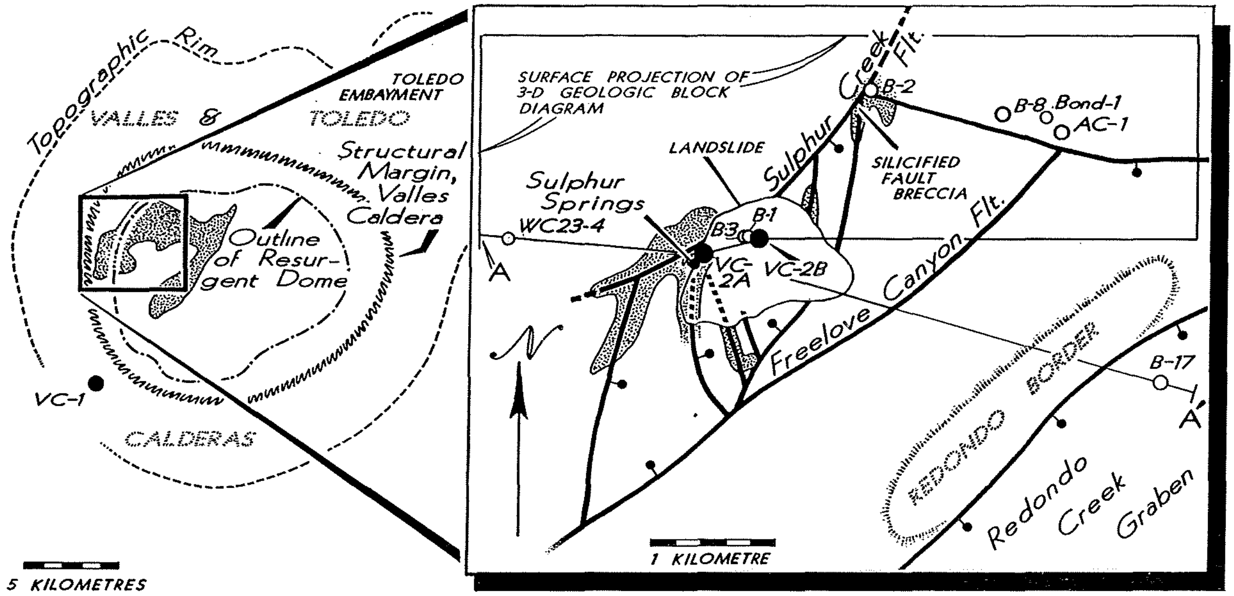
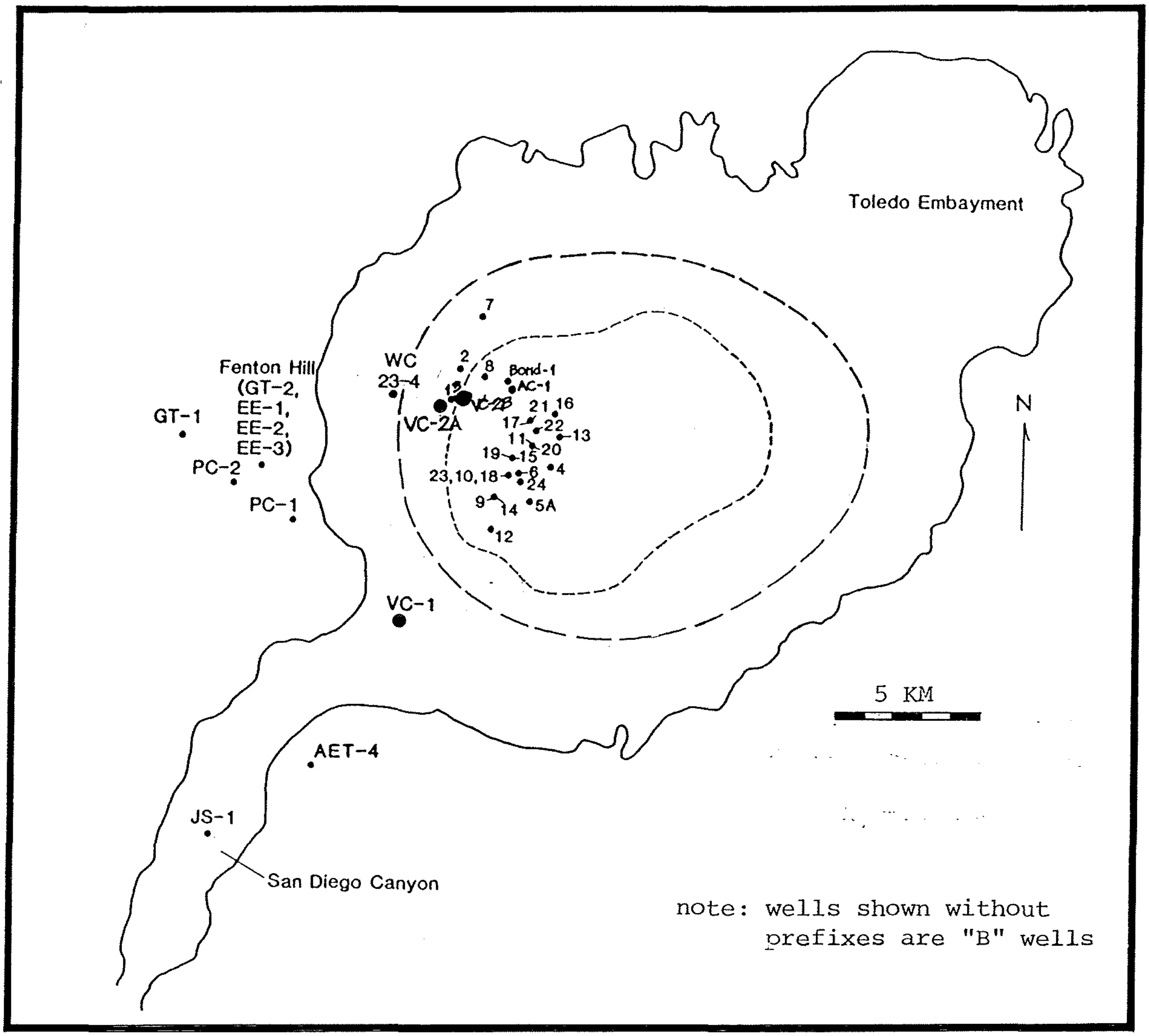
