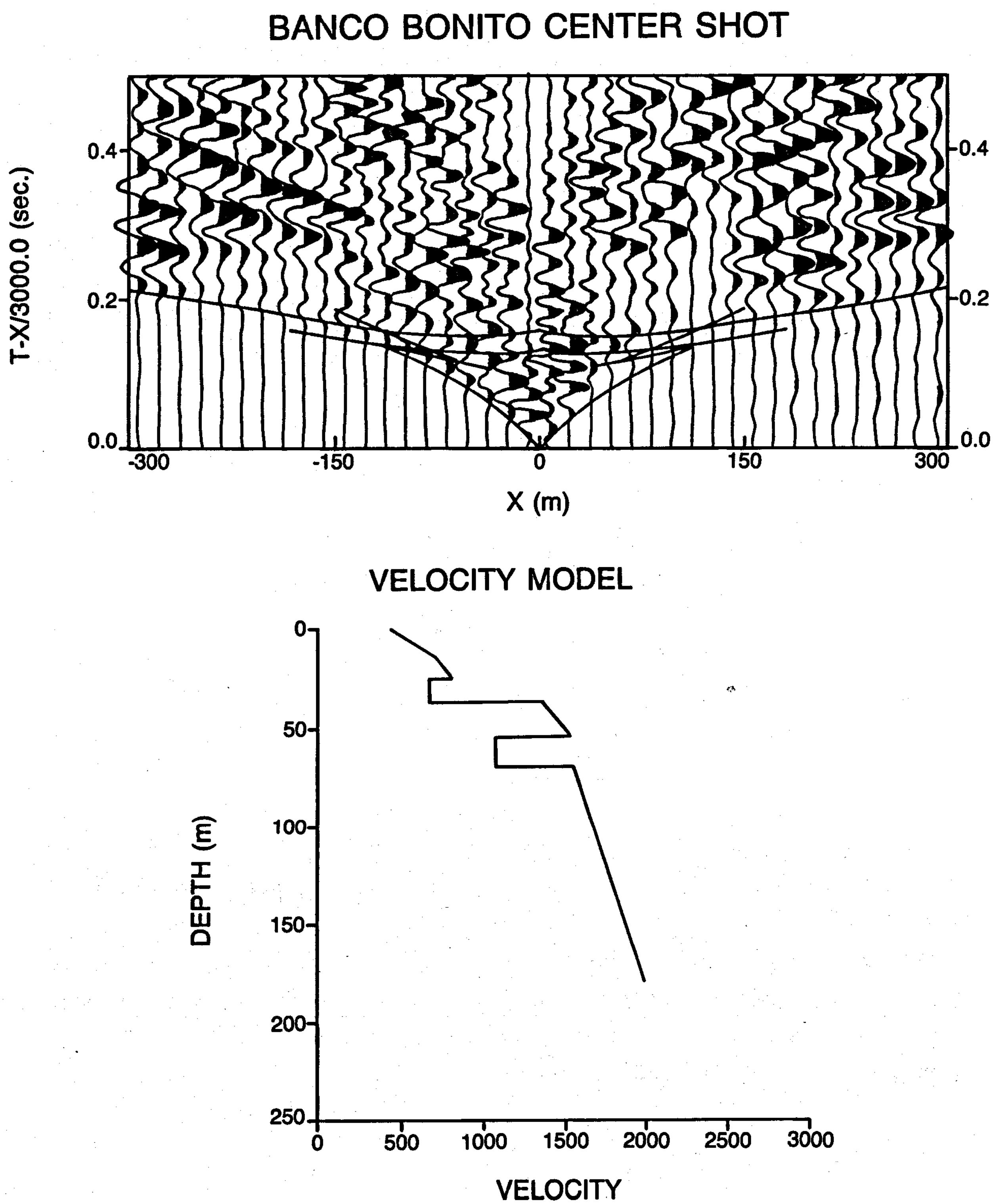



Fig. 6. Banco Bonito shallow seismic experiment.

Data and interpretations are presented in Goff et al. (1988) and White et al. (in prep.).

A 3-m zone centered at 428 m was perforated with 40 holes on July 24, 1985, and two *in situ* water samples were collected from this zone on August 18, 1985 (Table B-IX). From September 3 to 7, 1985, swabbing operations were conducted to remove water and leftover drilling fluids from VC-1. Because of limited permeability, these operations were only partially successful. Nonetheless, about 11,500 ℓ of hydrothermal fluid was extracted from the 428-m zone, and many chemical and isotopic samples were taken (Tables B-I through B-III and Figs. 7 through 9). On May 13, 1986, two more *in situ* water samples were obtained from the 428-m zone. A 6-m zone centered at 537 m was perforated with 40 holes on July 1, 1986, and two *in situ* samples were collected from this zone on August 26, 1986.

## G. VC-2a Rock Data

A stratigraphic column for VC-2a is presented in Fig. 10. A variety of physical and chemical analyses were performed on VC-2a core samples. Analyses of physical properties of selected core samples (Table B-X) and thermal conductivity measurements on four core samples (Table B-XI and Fig. 11) allow comparison of VC-2a data with VC-1 data (Table B-IV; Dey and Kranz, in press; Munroe and Sass 1987). Whole-rock chemistry every 16 m (Table B-XII and Figs. 12-14), neutron activation analysis (Table B-XIII), and gold plus 17 pathfinder element analysis (Table B-XIV and Fig. 15) were conducted to establish trends in major and trace element chemistry that may be associated with hydrothermal activity. ICP spectroscopy of selected samples from the molybdenum zone (Table B-XV) was conducted to evaluate the resource potential of the molybdenite mineralization (Hulen et al. 1987). Stable isotopic analyses of whole rocks and vein minerals, which measure hydrothermal activity, are presented in Table B-XVI and Fig. 16. Results of INAA of sediments and bacteria from the Sulphur Springs area are presented in Table B-XVII as part of a study being conducted by Los Alamos on bacteria growing in unusual environments.

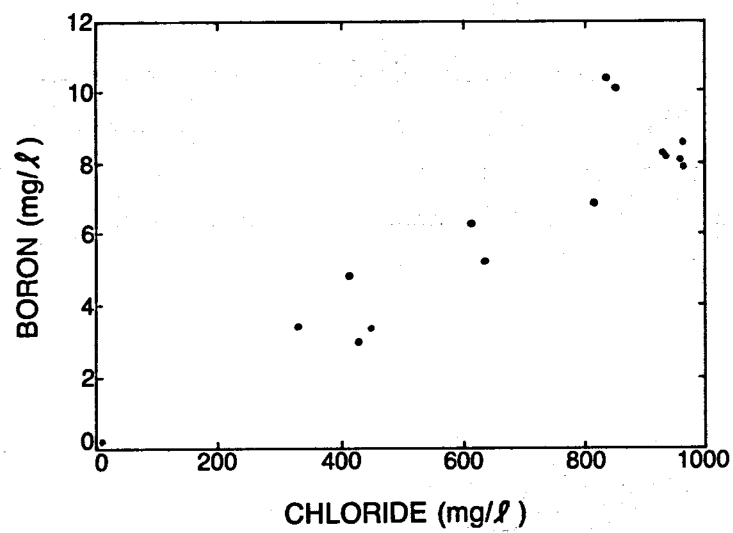
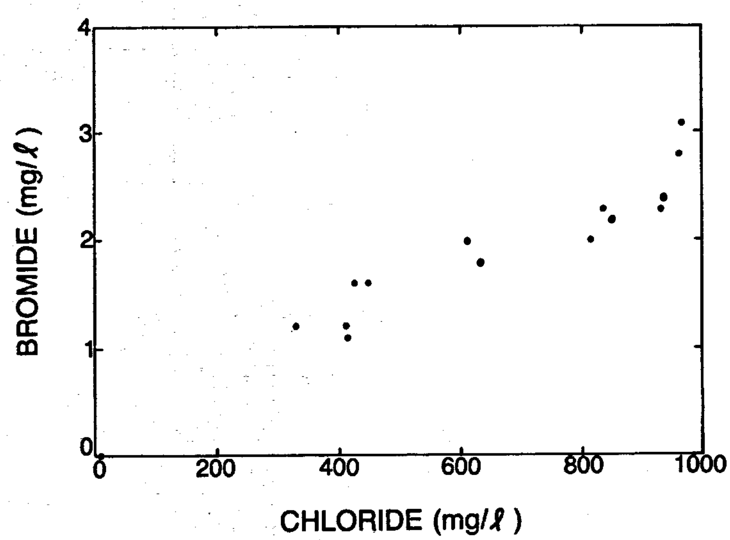



Fig. 7. Plot of boron vs. chloride in VC-1 water.

Fig. 8. Plot of bromide vs. chloride in VC-1 water.



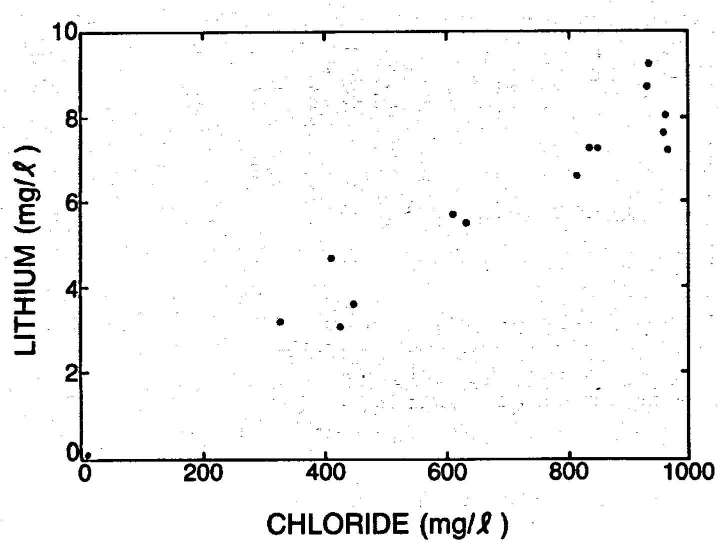




Fig. 9. Plot of lithium vs. chloride in VC-1 water.

## H. VC-2a Geophysical Data

A gamma log and neutron log of VC-2a were conducted by Southwest Surveys, Farmington, New Mexico, on September 27, 1986 (Fig. 17). These logs aided in the selection of the fluid zones that may be perforated at a later date for fluid sampling. Temperature logs taken by Sandia National Laboratories and Los Alamos National Laboratory are presented in Figs. 18 and 19.

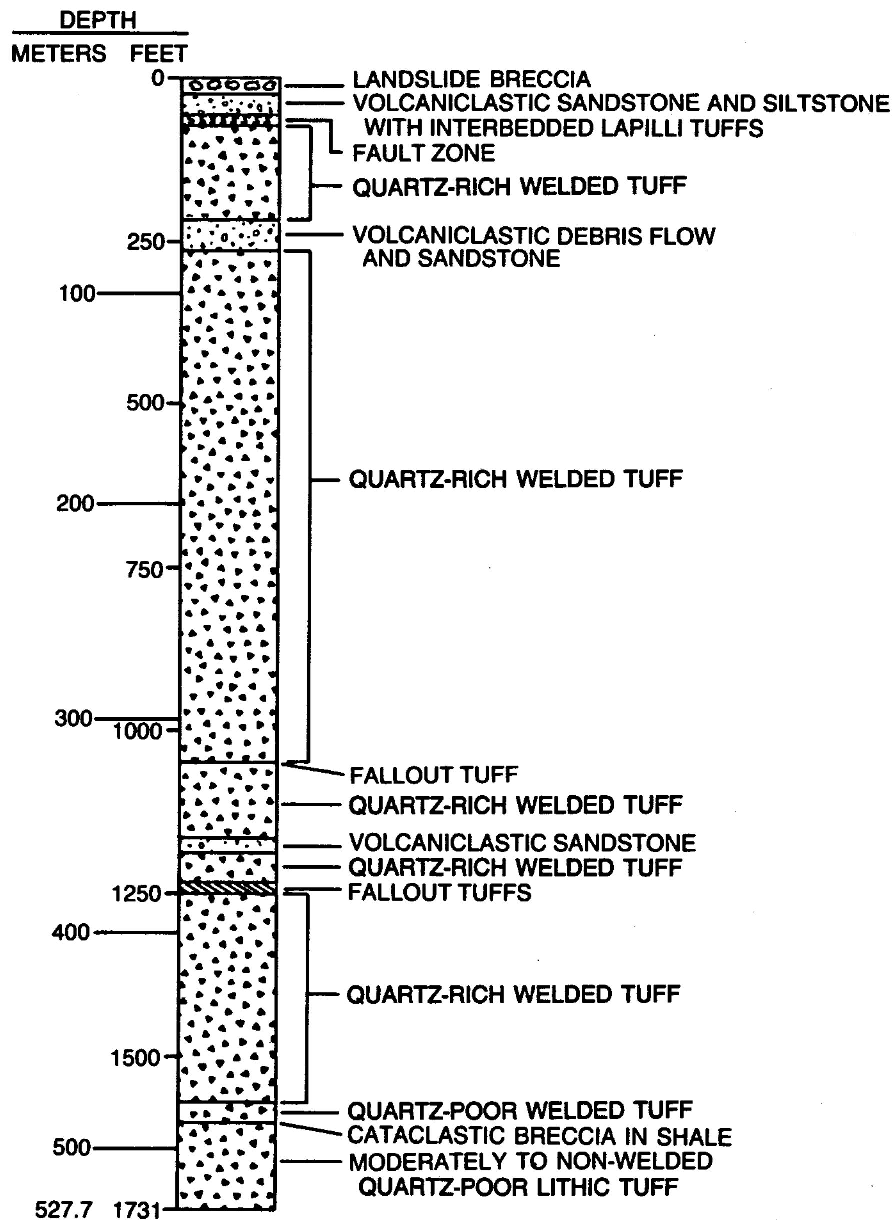



Fig. 10. Stratigraphic column for VC-2a.

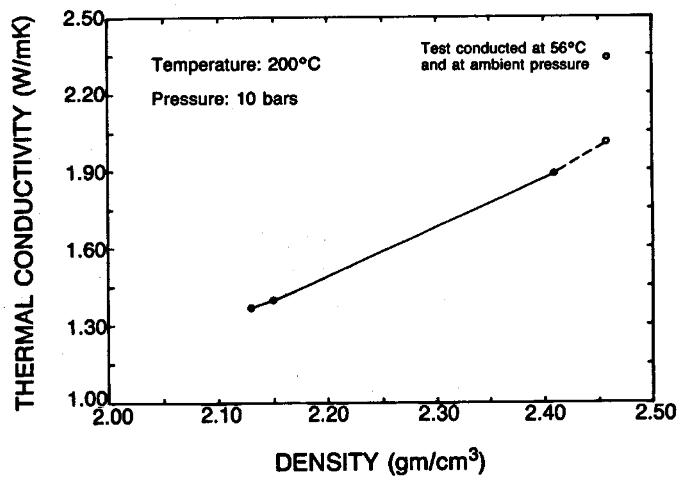



Fig. 11. Plot of thermal conductivities vs. bulk densities for VC-2a. Open circle indicates test performed by the divided bar method; closed circles indicate test by the needle probe method.

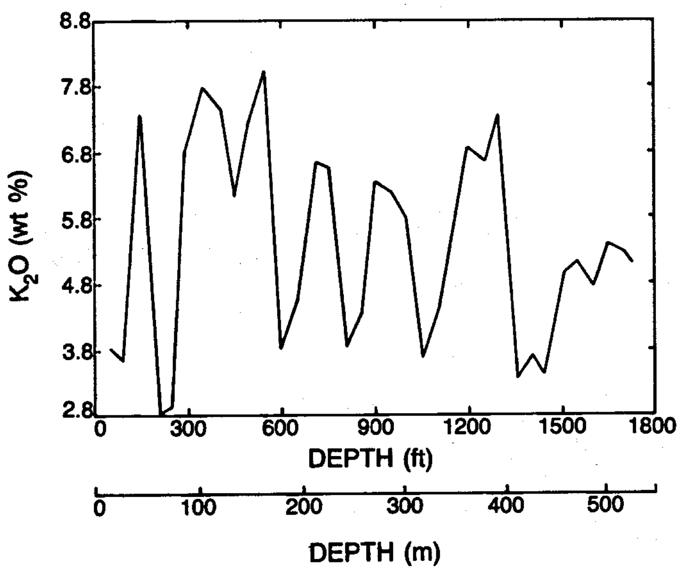



Fig. 12. Plot of potassium distribution vs. depth, VC-2a.

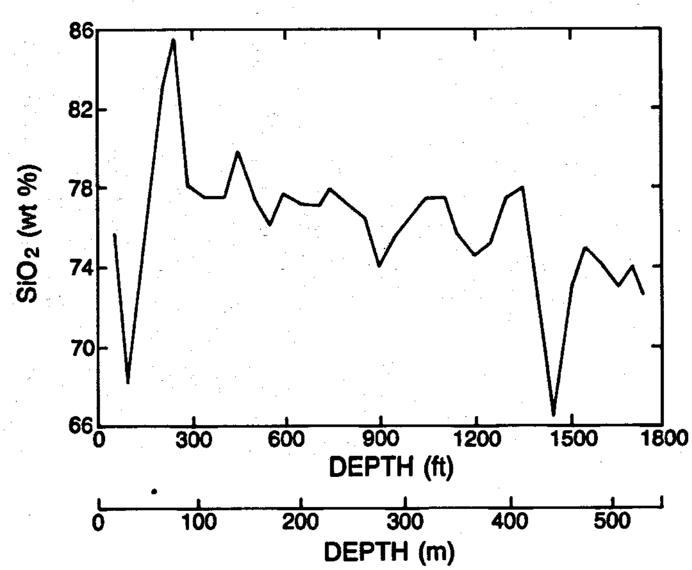



Fig. 13. Plot of $SiO_2$ distribution vs. depth, VC-2a.

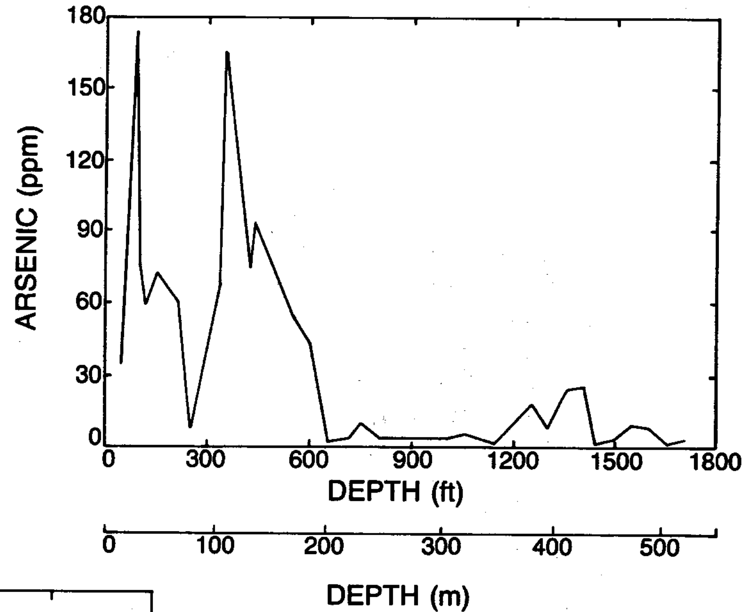



**Fig. 14.** Plot of arsenic distribution vs. depth, VC-2a.

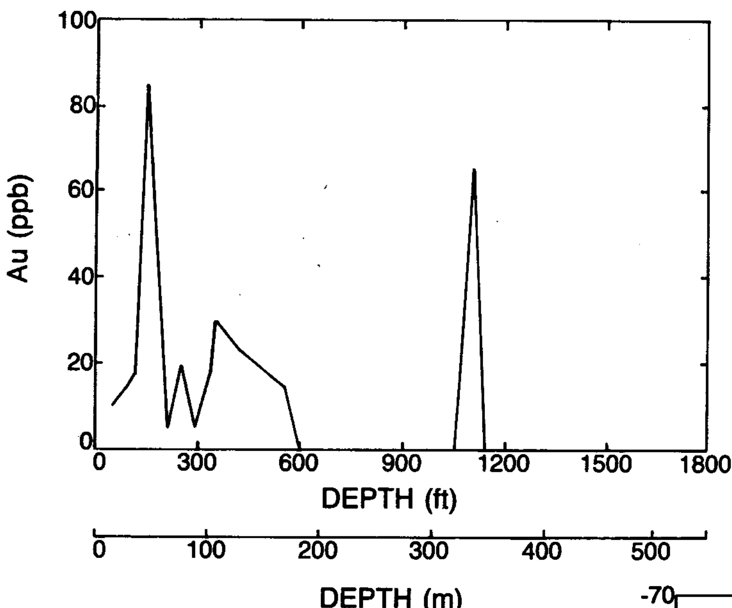



**Fig. 15.** Plot of gold distribution vs. depth, VC-2a.

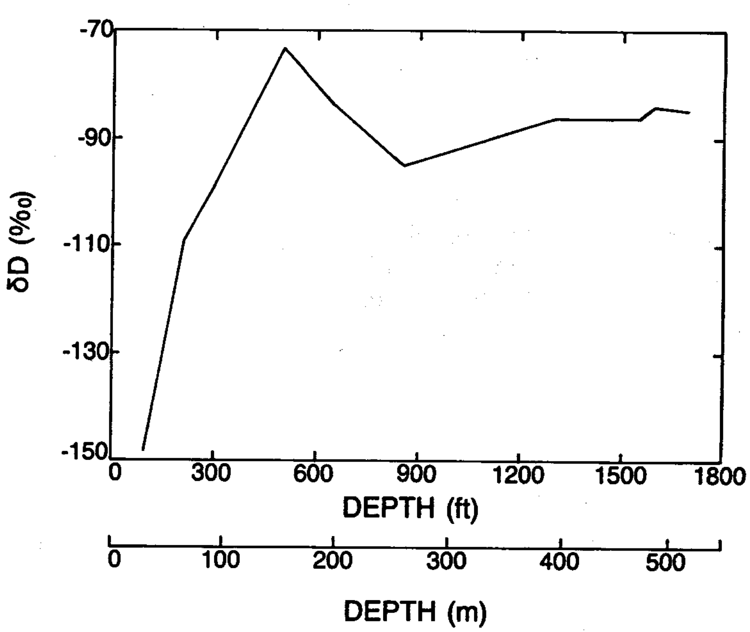



**Fig. 16.** Plot of deuterium in rocks vs. depth, VC-2a.

## I. VC-2a Water Data

Chemical and isotopic monitoring of the Sulphur Springs hot springs was done from April to October 1986 to make sure that no drilling fluid additives from VC-2a contaminated the springs. Data appear in Table B-XVIII. No contaminates were discovered.

Gas and fluid samples were obtained from various depths of VC-2a as part of a major scientific objective to study the hydrothermal system and the liquid-dominated geothermal system at depth. A gas sample was collected from the annulus of VC-2a on September 28, 1986, after completion of coring operations (Table B-XIX). Two more gas samples were collected from the annulus and from the 7.6-cm (3-in.) liner in the core hole on February 12, 1987.

On April 27, 1987, preparations began for the perforation and stimulation of VC-2a at a fluid entry identified in temperature logs at 489.3 m depth and 210°C. On April 28, additional temperature logs and fluid samples were obtained from the core hole. On April 29, after the VC-2a wellhead was torn down and repaired, a 2.4-m zone centered at 489 m was perforated with 9 holes (7 shots failed because of high temperature).

On April 30, an attempt was made to stimulate VC-2a by pressurizing the bore with compressed air and suddenly releasing the pressure. This attempt failed. At the end of the day, the fluid level in the core hole was lowered by bailing with a slender 10-m pipe with a check valve at one end. The objective of this experiment was to lower the hydrostatic pressure in the bore to below the flashing point. In all, 22 bailer runs were made on April 30, and the core hole began to geyser during each of the last 16 runs. Data from the bailer runs are listed in Tables B-I through B-III.

On May 1, 1987, an attempt was made to obtain an STP log of VC-2a with the bore shut in. During the logging operations, the spinner portion of the tool failed. After the tool was removed, the bore was prepared for additional bailing. When the main valve of VC-2a was opened at 11:00 a.m., the bore immediately geysered twice and then began to erupt continuously.

Chemical and isotopic samples were collected from the 489-m zone in VC-2a during a number of surface flow tests. Data appear in Tables B-I through B-III, Table B-IX, and Figs. 20-23.