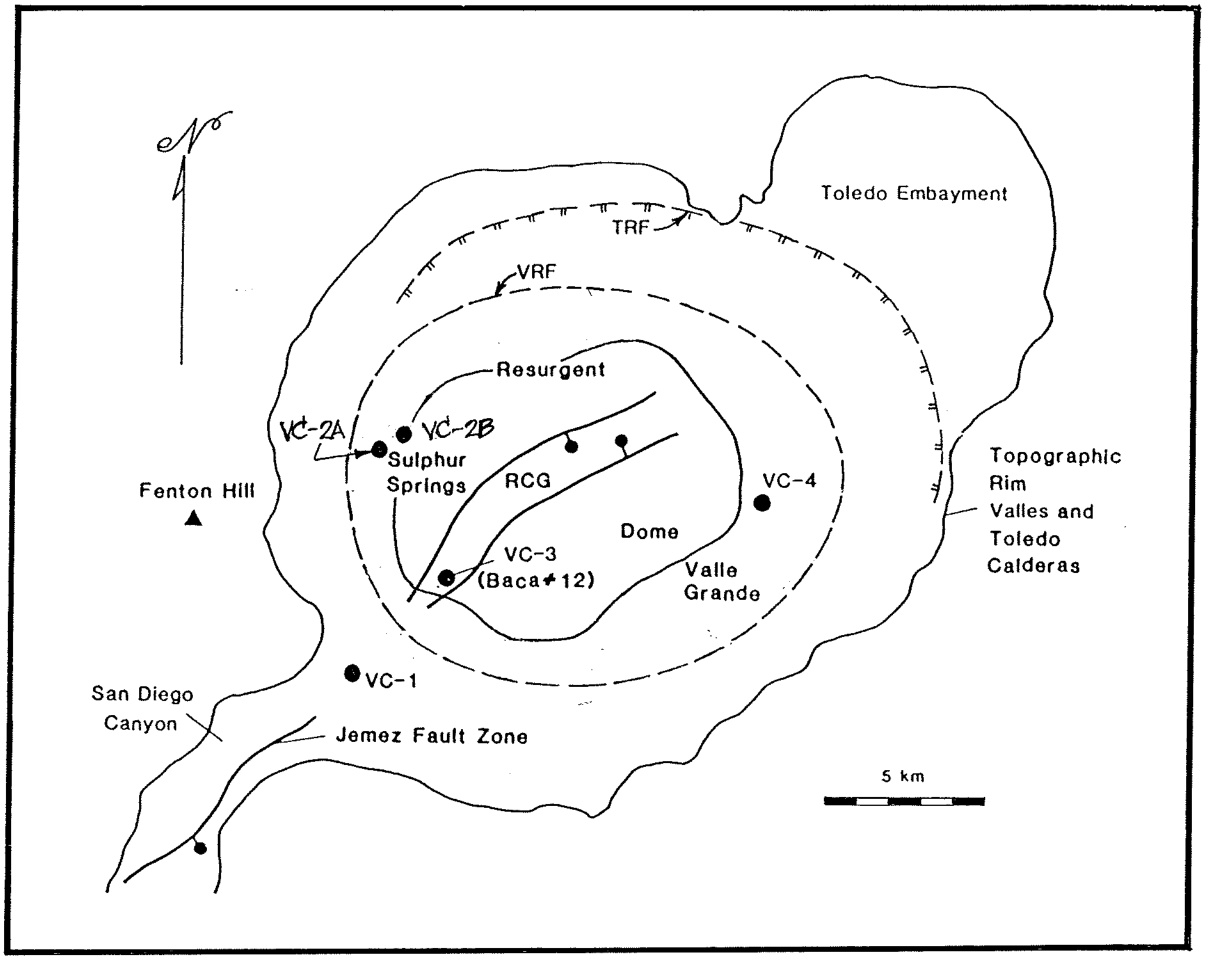
GL04706