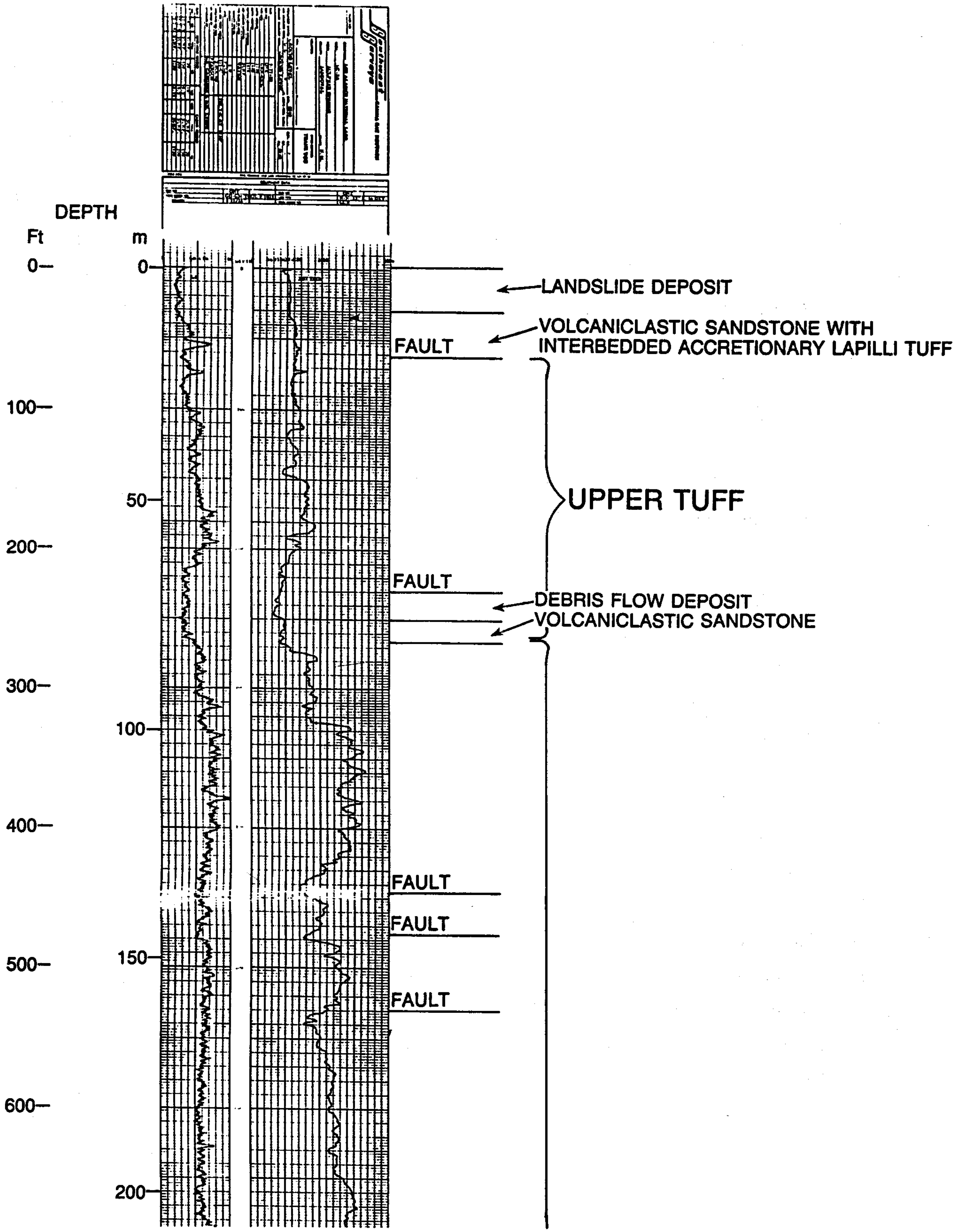
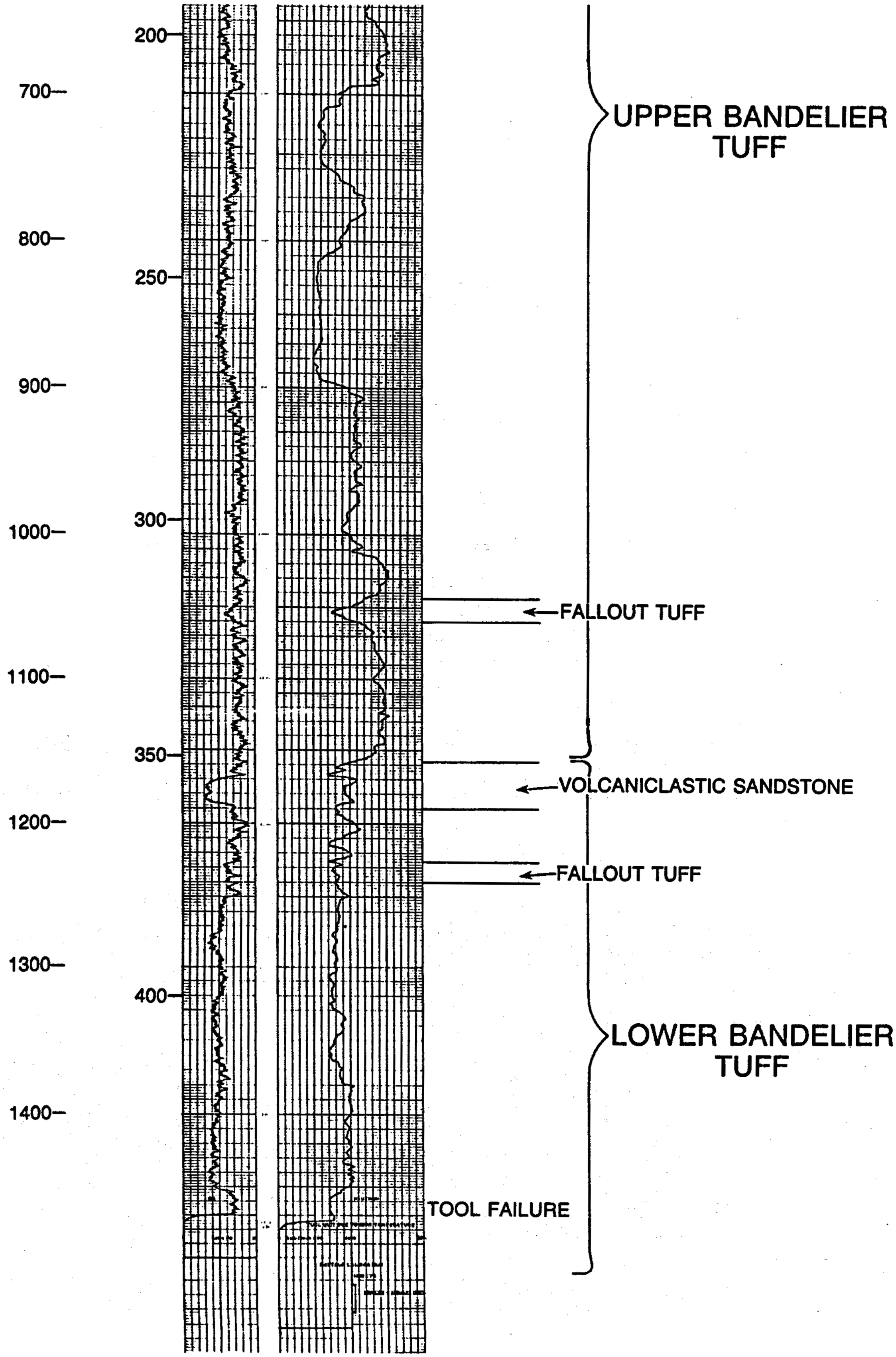



Fig. 17. Neutron and gamma logs for VC-2a. Lithology and major structures plotted for clarity.



200
250
300
350
400
700
800
900
1000
1100
1200
1300
1400
UPPER BANDELIER TUFF
FALLOUT TUFF
VOLCANICLASTIC SANDSTONE
FALLOUT TUFF
LOWER BANDELIER TUFF
TOOL FAILURE


Fig. 17. (cont)

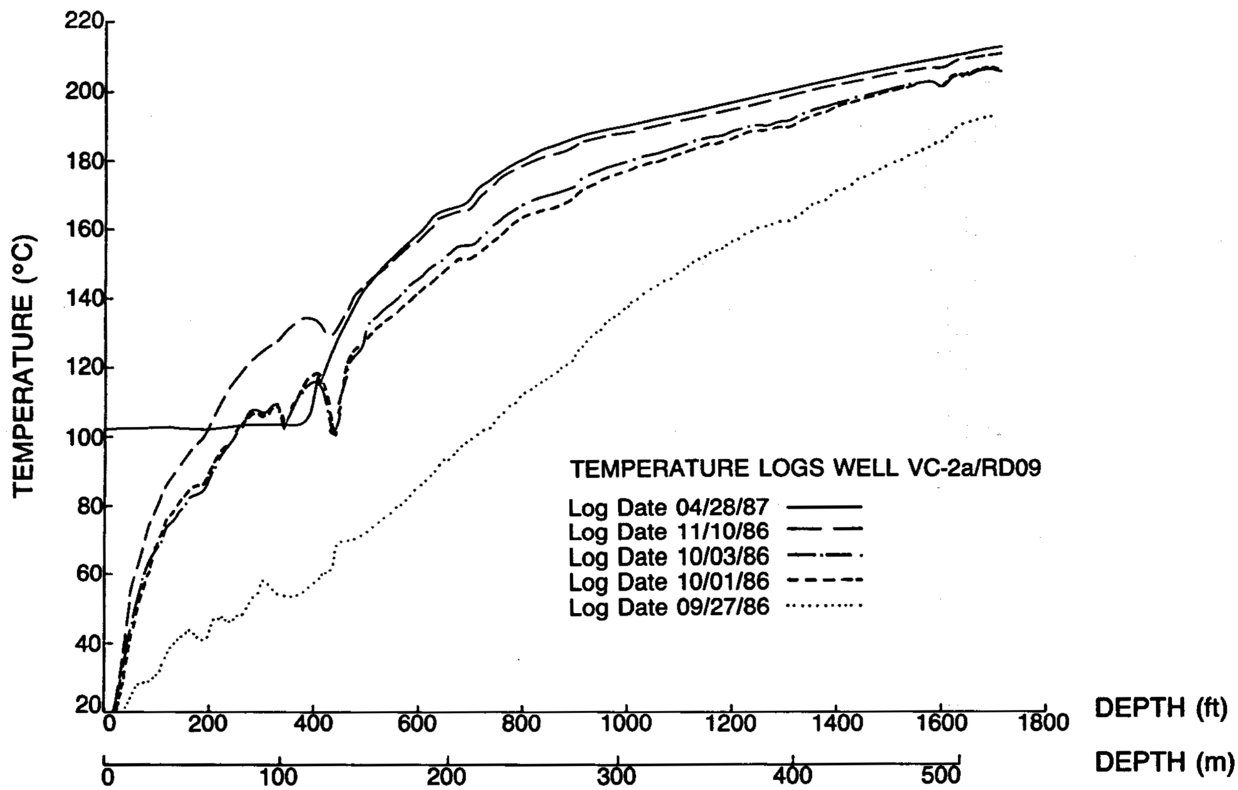



Fig. 18. Temperature logs for VC-2a. Logging operation provided by Sandia National Laboratories.

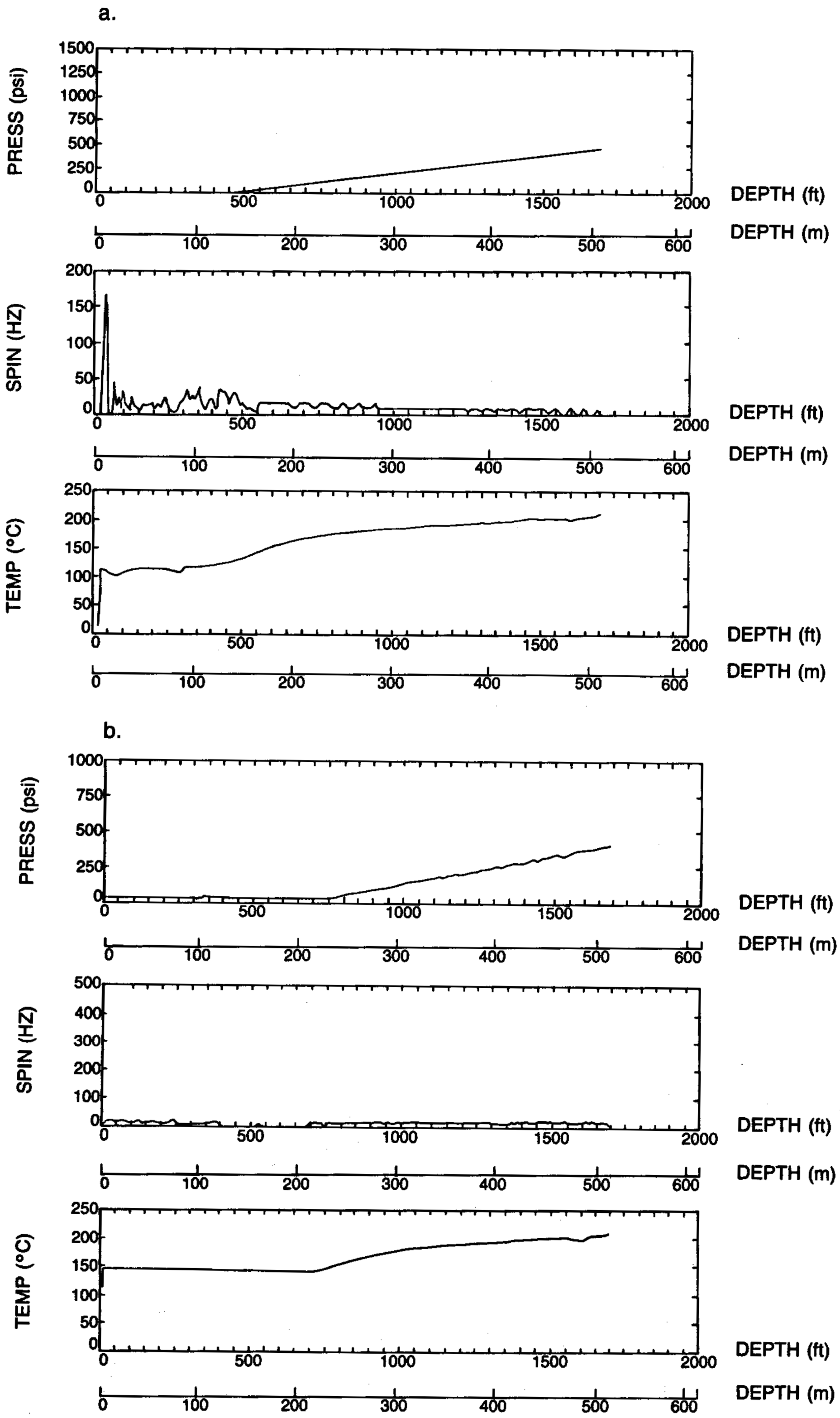



Fig. 19. a. Static temperature log for VC-2a, entering the hole, using the LANL slimhole STP tool, September 18, 1987. b. Static temperature log for VC-2a, using the LANL STP tool, November 4, 1987.

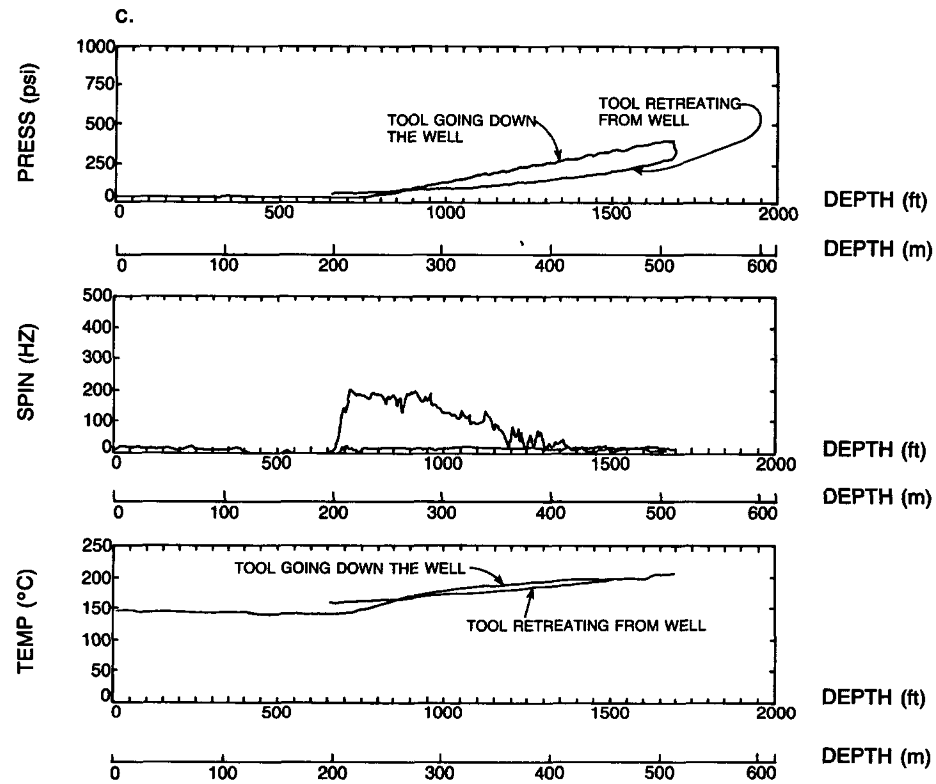



Fig. 19. (cont) c. Flowing temperature log for VC-2a, November 4, 1987, using the LANL STP tool.

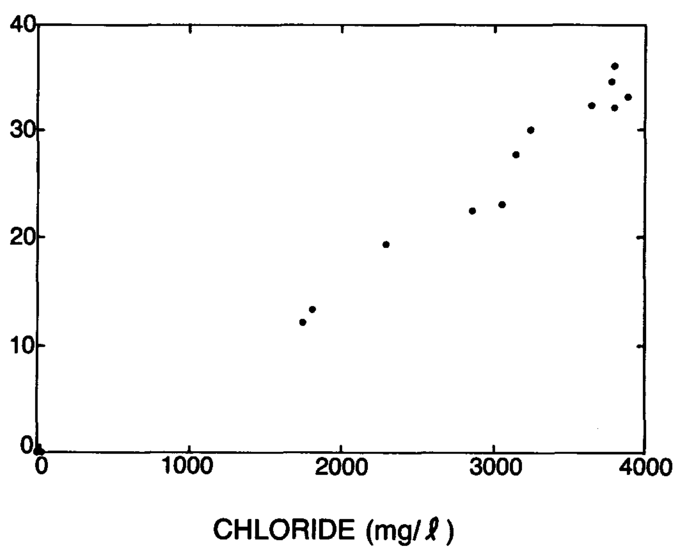



Fig. 20. Plot of boron vs. chloride in VC-2a water.

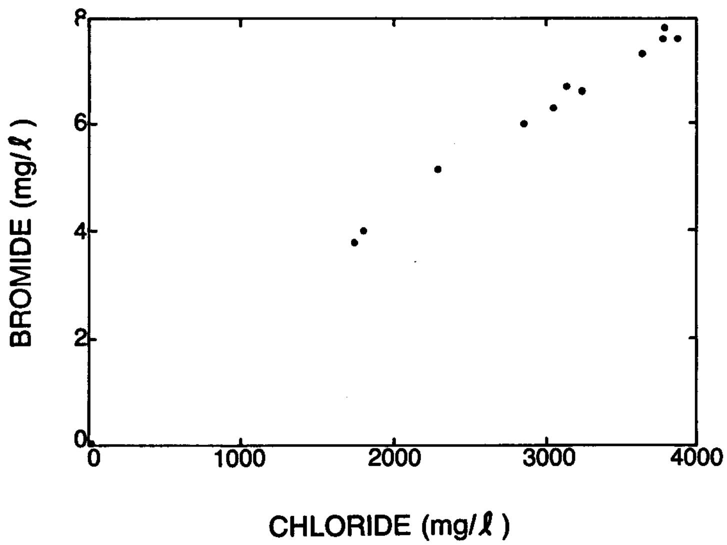



Fig. 21. Plot of bromide vs. chloride in VC-2a water.

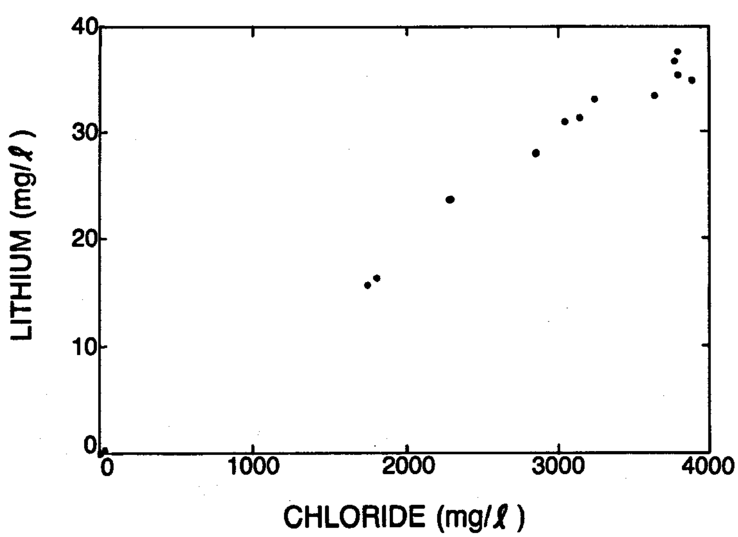



Fig. 22. Plot of lithium vs. chloride in VC-2a water.

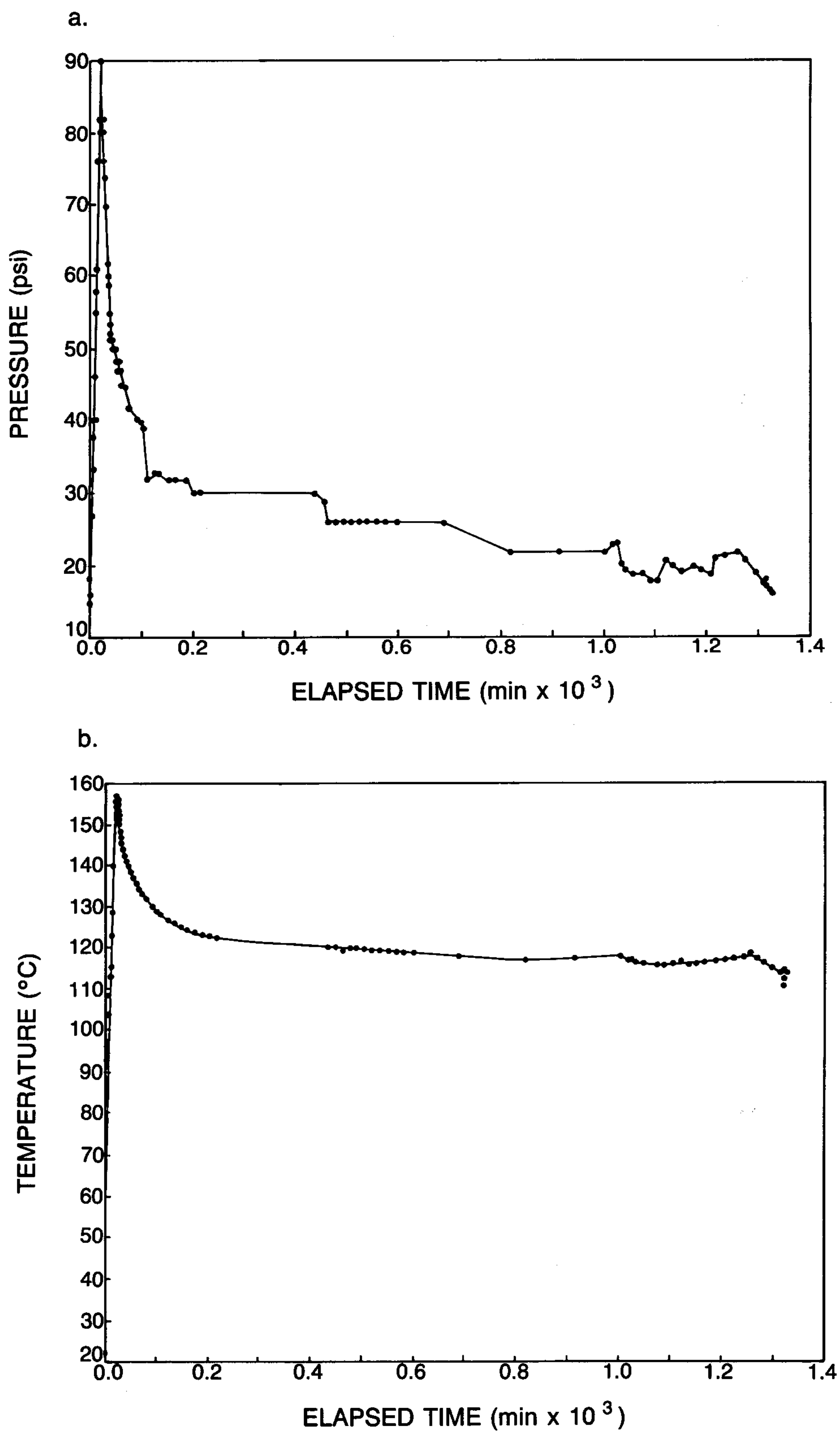



Fig. 23. Plot of selected flow test data from VC-2a, August 28, 1987. a. Pressure as a function of flowing time. b. Temperature as a function of flowing time.

## III. CONCLUSIONS

The physical and chemical data presented in this report are representative of many types of data used in investigations of VC-1 and VC-2a and are intended to stimulate interest in further research. It is hoped that the use of this report will continue to bring about unique and interesting research of the Valles caldera magma-hydrothermal system.

## ACKNOWLEDGMENTS

We thank Farmington Well Service (J. Maness); ESS-4, Los Alamos National Laboratory (Bert Dennis and crew); GRDO, Sandia National Laboratories (R. Jacobson and B. Meyers); Southwest Surveys, Farmington, New Mexico (D. Pearson and P. Aiken). Core holes VC-1 and VC-2a were funded by the US Department of Energy, Office of Basic Energy Sciences. Some scientific investigations were partially funded by an ISRD grant from Los Alamos National Laboratory.

## APPENDIX A

## COMPILATION OF PHOTOGRAPHS, CORE HOLES VC-1 AND VC-2a

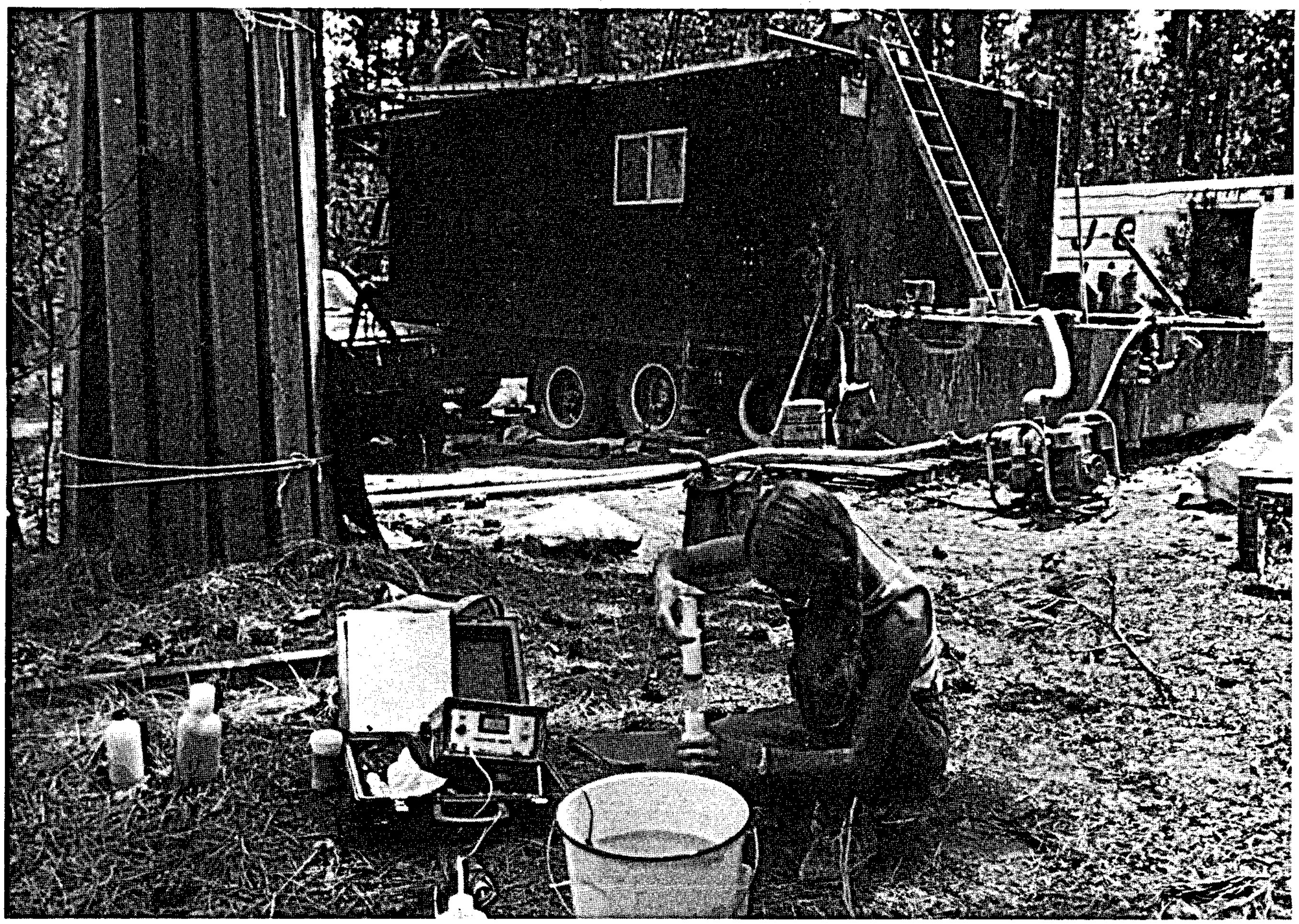


Fig. A-1. Fluid sampling, VC-1, August 1984: hydrogeochemist is filtering drilling mud and measuring the pH of fluid at the drill site for later chemical analysis.

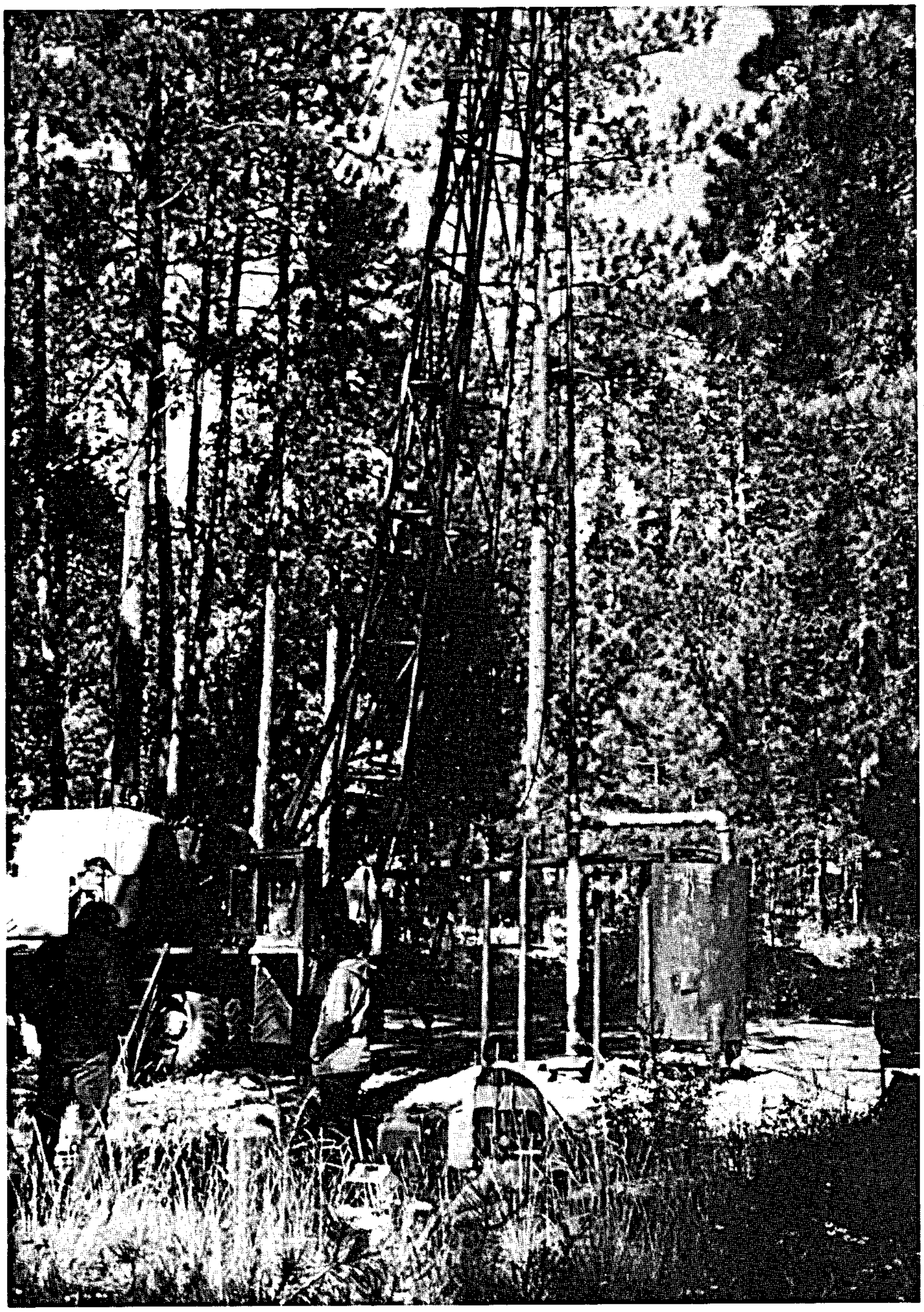


Fig. A-2. VC-1 during swabbing operations September 1985.

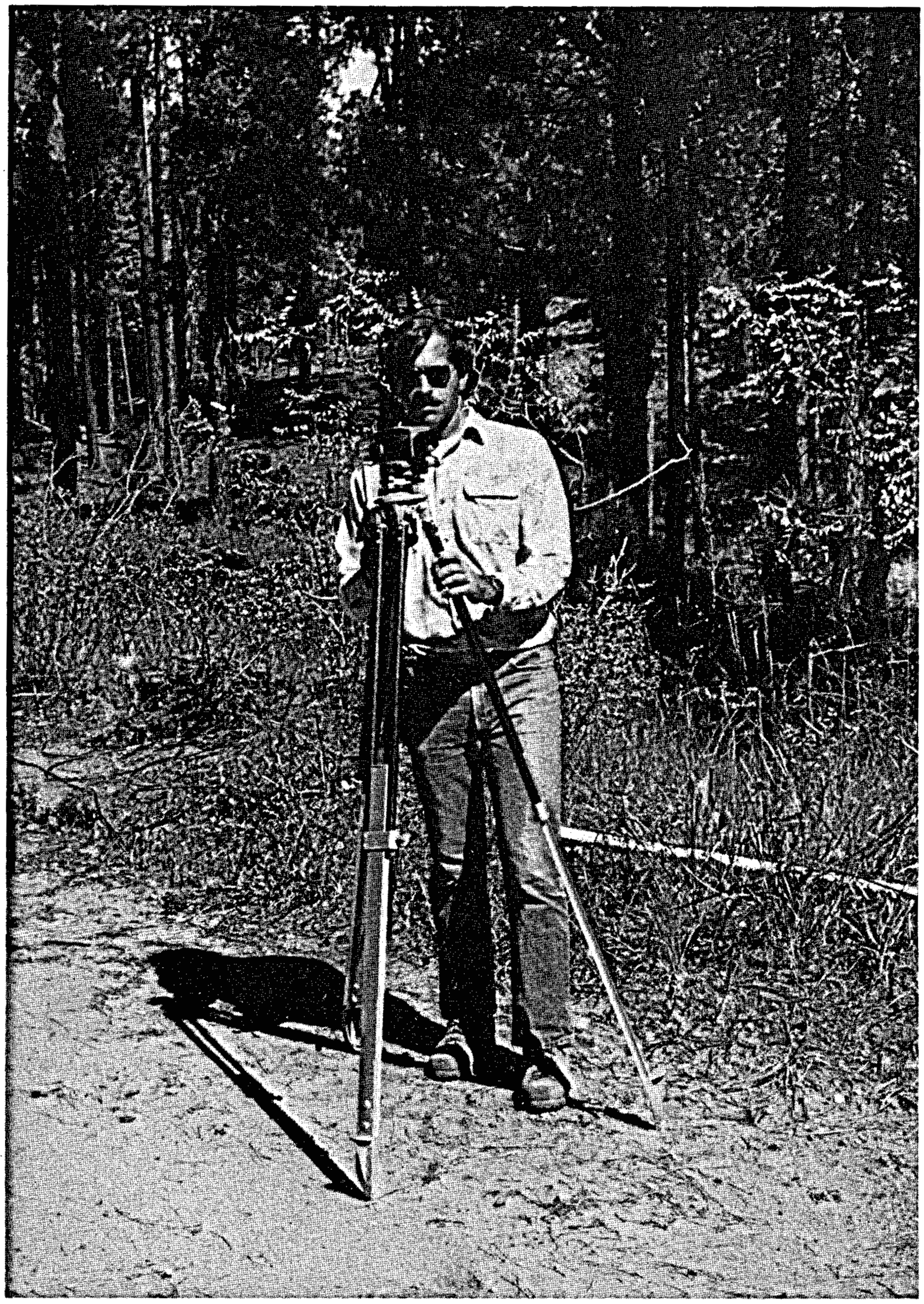


Fig. A-3. Surveying operations in preparation for seismic reflection profile through VC-1, October 1985.

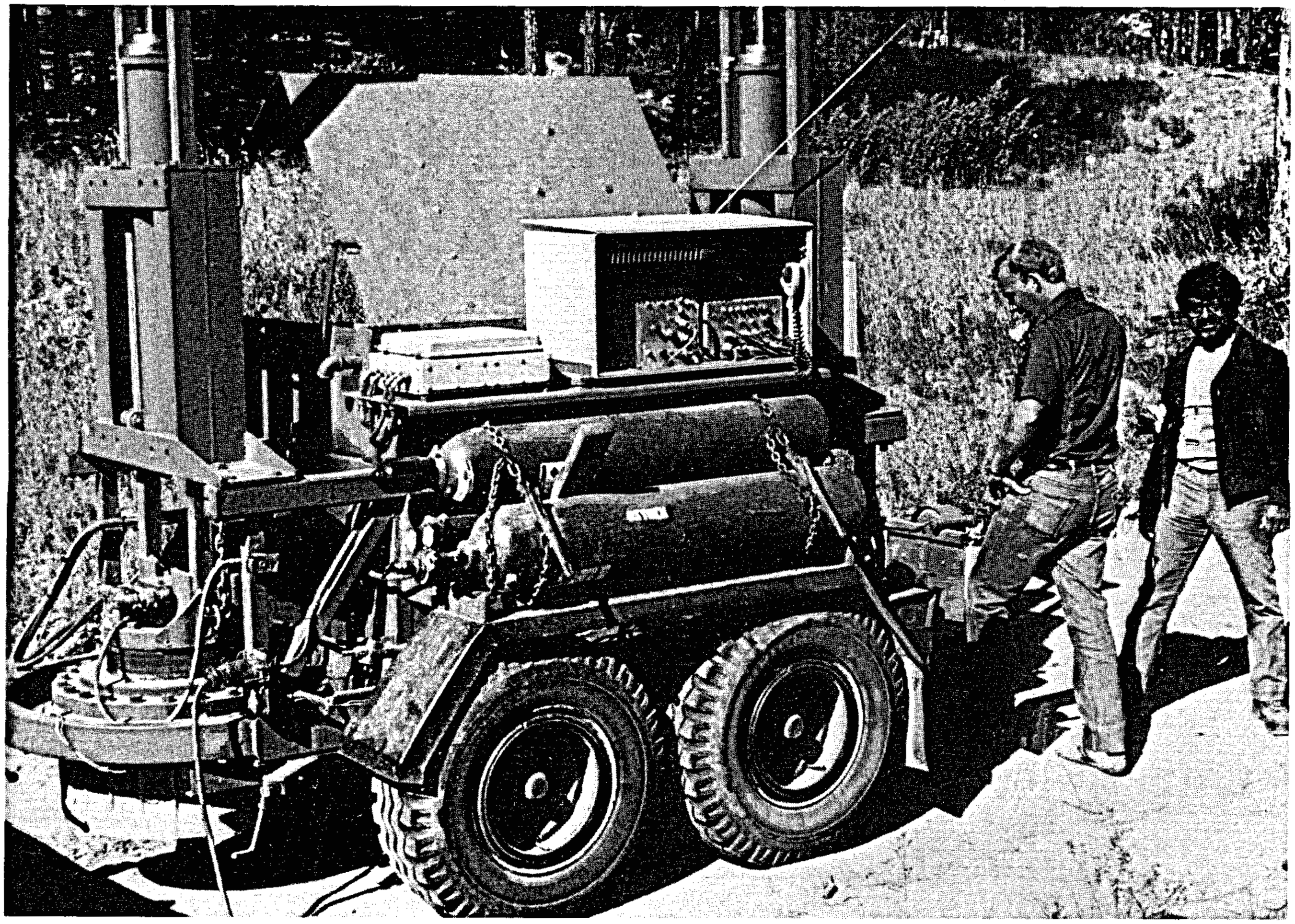


Fig. A-4. Vibroseismic equipment in operation during seismic profile, near VC-1, October 1985.

Fig. A-5. Looking east at the diamond core rig during setup over VC-2a, September 3, 1986; storage pond in foreground has pH = 3.

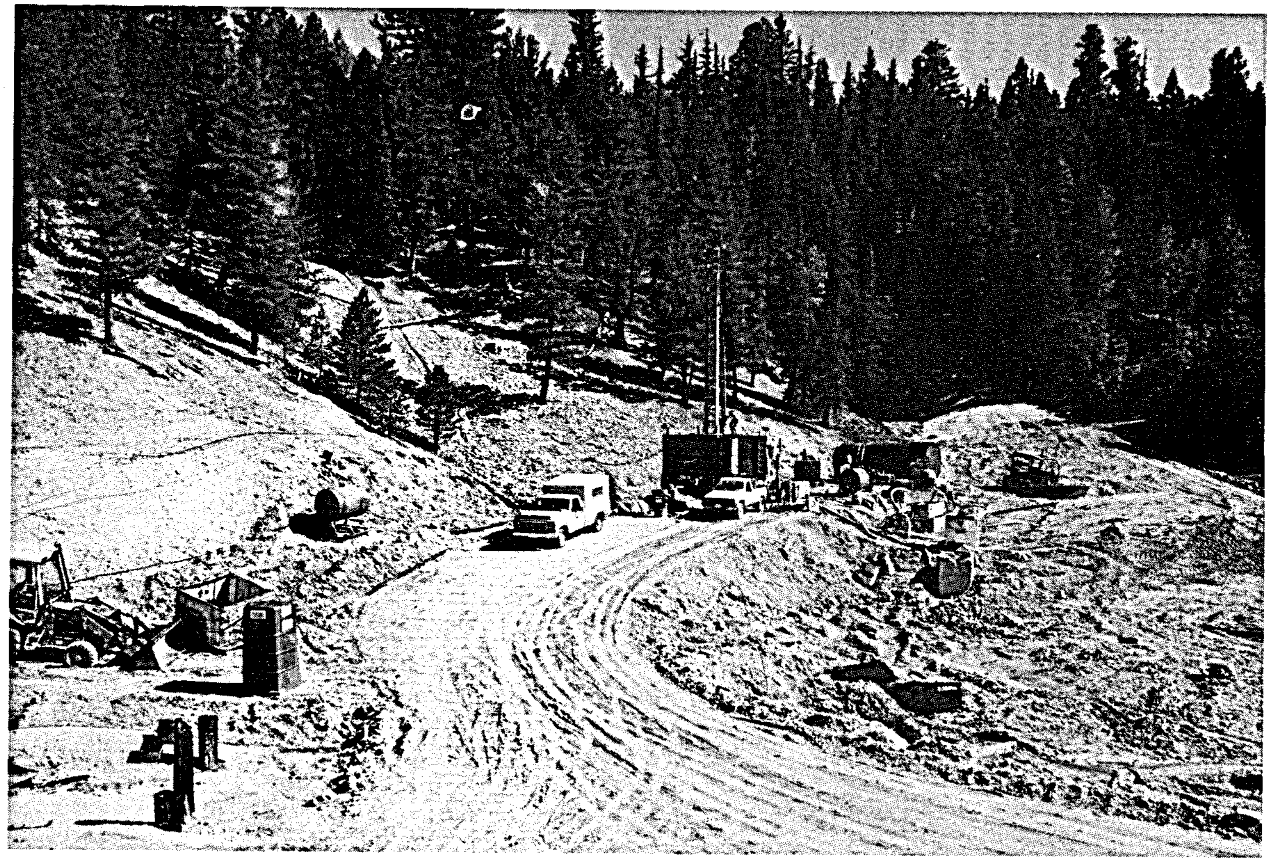


Fig. A-6. Coring operations at VC-2a: lower left is Footbath Spring (pH=1); water tank in background is for drilling fluids (40,000 ℓ capacity); weir tanks to right of the drill rig will be used for flow tests to be conducted at a later date.

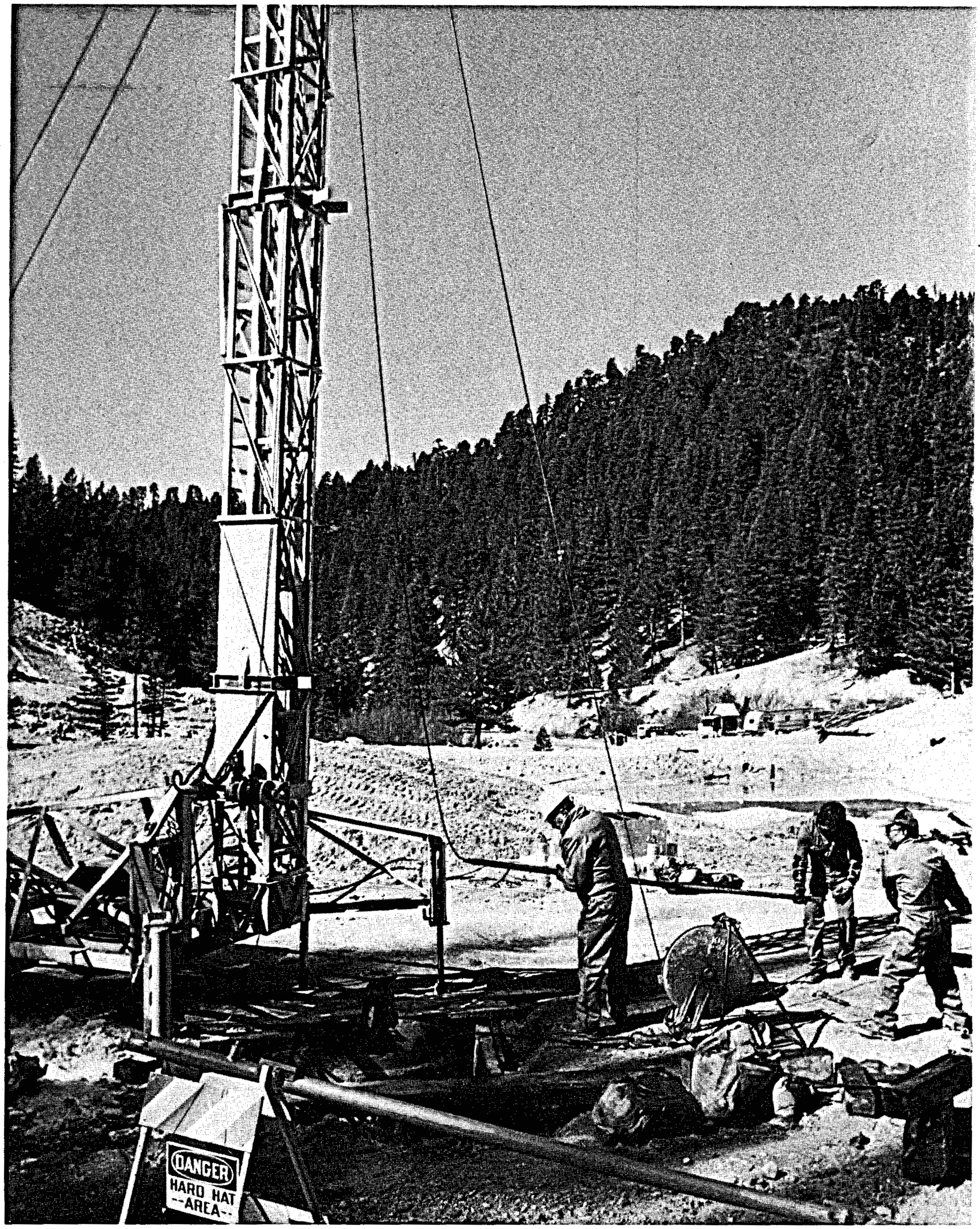



Fig. A-7. VC-2a during first STP logging run in October 1986. Tool was specially built by Los Alamos National Laboratory for hot slimholes.

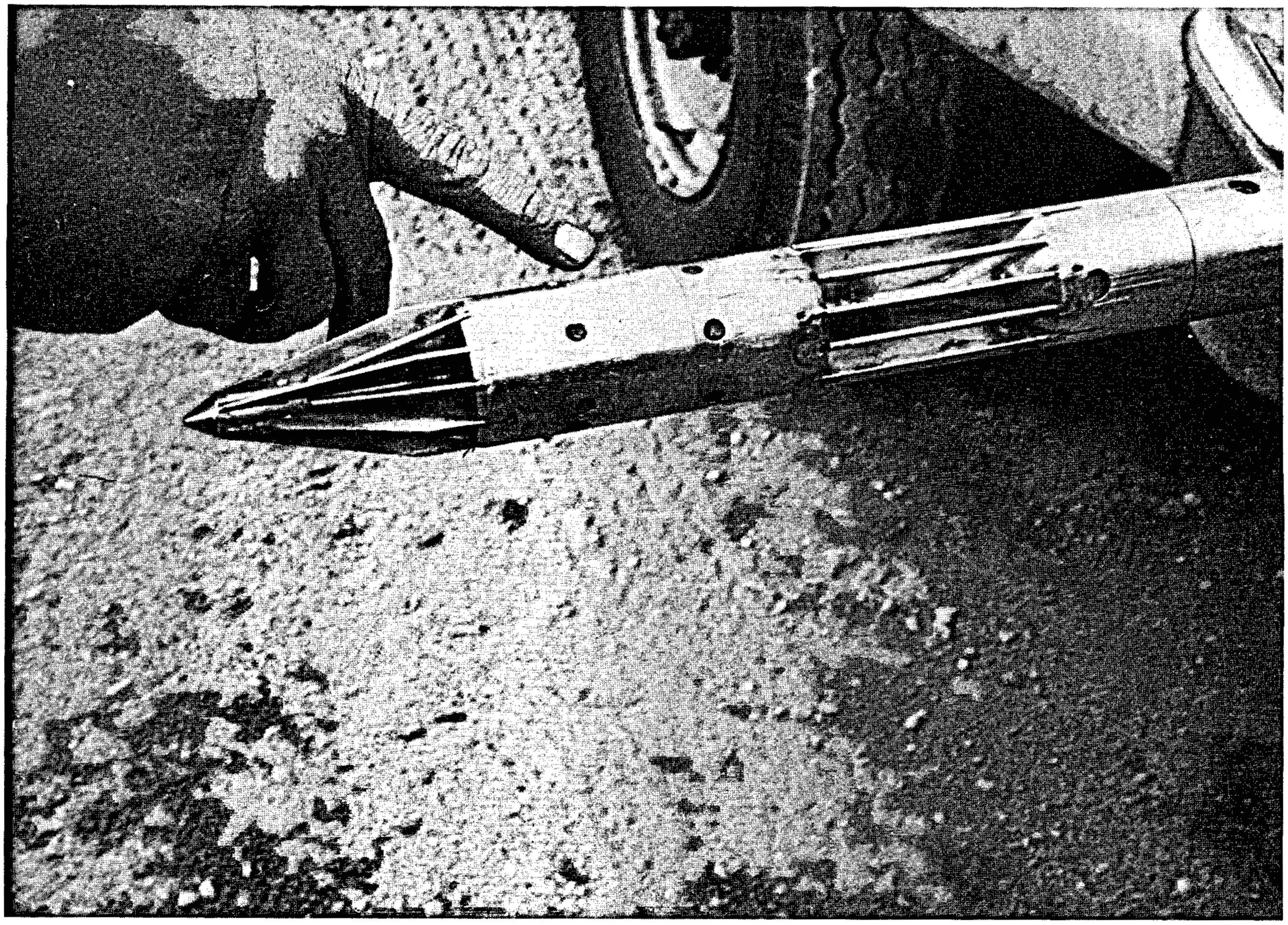


Fig. A-8. Close-up of the bottom tip of the STP tool that shows the impeller housing for the spinner device; this tool was useful in showing the two-phase flow zone in VC-2a during flow tests in November 1987.