Location map, showing position of CSDP coreholes VC-2B and VC-2A relative to the Sulphur Springs area of the Valles caldera complex. Stippling at left shows extent of active or recent surficial alteration. Stippling on right shows areas of phyllic, argillic, and advanced argillic acid-sulfate alteration. A-A' is cross-section of Figure 12 Note also location of 3-D geologic block diagram of Figure 9. Modified from Goff and Gardner (1980) and Charles et al. (1986).

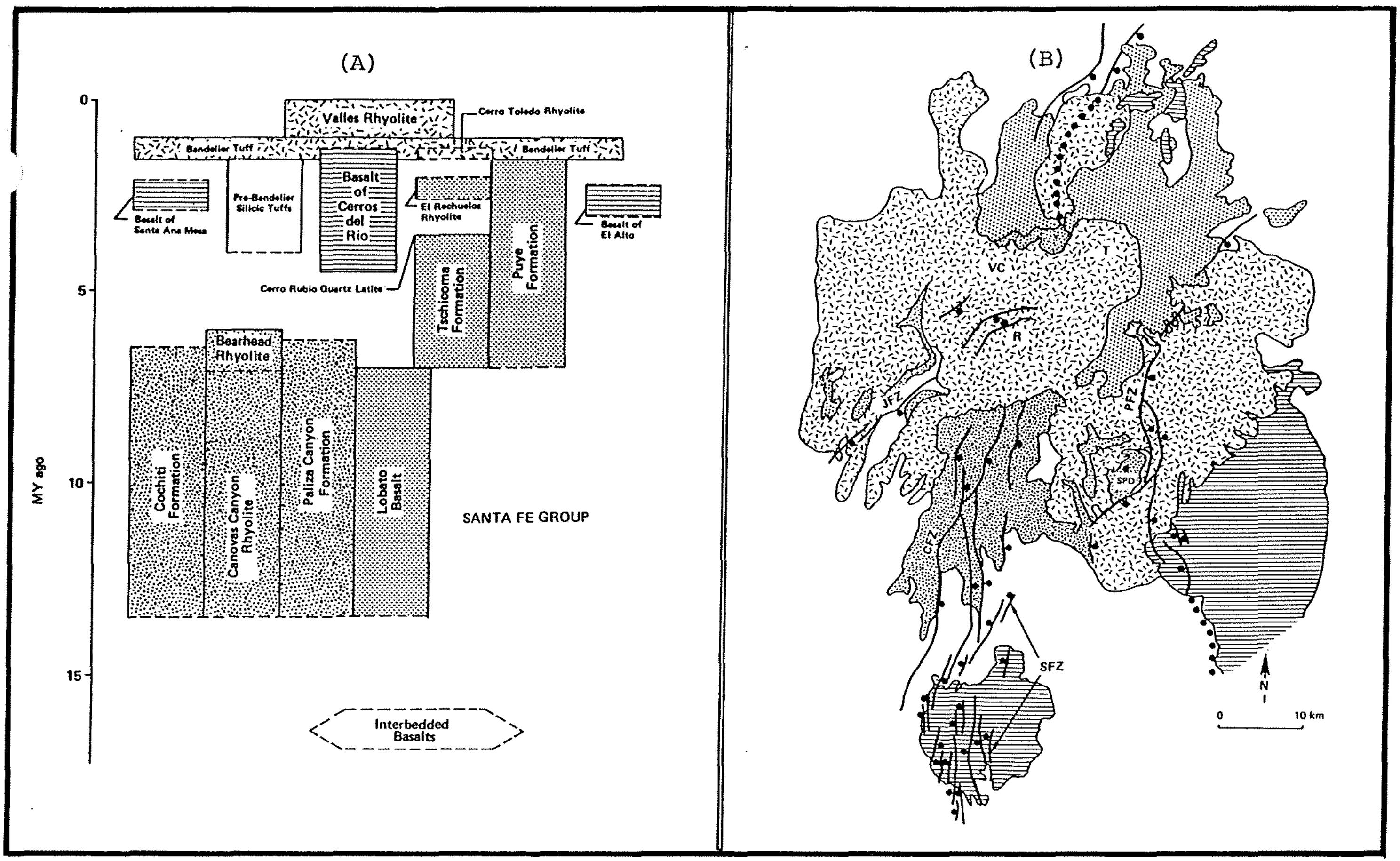


Map showing locations geothermal wells and scientific coreholes completed to date within and adjacent to the Valles caldera complex. Long dashes delineate the ring-fracture margin of the Valles caldera. Short dashes outline the Valles caldera's resurgent dome.

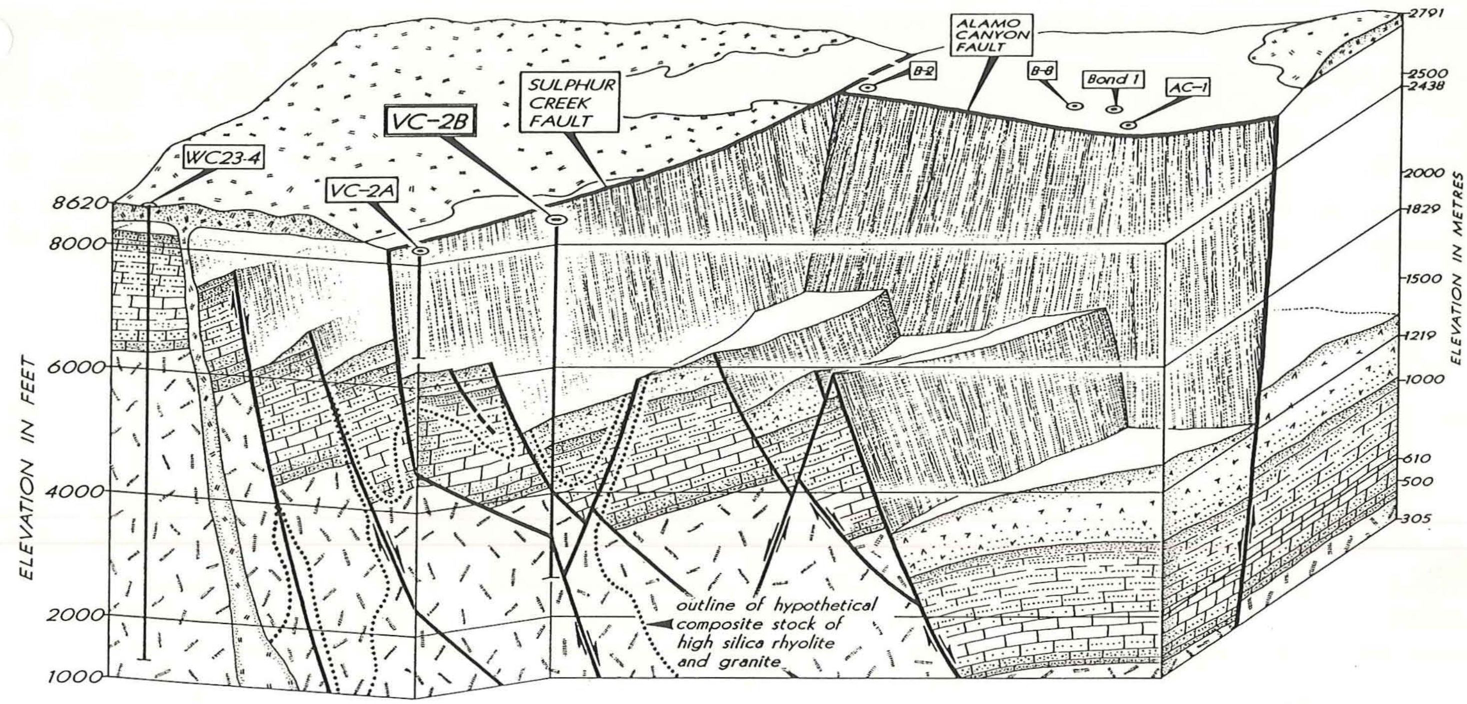


Map of the Valles caldera complex showing locations of completed and proposed CSDP coreholes. VC-1 and VC-2A are already completed. VC-5 will be located in the Toledo embayment. RCG - Redondo Creek graben. VRF - Valles caldera ring-fracture zone. TRF - Toledo caldera ring-fracture zone.

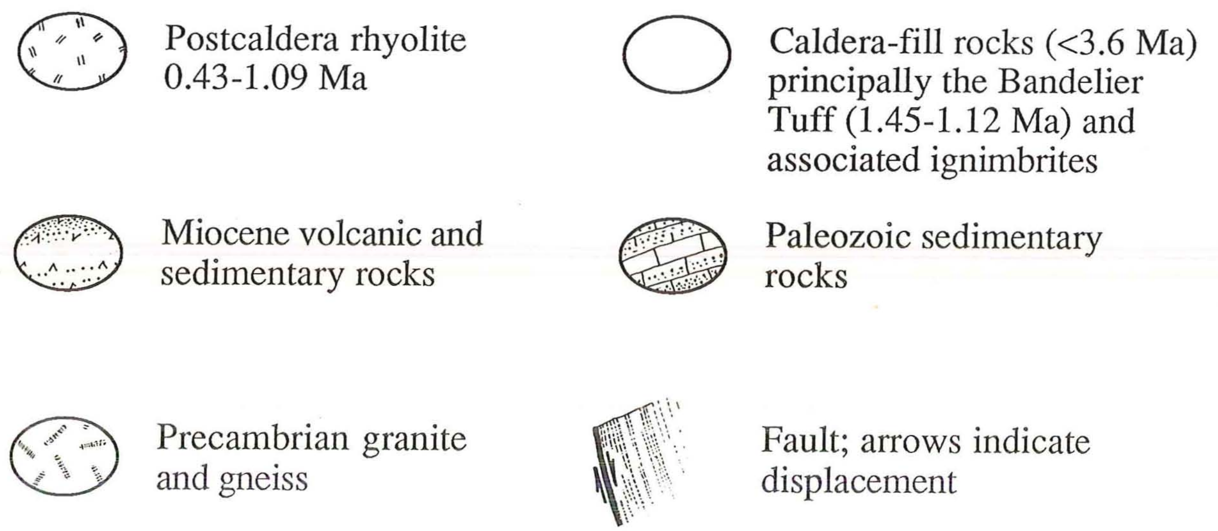
Qbt
Qls
VALLE
Tab
Qf
Qvvf
Warm Spring
Cerro Seco
9915
9500
9504
9704
Qbo
San Antonio Mtn
San Antonio Hot Spring
Valle Seco
Qvvt
Qcf
Qvvf
Sulphur Springs
Redondito
Redondo Peak
Headquarters Ranch
Cerro La Jara
Qvbb
Banco Bonito
South Mountain
9760
Battleship Rock



Generalized stratigraphic relations (A) and aereal distribution (B) of major rock units in the Jemez volcanic field. Irregular stipple - Keres Group formations. Regular stipple - Polvadera Group formations. Random dashes - Tewa Group formations. A - Dashed lines indicate uncertainty. B - Major fault zones and geomorphic features labeled as follows: JFZ - Jemez fault zone; SFZ - Santa Ana Mesa fault zone; CFZ - Canada de Cochiti fault zone; PFZ - Pajarito fault zone; VC - Valles caldera complex; R - resurgent dome of VC; T - Toledo embayment; SPD - St. Peter's dome. From Gardner et al. (1986), as modified from Gardner and Goff (1984) and Smith et al. (1970).



(Looking North)



Geologic block diagram showing interpreted subsurface structure and stratigraphy in the Sulphur Springs area of the west-central Valles caldera complex. For location, please refer to Figure 7. Caldera-fill units south of the Alamo Canyon fault and east of the Sulphur Creek fault are stripped away in the drawing to show conceptually complex configuration of basement rocks in the floor of the caldera. Wells B-1 and B-3 not shown for clarity. Surface geology from Goff and Gardner (1980).