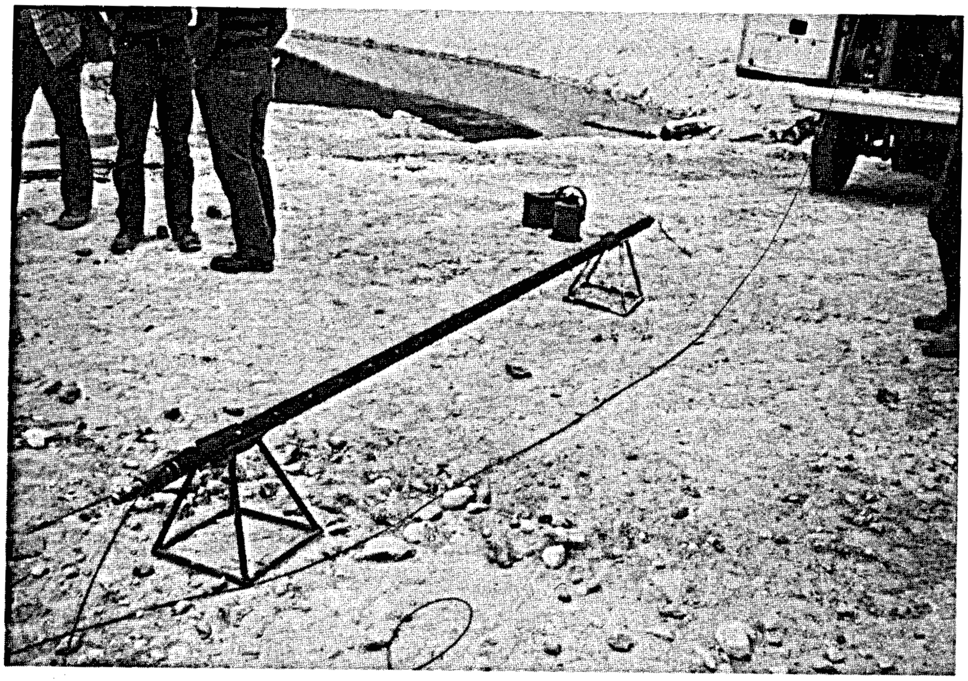


Fig. A-9. Perforating gun used to shoot holes in the 7.78-cm (3.06-in.) liner of VC-2a at 491 m and 210°C, April 29, 1987.

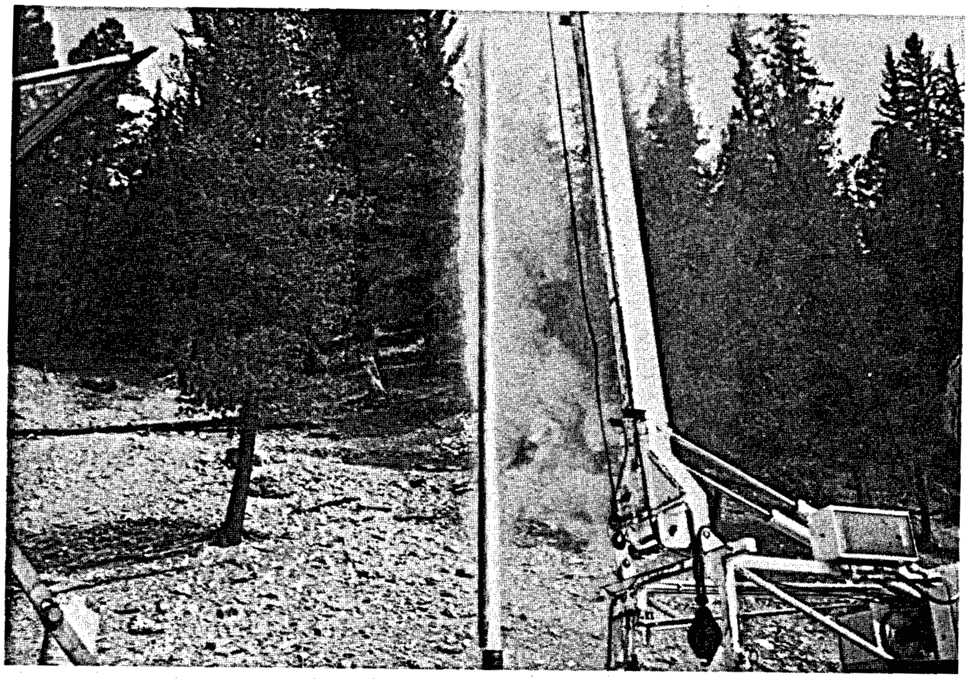


Fig. A-10. The 10-m bailer emerging from VC-2a on April 30, 1987, during stimulation operations: VC-2a began to geyser 30-s-duration eruptions during these operations.

Fig. A-11. VC-2a erupting immediately after final stimulation, May 1, 1987: fluid column is approximately 30 m high.

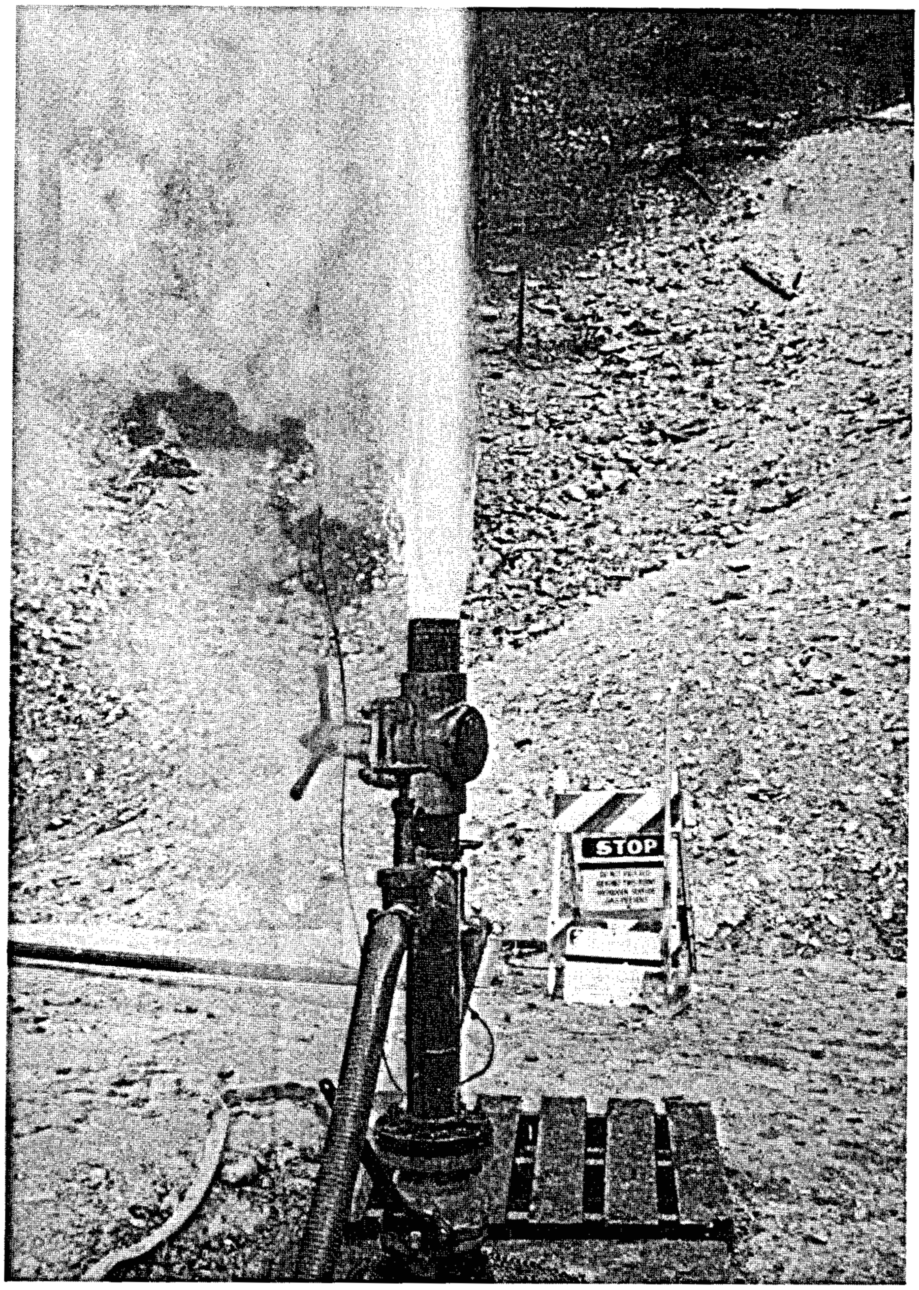



Fig. A-12. VC-2a, May 1, 1987. The fluid column contains water and flashed steam produced from the 491-m zone; the upper valve has an 8.27-cm (4-in.) diameter; the liner is 7.78-cm (3.06-in.) inside diameter; the wellhead was specially designed by Los Alamos and Sandia personnel (also see cover photo).

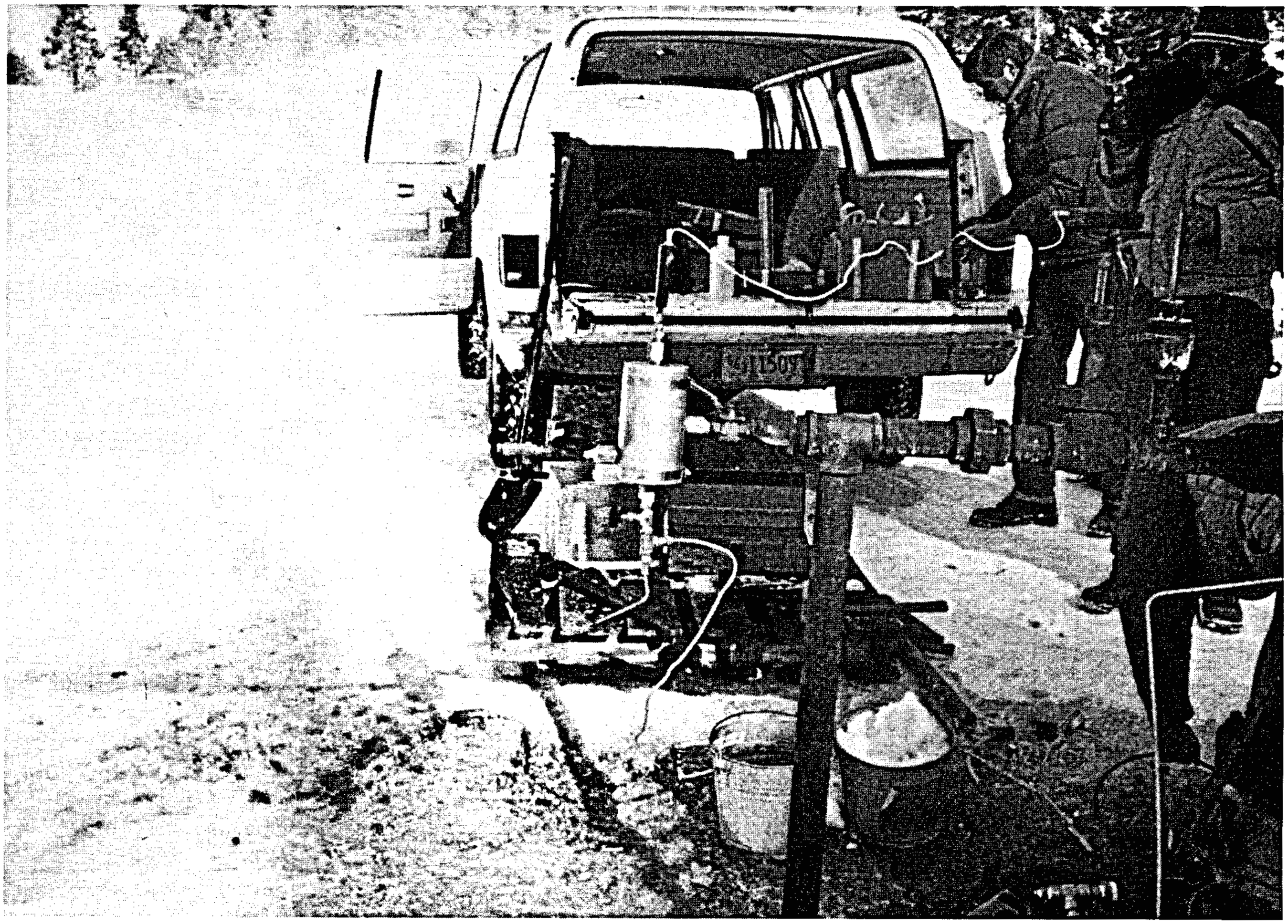


Fig. A-13. VC-2a during fluid sampling operations in December 1987: miniseparator is attached to elbow in 5.08-cm (2-in.) flow line; gas and water samples are collected at exact temperature and pressure for later chemical and isotopic analysis.

# APPENDIX B

# TABLES

## TABLE B-I. MAJOR ELEMENT ANALYSIS FOR VC-1 AND VC-2a FLUIDS, VALLES CALDERA, NEW MEXICO (values in mg/ℓ)

| Name | Field Number | Temp. °C | $SiO_2$ | Ca | Mg | Sr | Na | K | Li | $HCO_3$ | $CO_3$ | $SO_4$ | Cl | F | Br | B | TDS | $\Sigma_{cat}$ | $\Sigma_{an}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VC-1 Mud | VA-173 | 18.7 | 40 | 2.1 | 0.57 | 0.06 | 392 | 4.6 | 0.11 | 267 | - | 20.4 | 12.3 | 0.98 | <0.01 | 0.26 | 740 | 17.40 | 6.30 |
| VC-1 Downhole | VA-200 | 90 | 75 | 47.6 | 12.0 | 1.17 | 810 | 86 | 9.22 | 877 | 0 | 68.0 | 937 | 5.16 | 2.4 | 8.2 | 2883 | 42.66 | 42.95 |
| VC-1 Downhole | VA-201 | 90 | 75 | 47.5 | 11.9 | 1.18 | 844 | 85 | 8.72 | 919 | 0 | 71.5 | 933 | 4.67 | 2.3 | 8.3 | 2943 | 43.95 | 43.40 |
| VC-1 Swab | VA-204 | 90 | 26 | 28.2 | 3.0 | 6.1 | 514 | 44 | 3.2 | 760 | 0 | 12.5 | 331 | 2.80 | 1.2 | 3.43 | 1842 | 26.88 | 24.65 |
| VC-1 Swab | VA-205 | 90 | 21 | 33.2 | 5.8 | 0.72 | 587 | 49 | 3.1 | 799 | 0 | 12 | 428 | 1.78 | 1.6 | 2.99 | 2052 | 30.44 | 27.96 |
| VC-1 Swab | VA-206 | 90 | 26 | 33.7 | 6.4 | 0.85 | 658 | 56 | 3.6 | 866 | 0 | 110 | 450 | 1.15 | 1.6 | 3.38 | 2208 | 33.81 | 29.37 |
| VC-1 Swab | VA-207 | 90 | 53 | 12.5 | 2.21 | 0.43 | 719 | 55 | 5.5 | 694 | 0 | 165 | 635 | 3.79 | 1.8 | 5.27 | 2301 | 34.42 | 33.10 |
| VC-1 Swab | VA-208 | 90 | 31 | 6.8 | 1.58 | 0.25 | 781 | 58 | 6.6 | 497 | 9 | 95.0 | 817 | 4.47 | 2.0 | 6.86 | 2282 | 37.28 | 33.61 |
| VC-1 Swab | VA-209 | 90 | 74 | 49.0 | 17.8 | 1.33 | 883 | 85 | 8.0 | 942 | 0 | 1.33 | 964 | 3.94 | 2.8 | 8.55 | 3042 | 46.83 | 44.32 |
| VC-1 Swab | VA-210 | 90 | 37 | 42.4 | 12.5 | 1.29 | 887 | 75 | 7.2 | 748 | 0 | 1.29 | 967 | 3.77 | 3.1 | 7.91 | 2846 | 47.02 | 41.05 |
| VC-1 Swab | VA-211 | 90 | 34 | 14.0 | 6.1 | 0.50 | 731 | 61 | 5.7 | 781 | 0 | 0.50 | 613 | 3.03 | 2.0 | 6.31 | 2341 | 36.35 | 32.55 |
| VC-1 Swab | VA-212 | 90 | 39 | 16.2 | 5.1 | 0.53 | 873 | 74 | 7.6 | 671 | 0 | 0.53 | 960 | 3.89 | 2.8 | 8.10 | 2020 | 42.66 | 28.81 |
| VC-1 Downhole | VA-237 | 76.6 | 128 | 29.2 | 6.4 | 0.75 | 635 | 48 | 4.7 | 928 | 0 | 190 | 415 | 3.64 | 1.1 | 4.81 | 2407 | 31.60 | 31.22 |
| VC-1 Downhole | VA-238 | 70.0 | 133 | 29.5 | 6.4 | 0.76 | 641 | 49 | 4.7 | 963 | 0 | 200 | 413 | 3.87 | 1.2 | 4.84 | 2460 | 31.89 | 31.94 |
| VC-1 Downhole | VA-242 | 125 | 90 | 47.8 | 11.9 | 1.03 | 804 | 84 | 7.27 | 919 | 0 | 74.0 | 853 | 4.74 | 2.2 | 10.1 | 2921 | 41.92 | 41.13 |
| VC-1 Downhole | VA-243 | 125 | 87 | 45.4 | 11.6 | 1.03 | 813 | 86 | 7.25 | 937 | 0 | 75.6 | 837 | 4.93 | 2.3 | 10.4 | 2926 | 42.02 | 41.04 |
| VC-2A Mud | VA-251 | - | 10 | 4.2 | 5.1 | 0.08 | 265 | 18 | 0.05 | 405 | - | 53.2 | 19.6 | 1.67 | <0.2 | 0.70 | 1001 | 15.01 | 14.35 |
| VC-2A Mud | VA-253 | - | 13 | 3.4 | 8.5 | 0.12 | 234 | 19 | 0.08 | 345 | - | 22.5 | 20.9 | 1.74 | <0.2 | 0.35 | 899 | 13.64 | 13.16 |
| VC-2A Steam Condensate | VA-268 | 100 | 2 | 0.7 | 0.03 | <0.01 | 0.3 | 0.3 | <0.01 | 7.5 | 0 | 0.7 | 0.6 | <0.05 | <0.1 | 0.17 | 14.2 | 0.147 | 0.162 |
| VC-2A Bailer at 500 ft | VA-265 | - | 18 | 109 | 11.6 | 0.35 | 30.0 | 17 | 0.09 | 38.6 | 0 | 372 | 9.1 | 1.18 | <0.2 | 0.49 | 611 | 8.314 | 8.787 |
| VC-2A Bailer at 500 ft | VA-266 | - | 16 | 59.1 | 1.18 | 0.32 | 156 | 19 | 0.36 | 32.9 | 0 | 398 | 17.9 | 1.38 | <0.2 | 5.11 | 707.8 | 10.38 | 9.70 |
| VC-2A Bailer at 650 ft | VA-267 | - | 21 | 3.6 | 0.17 | 0.06 | 144 | 11.8 | 0.35 | 147 | 49.2 | 77.1 | 22.4 | 0.90 | <0.2 | 4.91 | 485.8 | 6.950 | 6.565 |
| VA-2A Bailer at 1100 ft | VA-268 | - | 20 | 6.3 | 0.39 | 0.08 | 133 | 11.2 | 0.31 | 233 | 0 | 80.5 | 22.3 | 0.95 | <0.2 | 4.35 | 514 | 6.607 | 6.388 |
| VC-2A Bailer at 1600 ft | VA-269 | - | 210 | 4.6 | 0.13 | 0.1 | 316 | 48 | 4.03 | 134 | 114 | 90.3 | 263 | 8.2 | 0.6 | 3.6 | 1204 | 16.15 | 15.82 |
| VC-2A Steam Condensate Formation Temp 210°C | VA-270S | 112 | 8 | 0.7 | 0.05 | 0.04 | 11.2 | 0.5 | 0.03 | 1127 | 0 | 4.4 | <0.5 | 0.08 | <0.02 | <0.05 | 1477 | 18.54 | 18.55 |
| VC-2A | VA-271 | - | 315 | 14.9 | 0.09 | 0.73 | 1040 | 174 | 15.8 | 179 | 139 | 76.2 | 1507 | 9.6 | 3.6 | 12.4 | 3497 | 52.86 | 52.28 |
| VC-2A Mud | VA-273 | 146.2 | 1 | <0.1 | <0.01 | <0.01 | 0.9 | 0.3 | 0.01 | 193 | 0 | 1.5 | 0.9 | <0.05 | <0.1 | 0.19 | 268.3 | 3.95 | 3.23 |

TABLE B-I. (cont)

| Name | Field Number | Temp. °C | $SiO_2$ | Ca | Mg | Sr | Na | K | Li | $HCO_3$ | $CO_3$ | $SO_4$ | Cl | F | Br | B | TDS | $\Sigma_{cat}$ | $\Sigma_{an}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VC-2A Separated Water | VA-274 | 146.2 | 260 | 12.6 | 0.41 | 0.23 | 1070 | 172 | 16.4 | 375 | 0 | 67.2 | 1807 | 9.2 | 4.0 | 13.3 | 3837 | 55.21 | 59.08 |
| VC-2A Separated Water | VA-277 | – | 270 | 5.2 | 0.13 | 0.27 | 1020 | 166 | 15.8 | 368 | 0 | 54.0 | 1745 | 6.89 | 3.8 | 12.1 | 3684 | 51.70 | 56.80 |
| VC-2A Steam Condensate | VA-278 | – | 2 | 0.3 | <0.01 | <0.01 | 6.8 | 1.4 | 0.09 | 181 | 0 | 2.6 | 13.3 | 0.06 | <0.1 | 0.29 | 270 | 3.79 | 3.41 |
| VC-2A Weirbox | VA-279 | 93.5 | 415 | 16.4 | 0.31 | 0.62 | 1510 | 256 | 23.8 | 132 | 113 | 85.2 | 2297 | 7.65 | 5.1 | 19.4 | 4895 | 76.55 | 73.04 |
| VC-2A Weirbox | VA-282 | 128 | 370 | 6.7 | 0.11 | 0.75 | 1720 | 304 | 28.0 | 45 | 148 | 72.9 | 2863 | 7.44 | 6.0 | 22.5 | 5607 | 86.79 | 88.40 |
| VC-2A Weirbox | VA-284 | – | 330 | 13.0 | 0.16 | 0.96 | 1790 | 328 | 31.0 | 120 | 110 | 72.2 | 3058 | 7.22 | 6.3 | 23.1 | 59.01 | 91.05 | 93.79 |
| VC-2A Steam Condensate | VA-285 | 134 | <1 | 0.2 | <0.01 | <0.01 | 2.5 | 0.8 | <0.01 | 53.7 | 0 | 3.1 | 2 | – | – | – | 84.9 | 1.08 | 1.07 |
| VC-2A Separated Water | VA-286 | – | 400 | 7.7 | 2.69 | 0.46 | 2480 | 412 | 37.6 | 63.5 | 187 | 82.8 | 3800 | 10.5 | 7.8 | 32.1 | 7545 | 124.23 | 116.67 |
| VC-2A Weirbox | VA-287 | 94.5 | 360 | 10.8 | 0.07 | 0.69 | 2080 | 360 | 31.2 | 56.2 | 145 | 57.5 | 3150 | 8.18 | 6.7 | 27.8 | 6307 | 104.27 | 96.37 |
| VC-2A Steam Condensate | VA-294 | 143 | 4 | 1.3 | 0.01 | 0.01 | 16.3 | 2.7 | 0.23 | 56.1 | 0 | 1.0 | 30.5 | 0.15 | <0.1 | 0.42 | 122.7 | 1.310 | 1.858 |
| VC-2A Separated Water | VA-295 | 133.5–140 | 426 | 4.1 | 1.24 | 0.61 | 2460 | 400 | 36.6 | 69.5 | 154 | 77.1 | 3780 | 7.8 | 7.6 | 34.5 | 7479 | 122.3 | 115.05 |
| VC-2A Weirbox | VA-296 | 94.8 | 404 | 8.9 | 0.19 | 0.67 | 2240 | 376 | 33.3 | 122 | 122 | 68.3 | 3650 | 8.7 | 7.3 | 32.3 | 7090 | 111.70 | 111.05 |
| VC-2A Weirbox | VA-297 | 94.5 | 383 | 8.2 | 0.25 | 1.16 | 2330 | 418 | 35.3 | 87.8 | 119 | 66.3 | 3800 | 6.8 | 7.6 | 35.9 | 7316 | 116.92 | 114.57 |
| VC-2A Weirbox | VA-298 | 94.5 | 381 | 7.7 | 0.16 | 1.18 | 2270 | 384 | 34.8 | 84.1 | 119 | 66.3 | 3890 | 6.4 | 7.6 | 33.1 | 7302 | 113.36 | 116.87 |
| VC-2A Steam Condensate | VA-299 | 118.5 | 1 | 0.5 | <0.01 | <0.01 | 1 | 0.7 | <0.01 | 110 | 0 | 3.2 | <5 | 0.04 | 0 | 0.02 | 129.6 | 0.500 | 1.94 |
| VC-2A Separated Water | VA-300 | 118.0 | 366 | 7.9 | 0.10 | 1.15 | 2180 | 345 | 33.0 | 41.5 | 132 | 62.9 | 3250 | 5.7 | 6.6 | 30.0 | 6478 | 108.33 | 98.623 |

TABLE B-II. TRACE ELEMENT ANALYSES FOR WATERS FROM VC-1 AND VC-2a, VALLES CALDERA, NEW MEXICO (values in mg/ℓ)

| Name | Field Number | Ag | Al | As | Ba | Cd | Co | Cr | Cs | Cu | Fe | Mn | Mo | $NH_4$ | Ni | $NO_3$ | Pb | $PO_4$ | Rb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VC-1 Mud | VA-173 | <0.001 | 0.4 | <0.1 | 0.01 | <0.001 | <0.001 | 0.001 | - | <0.001 | 0.13 | <0.01 | <0.1 | <0.02 | <0.001 | <0.01 | <0.002 | <0.1 | 0.001 | <0.01 |
| VC-1 Downhole | VA-200 | <0.001 | 0.1 | 0.3 | 0.34 | <0.001 | <0.001 | 0.005 | <0.002 | 0.037 | 1.30 | 0.15 | <0.1 | 5.1 | 0.015 | 0.09 | 0.18 | <0.1 | 0.49 | 0.43 |
| VC-1 Downhole | VA-201 | <0.001 | 0.1 | 0.2 | 0.37 | <0.001 | <0.001 | - | <0.002 | - | 1.14 | 0.09 | <0.1 | 3.85 | 0.014 | <0.1 | 0.08 | <0.1 | 0.54 | 0.27 |
| VC-1 Swab | VA-204 | - | <0.1 | <0.1 | 0.38 | - | - | - | - | - | 0.04 | 0.54 | 0.05 | 19.0 | - | <0.1 | - | <0.1 | 0 | <0.01 |
| VC-1 Swab | VA-205 | - | <0.1 | <0.1 | 0.31 | - | - | - | - | - | 5.5 | 1.57 | <0.1 | 11.0 | - | <0.1 | - | <0.1 | - | 0.10 |
| VC-1 Swab | VA-206 | - | <0.1 | <0.1 | 0.36 | - | - | - | - | - | 5.2 | 1.54 | 0.2 | 10.2 | - | <0.1 | - | <0.1 | - | 0.12 |
| VC-1 Swab | VA-207 | - | <0.1 | <0.1 | 0.19 | - | - | - | - | - | 0.40 | 0.17 | 0.4 | 0.36 | - | <0.1 | - | <0.1 | - | 0.02 |
| VC-1 Swab | VA-208 | - | <0.1 | 0.2 | 0.14 | - | - | - | - | - | 0.08 | 0.03 | 0.4 | 5.0 | - | <0.1 | - | <0.1 | - | <0.01 |
| VC-1 Swab | VA-209 | - | <0.1 | <0.1 | 0.78 | - | - | - | - | - | 14.9 | 0.55 | <0.1 | 3.05 | - | <0.1 | - | <0.1 | - | 0.14 |
| VC-1 Swab | VA-210 | - | <0.1 | <0.1 | 0.37 | - | - | - | - | - | 35.5 | 1.14 | <0.1 | 3.54 | - | <0.1 | - | <0.1 | - | 0.13 |
| VC-1 Swab | VA-211 | - | 0.2 | <0.1 | 0.15 | - | - | - | - | - | 10.1 | 0.67 | 0.5 | 4.93 | - | <0.1 | - | <0.1 | - | 0.09 |
| VC-1 Swab | VA-212 | - | <0.1 | <0.1 | 0.11 | - | - | - | - | - | 2.8 | 0.65 | 0.1 | 3.29 | - | <0.1 | - | <0.1 | - | <0.01 |
| VC-1 Downhole | VA-237 | <0.001 | <0.1 | 0.8 | 0.26 | <0.001 | <0.001 | <0.001 | - | 0.007 | 1.13 | 0.08 | 7.18 | 1.14 | 0.014 | 0.2 | 0.032 | <0.1 | 0.42 | 0.21 |
| VC-1 Downhole | VA-238 | <0.001 | <0.1 | 0.6 | 0.25 | <0.001 | <0.001 | <0.001 | - | 0.005 | 1.19 | 0.08 | 6.28 | 1.10 | 0.003 | <0.1 | 0.018 | <0.1 | 0.40 | 0.14 |
| VC-1 Downhole | VA-242 | <0.001 | <0.1 | <0.1 | 1.49 | <0.001 | 0.007 | 0.002 | - | <0.001 | 5.73 | 0.16 | 0.12 | 2.12 | 0.16 | <0.2 | 0.006 | <0.2 | 0.81 | 0.58 |
| VC-1 Downhole | VA-243 | 0.001 | <0.1 | <0.1 | 1.53 | <0.001 | 0.002 | 0.001 | - | 0.004 | 3.31 | 0.15 | 0.16 | 1.28 | 0.09 | 0.2 | 0.011 | <0.2 | 0.77 | 0.05 |
| VC-2A Mud | VA-251 | - | 4.5 | <0.1 | 0.08 | - | - | - | - | - | <0.03 | 0.02 | <0.1 | 34.2 | - | <0.5 | - | <0.1 | 0.074 | 0.08 |
| VC-2A Mud | VA-253 | - | <0.1 | <0.1 | <0.05 | - | - | - | - | - | <0.02 | 0.04 | <0.1 | 38.0 | - | 0.7 | - | <0.1 | 0.045 | <0.01 |
| VC-2A Steam Condensate | VA-263 | <0.001 | <0.1 | <0.1 | 0.01 | <0.001 | <0.002 | <0.002 | 0.031 | <0.002 | 0.39 | 0.05 | <0.1 | 1.15 | <0.002 | <0.1 | <0.002 | <0.1 | 0.018 | 0.07 |
| VC-2A Bailer at 500 ft | VA-265 | <0.001 | <0.1 | <0.1 | 0.16 | <0.001 | <0.002 | 0.004 | 0.011 | <0.002 | 1.84 | 0.84 | <0.1 | 0.49 | 0.029 | 0.5 | <0.002 | <0.2 | 0.060 | 0.16 |
| VC-2A Bailer at 500 ft | VA-266 | <0.001 | <0.1 | <0.1 | 0.14 | <0.001 | <0.002 | 0.003 | 0.023 | <0.002 | 0.16 | 0.05 | <0.1 | <0.05 | 0.010 | <0.2 | 0.006 | <0.2 | 0.064 | 0.07 |
| VC-2A Bailer at 650 ft | VA-267 | <0.001 | 0.5 | <0.1 | 0.09 | <0.001 | <0.002 | 0.005 | 0.008 | 0.003 | 0.12 | <0.01 | <0.1 | 1.33 | 0.011 | 0.9 | 0.005 | <0.2 | 0.036 | 0.13 |
| VC-2A Bailer at 1100 ft | VA-268 | <0.001 | 0.4 | <0.1 | 0.08 | <0.001 | <0.002 | <0.002 | 0.008 | 0.006 | 0.11 | 0.03 | <0.1 | 1.61 | 0.006 | 0.3 | 0.003 | <0.2 | 0.03 | 0.10 |
| VC-2A Bailer at 1600 ft | VA-269 | <0.001 | 0.3 | <0.1 | 0.05 | <0.001 | <0.002 | <0.002 | 0.48 | <0.002 | 0.2 | 0.01 | <0.1 | 5.6 | 0.005 | 0.7 | 0.003 | <0.2 | 0.56 | 0.04 |
| VC-2A Steam Condensate Formation Temp. 210°C | VA-270S | <0.001 | <0.1 | <0.1 | 0.01 | <0.001 | <0.002 | 0.009 | 0.050 | <0.002 | 0.16 | 0.02 | <0.1 | 325 | 0.002 | <0.1 | <0.002 | <0.1 | 0.013 | 0.20 |

# TABLE B-II. (cont)

| Name | Field Number | Ag | Al | As | Ba | Cd | Co | Cr | Cs | Cu | Fe | Mn | Mo | $NH_4$ | Ni | $NO_3$ | Pb | $PO_4$ | Rb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VC-2A | VA-271 | <0.001 | <0.1 | 0.7 | 0.48 | 0.004 | <0.002 | <0.002 | 1.50 | <0.002 | 0.04 | 0.09 | <0.1 | 4.8 | 0.002 | <0.4 | <0.002 | <0.4 | 2.20 | 0.01 |
| VC-2A | VA-273 | <0.001 | <0.1 | <0.1 | 0.04 | <0.001 | <0.002 | <0.002 | 0.014 | <0.002 | 0.06 | <0.01 | <0.1 | 70.4 | <0.002 | <0.1 | <0.002 | <0.1 | 0.005 | <0.01 |
| VA-2A Separated Water | VA-274 | <0.001 | 0.5 | 0.2 | 0.08 | <0.001 | <0.002 | <0.002 | 1.7 | <0.002 | 1.81 | 0.36 | <0.1 | 22.3 | <0.002 | <0.2 | <0.002 | <0.2 | 2.6 | 0.06 |
| VA-2A Separated Water | VA-277 | <0.001 | 0.1 | 0.4 | 0.08 | <0.001 | <0.002 | <0.002 | 1.9 | <0.002 | 0.57 | 0.04 | <0.1 | 11.2 | <0.002 | <0.2 | <0.002 | <0.2 | 3.4 | 0.01 |
| VA-2A Steam Condensate | VA-278 | <0.001 | <0.1 | <0.1 | <0.01 | <0.001 | <0.002 | <0.002 | 0.045 | <0.002 | 0.03 | <0.01 | <0.1 | 62.0 | <0.002 | <0.1 | <0.002 | <0.1 | 0.057 | <0.01 |
| VC-2A Weirbox | VA-279 | <0.001 | <0.1 | 1.2 | 0.19 | <0.001 | <0.002 | <0.002 | 2.3 | <0.002 | 0.30 | 0.01 | <0.1 | 5.7 | <0.002 | <0.3 | <0.002 | <0.3 | 3.8 | 0.03 |
| VC-2A Weirbox | VA-282 | <0.001 | <0.1 | 2.0 | 0.22 | <0.001 | <0.002 | <0.002 | 2.6 | <0.002 | 0.01 | <0.01 | <0.1 | 3.7 | <0.002 | <0.3 | <0.002 | <0.3 | 4.6 | 0.01 |
| VC-2A Weirbox | VA-284 | <0.001 | <0.1 | 2.2 | 0.27 | <0.001 | <0.002 | <0.002 | 2.7 | <0.002 | 0.05 | <0.01 | <0.1 | 1.9 | <0.002 | <0.3 | <0.002 | <0.3 | 4.6 | 0.02 |
| VC-2A Steam Condensate | VA-285 | <0.001 | <0.05 | <0.05 | <0.01 | <0.001 | <0.002 | <0.002 | 0.045 | <0.002 | 0.10 | <0.01 | <0.002 | 16.8 | 0.003 | <0.1 | 0.002 | <0.1 | 0.006 | 0.06 |
| VC-2A Separated Water | VA-286 | <0.001 | 1.69 | 1.92 | 0.07 | <0.001 | <0.002 | <0.002 | 4.32 | <0.002 | 6.44 | 0.20 | <0.002 | 1.33 | 0.002 | <0.2 | 0.012 | <0.2 | 5.3 | 0.14 |
| VC-2A Weirbox | VA-287 | <0.001 | <0.05 | 1.93 | 0.14 | <0.001 | <0.002 | <0.002 | 4.12 | <0.002 | 0.31 | <0.01 | <0.002 | 1.32 | 0.002 | <0.5 | 0.008 | <0.5 | 5.0 | 0.07 |
| VC-2A Steam Condensate | VA-294 | <0.001 | <0.05 | <0.05 | <0.01 | <0.001 | <0.002 | <0.002 | 0.054 | <0.002 | <0.09 | 0.04 | <0.002 | 7.7 | <0.002 | <0.1 | <0.005 | <0.1 | 0.045 | <0.01 |
| VC-2A Separated Water | VA-295 | <0.001 | 0.84 | 1.78 | 0.09 | <0.001 | <0.002 | <0.002 | 4.25 | <0.002 | 2.64 | 0.09 | <0.002 | 0.76 | <0.002 | <0.2 | 0.002 | <0.2 | 5.25 | 0.06 |
| VC-2A Weirbox | VZ-296 | <0.001 | 0.07 | 2.34 | 0.12 | <0.001 | <0.002 | <0.002 | 4.15 | <0.002 | 0.35 | 0.01 | <0.002 | 0.74 | <0.002 | <0.2 | 0.004 | <0.2 | 5.20 | 0.02 |
| VC-2A Weirbox | VA-297 | <0.001 | 0.12 | 2.85 | 0.18 | <0.001 | <0.002 | <0.002 | 4.10 | <0.002 | 0.52 | 0.02 | <0.002 | 0.83 | <0.002 | <0.2 | 0.005 | <0.2 | 5.55 | 0.01 |
| VC-2A Weirbox | VA-298 | <0.001 | 0.15 | 2.83 | 0.18 | <0.001 | <0.002 | <0.002 | 4.10 | <0.002 | 0.46 | 0.02 | <0.002 | 0.79 | <0.002 | <0.2 | 0.004 | <0.2 | 5.65 | 0.01 |
| VC-2A Steam Condensate | VA-299 | <0.001 | <0.05 | <0.05 | <0.01 | <0.001 | 0.002 | <0.002 | 0.042 | <0.002 | 0.05 | 0.01 | <0.002 | 7.8 | <0.002 | <0.1 | <0.002 | <0.1 | 0.018 | <0.01 |
| VC-2A Separated Water | VA-300 | <0.001 | 0.14 | 2.26 | 0.11 | <0.001 | <0.002 | <0.002 | 3.70 | <0.002 | 0.37 | 0.02 | <0.002 | 0.82 | <0.002 | <0.2 | 0.005 | <0.2 | 5.20 | 0.77 |

## TABLE B-III. HYDROGEN, CARBON, AND OXYGEN ISOTOPES FOR WATERS FROM VC-1 AND VC-2a, VALLES CALDERA, NEW MEXICO

| Name | Field Number | Date | $\delta D$ (°/oo) | $\delta^{13}C$ (°/oo) | $\delta^{18}O$ (°/oo) | Tritium (T.U.) | $\delta^{18}O$ on $SO_4$ (°/oo) |
|---|---|---|---|---|---|---|---|
| VC-1 Mud | VA-193 | 8/16/84 | – | – | – | – | – |
| VC-1 Downhole | VA-200 | 8/18/85 | -87.3 | -1.4 | -11.38 | – | – |
| VC-1 Downhole | VA-201 | 8/18/85 | – | – | – | 0.77 | – |
| VC-1 Swab | VA-204 | 9/4/85 | – | – | – | – | – |
| VC-1 Swab | VA-205 | 9/4/85 | -91.5 | – | -12.70 | – | – |
| VC-1 Swab | VA-206 | 9/4/85 | -91.6 | – | -12.55 | 1.22 | – |
| VC-1 Swab | VA-207 | 9/4/85 | – | – | – | – | – |
| VC-1 Swab | VA-208 | 9/4/85 | – | – | – | – | – |
| VC-1 Swab | VA-209 | 9/5/85 | -88.8 | – | -11.40 | 0.66 | 1.0 |
| VC-1 Swab | VA-210 | 9/5/85 | – | – | – | – | – |
| VC-1 Swab | VA-211 | 9/6/85 | -90.7 | – | -12.18 | 1.13 | -0.3 |
| VC-1 Swab | VA-212 | 9/6/85 | -88.3 | – | -11.35 | – | – |
| VC-1 Downhole | VA-237 | 5/13/86 | -89.75 | – | -12.19 | 0.18 | – |
| VC-1 Downhole | VA-238 | 5/13/86 | – | – | – | – | -0.28 |
| VC-1 Downhole | VA-242 | 8/26/86 | -88.5 | – | -11.33 | 0.76 | – |
| VC-1 Downhole | VA-243 | 8/26/86 | – | -2.8 | – | – | -0.16 |
| VC-2A Mud | VA-251 | 9/23/86 | – | – | – | – | – |
| VC-2A Mud | VA-253 | 9/23/86 | – | – | – | – | – |
| VC-2A Steam Condensate | VA-273 | 5/12/87 | -87[a] | – | – | – | – |
| VC-2A Separated Water | VA-274 | 5/12/87 | -80[a] | – | – | 0.72 | – |
| VC-2A Separated Water | VA-277 | 5/13/87 | -77[a] / -76.8 | – | -8.49 | 0.64 | – |
| VC-2A Steam Condensate | VA-278 | 5/13/87 | -88[a] / -85.8 | – | -11.11 | – | – |
| VC-2A Weirbox | VA-279 | 5/13/87 | – | – | – | – | – |
| VC-2A Weirbox | VA-282 | 5/14/87 | -73[a] / -69.5 | – | -6.71 | 0.61 | – |
| VC-2A Weirbox | VA-284 | 5/17/87 | – | – | – | – | – |
| VC-2A Steam Condensate | VA-285 | 7/30/87 | -83.5 | – | -10.38 | – | – |
| VC-2A Steam Condensate | VA-286 | 7/30/87 | -71.7 | – | -6.39 | 0.47 | – |
| VC-2A Weirbox | VA-287 | 7/30/87 | – | – | – | – | – |
| VC-2A Steam Condensate | VA-294 | 8/27/87 | -84.3 | – | -9.88 | – | – |
| VC-2A Separated Water | VA-295 | 8/27/87 | -72.7 | – | -6.41 | 0.06 | – |
| VC-2A Weirbox | VA-296 | 8/27/87 | -64.6 | – | -5.53 | – | – |
| VC-2A Weirbox | VA-297 | 8/28/87 | – | – | – | – | – |
| VC-2A Weirbox | VA-298 | 8/28/87 | – | – | – | – | – |
| VC-2A Steam Condensate | VA-299 | 8/28/87 | -91.2 | – | -10.85 | – | – |
| VC-2A Separated Water | VA-300 | 8/28/87 | -72.8 | – | -6.97 | – | – |

[a]Analyses performed by Cathy Janik, US Geological Survey, Menlo Park, CA.

## TABLE B-IV. PHYSICAL PROPERTIES OF SELECTED CORE FROM VC-1[a]

| Depth (m) | Density (g/cm$^3$) | Porosity (%) | Vp (km/s) vert:horiz1:horiz2 | Vs (km/s) Vert:horiz1:horiz2 | Principal Crack Strain Rate $t_3/t_1$ | $t_2/t_1$ |
|---|---|---|---|---|---|---|
| 244 | 1.75 | 24.5 | 2.54:3.37:4.12 | 1.53:1.92:2.18 | 0.18 | 0.62 |
| 398 | 2.35 | 17.1 | 2.85:3.17:3.23 | 1.58:1.93:1.87 | 0.37 | 0.76 |
| 472 | 2.30 | 15.0 | 2.76:3.48:3.27 | 1.54:1.81:1.92 | 0.50 | 0.67 |
| 546 | 2.40 | 11.9 | | | | |
| 648 | 2.69 | 0.5 | 5.58:5.66:5.85 | 2.52:3.00:3.12 | 0.57 | 0.70 |
| 812 | 2.54 | 3.9 | 4.68:5.03:4.76 | 2.73:2.96:2.77 | 0.52 | 0.64 |

[a]From Dey and Krantz (in press).

TABLE B-V. DIVALENT CATION ANALYSIS OF IMPURE CARBONATES AND SHALES FROM PENNSYLVANIAN MADERA LIMESTONE, VC-1, VALLES CALDERA, NEW MEXICO (values in wt%)

| Sample Number | Depth m (ft) | Ba | Ca | Cd | Co | Cu | Fe | Mg | Mn | Sr | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VC-1 217-B | 426.4 (1407) | 0.0029 | 10.8 | 0.00065 | 0.00060 | 0.00030 | 1.27 | 0.510 | 0.0578 | 0.0283 | 0.00178 |
| VC-1 228-1 | 454.8 (1501) | 0.00133 | 18.5 | 0.00020 | 0.00043 | 0.00023 | 0.104 | 0.200 | 0.0363 | 0.0393 | 0.00118 |
| VC-1 240-7 | 484.8 (1600) | 0.00065 | 0.108 | <0.00005 | <0.00005 | 0.00010 | 0.0156 | 0.0212 | 0.00055 | 0.00153 | 0.00145 |
| VC-1 251-3 | 513.3 (1694) | 0.00128 | 7.65 | 0.00015 | 0.00030 | 0.00015 | 0.773 | 1.88 | 0.127 | 0.00780 | 0.00075 |
| VC-1 262-3 | 547.3 (1806) | 0.00103 | 0.735 | 0.00023 | 0.00135 | 0.00109 | 0.508 | 0.169 | 0.00563 | 0.0142 | 0.00123 |
| VC-1 272-2A | 577.3 (1905) | 0.00293 | 19.8 | 0.00015 | 0.00040 | 0.00018 | 0.00465 | 0.151 | 0.0435 | 0.0219 | 0.00025 |
| VC-1 283-12 | 611.2 (2017) | 0.00098 | 0.335 | <0.00005 | 0.00008 | 0.00008 | 0.0513 | 0.032 | 0.00058 | 0.00653 | 0.0015 |
| VC-1 292-2 | 637.3 (2103) | 0.00215 | 7.35 | 0.00025 | 0.00040 | 0.00050 | 0.528 | 0.540 | 0.0198 | 0.0184 | 0.00240 |
| VC-1 303-7 | 670.9 (2214) | 0.00038 | 6.95 | 0.00030 | 0.00028 | 0.00013 | 0.325 | 0.265 | 0.00813 | 0.0111 | 0.00173 |
| VC-1 312-1C | 698.5 (2305) | 0.00128 | 1.53 | 0.00015 | 0.00040 | 0.00038 | 0.738 | 0.115 | 0.00098 | 0.00638 | 0.00048 |
| VC-1 322-2B | 728.2 (2403) | 0.00115 | 19.8 | 0.00030 | 0.00040 | 0.00015 | 0.0780 | 0.128 | 0.0320 | 0.0295 | 0.00065 |
| VC-1 333-3 | 758.2 (2502) | 0.00123 | 0.305 | <0.00005 | 0.00005 | <0.00005 | 0.111 | 0.0335 | 0.00095 | 0.00330 | 0.00018 |
| VC-1 344-2C | 790.6 (2609) | 0.00093 | 14.7 | 0.00115 | 0.00043 | 0.00018 | 0.493 | 0.390 | 0.051 | 0.0135 | 0.00083 |
| VC-1 349-1 | 803.6 (2652) | 0.00128 | 0.181 | 0.00045 | 0.00030 | 0.00008 | 1.16 | 0.144 | 0.00178 | 0.00195 | 0.00168 |

TABLE B-VI. HYDROTHERMAL BRECCIA, 847 m, VC-1, VALLES CALDERA, NEW MEXICO

| | S (ppm) | Al (wt%) | Cu (ppm) | Mo (ppm) | Zn (ppm) |
|---|---|---|---|---|---|
| Concentration | 168 | 9.6 | 110.0 | 5.21 | 74.0 |
| Accuracy | ±54 | ±0.78 | ±55 | ±18 | ±40 |
| Detection limit | 6.80 | N/A | 1.47 | 0.26 | 3.0 |

Analysis by XRF.

TABLE B-VII. $\delta^{13}C$ and $\delta^{18}O$ ANALYSES OF SHALE AND LIMESTONE, MADERA LIMESTONE, VC-1, VALLES CALDERA, NEW MEXICO

| Sample Number | Depth (ft) | $\delta^{13}C$ (°/∘∘) | $\delta^{18}O$ (°/∘∘) | Lithology |
|---|---|---|---|---|
| 216-2b | 1389 | -7.5 | 4.7 | Shale |
| 217-8[a] | 1407.5 | -5.1 | 13.1 | Limestone |
| 220-13 | 1435 | -1.2 | 10.0 | Limestone |
| 223-6a[a] | 1459 | -0.3 | 15.8 | Sandstone |
| 225-14a | 1481 | -1.3 | 5.0 | Limestone |
| 231-4b | 1539 | -1.4 | 2.3 | Limestone |
| 238-10 | 1582 | -1.3 | 6.2 | Limestone |
| 243-2 | 1625 | 3.7 | 0.9 | Shale |
| 248-13b | 1671 | -5.2 | 11.6 | Shale |
| 251-3[a] | 1694.7 | -1.0 | 4.3 | Sandstone |
| 253-8a | 1719 | -1.9 | 0.7 | Shale |
| 258-1 | 1761 | -5.3 | 5.0 | Limestone |
| 262-3 | 1806 | -5.4 | 0.8 | Shale |
| 268-2b | 1862 | -3.6 | 24.0 | Shale |
| 272-3b | 1905.5 | -3.5 | 11.4 | Limestone |
| 276-5f | 1950.3 | -2.4 | 17.3 | Limestone |
| 282-1 | 2000.9 | -5.3 | 8.3 | Limestone |
| 286-3b | 2044 | -3.0 | 16.9 | Limestone |
| 291-5b | 2093 | -3.3 | 8.1 | Limestone |
| 295-5b | 2138 | -3.0 | 13.0 | Shale |
| 298-19b | 2170.6 | -1.8 | 9.1 | Limestone |
| 305-10 | 2241 | -2.4 | 9.0 | Limestone |
| 309-1a | 2271 | -3.6 | 16.6 | Limestone |
| 314-6b | 2328 | -3.3 | 11.0 | Shale |
| 319-3b | 2374 | -5.1 | 15.8 | Shale |
| 325-1a | 2431 | -4.1 | 16.6 | Shale |
| 329-6b | 2470 | -4.4 | 1.0 | Shale |
| 334-5b | 2517 | 0.2 | 13.3 | Shale |
| 338-3[a] | 2550.5 | -4.1 | 7.2 | Shale |
| 339-17a | 2564.5 | -5.8 | 17.8 | Shale |
| 344-2c | 2608 | -3.2 | 5.3 | Limestone |
| 349-1[a] | 2651 | -17.4 | 2.9 | Limestone |
| 349-7b | 2654.5 | -6.5 | 11.6 | Shale |
| 354-12b | 2707 | -4.7 | 22.9 | Limestone |
| 354-15[a] | 2709 | 1.0 | 10.0 | Shale |
| 359-15b[a] | 2741 | 1.6 | 2.1 | Shale |
| 359 | 2751 | 1.6 | 2.7 | Shale |
| 366[a] | 2802.5 | -2.9 | 8.3 | Limestone |

[a]These analyses do not appear in Fig. 4.

TABLE B-VIII. VC-1 LEVELING SURVEY FOR SEISMIC REFRACTION AND CDP LINE (October 3, 1985; J. Gardner, L. Maassen, F. Goff)

Note: Assume Sta. 74 has an elevation of 8210 ft (2503.05 m); station spacing is 15 m.

| Station | Elevation | Bearing | | | |
|---|---|---|---|---|---|
| | | From | To | Bearing | |
| 74 | 2503.05 | 74 | 73 | S38E | From Sta. 74 to Sta. 35, bearings are measured station to station. |
| 73 | 02.57 | 73 | 72 | S32E | |
| 72 | 01.98 | 72 | 71 | S25E | |
| 71 | 01.33 | 71 | 70 | S23E | |
| 70 | 2500.78 | 70 | 69 | S21E | |
| 69 | 00.14 | 69 | 68 | S24E | |
| 68 | 2499.49 | 68 | 67 | S23E | |
| 67 | 98.95 | 67 | 66 | S25E | |
| 66 | 98.48 | 66 | 65 | S29E | |
| 65 | 98.06 | 65 | 64 | S35E | |
| 64 | 97.62 | 64 | 63 | S40E | |
| 63 | 97.34 | 63 | 62 | S40E | |
| 62 | 97.00 | 62 | 61 | S42E | |
| 61 | 96.75 | 61 | 60 | S40E | |
| 60 | 2496.59 | 60 | 59 | S32E | |
| 59 | 96.56 | 59 | 58 | S23E | |
| 58 | 96.49 | 58 | 57 | S17E | |
| 57 | 96.65 | 57 | 56 | S11E | |
| 56 | 96.80 | 56 | 55 | S8E | |
| 55 | 97.33 | 55 | 54 | S15E | |
| 54 | 98.06 | 54 | 53 | S37E | |
| 53 | 2498.55 | 53 | 52 | S35E | |
| 52 | 2498.62 | 52 | 51 | S40E | Gate is 1.6 m south of Sta. 52. |
| 51 | 98.45 | 51 | 50 | S43E | |
| 50 | 2498.12 | 50 | 49 | S56E | |

TABLE B-VIII. (cont)

| Station | Elevation |
|---|---|
| 49 | 97.75 |
| 48 | 97.33 |
| 47 | 97.04 |
| 46 | 96.62 |
| 45 | 96.47 |
| 44 | 96.04 |
| 43 | 95.43 |
| 42 | 94.70 |
| 41 | 94.11 |
| 40 | 2493.67 |
| 39 | 93.48 |
| 38 | 93.41 |
| 37 | 93.16 |
| 36 | 92.67 |
| 35 | 92.40 |
| 34 | 93.37 |
| 33 | 92.18 |
| 32 | 91.99 |
| 31 | 91.63 |
| 30 | 2491.34 |
| 29 | 91.05 |
| 28 | 90.82 |
| 27 | 2490.64 |
| 26 | 2490.57 |
| 25 | 90.88 |
| 24 | 90.94 |
| 23 | 91.11 |

| Bearing | | |
|---|---|---|
| From | To | Bearing |
| 49 | 48 | S56E |
| 48 | 47 | S62E |
| 47 | 46 | S56E |
| 46 | 45 | S50E |
| 45 | 44 | S47E |
| 44 | 43 | S48E |
| 43 | 42 | S53E |
| 42 | 41 | S62E |
| 41 | 40 | S71E |
| 40 | 39 | S70E |
| 39 | 38 | S73E |
| 38 | 37 | S63E |
| 37 | 36 | S58E |
| 36 | 35 | S56E |
| 35 | 34 | S51E |
| 35 | 33 | S46E |
| 35 | 32 | S44E |
| 35 | 31 | S42E |
| 35 | 30 | S40E |
| 35 | 29 | S39E |
| 35 | 28 | S38E |
| 28 | 27 | S32E |
| 28 | 26 | S32E |
| 28 | 25 | S33E |
| 28 | 24 | S33E |
| 24 | 23 | S46E |
| 24 | 22 | S43E |

Bearings determined from level stations beyond Sta. 36.