Table 1. Stratigraphic data for geothermal wells and scientific coreholes within and adjacent to the southwestern Valles caldera.

Borehole	Collar El. (m)	Unit	Top El. (m)	Bottom El. (m)	Thickness (m)
B-1	2566.3	UT?	2426.1?	2279.8?	146.3?
		S_2?	2279.8?	1786.0?(TD)	>493.8?
B-3	2566.3	UT?	2352.9?	2255.4?	97.5?
		S_2?	2255.4?	1895.8?(TD)	>359.6?
B-2	2590.6	UT	2354.5	2226.5	128.0
		S_2	2226.5	2182.3	44.2
		Ts	2182.9	2029.9	153.0
		S_3	2029.9	2026.8	3.1
		O	2026.8	1862.2	64.6
		SF	1862.2	1691.6	170.6
		A	1691.6	1328.9	362.7
		M	1328.9	1066.7	262.2
		PG	1066.7	865.6(TD)	201.1
B-7	2651.6	Ts	1950.6	1850.7	99.9
		S_3	1850.7	1828.7	22.0
		O	1828.7	1719.0	109.7
		SF	1719.0	1444.7	274.3
		A	1444.7	1225.2	219.5
		M	1225.2	987.5	237.7
		PG	987.5	960.1(TD)	27.4
B-8	2636.4	UT	2459.6	2259.1	200.5
		S_2	2259.1	2228.0	31.1
		Ts	2228.0	2134.7	93.3
		S_3	2134.7	2125.6	9.1
		O	2125.6	1819.6	306.0
		LT	1819.6	1685.5	134.1
		SF	1685.5	1545.3	140.2
		A	1545.3	1300.2(TD)	245.1
AC-1	2657.7	UT	2413.9	2321.2	92.7
		S_2	2321.2	2309.1	12.2
		TS	2309.1	1694.5	614.5
		S_3	1694.5	1676.3	18.2
		O	1676.3	1146.0	530.3
		S_4	1146.0	810.7	335.3
		LT	810.7	438.9	371.8
		PC	438.9	402.3(TD)	36.6

670.1

Table 1, continued

Borehole	Collar El. (m)	Unit	Top El. (m)	Bottom El. (m)	Thickness (m)
Bond-1	2650.7	"IG"	2352.0	1876.6	475.4
		SF	1876.6	1530.6(TD)	346.0
WC-234	2625.4	"IG"	2500.4	2457.8	42.6
		A	2457.8	2210.9	246.9
		M	2210.9	1962.5	248.4
		Sa	1962.5	1884.8	77.7
		PG	1884.8	661.1(TD)	1223.7
VC-1	2492.4	UT?	2,343.7	2194.7	149.0
		S_2?	2,194.7	2158.4	36.3
		A	2,158.4	2070.6	87.8
		M	2070.6	1684.7	385.9
		Sa	1684.7	1666.1	18.6
		BX	1666.1	1636.3(TD)	29.8
VC-2A	2560.2	UT	2538.6	2494.4	44.2
		S_2	2494.4	2480.0	14.4
		Ts	2480.0	2204.5	275.5
		S_3	2204.5	2198.5	6.0
		O	2198.5	2083.2	115.3
		LT	2083.2	2032.4(TD)	>50.8

-ABBREVIATIONS-

UT - Upper Tuffs
S_2 - S_2 clastic deposits
Ts - Tshirege Member of Bandelier Tuff
S_3 - S_3 clastic deposits
Ot - Otowi Member of Bandelier Tuff
S_4 - S_4 clastic deposits
LT - Lower Tuffs
"IG" - Intracaldera rhyolitic ignimbrite sequence, undivided
PC - Paliza Canyon Formation (intermediate-composition volcanic rocks; Miocene)
SF - Santa Fe Group sandstones (Miocene)
A - Abo Formation (redbeds; Permian)
M - Madera Formation (carbonates; Pennsylvanian)
Sa - Sandia Formation (carbonates and siliciclastic rocks; Pennsylvanian)
PG - Granite and granitic orthogneiss (Precambrian)
BX - Complex, multilithologic, tectonic and hydrothermal breccia sequence