TABLE B-VIII. (cont)

| Station | Elevation |
|---|---|
| 22 | 91.06 |
| 21 | 90.84 |
| 20 | 2490.82 |
| 19 | 90.60 |
| 18 | 90.13 |
| 17 | 89.05 |
| 16 | 87.82 |
| 15 | 87.38 |
| 14 | 86.96 |
| 13 | 86.85 |
| 12 | 86.98 |
| 11 | 87.56 |
| 10 | 2488.70 |
| 9 | 89.56 |
| 8 | 90.50 |
| 7 | 91.20 |
| 6 | 91.24 |
| 5 | 91.17 |
| 4 | 91.16 |
| 3 | 91.46 |
| 2 | 2491.87 |
| 1 | 2492.42 |
| 0 | 2492.37 |
| Top of gate valve, VC-1 | 2492.16 |
| -1 | 92.13 |
| -2 | 91.46 |
| -3 | 90.60 |

| Bearing | | | |
|---|---|---|---|
| From | To | Bearing | |
| 24 | 21 | S40E | |
| 24 | 20 | S37E | |
| 24 | 19 | S34E | |
| 19 | 18 | S20E | |
| 19 | 17 | S19E | |
| 19 | 16 | S16E | |
| 19 | 15 | S10E | |
| 15 | 14 | South | |
| 15 | 13 | S3W | |
| 15 | 12 | S5W | |
| 15 | 11 | S10W | |
| 15 | 10 | S12W | |
| 10 | 9 | S12W | |
| 9 | 8 | S5W | |
| 9 | 7 | S4W | |
| 7 | 6 | S6W | |
| 7 | 5 | S6W | |
| 7 | 4 | S4W | |
| 4 | 3 | S12E | |
| 4 | 2 | S15E | |
| 4 | 1 | S16E | |
| 1 | 0 | S30E | |
| 1 | VC-1 | S62E | 2492.16 m (8174.3 ft) distance from wellhead to Sta. 0 is 8.5 m. |
| 1 | -1 | S29E | |
| 1 | -2 | S30E | |
| 1 | -3 | S34E | |
| -3 | -4 | S35E | |

TABLE B-VIII. (cont)

| Station | Elevation |
|---|---|
| -4 | 89.74 |
| -5 | 89.13 |
| -6 | 88.54 |
| -7 | 88.08 |
| -8 | 88.11 |
| -9 | 89.26 |
| -10 | 2490.31 |
| -11 | 91.42 |
| -12 | 92.11 |
| -13 | 92.10 |
| -14 | 92.20 |
| -15 | 92.18 |
| -16 | 92.37 |
| -17 | 92.58 |
| -18 | 93.39 |
| -19 | 94.48 |
| -20 | 2495.84 |
| -21 | 97.08 |
| -22 | 2498.31 |
| -23 | 2498.19 |
| -24 | 97.46 |
| -25 | 97.62 |
| -26 | 98.03 |
| -27 | 98.86 |
| -28 | 99.40 |
| -29 | 2500.51 |
| -30 | 2501.08 |

| Bearing | | | |
|---|---|---|---|
| From | To | Bearing | Note |
| -3 | -5 | S36E | |
| -3 | -6 | S37E | |
| -3 | -7 | S38E | |
| -3 | -8 | S38E | |
| -3 | -11 | S40E | Jumped two stations in bearing measurement. |
| -9 | -11 | S32E | |
| -10 | -11 | S29E | |
| -11 | -12 | S52E | |
| -11 | -13 | S54E | |
| -11 | -14 | S52E | |
| -11 | -15 | S50E | |
| -11 | -16 | S48E | |
| -11 | -17 | S47E | |
| -17 | -22 | S34E | |
| -18 | -22 | S33E | |
| -19 | -22 | S33E | |
| -20 | -22 | S34E | |
| -21 | -22 | S33E | |
| -22 | -23 | S51E | |
| -22 | -24 | S53E | |
| -22 | -25 | S41E | |
| -22 | -26 | S40E | |
| -22 | -27 | S39E | |
| -27 | -34 | S26E | |
| -28 | -34 | S27E | |
| -29 | -34 | S26E | |
| -30 | -34 | S27E | |

TABLE B-VIII. (cont)

| Station | Elevation |
|---|---|
| -31 | 01.77 |
| -32 | 02.15 |
| -33 | 01.78 |
| -34 | 01.29 |
| -35 | 01.39 |
| -36 | 2499.96 |
| -37 | 98.96 |
| -38 | 97.74 |
| -39 | 95.50 |
| -40 | 2494.26 |
| -41 | 93.12 |
| -42 | 92.13 |
| -43 | 91.50 |
| -44 | 91.36 |
| -45 | 91.12 |
| -46 | 90.78 |
| -47 | 90.53 |
| -48 | 2490.86 |
| -49 | 2491.36 |
| -50 | 2491.69 |
| -51 | 91.84 |
| -52 | 92.45 |
| -53 | 92.80 |
| -54 | 92.83 |
| -55 | 92.09 |
| -56 | 90.80 |
| -57 | 89.12 |

| Bearing | | |
|---|---|---|
| From | To | Bearing |
| -31 | -34 | S27E |
| -32 | -34 | S27E |
| -33 | -34 | S27E |
| -34 | -35 | S40E |
| -34 | -36 | S40E |
| -34 | -37 | S40E |
| -34 | -38 | S36E |
| -34 | -39 | S34E |
| -39 | -40 | S17E |
| -39 | -41 | S12E |
| -39 | -42 | S9E |
| -39 | -43 | S9E |
| -39 | -44 | S11E |
| -44 | -52 | S29E |
| -45 | -52 | S29E |
| -46 | -52 | S26E |
| -47 | -52 | S23E |
| -48 | -52 | S23E |
| -49 | -52 | S26E |
| -50 | -52 | S26E |
| -51 | -52 | S23E |
| -52 | -53 | S17E |
| -52 | -54 | S12E |
| -52 | -55 | S9E |
| -52 | -56 | S9E |
| -52 | -57 | S9E |
| -57 | -58 | S15E |

TABLE B-VIII. (cont)

| Station | Elevation |
|---|---|
| -58 | 87.81 |
| -59 | 86.31 |
| -60 | 2485.50 |
| -61 | 83.97 |
| -62 | 82.41 |
| -63 | 81.54 |
| -64 | 80.84 |
| -65 | 80.28 |
| -66 | 79.85 |
| -67 | 80.50 |
| -68 | 80.87 |
| -69 | 81.09 |
| -70 | 2481.25 |
| -71 | 81.94 |
| -72 | 82.83 |
| -73 | 82.25 |
| -74 | 81.42 |
| -75 | 2481 |

| Bearing | | |
|---|---|---|
| From | To | Bearing |
| -57 | -59 | S18E |
| -57 | -60 | S18E |
| -57 | -61 | S15E |
| -57 | -62 | S13E |
| -62 | -63 | S16E |
| -62 | -64 | S16E |
| -62 | -65 | S18E |
| -65 | -71 | S26E |
| -66 | -71 | S26E |
| -67 | -71 | S26E |
| -68 | -71 | S23E |
| -69 | -71 | S19E |
| -70 | -71 | S14E |
| -71 | -72 | S2W |
| -71 | -73 | S5W |
| -71 | -74 | S7W |
| -71 | -75 | S5W |

TABLE B-IX. FIELD DATA, VC-1 AND VC-2a FLUIDS, VALLES CALDERA, NEW MEXICO

| Name | Field Number | Date | Field pH | Temp. (°C) | Field Eh (mV) | Conductivity µmho/cm |
|---|---|---|---|---|---|---|
| VC-1 (mud) | VA-173 | 8/16/84 | 9.89 | 18.7 | 366[a] | 1650[b] |
| VC-1 (downhole)[c] | VA-200 | 8/18/85 | 6.78 | 90.0 | 150 | 4960[b] |
| VC-1 (downhole)[c] | VA-201 | 8/18/85 | 6.88 | 90.0 | 120 | 4670[b] |
| VC-1 (swab) | VA-204 | 9/4/85 | 7.24 | 90.0 | 144[a] | 2590[b] |
| VC-1 (swab) | VA-205 | 9/4/85 | 7.05 | 90.0 | 156[a] | 2890[b] |
| VC-1 (swab) | VA-206 | 9/4/85 | 7.0 | 90.0 | 138[a] | 2930[b] |
| VC-1 (swab) | VA-207 | 9/4/85 | 7.59 | 90.0 | 135 | 3650[b] |
| VC-1 (swab) | VA-208 | 9/4/85 | 8.09 | 90.0 | 240[a] | 3550[b] |
| VC-1 (swab) | VA-209 | 9/5/85 | 7.06 | 90.0 | 284[a] | 4780[b] |
| VC-1 (swab) | VA-210 | 9/5/85 | 6.19 | 90.0 | 235[a] | 4250[b] |
| VC-1 (swab) | VA-211 | 9/6/85 | 6.60 | 90.0 | 250[a] | 4430[b] |
| VC-1 (swab) | VA-212 | 9/6/85 | 7.07 | 90.0 | 262[a] | 4000[b] |
| VC-1 (downhole)[d] | VA-237 | 5/13/86 | 7.58 | 76.6 | - | 4300[b] |
| VC-1 (downhole)[c] | VA-238 | 5/13/86 | 7.46 | 70.0 | 90 | - |
| VC-1 (downhole)[d] | VA-242 | 8/26/86 | 6.68 | 125 | -120 | 5050[b] |
| VC-1 (downhole)[d] | VA-243 | 8/26/86 | 6.74 | 125 | -65 | 5020[b] |
| VC-2A (mud) | VA-251 | 9/23/86 | - | - | - | - |
| VC-2A (mud) | VA-253 | 9/23/86 | - | - | - | - |
| VC-2A (steam condensate) | VA-263 | 4/28/87 | 4 | 100 | 24 | - |
| VC-2A (bailer at 500 ft) | VA-265 | 4/30/87 | 6.5 | - | 799 | - |
| VC-2A (bailer at 500 ft) | VA-266 | 4/30/87 | 8.6 | - | 1049 | - |
| VC-2A (bailer at 650 ft) | VA-267 | 4/30/87 | 7.9 | - | 646 | - |
| VC-2A (bailer at 1100 ft) | VA-268 | 4/30/87 | 8.9 | - | 628 | - |
| VC-2A (bailer at 1600 ft) | VA-269 | 4/30/87 | 7.0 | - | 1674 | - |
| VC-2A (steam condensate) | VA-270S | 5/1/87 | 8.3 | 112 | 1960 | - |
| VC-2A (formation temp. 210°C) | VA-271 | 5/6/87 | | | 5940 | |
| VC-2A (steam condensate) | VA-273 | 5/12/87 | - | 146.2[e] | - | - |
| VC-2A (separated water) | VA-274 | 5/12/87 | 6.0 | 146.2[e] | - | - |
| VC-2A (separated water) | VA-277 | 5/13/87 | 7.8 | 117[e] | - | - |
| VC-2A (steam condensate) | VA-278 | 5/13/87 | 5.5 | 117[e] | - | - |
| VC-2A (weirbox sample) | VA-279 | 5/13/87 | 8.6 | 93.5 | - | - |
| VC-2A (weirbox sample) | VA-282 | 5/14/87 | 8.8 | 128 | - | - |
| VC-2A (weirbox sample) | VA-284 | 5/17/87 | - | - | - | - |
| VC-2A (steam condensate) | VA-285 | 7/30/87 | 5.0 | 134[e] | - | - |
| VC-2A (separated water) | VA-286 | 7/30/87 | - | - | - | - |
| VC-2A (weirbox sample) | VA-287 | 7/30/87 | 8.5 | 94.5 | - | - |
| VC-2A (steam condensate) | VA-294 | 8/27/87 | 5.5 | 143[e] | - | - |
| VC-2A (separated water) | VA-295 | 8/27/87 | 8.8 | 133.5-140[e] | - | - |
| VC-2A (weirbox sample) | VA-296 | 8/27/87 | 9 | 94.8 | - | - |
| VC-2A (weirbox sample) | VA-287 | 8/28/87 | | 94.5 | - | - |
| VC-2A (weirbox sample) | VA-298 | 8/28/87 | | 94.5 | - | - |
| VC-2A (steam condensate) | VA-299 | 8/28/87 | 5.0 | 118.5[e] | - | - |
| VC-2A (separated water) | VA-300 | 8/28/87 | 8.8 | 118.0[e] | - | - |

[a]Laboratory Eh.
[b]Field conductivity.
[c]Downhole sampler provided by Southwest Surveys.
[d]Downhole sampler provided by INC-7, LANL.
[e]Temperature of separation.

## TABLE B-X. PHYSICAL PROPERTIES OF SELECTED CORE SAMPLES FROM VC-2a, VALLES CALDERA, NEW MEXICO[a]

| Sample Number | Depth ft | Depth (m) | Rock Unit | Permeability Horiz (md) | Permeability Horiz-90 (md)[b] | Permeability Vert (md) | Porosity (%) | Saturation Oil (%) | Saturation $H_2O$ (%) | Grain Density g/cm³ | Bulk Density g/cm³ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VC2A32-11 | 115 | (34.8) | Upper Tuff | 160 | 0.10 | 142 | 10.7 | 0.0 | 86.3 | 2.65 | 2.46 |
| VC2A80-4 | 337 | (102.1) | Upper Bandelier Tuff | 84.0 | 1.2 | 0.63 | 7.4 | 0.0 | 80.2 | 2.61 | 2.48 |
| VC2A138-1 | 616 | (186.6) | Upper Bandelier Tuff | 0.05 | 0.05 | 0.03 | 12.4 | 0.0 | 89.7 | 2.63 | 2.41 |
| VC2A189-1B | 868 | (263.0) | Upper Bandelier Tuff | 0.26 | 0.25 | 0.22 | 30.3 | 0.0 | 91.0 | 2.65 | 2.13 |
| VC2A242-5 | 1125.4 | (341.0) | Upper Bandelier Tuff | 517 | 0.04 | 0.08 | 7.1 | 0.0 | 82.9 | 2.62 | 2.49 |
| VC2A253-1B | 1177.0 | (356.6) | Volcaniclastic Sandstone | 0.78 | 0.67 | 0.66 | 28.9 | 0.0 | 82.8 | 2.65 | 2.13 |
| VC2A301-1A | 1411.0 | (427.5) | Lower Bandelier Tuff | 0.17 | 0.16 | 0.16 | 25.9 | 0.0 | 69.6 | 2.66 | 2.15 |
| VC2A351-1 | 1651.0 | (500.3) | Lower Tuff | 0.30 | 0.29 | 0.29 | 28.3 | 0.0 | 71.5 | 2.67 | 2.11 |

[a]Analysis by Terra Tek Core Services.
[b]md = millidarcy.

## TABLE B-XI. THERMAL CONDUCTIVITY RESULTS OF SELECTED CORE SAMPLES FROM VC-2a, VALLES CALDERA, NEW MEXICO[a]

| Sample Number | Depth ft | Depth (m) | Rock Unit | Bulk Density g/cm³ | Thermal Conductivity (W/m•K) |
|---|---|---|---|---|---|
| VC2A253-1B | 1177.0 | (356.6) | Volcaniclastic Sandstone | 2.13 | 1.37 |
| VC2A301-1A | 1411.0 | (427.5) | Lower Bandelier Tuff | 2.15 | 1.40 |
| VC2A138-1 | 616 | (186.6) | Upper Bandelier Tuff | 2.41 | 1.89 |
| VC2A32-11[b] | 115 | (34.8) | Upper Tuff | 2.46 | 2.02 |

[a]Analysis by Terra Tek Core Services.
[b]Test performed by divided bar method. All others performed by the needle probe method.

TABLE B-XII. WHOLE ROCK CHEMISTRY FOR VC-2a CORE, VALLES CALDERA, NEW MEXICO (oxide values in wt%; trace element values in ppm)

| Sample Number | Depth ft | Depth (m) | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MnO | MgO | CaO | $K_2O$ | $Na_2O$ | $P_2O_5$ | $H_2O^+$ | $H_2O^-$ | Totals | Ba | Rb | Sr | V | Cr | Ni | Zn | Y | Zr | Nb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VC2A-16-6-50.8 | 50.8 | (15.4) | 75.78 | 0.037 | 13.06 | 1.76 | 0.02 | 1.04 | 0.25 | 3.83 | 0.02 | 0.07 | 4.16 | 0.35 | 100.38 | 314 | 168 | 19 | 23 | 8 | 5 | 53 | 38 | 231 | 28 |
| VC2A-27-7B-95.8 | 95.8 | (29.0) | 68.1 | 0.59 | 12.94 | 2.57 | 0.04 | 0.33 | 5.52 | 3.62 | 0.02 | 0.12 | 5.17 | 0.15 | 99.17 | 284 | 137 | 25 | 23 | 35 | 13 | 63 | 38 | 231 | 29 |
| VC2A-42-1-151 | 151 | (45.8) | 74.93 | 0.21 | 12.41 | 1.71 | 0.02 | 0.0 | 0.11 | 7.37 | 0.05 | 0.03 | 1.96 | 0.02 | 98.61 | 599 | 245 | 41 | 0 | 6 | 8 | 77 | 44 | 314 | 30 |
| VC2A-54-5-212.5 | 212.5 | (64.4) | 83.06 | 0.18 | 8.61 | 1.58 | 0.02 | 0.59 | 0.15 | 2.82 | 0.0 | 0.03 | 2.86 | 0.17 | 99.89 | 306 | 160 | 26 | 17 | 1 | 13 | 57 | 37 | 268 | 29 |
| VC2A-63-3-252.8 | 252.8 | (76.6) | 85.88 | 0.33 | 7.89 | 1.17 | 0.02 | 0.68 | 0.2 | 2.96 | 0.03 | 0.04 | <0.01 | 0.19 | 99.07 | 296 | 157 | 46 | 32 | 13 | 18 | 38 | 19 | 263 | 19 |
| VC2A-71-2-292.8 | 292.8 | (88.7) | 78.20 | 0.08 | 11.04 | 1.24 | 0.03 | 0.0 | 0.07 | 6.73 | 0.05 | 0.0 | 1.64 | 0.10 | 99.18 | 431 | 257 | 38 | 0 | 3 | 14 | 52 | 56 | 203 | 35 |
| VC2A-83-2B-352.7 | 352.7 | (106.9) | 77.54 | 0.09 | 10.98 | 1.29 | 0.02 | 0.0 | 0.06 | 7.80 | 0.09 | 0.0 | 1.38 | 0.12 | 99.37 | 401 | 289 | 36 | 0 | 1 | 5 | 69 | 62 | 203 | 35 |
| VC2A-95-4B-407 | 407 | (123.3) | 77.54 | 0.08 | 10.90 | 0.95 | 0.02 | 0.0 | 0.07 | 7.49 | 0.14 | 0.01 | 1.38 | 0.07 | 98.65 | 397 | 294 | 42 | 4 | 5 | 13 | 44 | 65 | 210 | 36 |
| VC2A-104-4-452 | 452 | (136.9) | 79.99 | 0.09 | 10.52 | 1.01 | 0.02 | 0.4 | 0.8 | 6.11 | 0.08 | 0.0 | 1.49 | 0.12 | 100.63 | 288 | 249 | 37 | 7 | 0 | 4 | 44 | 59 | 231 | 37 |
| VC2A-115-1-500.5 | 500.5 | (151.6) | 77.75 | 0.09 | 11.54 | 1.06 | 0.03 | 0.0 | 0.11 | 7.24 | 0.10 | 0.0 | - | - | 97.92 | 307 | 316 | 39 | 3 | 7 | 9 | 47 | 60 | 215 | 34 |
| VC2A-123-12B-553 | 553 | (167.6) | 75.95 | 0.09 | 12.02 | 1.14 | 0.02 | 0.09 | 0.07 | 8.05 | 0.10 | 0.0 | 1.73 | 0.09 | 99.35 | 444 | 346 | 30 | 1 | 9 | 5 | 68 | 76 | 234 | 37 |
| VC2A-134-8-600 | 600 | (181.8) | 77.73 | 0.08 | 10.97 | 1.30 | 0.07 | 0.20 | 1.14 | 3.82 | 2.02 | 0.0 | 1.97 | 0.09 | 99.39 | 342 | 151 | 55 | 0 | 6 | 20 | 103 | 62 | 198 | 36 |
| VC2A-146-7-653.3 | 653.3 | (197.9) | 77.13 | 0.09 | 11.94 | 1.18 | 0.05 | 0.07 | 0.43 | 4.57 | 3.12 | 0.0 | 1.16 | 0.07 | 99.81 | 296 | 177 | 61 | 3 | 4 | 7 | 66 | 64 | 213 | 38 |
| VC2A-158-1-713 | 713 | (216.0) | 77.11 | 0.08 | 12.22 | 1.42 | 0.04 | 0.65 | 0.10 | 6.68 | 0.07 | 0.0 | 1.50 | 0.11 | 99.98 | 229 | 341 | 34 | 0 | 0 | 11 | 90 | 84 | 226 | 41 |
| VC2A-165-4-752 | 752 | (227.9) | 77.90 | 0.08 | 10.37 | 1.10 | 0.12 | 0.51 | 1.05 | 6.57 | 0.11 | 0.01 | 2.21 | 0.08 | 100.11 | 262 | 289 | 44 | 1 | 1 | 9 | 56 | 84 | 194 | 40 |
| VC2A-176-4-807 | 807 | (244.5) | 77.16 | 0.08 | 10.77 | 1.12 | 0.08 | 0.34 | 0.67 | 3.83 | 2.31 | 0.01 | 1.20 | 0.11 | 97.68 | 355 | 190 | 67 | 8 | 7 | 11 | 64 | 81 | 205 | 42 |
| VC2A-187-1-857 | 857 | (259.7) | 76.53 | 0.09 | 11.46 | 1.70 | 0.09 | 0.26 | 1.17 | 4.35 | 1.57 | 0.01 | 1.60 | 0.10 | 98.93 | 339 | 260 | 57 | 0 | 2 | 8 | 92 | 89 | 214 | 43 |
| VC2A-196-3-904.4 | 904.4 | (274.0) | 73.92 | 0.07 | 12.14 | 1.46 | 0.06 | 0.61 | 1.01 | 6.38 | 1.58 | 0.0 | 1.36 | 0.09 | 98.68 | 271 | 286 | 63 | 9 | 19 | 23 | 97 | 87 | 231 | 46 |
| VC2A-201-9-954.4 | 954.4 | (289.2) | 75.41 | 0.06 | 11.24 | 1.30 | 0.08 | 0.19 | 1.07 | 6.20 | 1.18 | 0.0 | 1.35 | 0.07 | 98.15 | 344 | 360 | 50 | 8 | 0 | 10 | 77 | 93 | 228 | 52 |
| VC2A-215-3A-999.8 | 999.8 | (302.9) | 76.36 | 0.06 | 11.62 | 1.38 | 0.06 | 0.25 | 0.21 | 5.78 | 1.86 | 0.0 | 1.18 | 0.06 | 98.82 | 319 | 345 | 48 | 0 | 2 | 8 | 100 | 107 | 241 | 56 |
| VC2A-266-4-1051.8 | 1051.8 | (318.7) | 77.49 | 0.09 | 11.93 | 1.50 | 0.12 | 0.32 | 0.68 | 3.67 | 3.08 | 0.0 | 1.29 | 0.07 | 100.24 | 231 | 229 | 59 | 12 | 5 | 8 | 75 | 96 | 230 | 48 |
| VC2A-238-1-1108 | 1108 | (335.6) | 77.53 | 0.06 | 11.58 | 1.36 | 0.04 | 0.0 | 0.24 | 4.47 | 3.61 | 0.0 | 0.84 | 0.08 | 99.81 | 369 | 248 | 48 | 0 | 13 | 9 | 84 | 102 | 241 | 52 |
| VC2A-248-1A-1150 | 1150 | (348.5) | 75.60 | 0.05 | 10.73 | 1.37 | 0.12 | 0.27 | 0.97 | 5.61 | 1.95 | 0.0 | 1.14 | 0.12 | 97.93 | 369 | 244 | 94 | 9 | 5 | 7 | 95 | 105 | 232 | 50 |
| VC2A-259-1A-1201 | 1201 | (363.9) | 74.52 | 0.07 | 11.87 | 1.64 | 0.16 | 0.78 | 0.84 | 6.86 | 0.12 | 0.0 | 1.69 | 0.12 | 98.49 | 520 | 334 | 63 | 0 | 9 | 24 | 107 | 107 | 253 | 53 |
| VC2A-269-4B-1254 | 1254 | (380.0) | 75.16 | 0.13 | 11.83 | 1.38 | 0.08 | 0.08 | 0.95 | 6.66 | 0.17 | 0.0 | 1.83 | 0.08 | 98.35 | 512 | 250 | 45 | 4 | 9 | 6 | 43 | 42 | 248 | 31 |
| VC2A-279-1A3-1302 | 1302 | (394.5) | 77.37 | 0.14 | 11.50 | 1.27 | 0.04 | 0.04 | 0.31 | 7.37 | 0.11 | 0.04 | 1.68 | 0.06 | 99.93 | 485 | 248 | 56 | 11 | 3 | 19 | 56 | 39 | 213 | 32 |
| VC2A-289-36-1357 | 1357 | (411.2) | 78.03 | 0.15 | 12.15 | 1.75 | 0.02 | 0.17 | 0.27 | 3.35 | 0.16 | 0.01 | 3.13 | 0.22 | 99.41 | 147 | 167 | 33 | 10 | 8 | 11 | 500 | 56 | 195 | 35 |
| VC2A-300-36-1408 | 1408 | (426.6) | 72.21 | 0.39 | 11.66 | 2.44 | 0.08 | 0.29 | 1.81 | 3.72 | 2.94 | 0.13 | 2.08 | 0.12 | 97.87 | 729 | 119 | 182 | 11 | 35 | 45 | 89 | 33 | 143 | 25 |
| VC2A-307-16-1443 | 1443 | (437.2) | 66.30 | 0.60 | 13.86 | 3.70 | 0.34 | 2.29 | 2.97 | 3.44 | 2.15 | 0.21 | 2.13 | 0.14 | 98.13 | 949 | 158 | 186 | 51 | 19 | 29 | 75 | 24 | 192 | 25 |
| VC2A-322C-1-1510 | 1510 | (457.6) | 72.87 | 0.26 | 12.26 | 2.04 | 0.12 | 0.57 | 1.77 | 4.98 | 1.40 | 0.07 | 2.09 | 0.17 | 98.60 | 668 | 273 | 110 | 2 | 11 | 11 | 85 | 69 | 223 | 49 |
| VC2A-331-K2-1553 | 1553 | (470.6) | 75.02 | 0.24 | 11.57 | 1.76 | 0.08 | 0.35 | 1.05 | 5.14 | 1.33 | 0.05 | 1.74 | 0.12 | 98.45 | 652 | 254 | 95 | 12 | 13 | 16 | 69 | 71 | 198 | 45 |
| VC2A-341B-1601 | 1601 | (485.2) | 74.15 | 0.15 | 12.67 | 1.62 | 0.12 | 0.33 | 1.48 | 4.76 | 1.59 | 0.02 | 1.50 | 0.21 | 98.60 | 360 | 247 | 84 | 9 | 6 | 17 | 62 | 53 | 248 | 36 |
| VC2A-351C-1652 | 1652 | (500.6) | 72.90 | 0.25 | 12.40 | 2.32 | 0.09 | 0.42 | 1.59 | 5.40 | 1.31 | 0.08 | 1.37 | 0.21 | 98.34 | 643 | 265 | 94 | 14 | 9 | 16 | 91 | 73 | 224 | 46 |
| VC2A-360-4-1701 | 1701 | (515.5) | 73.93 | 0.24 | 12.58 | 2.34 | 0.08 | 0.36 | 1.07 | 5.27 | 1.64 | 0.06 | 1.29 | 0.11 | 98.97 | 606 | 277 | 100 | 9 | 6 | 8 | 89 | 73 | 221 | 46 |
| VC2A-366F-1731 | 1731 | (524.4) | 72.51 | 0.24 | 12.68 | 2.14 | 0.06 | 0.22 | 1.34 | 5.08 | 2.11 | 0.07 | 1.12 | 0.12 | 97.69 | 686 | 229 | 133 | 19 | 3 | 24 | 72 | 83 | 219 | 49 |