Stratigraphic Data for Wells in the Baca Project Area

Well	Elevation, m	Unit	Top El	Bottom El	Thickness
Baca 4	2840	UT	2779	2316	463
		T	2316	1709	607
		S_3	1709	1639	70
		O	1639	1462	177
		S_4	1462	1414	48
		LT	1414	1017	397
		PC	1017	925 TD	
Baca 5	2841	UT	2713	2573	140
		T	2573	1417	1156
		S_3	1417	1387	30
		O	1387	1022	365
		LT	1022	809	213
		PC	809	716 TD	
Baca 6	2562	UT	2560	2524	36
		S_2	2524	2499	25
		T	2499	1845	654
		O*	1845	1230?	
		PC	1230?	1212 TD	
Baca 9,9RD	2633	UT	2609	2481	128
		T	2481	1884	597
		S_3	1884	1878	6
		O	1878	1506	372
		LT	1506	1018 TD	
Baca 10	2662	UT	2568	2552	16
		S_2	2552	2504	48
		T	2504	1636	868
		S_3	1636	1629	7
		O	1629	1269	360
		LT	1269	1077	192
		PC	1077	862	215
		SF	862	840 TD	
Baca 11	2763	UT	2665	2367	298
		S_2	2367	2342	25
		T	2342	1846	496
		O	1846	1337	509
		LT	1337	1153	184
		PC	1153	776	377
		SF	776	666 TD	
Baca 12	2569	T	2520	1508	1012
		S_3	1508	LCZ	6+
		O	LCZ	644	833(?)
		LT	644	565	79
		PC	565	263	302
		A	263	−238	501
		M	−238	−531	293
		PG	−532	−642 TD	
Baca 13	2832	PC	1115	401	714
		A	401	360 TD	
Baca 14	2623	PC	926	827	99
		SF	827	665	162
		A	665	629 TD	
Baca 15	2779	UT	2736	2401	335
		S_2	2401	2395	6
		T	2395	1874	521
		S_3	1874	1851	23
		O	1851	1383	468
		LT	1383	1213	170
		PC	1213	1161 TD	
Baca 16	2933	T	2665	1877	788
		S_3	1877	1835	42
		O	1835	1326	509
		LT	1326	1257	69
		PC	1257	887	370
		SF	887	852 TD	
Baca 170H	2853	T	2512	1880	632
		S_3	1880	1874	6
		O	1874	1381	493
		LT	1381	1191	190
		PC	1191	1108 TD	
Baca 17 RD	2853	S_3	1867	1861	6
		O	1861	1362	499
		LT	1362	1197	165
		PC	1197	979	218
Baca 18	2662	S_2	2547	2486	61
		T	2486	1640	846
		O	1640	1261 TD	
Baca 18 RD	2662	O	1646	1259	387
		LT	1259	1130	129
		PC	1130	1103 TD	
Baca 19	2779	UT	2740	2334	406
		S_2	2334	2328	6
		T	2328	1840	488
		S_3	1840	1825	15
		O	1825	1334	491
		LT	1334	1114	220
Baca 20	2763	UT	2659	2367	292
		S_2	2367	2355	12
		T	2355	1846	509
		S_3	1846	1843	3
		O	1843	1350	493
		LT	1350	1129	221
		PC	1129	671 TD	
Baca 20 RD	2763	S_3	1848	18846	2
		O	1846	1441 TD	
Baca 21	2853	T	2502	1992 TD	
Baca 22	2826	UT	2594	2301	293
		S_2	2301	2277	24
		T	2277	1856	421
		S_3	1856	1850	6
		O	1850	1439	411
		LT	1439	1210	229
		PC	1210	994 TD	
Baca 22 RD1	2826	S_3	1858	1849	9
		O	1849	1452	397
		LT	1452	1170	282
		PC	1170	861 TD	
Baca 22 RD2	2826	S_3	1840	1834	6
		O	1834	1433	401
		LT	1433	1219	214
		PC	1219	999 TD	
Baca 22 RD3	2826	S_3	1850	1838	12
		O	1838	1442	396
		LT	1442	1178	264
		PC	1178	733	445
		SF	733	497	236
		A	497	235	262
		M	235	144 TD	
Baca 23	2662	UT	2601	2541	60
		S_2	2541	2516	25
		T	2516	1632	884
		O	1632	1215	417
		LT	1215	1070	145
		PC	1070	928 TD	
Baca 24	2664	UT	2611	2456	155
		S_2†			
		T	2454	1570	884
		S_3	1570	1567	3
		O	1567	1252	315
		LT	1252	1134	118
		PC	1134	990 TD	