TABLE B-XII (cont). WHOLE ROCK CHEMISTRY FOR SELECTED, UNALTERED ROCKS FROM THE JEMEZ REGION (oxide values in wt%; trace element values in ppm)

| Sample Number | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MnO | MgO | CaO | $K_2O$ | $Na_2O$ | $P_2O_5$ | $H_2O^+$ | $H_2O^-$ | Totals | Ba | Rb | Sr | V | Cr | Ni | Zn | Y | Zr | Nb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Welded Upper Bandelier Tuff F81-160 | 75.3 | 0.07 | 11.70 | 1.46 | 0.07 | 0.08 | 0.31 | 4.28 | 4.07 | 0.01 | | 1.99 | 99.34 | - | 250 | - | - | - | - | 70 | - | 240 | - |
| Welded Upper Bandelier Tuff F83-275 | 76.5 | 0.12 | 11.80 | 1.43 | 0.05 | 0.05 | 0.23 | 4.74 | 3.72 | 0.01 | | 1.22[a] | 99.87 | - | - | - | - | - | - | - | - | - | - |
| Upper Bandelier Tsankawi Pumice F82-94 | 72.7 | 0.08 | 12.2 | 1.47 | 0.08 | 0.05 | 0.33 | 5.36 | 3.08 | 0.005 | | 4.01[a] | 99.365 | - | 330 | - | - | - | - | 33 | - | 350 | - |
| Welded Lower Bandelier Tuff F83-45 | 77.0 | 0.08 | 12.1 | 1.48 | 0.05 | 0.06 | 0.25 | 4.39 | 4.23 | 0.01 | | 0.28[a] | 99.93 | - | 180 | 20 | 17 | - | - | 90 | - | 140 | - |
| Lower Bandelier Pumice F82-11 | 73.6 | 0.04 | 11.9 | 1.40 | 0.07 | 0.10 | 0.24 | 4.61 | 4.36 | 0.005 | | 4.26[a] | 100.585 | - | 330 | 9.9 | 16 | 5 | - | 20 | - | 190 | - |
| Lower Bandelier Guaje Pumice F83-12 | 74.2 | 0.08 | 11.8 | 1.50 | 0.05 | 0.09 | 0.30 | 5.88 | 2.86 | 0.005 | | 2.95[a] | 99.385 | - | 184 | 6.1 | - | - | - | - | - | 186 | 83 |
| Pre-Bandelier Ignimbrite "B" F82-92 | 74.4 | 0.10 | 11.8 | 1.54 | 0.06 | 0.08 | 0.33 | 4.67 | 4.00 | 0.005 | | 3.35[a] | 100.335 | - | 155 | 2.1 | - | 5 | - | 40 | - | 180 | 71 |
| Pre-Bandelier Ignimbrite "A" F82-91 | 73.0 | 0.11 | 12.0 | 1.25 | 0.06 | 0.42 | 0.45 | 4.90 | 2.90 | 0.005 | | 4.70[a] | 99.795 | - | 145 | 12 | - | - | - | - | - | - | 71 |
| Cerro Rubio Quartz Latite F83-245 | 66.9 | 0.47 | 15.2 | 3.43 | 0.05 | 1.42 | 3.32 | 3.20 | 3.60 | 0.15 | | 0.28[a] | 98.02 | 1170 | 52 | 500 | 64 | 51 | - | 73 | - | 160 | - |
| Paliza Canyon Dacite Type 1 JG81-31 | 66.48 | 0.68 | 15.75 | 3.27 | 0.07 | 0.58 | 1.91 | 3.81 | 5.49 | 0.19 | | 0.57[a] | 98.80 | 2400 | 95 | 505 | 31 | - | - | 52 | - | 454 | 39 |
| Paliza Canyon Andesite, Type 1 JG82-28 | 59.98 | 1.09 | 16.37 | 6.40 | 0.08 | 2.66 | 5.27 | 2.55 | 4.25 | 0.40 | | 0.47[a] | 99.52 | 1280 | 55 | 718 | 144 | 25 | - | 71 | - | 241 | 19.6 |

[a]Combined $H_2O/H_2O^-$.

TABLE B-XIII. WHOLE ROCK CHEMISTRY FOR SELECTED, UNALTERED ROCKS FROM THE JEMEZ REGION (oxide values in wt%; trace element values in ppm)

| Sample Number | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MnO | MgO | CaO | $K_2O$ | $Na_2O$ | $P_2O_5$ | $H_2O^+$ | $H_2O^-$ | Totals | Ba | Rb | Sr | V | Cr | Ni | Zn | Y | Zr | Nb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Welded Upper Bandelier Tuff F81-160 | 75.3 | 0.07 | 11.70 | 1.46 | 0.07 | 0.08 | 0.31 | 4.28 | 4.07 | 0.01 | | 1.99 | 99.34 | - | 250 | - | - | - | - | 70 | - | 240 | - |
| Welded Upper Bandelier Tuff F83-275 | 76.5 | 0.12 | 11.80 | 1.43 | 0.05 | 0.05 | 0.23 | 4.74 | 3.72 | 0.01 | | 1.22[a] | 99.87 | - | - | - | - | - | - | - | - | - | - |
| Upper Bandelier Tsankawi Pumice F82-94 | 72.7 | 0.08 | 12.2 | 1.47 | 0.08 | 0.05 | 0.33 | 5.36 | 3.08 | 0.005 | | 4.01[a] | 99.365 | - | 330 | - | - | - | - | 33 | - | 350 | - |
| Welded Lower Bandelier Tuff F83-45 | 77.0 | 0.08 | 12.1 | 1.48 | 0.05 | 0.06 | 0.25 | 4.39 | 4.23 | 0.01 | | 0.28[a] | 99.93 | - | 180 | 20 | 17 | - | - | 90 | - | 140 | - |
| Lower Bandelier Pumice F82-11 | 73.6 | 0.04 | 11.9 | 1.40 | 0.07 | 0.10 | 0.24 | 4.61 | 4.36 | 0.005 | | 4.26[a] | 100.585 | - | 330 | 9.9 | 16 | 5 | - | 20 | - | 190 | - |
| Lower Bandelier Guaje Pumice F83-12 | 74.2 | 0.08 | 11.8 | 1.50 | 0.05 | 0.09 | 0.30 | 5.88 | 2.86 | 0.005 | | 2.95[a] | 99.385 | - | 184 | 6.1 | - | - | - | - | - | 186 | 83 |
| Pre-Bandelier Ignimbrite "B" F82-92 | 74.4 | 0.10 | 11.8 | 1.54 | 0.06 | 0.08 | 0.33 | 4.67 | 4.00 | 0.005 | | 3.35[a] | 100.335 | - | 155 | 2.1 | - | 5 | - | 40 | - | 180 | 71 |
| Pre-Bandelier Ignimbrite "A" F82-91 | 73.0 | 0.11 | 12.0 | 1.25 | 0.06 | 0.42 | 0.45 | 4.90 | 2.90 | 0.005 | | 4.70[a] | 99.795 | - | 145 | 12 | - | - | - | - | - | - | 71 |
| Cerro Rubio Quartz Latite F83-245 | 66.9 | 0.47 | 15.2 | 3.43 | 0.05 | 1.42 | 3.32 | 3.20 | 3.60 | 0.15 | | 0.28[a] | 98.02 | 1170 | 52 | 500 | 64 | 51 | - | 73 | - | 160 | - |
| Paliza Canyon Dacite Type 1 JG81-31 | 66.48 | 0.68 | 15.75 | 3.27 | 0.07 | 0.58 | 1.91 | 3.81 | 5.49 | 0.19 | | 0.57[a] | 98.80 | 2400 | 95 | 505 | 31 | - | - | 52 | - | 454 | 39 |
| Paliza Canyon Andesite, Type 1 JG82-28 | 59.98 | 1.09 | 16.37 | 6.40 | 0.08 | 2.66 | 5.27 | 2.55 | 4.25 | 0.40 | | 0.47[a] | 99.52 | 1280 | 55 | 718 | 144 | 25 | - | 71 | - | 241 | 19.6 |

[a]Combined $H_2O/H_2O^-$.

TABLE B-XIII. INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS, VC-2A, VALLES CALDERA, NEW MEXICO (values in ppm)

| Element | VC2A105.5 | VC2A119 | VC2A129.5 | VC2A340 | VC2A425 | VC2A440 | VC2A553 | VC2A653.3 | VC2A752 | VC2A857 | VC2A954.4 | VC2A1051.8 | VC2A1142 | VC2A1254 | VC2A1357 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Na | 118 | 420 | 490 | 920 | 142 | 116 | 1080 | 24200 | 980 | 12300 | 9100 | 16100 | 22900 | 1620 | 940 |
| Mg | <1000 | <1100 | <1000 | 1300 | 3100 | <900 | <1600 | <3000 | 4000 | <1800 | <2000 | 4700 | <1700 | <1400 | 2100 |
| Al | 65000 | 59000 | 59000 | 52000 | 53000 | 51000 | 64000 | 61000 | 53000 | 58000 | 60000 | 56000 | 58000 | 61000 | 64000 |
| Cl | <30 | <40 | <30 | <30 | <40 | <30 | <60 | <130 | <50 | <120 | <130 | <130 | <110 | <240 | <760 |
| K | 32000 | 57000 | 55000 | 62000 | 22600 | 21200 | 71000 | 38000 | 56000 | 41000 | 55000 | 44000 | 42000 | 63000 | 30300 |
| Ca | <1100 | <900 | 680 | <500 | <800 | <800 | <1100 | 3200 | 7500 | 8600 | 8200 | 7400 | 4500 | 6600 | <1400 |
| Sc | 2.63 | 2.31 | 2.40 | 1.03 | 1.92 | 1.62 | 1.16 | 1.11 | 0.90 | 1.18 | 0.79 | 0.78 | 0.74 | 1.89 | 4.5 |
| Ti | 1310 | 1170 | 1270 | 440 | 490 | 580 | 470 | <3000 | <3000 | <4000 | <4000 | <4000 | <3000 | 800 | 820 |
| V | 14 | 8.6 | 5.4 | <3 | <4 | <4 | <7 | <6 | <4 | <7 | <8 | <7 | <5 | <6 | 11 |
| Cr | 7.8 | 6.9 | 9.5 | 2.7 | 3.6 | 2.4 | 7.4 | 3.7 | 3.2 | 4.4 | <1.4 | 3.8 | 3.2 | 2.1 | 9.3 |
| Mn | 250 | 60 | 65 | 137 | 211 | 90 | 175 | 380 | 900 | 690 | 640 | 940 | 780 | 640 | 154 |
| Fe | 13600 | 13000 | 13300 | 10800 | 10800 | 10900 | 8300 | 10400 | 8000 | 11200 | 9800 | 11000 | 10500 | 10500 | 13700 |
| Co | 18.2 | 14.2 | 18.9 | 53 | 15.6 | 24.4 | 47 | 34.5 | 28.6 | 50 | 73 | 79 | 27.4 | 73 | 60 |
| Cu | <150 | <140 | <120 | <100 | <140 | <130 | <200 | <300 | <150 | <300 | <300 | <300 | <200 | <200 | <200 |
| Zn | 83 | 94 | 320 | 60 | 910 | 24 | 160 | 180 | 61 | 102 | 180 | 260 | 79 | 49 | 850 |
| Ga | 23 | 15 | 21 | 21 | 21 | 18 | 28 | 17 | 21 | 24 | 20 | 20 | 19 | 22 | 17 |
| As | 75 | 59 | 60 | 68 | 74 | 94 | 54 | <2 | 10.1 | 3.4 | 3.8 | 6.2 | <1.6 | 18.5 | 25 |
| Se | 1.9 | 0.7 | <1.3 | 0.6 | 1.6 | 1.2 | <3 | 0.9 | 0.8 | 1.4 | 1.5 | <1.7 | <1.4 | <2 | <3 |
| Br | <1.4 | <1.3 | <1.3 | <1.1 | <1.4 | <1.4 | <2 | <4 | <1.0 | <3 | <3 | <3 | <2 | <2 | <1.5 |
| Rb | 121 | 214 | 235 | 278 | 146 | 129 | 338 | 189 | 320 | 286 | 337 | 276 | 275 | 270 | 175 |
| Sr | <170 | <110 | <100 | <100 | <140 | <130 | <200 | <200 | <200 | <300 | <300 | <300 | <200 | <300 | <170 |
| Zr | 290 | 260 | 350 | 330 | 230 | 230 | 160 | 230 | 300 | 260 | 210 | 240 | 400 | 300 | 170 |
| Mo | 31 | 60 | 333 | 192 | 103 | 442 | <60 | <180 | 7 | <80 | <70 | <180 | 18 | <70 | <40 |
| Ag | <3 | <1.4 | <1.5 | <1.4 | <1.7 | 4.2 | <2 | <1.6 | <1.3 | <3 | <2 | <1.9 | <1.2 | <3 | 4.8 |
| In | <0.12 | <0.11 | 0.10 | <0.09 | <0.11 | 1.7 | <0.16 | <0.2 | <0.14 | <0.2 | <0.2 | <0.2 | <0.18 | <0.19 | 0.98 |
| Sb | 4.3 | 2.53 | 2.61 | 3.54 | 5.6 | 8.7 | 1.60 | <0.4 | <0.37 | <0.4 | <0.3 | 0.69 | 0.54 | 0.89 | 1.89 |
| I | <12 | <6 | <7 | <8 | <11 | <9 | <11 | <19 | <15 | <20 | <18 | <20 | <17 | <20 | <9 |
| Cs | 1.64 | 2.14 | 2.14 | 3.3 | 4.2 | 2.36 | 7.8 | 5.7 | 6.1 | 7.6 | 5.0 | 4.2 | 4.0 | 4.0 | 6.6 |
| Ba-131 | 250 | 570 | 410 | 230 | 60 | 40 | 180 | 130 | 100 | 160 | <200 | 50 | 80 | 200 | <300 |
| Ba-139 | <1900 | 500 | 450 | 190 | <2000 | <1400 | <3000 | <4000 | <3000 | <3000 | <5000 | <5000 | <3000 | <3000 | <2000 |
| La | 70 | 61 | 59 | 53 | 59 | 45 | 66 | 58 | 47 | 53 | 50 | 49 | 54 | 61 | 47 |
| Ce | 135 | 121 | 116 | 104 | 124 | 110 | 139 | 124 | 100 | 112 | 113 | 113 | 116 | 105 | 105 |
| Nd | 41 | 33 | 47 | 41 | 65 | 57 | 49 | 50 | 41 | 41 | 30 | 60 | 39 | 30 | 24 |
| Sm | 9.1 | 8.0 | 6.9 | 8.5 | 11.4 | 12.4 | 10.8 | 9.8 | 9.8 | 10.8 | 10.4 | 10.2 | 10.4 | 7.1 | 8.0 |
| Eu | 0.50 | 0.44 | 0.40 | 0.23 | 0.30 | 0.25 | 0.16 | 0.21 | 0.11 | 0.26 | 0.20 | 0.076 | 0.070 | 0.30 | 0.43 |
| Tb | 1.18 | 0.90 | 0.97 | 1.36 | 1.77 | 1.82 | 1.59 | 1.75 | 1.85 | 1.81 | 1.93 | 2.3 | 2.26 | 0.91 | 1.52 |
| Dy | 7.2 | 6.0 | 6.1 | 9.9 | 12.6 | 13.2 | 10.9 | 11.6 | 12.1 | 12.5 | 14.2 | 14.8 | 15.1 | 5.8 | 9.7 |
| Yb | 4.7 | 3.4 | 3.4 | 5.6 | 6.7 | 7.4 | 6.8 | 6.2 | 9.2 | 9.1 | 9.1 | 9.8 | 10.3 | 3.6 | 5.9 |
| Lu | 0.59 | 0.51 | 0.49 | 0.74 | 0.87 | 0.85 | 0.94 | 0.91 | 1.27 | 1.01 | 1.24 | 1.48 | 1.49 | 0.45 | 0.84 |
| Hf | 8.7 | 8.7 | 8.0 | 7.9 | 8.2 | 8.3 | 9.7 | 9.2 | 9.6 | 9.6 | 12.4 | 12.3 | 13.2 | 7.1 | 8.4 |
| Ta | 2.85 | 2.5 | 2.68 | 4.0 | 4.6 | 4.1 | 4.9 | 5.7 | 6.1 | 6.5 | 8.4 | 9.5 | 9.4 | 3.3 | 5.2 |
| W | 170 | 121 | 190 | 430 | 170 | 400 | 460 | 420 | 260 | 480 | 520 | 680 | 340 | 630 | 123 |
| Au | 0.015 | 0.018 | 0.033 | 0.019 | 0.023 | 0.022 | <0.009 | <0.015 | <0.006 | <0.017 | <0.011 | <0.014 | <0.011 | <0.014 | <0.006 |
| Hg | <0.6 | <0.3 | <0.3 | <0.3 | <0.3 | <0.5 | <0.4 | <0.3 | <0.3 | <0.7 | <0.4 | <0.4 | <0.3 | <0.6 | <0.4 |
| Th | 14.7 | 11.7 | 11.6 | 16.2 | 17.5 | 17.8 | 20.6 | 21.5 | 21.5 | 24.5 | 29.0 | 30.3 | 30.1 | 15.4 | 20.1 |
| U | 9.9 | 11.3 | 13.3 | 16.5 | 9.1 | 13.0 | 6.2 | 6.4 | 6.8 | 7.6 | 10.3 | 9.7 | 11.2 | 5.0 | 8.1 |

TABLE B-XIV. GOLD PLUS 17 PATHFINDER ELEMENTS, VC-2a, VALLES CALDERA, NEW MEXICO (values in ppm, except where noted)

| Sample No. | Au (ppb) | Cu | Pb | Zn | Mo | Ag | Co | Ni | Cr | Mn | W | Bi | As | Sb | Hg (ppb) | Ba | Se | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VC2A 16-6 50.8 | 10 | 8 | 24 | 63 | 5 | 0.8 | 4 | 14 | 51 | 45 | <10 | <2 | 35 | <5 | 90 | 160 | <5 | 3 |
| VC2A 27-7B 95.8 | 15 | 11 | 27 | 56 | 66 | 0.6 | 7 | 24 | 75 | 153 | <10 | <2 | 179 | 6 | 135 | 30 | <5 | 2 |
| VC2A 42-1 151 | 85 | 4 | 35 | 109 | 112 | 0.8 | 2 | 10 | 78 | 33 | <10 | <2 | 73 | <5 | 15 | 410 | 10 | 2 |
| VC2A 54-5 212.5 | 5 | 3 | 19 | 43 | 61 | 1.1 | 1 | 7 | 56 | 67 | <10 | <2 | 61 | <5 | 10 | 50 | 6 | 3 |
| VC2A 63-3 252.8 | 20 | 7 | 13 | 20 | 5 | 0.7 | 3 | 8 | 166 | 88 | <10 | <2 | 7 | <5 | <5 | 250 | <5 | 2 |
| VC2A 71-2a 292.8 | 5 | 3 | 31 | 58 | 14 | 0.9 | 1 | 7 | 111 | 38 | <10 | <2 | 37 | <5 | 10 | 80 | <5 | <1 |
| VC2A 83-2B 352 | 30 | 3 | 33 | 61 | 2 | 0.8 | 1 | 8 | 105 | 42 | <10 | <2 | 166 | <5 | 25 | 70 | 10 | <1 |
| VC2A 123-12B 553 | 15 | 4 | 40 | 79 | 3 | 1.6 | 1 | 8 | 152 | 78 | <10 | <2 | 54 | <5 | 20 | 20 | 22 | 2 |
| VC2A 134-8 600 | <5 | 2 | 40 | 112 | 2 | 0.8 | <1 | 6 | 74 | 710 | <10 | <2 | 44 | <5 | 35 | <20 | <5 | <1 |
| VC2A 158-1 713 | <5 | 2 | 46 | 67 | 1 | 0.8 | 1 | 6 | 79 | 262 | <10 | <2 | <5 | <5 | <5 | <20 | <5 | <1 |
| VC2A 176-4 807 | <5 | 3 | 41 | 81 | 2 | 0.7 | 1 | 8 | 83 | 590 | <10 | <2 | <5 | <5 | <5 | <20 | <5 | <1 |
| VC2A 196-3 904.4 | <5 | 3 | 39 | 110 | 2 | 0.6 | 1 | 9 | 159 | 617 | <10 | <2 | <5 | <5 | <5 | <20 | <5 | <1 |
| VC2A 215-3A 999.8 | <5 | 1 | 40 | 99 | 1 | 0.7 | 1 | 7 | 81 | 480 | <10 | <2 | <5 | <5 | <5 | <20 | <5 | <1 |
| VC2A 238-1 1108 | 65 | 2 | 52 | 116 | 2 | 0.6 | 1 | 6 | 104 | 935 | <10 | <2 | <5 | <5 | <5 | <20 | <5 | <1 |
| VC2A 259-1A 1201 | <5 | 2 | 53 | 121 | 1 | 0.5 | <1 | 9 | 87 | 1612 | <10 | <2 | 10 | <5 | <5 | 160 | <5 | <1 |
| VC2A 279-1A3 1302 | <5 | 3 | 24 | 40 | 2 | 1.1 | 1 | 9 | 107 | 199 | <10 | <2 | 8 | <5 | <5 | 290 | 24 | <1 |
| VC2A 300-3C 1408 | <5 | 7 | 37 | 102 | 3 | 0.6 | 4 | 22 | 139 | 536 | <10 | <2 | 26 | <5 | <5 | 400 | 9 | <1 |
| VC2A 322-C1 1510 | <5 | 6 | 44 | 76 | 2 | 0.6 | 3 | 11 | 84 | 811 | <10 | <2 | <5 | <5 | <5 | 400 | <5 | <1 |
| VC2A 341-1B 1601 | <5 | 2 | 37 | 38 | 2 | 0.7 | 1 | 5 | 33 | 822 | <10 | <2 | 9 | <5 | <5 | 150 | <5 | <1 |
| VC2A 360-4a 1701 | <5 | 5 | 35 | 72 | <1 | 0.6 | 2 | 8 | 57 | 567 | <10 | <2 | <5 | <5 | <5 | 450 | <5 | <1 |

TABLE B-XV. ANALYSIS OF SELECTED SAMPLES FROM VC-2a BY INDUCTIVELY COUPLED PLASMA SPECTROSCOPY (data reproduced from J. Hulen, University of Utah Research Institute)

| Element | Value Expressed As | VC2A-130 | VC2A-100 | VC2A-83 | VC2A-188 |
|---|---|---|---|---|---|
| Na | % Ox | 0.064 | 0.015 | 0.042 | 0.011 |
| K | % Ox | 5.33 | 1.88 | 3.57 | 1.95 |
| Ca | % Ox | 0.080 | 3.94 | 0.87 | 0.408 |
| Mg | % Ox | 0.152 | 0.213 | 0.643 | 0.228 |
| Fe | % Ox | 2.93 | 1.72 | 2.28 | 5.16 |
| Al | % Ox | 10.60 | 5.24 | 9.59 | 7.01 |
| Si[a] | % Ox | 76.10 | 80.20 | 76.30 | 79.45 |
| Ti | % Ox | 0.189 | 0.293 | 0.293 | 0.100 |
| P | % Ox | 0.022 | 0.057 | 0.034 | 0.017 |
| Sr | ppm | 20 | 24 | 9 | 9 |
| Ba | % Ox | 0.035 | 0.013 | 0.017 | 0.006 |
| V | ppm | <250 | <250 | <250 | <250 |
| Cr | ppm | 24 | 40 | 13 | 3 |
| Mn | % Ox | 0.011 | 0.035 | 0.029 | 0.022 |
| Co | ppm | 36 | 25 | 14 | 38 |
| Ni | ppm | 14 | 18 | 9 | <5.00 |
| Cu | ppm | 6 | 17 | 10 | 9 |
| Mo | ppm | 849 | 3340 | <50.0 | 3416 |
| Pb | ppm | 26 | 462 | 33 | 43 |
| Zn | ppm | 119 | 1630 | 63 | 95 |
| Cd | ppm | <5.00 | 13 | <5.00 | <5.00 |
| Ag | ppm | 4 | 3 | 2 | 11 |
| Au | ppm | <4.00 | <4.00 | <4.00 | <4.00 |
| As | ppm | 154 | 109 | 108 | 235 |
| Sb | ppm | <30.0 | <30.0 | <30.0 | <30.0 |
| Bi | ppm | <100 | <100 | <100 | <100 |
| U | ppm | <2500 | <2500 | <2500 | <2500 |
| Te | ppm | <50.0 | <50.0 | <50.0 | <50.0 |
| Sn | ppm | 8 | 11 | 10 | 8 |
| W | ppm | <1200 | <1200 | <1200 | <1200 |
| Li | ppm | 8 | 4 | 5 | 23 |
| Be | ppm | 2.0 | 1.6 | 2.1 | 2.2 |
| B | ppm | <400 | <400 | <400 | <400 |
| Zr | ppm | 158 | 90 | 159 | 100 |
| La | ppm | 65 | 128 | 66 | 41 |
| Ce | ppm | 111 | 233 | 110 | 69 |
| Th | ppm | <150 | <150 | <150 | <150 |
| S[b] | % | 2.31 | 1.38 | 1.54 | 4.05 |
| LOI | % | | 3.57 | 3.26 | |
| Total | | 95.52 | 98.57 | 98.75 | 94.36 |

[a]Silica by colorimetry.
[b]Sulfur by Leco Sulfur Analyzer.

TABLE B-XVI. STABLE ISOTOPES, VC-2a, VALLES CALDERA, NEW MEXICO

| Sample Number | Depth m | (ft) | Rock or Mineral | $\delta D$ (°/oo) | $\delta^{18}O$ (°/oo) | $\delta^{13}C$ (°/oo) |
|---|---|---|---|---|---|---|
| VC2A27-78 95.8 | 29.0 | (95.8) | Rock | -148 | 7.0 | |
| VC2A56-6-Q193 | 58.5 | (193) | Quartz | | 4.0 | |
| VC2A54-4 212.5 | 64.4 | (212.5) | Rock | -109 | 6.1 | |
| VC2A71-2A 292.8 | 88.7 | (292.8) | Rock | -100 | 4.4 | |
| VC2A75-3D-C315 | 95.5 | (315) | Calcite | | -5.0 | -4.1 |
| VC2A89-8-Q383 | 116.0 | (383) | Quartz | | 3.1 | |
| VC2A-113-R494 | 149.7 | (494) | Rhodochrosite | | 4.6 | -4.4 |
| VC2A115-1 500.5 | 151.6 | (500.5) | Rock | -73 | 4.7 | |
| VC2A146-7 (653.3) | 197.9 | (653.3) | Rock | -84 | 4.0 | |
| VC2A187-1 857 | 259.7 | (857) | Rock | -95 | 4.1 | |
| VC2A216-1-C1000 | 303.0 | (1000) | Calcite | | 0.0 | -4.8 |
| VC2A241-6A-C1126 | 341.2 | (1126) | Calcite | | 2.7 | -4.6 |
| VC2A241-6A-Q1126 | 341.2 | (1126) | Quartz | | 6.5 | |
| VC2A252-4A1C1171 | 354.8 | (1171) | Calcite | | -1.0 | -6.0 |
| VC2A279-1A31302 | 394.5 | (1302) | Rock | -86 | 4.4 | |
| VC2A331-K21553 | 470.6 | (1553) | Rock | -86 | 3.9 | |
| VC2A341-B1601 | 485.2 | (1601) | Rock | -84 | 6.0 | |
| VC2A360-4 1701 | 515.5 | (1701) | Rock | -85 | 4.1 | |
| VC2A362-3-C1712 | 518.7 | (1712) | Calcite | | -0.3 | -5.5 |

# TABLE B-XVII. ANALYSIS OF SEDIMENTS AND BACTERIA FROM THE SULPHUR SPRINGS AREA, VALLES CALDERA, NEW MEXICO

| | Sample Number | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 6 | 7 | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 18 |
| Na | 40.8 | 150 | 670 | 1420 | 4190 | 1890 | 3890 | 4380 | 5110 | 2580 | 435 | 111 | 2030 |
| Mg | <310 | 1060 | 1430 | 1780 | 2530 | 5580 | 2160 | 2900 | 2490 | <2300 | <1300 | <490 | 2070 |
| Al | 4040 | 11590 | 17100 | 24600 | 33400 | 86600 | 48800 | 52200 | 36800 | 47800 | 15600 | 4010 | 37400 |
| Cl | <20 | <41 | <47 | <34 | 77 | 188 | 119 | <75 | 92 | <98 | <110 | <23 | <52 |
| K | <950 | 4900 | 8000 | 12500 | 27200 | 17200 | 18300 | 16000 | 15200 | 15300 | 10000 | <970 | 14200 |
| Ca | <560 | <750 | <1400 | <790 | <1300 | 6690 | <930 | 3580 | 3860 | <2000 | <2300 | <600 | <1100 |
| Ti | 2780 | 870 | 3680 | 2710 | 1770 | 3360 | 2440 | 2470 | 2410 | 4070 | 1510 | 4300 | 4400 |
| V | 5.56 | 7.2 | 15.2 | 22.9 | 95.3 | 54.0 | 64.1 | 46.7 | 26.3 | 43.2 | 14.3 | 7.80 | 32.5 |
| Mn | 9.71 | 17.9 | 30.2 | 40.0 | 72.8 | 244 | 72.5 | 79.1 | 77.5 | 51.1 | 55.1 | 7.71 | 46.2 |
| Cu | <53 | <90 | <130 | <96 | <220 | 210 | <180 | <190 | <130 | <250 | <180 | <72 | <170 |
| Sr | <35 | <86 | <100 | <87 | <140 | <280 | 169 | <130 | <110 | <200 | <160 | <56 | <97 |
| In | <0.026 | <0.056 | <0.054 | <0.044 | 0.133 | <0.15 | 0.159 | <0.079 | <0.053 | <0.18 | <0.098 | <0.034 | <0.066 |
| I | <6.8 | <14 | <17 | <12 | <21 | 63 | <19 | <21 | <14 | <30 | <28 | <8.6 | <17 |
| Ba | 296 | 99 | 537 | 487 | 569 | 467 | 1220 | 613 | 907 | 704 | <4800 | 2970 | 616 |
| Dy | 3.84 | 1.13 | 5.66 | 3.53 | 2.14 | 12.8 | 2.96 | 3.54 | 23.58 | 4.13 | 3.11 | 5.50 | 5.30 |
| U | 4.48 | 1.340 | 5.38 | 3.72 | 2.01 | 3.50 | 3.16 | 3.39 | 2.73 | 3.62 | 2.55 | 6.73 | 4.23 |
| Ga | <21 | <19 | <55 | <29 | <53 | <59 | <48 | <45 | <35 | <40 | <51 | <24 | <49 |
| As | 35.9 | 44.4 | 62.7 | 18.8 | 65.6 | 13.4 | 16.3 | 6.24 | 4.98 | 10.5 | 9.6 | 1.34 | 4.59 |
| Br | <1.4 | <1.5 | <3.4 | 1.54 | <2.9 | 23.3 | <2.7 | <2.3 | <2.1 | 3.0 | 2.80 | <1.3 | <3.0 |
| Mo | 7.3 | <34 | <76 | 3.1 | <47 | <82 | <66 | <140 | <33 | <56 | <71 | 28.9 | <50 |
| Sb | 2.39 | 1.162 | 3.02 | 2.06 | 0.73 | 2.45 | 0.65 | 1.26 | 0.791 | 4.13 | 0.99 | 1.122 | 3.33 |
| La | 11.42 | 9.45 | 33.7 | 24.8 | 29.1 | 85.3 | 34.0 | 40.9 | 28.3 | 35.9 | 21.1 | 28.5 | 45.3 |
| Sm | 1.94 | 1.012 | 4.91 | 3.08 | 2.17 | 19.99 | 3.10 | 3.97 | 2.97 | 3.80 | 3.05 | 3.20 | 5.02 |
| Yb | 4.22 | 1.03 | 5.04 | 3.14 | 1.71 | 5.40 | 2.20 | 2.99 | 2.53 | 2.88 | 2.53 | 6.60 | 4.26 |
| W | 5.1 | <3.5 | <8.8 | 3.63 | <6.7 | <9.3 | <6.6 | <6.0 | 3.0 | <6.6 | <8.1 | 6.2 | 6.2 |
| Au | <0.0050 | <0.0056 | <0.0015 | <0.0062 | <0.0099 | <0.0014 | <0.011 | <0.0084 | <0.0074 | <0.010 | <0.014 | <0.0050 | <0.011 |
| Sc | 1.568 | 2.41 | 24.9 | 2.54 | 4.34 | 8.71 | 3.60 | 4.94 | 3.20 | 6.75 | 19.0 | 3.69 | 8.22 |
| Cr | 10.0 | 9.9 | 18.4 | 14.4 | 36.0 | 43.4 | 28.0 | 27.7 | 19.5 | 43.7 | 17.2 | 9.5 | 24.6 |
| Fe | 11030 | 1005 | 2020 | 10390 | 169400 | 93500 | 76200 | 17470 | 14900 | 9240 | 3310 | 426 | 4880 |
| Co | 2.95 | 0.43 | 0.25 | 0.89 | 1.33 | 8.08 | 1.36 | 2.75 | 2.11 | 1.93 | 1.17 | 0.34 | 1.09 |
| Zn | 31 | <9.8 | <30 | 18 | <17 | <41 | 30 | <13 | <6.6 | <16 | <28 | <5.8 | <15 |
| Se | 1.98 | <3.8 | <10 | 0.74 | 1.23 | <9.1 | <6.3 | 0.93 | 1.9 | 0.97 | 1.8 | <3.3 | 2.7 |
| Rb | <8.7 | 37.3 | 51 | 87.6 | 85 | 146 | 70 | 80.4 | 72.0 | 97.0 | 50 | <8.0 | 83.3 |
| Zr | 559 | <180 | <520 | 317 | <310 | 320 | <300 | 295 | 486 | <310 | <490 | 1430 | 360 |
| Ag | <2.1 | <2.5 | <12 | <2.7 | <4.9 | <7.1 | <6.5 | <3.5 | <2.4 | <4.5 | <11 | <2.3 | <4.4 |
| Cs | 0.28 | 1.69 | 4.1 | 2.85 | 4.08 | 132.10 | 6.23 | 8.19 | 4.94 | 12.39 | 2.89 | 0.26 | 7.03 |
| Ce | 23.3 | 20.1 | 71.5 | 49.4 | 51.5 | 222 | 67.8 | 78.4 | 57.9 | 76.5 | 44.8 | 57.0 | 81.3 |
| Nd | <12 | <18 | <71 | <15 | <25 | 110 | <39 | 33.4 | <14 | <32 | <68 | <14 | 40 |
| Eu | 0.265 | 0.291 | 0.79 | 0.594 | 0.351 | 3.26 | 0.61 | 0.693 | 0.541 | 0.606 | 0.539 | 0.459 | 0.863 |
| Tb | 0.629 | 0.196 | 0.86 | 0.520 | 0.19 | 2.72 | 0.41 | 0.391 | 0.450 | 0.578 | 0.85 | 0.709 | 0.88 |
| Lu | 0.583 | 0.162 | 0.704 | 0.509 | 0.240 | 0.846 | 0.361 | 0.410 | 0.362 | 0.562 | 0.492 | 1.013 | 0.777 |
| Hf | 13.33 | 1.82 | 13.3 | 9.00 | 6.37 | 3.88 | 11.20 | 7.89 | 10.37 | 8.13 | 5.03 | 42.4 | 10.79 |
| Ta | 2.48 | 0.67 | 3.44 | 2.03 | 1.53 | 2.07 | 2.19 | 1.66 | 1.58 | 2.87 | 1.34 | 3.99 | 2.80 |
| Hg | 156 | 17.1 | 18.0 | 1.88 | 1.14 | <1.3 | <5.1 | <0.64 | <0.44 | 8.7 | 9.1 | 10.3 | 7.9 |
| Th | 9.67 | 4.46 | 22.56 | 11.58 | 11.68 | 12.29 | 12.02 | 11.76 | 8.63 | 13.02 | 13.55 | 12.7 | 14.75 |
| Ir | - | - | 0.013 | - | - | - | - | - | - | - | ≤0.008 | - | - |

All values are in ppm, except for Ir, which is in ppb.
Analyses by Group INC-5, LANL, by INAA.

## TABLE B-XVII. (cont)

**Sample Descriptions**

1. Freshly excavated mud, >80°C.
2. Large rectangular spring; high gassing rates; high sulfur content; pH 1-2; 30°C, rod-shaped bacteria predominating.
3. Blue-green coccus (*Cyanidium* sp.?) in surface sediments; high sulfur; pH 1-2; 36°C.
6. Cold water stream, no visible sulfur; brown-orange sediments; acid pH ?; 20°C.
7. Yellow sediments next to red ones; dry.
10. Bog sediments; dry; iron oxidation?
12. Brown-cream sediments, downstream from hottest springs (Sample 14).
14. 90°C spring.
15. Dark brown mud, 56°C, near the house. *Sulfolobus*-like bacteria observed under light microscopy.
16. Dark green mat downstream from the coccus.
17. White dry soil.
18. Blue-green mat; 25°C; oxygenic photosynthesis? (trapped gas bubbles).

# TABLE B-XVIII. MAJOR AND TRACE ELEMENT AND ION AND ISOTOPIC DATA OF HOT SPRINGS, SULPHUR SPRINGS, VALLES CALDERA, NEW MEXICO (values in mg/ℓ)

| Sample No. | Description | Date | Temp. °C | $SiO_2$ | Ca | Mg | Sr | Na | K | Li | $HCO_3$ | $CO_3$ | $SO_4$ | Cl | F | Br | B | TDS | $\Sigma_{cat}$ | $\Sigma_{an}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VA-230 | Footbath Spg. | 4/17/86 | 18 | 125 | 44.4 | 10.6 | 0.22 | 16.1 | 29 | 0.02 | 0 | 0 | 3080 | 32.0 | 6.04 | <0.1 | 0.37 | 3561 | 47.11 | 65.69 |
| VA-233 | Footbath Spg. | 4/30/86 | 19.6 | 111 | 30.8 | 8.5 | 0.10 | 7.2 | 26 | 0.07 | 0 | 0 | 3625 | 11 | 1.17 | <0.5 | 0.14 | 4018 | 48.42 | 76.19 |
| VA-240 | Footbath Spg. | 6/18/86 | 38.0 | 126 | 42.6 | 10.9 | 0.17 | 18.3 | 43 | 0.06 | 0 | 0 | 4430 | 13.1 | 1.15 | <0.1 | 0.23 | 4894 | 57.23 | 93.02 |
| VA-246 | Footbath Spg. | 9/3/86 | 27.5 | 98 | 20.8 | 5.3 | 0.24 | 19 | 24 | <0.01 | 0 | 0 | 1995 | 4.0 | 1.00 | <0.2 | 0.16 | 2311 | 28.77 | 41.98 |
| VA-248 | Footbath Spg. | 9/10/86 | 39.4 | 92 | 87.6 | 6.1 | 0.20 | 10 | 28 | <0.01 | 0 | 0 | 2100 | 4.8 | 1.02 | <0.2 | 0.09 | 2495 | 32.37 | 44.19 |
| VA-250A | Footbath Spg. | 10/23/86 | – | 113 | 486 | 19.0 | 1.28 | 12 | 20 | 0.06 | 157 | 0 | 1083 | 0.8 | 0.44 | <0.2 | <0.05 | 1896.6 | 27.00 | 25.32 |
| VA-250B | Footbath Spg. | 10/23/86 | 46.5 | 118 | 127 | 6.8 | 0.2 | 8 | 35 | 0.03 | 0 | 0 | 1961 | 5.6 | 1.25 | <0.2 | 0.17 | 2348.2 | 32.4 | 41.3 |
| VA-239 | Women's Bath. | 6/18/86 | 89.3 | 107 | 466 | 15.4 | 0.35 | 13.5 | 22 | 0.08 | 0 | 0 | 2154 | 24.3 | 0.84 | <0.1 | 0.13 | 2954 | 39.59 | 45.83 |
| VA-235 | Lemonade Spg. | 5/9/86 | – | 221 | 166 | 34.3 | 0.06 | 8.2 | 7.5 | 0.04 | 0 | 0 | 1440 | 2.4 | 1.18 | <0.1 | <0.02 | 1965 | 24.84 | 30.33 |
| VA-231 | Tony's Spg. | 4/17/86 | 31 | 205 | 8.6 | 2.0 | 0.13 | 1.4 | 13.8 | <0.01 | 0 | 0 | 2775 | 2.0 | 0.30 | <0.1 | 0.25 | 3069 | 28.70 | 58.19 |
| VA-234 | Tony's Spg. | 4/30/86 | 38.3 | 165 | 3.2 | 1.5 | 0.06 | 1.3 | 7.8 | <0.01 | 0 | 0 | 3756 | 8 | 0.06 | <0.5 | 0.03 | 3984 | 45.67 | 78.79 |
| VA-241 | Tony's Spg. | 6/18/86 | 45 | 185 | 11.0 | 8.3 | 0.24 | 5.7 | 37 | 0.04 | 0 | 0 | 11950 | <5 | 0.02 | <1 | 0.14 | 12354 | 129.47 | 249.87 |
| VA-247 | Tony's Spg. | 9/3/86 | 35 | 209 | 8.4 | 4.9 | 0.10 | 4 | 4 | <0.01 | 0 | 0 | 3240 | 2.0 | 0.19 | <0.2 | <0.01 | 3573 | 50.88 | 67.88 |
| VA-249 | Tony's Spg. | 9/10/86 | 34 | 214 | 9.3 | 5.3 | 0.09 | 5 | 5 | <0.01 | 0 | 0 | 3800 | 1.5 | 0.18 | <0.2 | <0.01 | 4147 | 48.22 | 79.54 |
| VA-252 | Tony's Spg. | 9/23/86 | 41.1 | 235 | 10.0 | 5.6 | 0.08 | 1 | 9 | <0.01 | 0 | 0 | 4400 | 9.6 | 0.18 | <0.5 | 0.02 | 4799 | 63.35 | 92.25 |

Trace Elements

| Sample No. | Description | Date | Temp. °C | Ag | Al | As | Ba | Cd | Co | Cr | Cs | Cu | Fe | Mn | Mo | $NH_4$ | Ni | $N_3$ | Pb | $PO_4$ | Rb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VA-230 | Footbath Spg. | 4/17/86 | 18 | <0.001 | 49.4 | <0.1 | <0.01 | 0.005 | 0.053 | 0.25 | 0.005 | 0.021 | 48.8 | 0.38 | <0.1 | 1.22 | 0.29 | <1 | 0.09 | <0.1 | 0.27 | 0.94 |
| VA-233 | Footbath Spg. | 4/30/86 | 19.6 | <0.001 | 85.6 | 0.1 | <0.01 | 0.002 | 0.046 | 0.19 | 0.011 | 0.008 | 127 | 1.76 | 0.2 | 0.02 | 0.16 | 0.6 | 0.08 | <0.5 | 0.21 | 0.98 |
| VA-240 | Footbath Spg. | 6/18/86 | 38.0 | <0.001 | 89.3 | <0.1 | 0.02 | 0.009 | 0.058 | 0.68 | 0.012 | 0.026 | 120 | 1.80 | <0.1 | 2.26 | 0.21 | 0.4 | 0.70 | <0.5 | 0.31 | 1.62 |
| VA-246 | Footbath Spg. | 9/3/86 | 27.5 | <0.001 | 35.5 | 0.2 | 0.03 | 0.002 | 0.070 | 0.37 | <0.001 | 0.12 | 106 | 0.62 | <0.1 | 0.18 | 0.12 | 0.2 | 0.09 | <0.2 | 0.18 | 0.81 |
| VA-248 | Footbath Spg. | 9/10/86 | 39.4 | <0.001 | 48.8 | 0.5 | <0.01 | 0.002 | 0.065 | 0.039 | <0.001 | 0.009 | 113 | 0.71 | <0.1 | 1.48 | 0.30 | 0.4 | 0.09 | 0.2 | 0.18 | 0.84 |
| VA-250A | Footbath Spg. | 10/23/86 | – | – | <0.1 | <0.1 | <0.05 | – | – | – | 0.008 | – | 2.12 | 0.89 | <0.1 | 0.26 | – | <0.5 | – | <1 | 0.075 | 0.16 |
| VA-250B | Footbath Spg. | 10/23/86 | 46.5 | – | 49.3 | 0.4 | 0.08 | – | – | – | 0.053 | – | 33.5 | 0.97 | <0.1 | 0.05 | – | <0.5 | – | <1 | 0.26 | 0.81 |
| VA-239 | Women's Bath. | 6/18/86 | 89.3 | <0.001 | 70.1 | <0.1 | 0.04 | 0.002 | 0.018 | 3.19 | 0.032 | 0.028 | 68.7 | 4.31 | <0.1 | 2.25 | 0.93 | 0.3 | 0.008 | <0.2 | 0.24 | 0.40 |
| VA-235 | Lemonade Spg. | 5/9/86 | – | <0.001 | 46.1 | <0.1 | 0.04 | 0.001 | 0.003 | 0.034 | 0.025 | <0.001 | 25.2 | 2.62 | <0.1 | 8.5 | 0.017 | 1.3 | <0.001 | <0.5 | 0.74 | 0.18 |
| VA-231 | Tony's Spg. | 4/17/86 | 31 | <0.001 | 28.9 | <0.1 | <0.01 | 0.001 | 0.003 | 0.058 | 0.006 | 0.002 | 25.1 | 0.46 | <0.1 | 5.3 | 0.050 | 0.6 | 0.026 | <0.5 | 0.064 | 0.08 |
| VA-234 | Tony's Spg. | 4/30/86 | 38.3 | <0.001 | 24.7 | <0.1 | 0.01 | <0.001 | 0.003 | 0.014 | 0.017 | 0.001 | 11.3 | 0.13 | 0.1 | 4.8 | 0.038 | <0.5 | 0.032 | <0.5 | 0.058 | 0.07 |
| VA-241 | Tony's Spg. | 6/18/86 | 45 | <0.001 | 156 | <0.1 | 0.06 | <0.001 | 0.015 | 2.78 | 0.069 | 0.059 | 47.0 | 0.25 | <0.1 | 29 | 0.27 | 0.6 | 0.21 | <0.5 | 0.31 | 0.23 |
| VA-247 | Tony's Spg. | 9/3/86 | 35 | <0.001 | 66.9 | 0.4 | <0.01 | 0.002 | 0.075 | 0.033 | <0.001 | 0.003 | 18.6 | 0.24 | <0.1 | 13.8 | 0.19 | <0.2 | 0.09 | <0.2 | 0.046 | 0.37 |
| VA-249 | Tony's Spg. | 9/10/86 | 34 | <0.001 | 75.1 | 0.6 | <0.01 | 0.001 | 0.070 | 0.035 | <0.001 | 0.002 | 19.9 | 0.25 | <0.1 | 10.3 | 0.14 | <0.2 | 0.08 | <0.2 | 0.046 | 0.50 |
| VA-252 | Tony's Spg. | 9/23/86 | 41.1 | – | 74.4 | 0.4 | <0.05 | – | – | – | 0.006 | – | 21.3 | 0.30 | <0.1 | 11.6 | – | <0.5 | – | <1 | 0.023 | 0.27 |

TABLE B-XVIII. (cont)

| Sample No. | Description | Date | Elevation (m) | $\delta D$ (°/oo) | $\delta^{18}O$ (°/oo) | $^{3}H$ (Tu) |
|---|---|---|---|---|---|---|
| **Isotopes** | | | | | | |
| VA-230 | Footbath Spg. | 4/17/86 | 2500 | -91.30 | -23.08 | 9.6 |
| VA-233 | Footbath Spg. | 4/30/86 | 2500 | - | - | - |
| VA-240 | Footbath Spg. | 6/18/86 | 2500 | - | - | - |
| VA-246 | Footbath Spg. | 9/3/86 | 2500 | -57.9 | -18.51 | - |
| VA-248 | Footbath Spg. | 9/10/86 | 2500 | - | - | - |
| VA-250A | Footbath Spg. | 10/23/86 | 2500 | - | - | - |
| VA-250B | Footbath Spg. | 10/23/86 | 2500 | - | - | - |
| VA-239 | Women's Bath. | 6/18/86 | 2500 | - | - | - |
| ~~VA-235~~ | ~~Lemonade Spg.~~ | ~~5/9/86~~ | ~~2500~~ | - | - | - |
| VA-231 | Tony's Spg. | 4/17/86 | 2500 | -49.0 | -7.64 | 2.1 |
| VA-234 | Tony's Spg. | 4/30/86 | 2500 | - | - | - |
| VA-241 | Tony's Spg. | 6/18/86 | 2500 | - | - | - |
| VA-247 | Tony's Spg. | 9/3/86 | 2500 | -52.8 | -10.50 | - |
| VA-249 | Tony's Spg. | 9/10/86 | 2500 | - | - | - |
| VA-252 | Tony's Spg. | 9/23/86 | 2500 | - | - | - |

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1988—673-104/80058