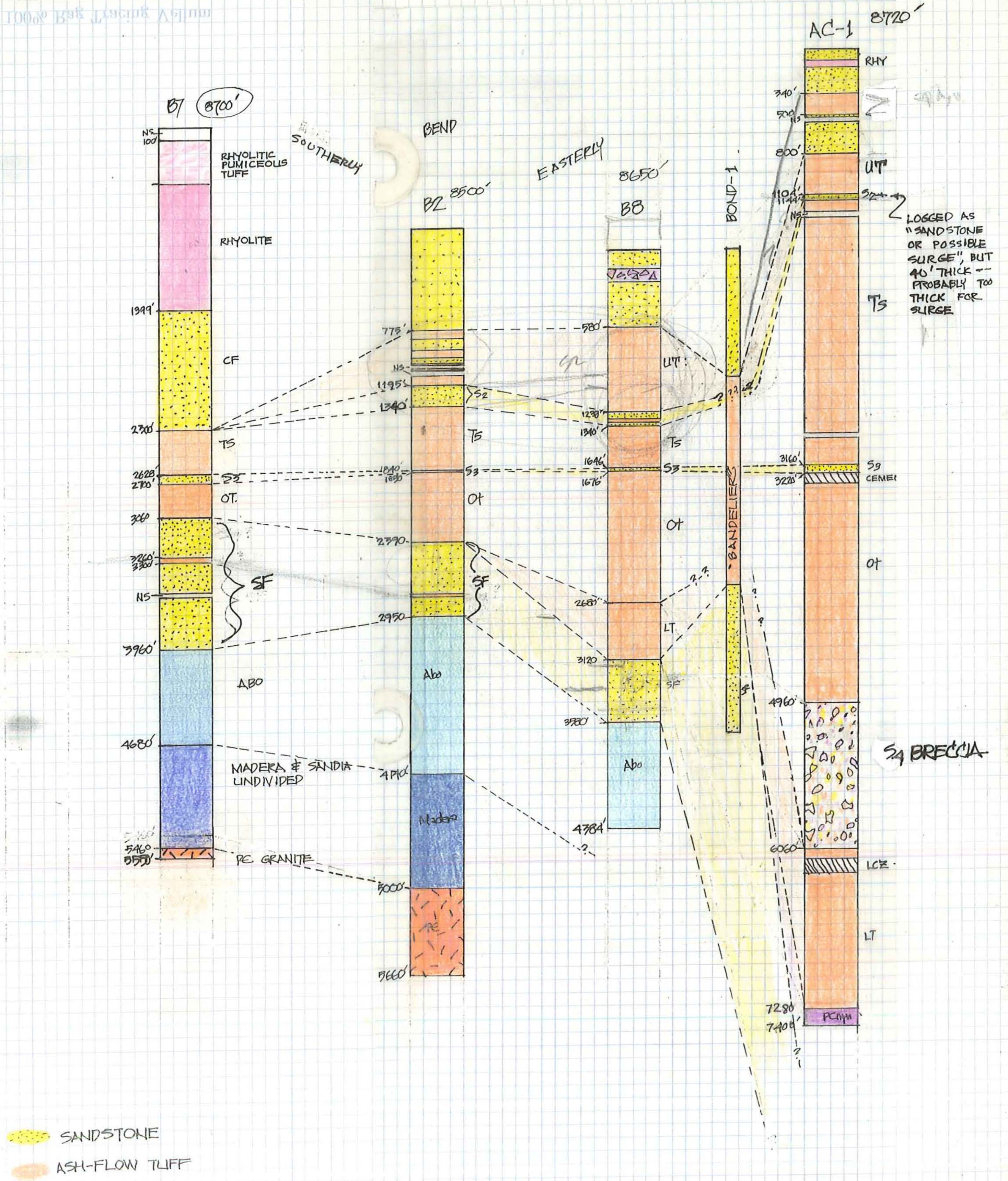
Data are in elevation (in meters) above sea level. UT, Upper Tuffs; S_2, S_2 sandstone; T, Tshirege Member of Bandelier Tuff; S_3, S_3 sandstone; O, Otowi Member of Bandelier Tuff; S_4, S_4 sandstone; LT, Lower Tuffs; PC, Paliza Canyon Formation; SF, Santa Fe sandstone and Abiquiu Tuff, undivided; A, Abo Formation; M, Madera Formation; PG, Precambrian granite and gneiss.

*May include some Lower Tuffs.

†No sample.

109-1300'

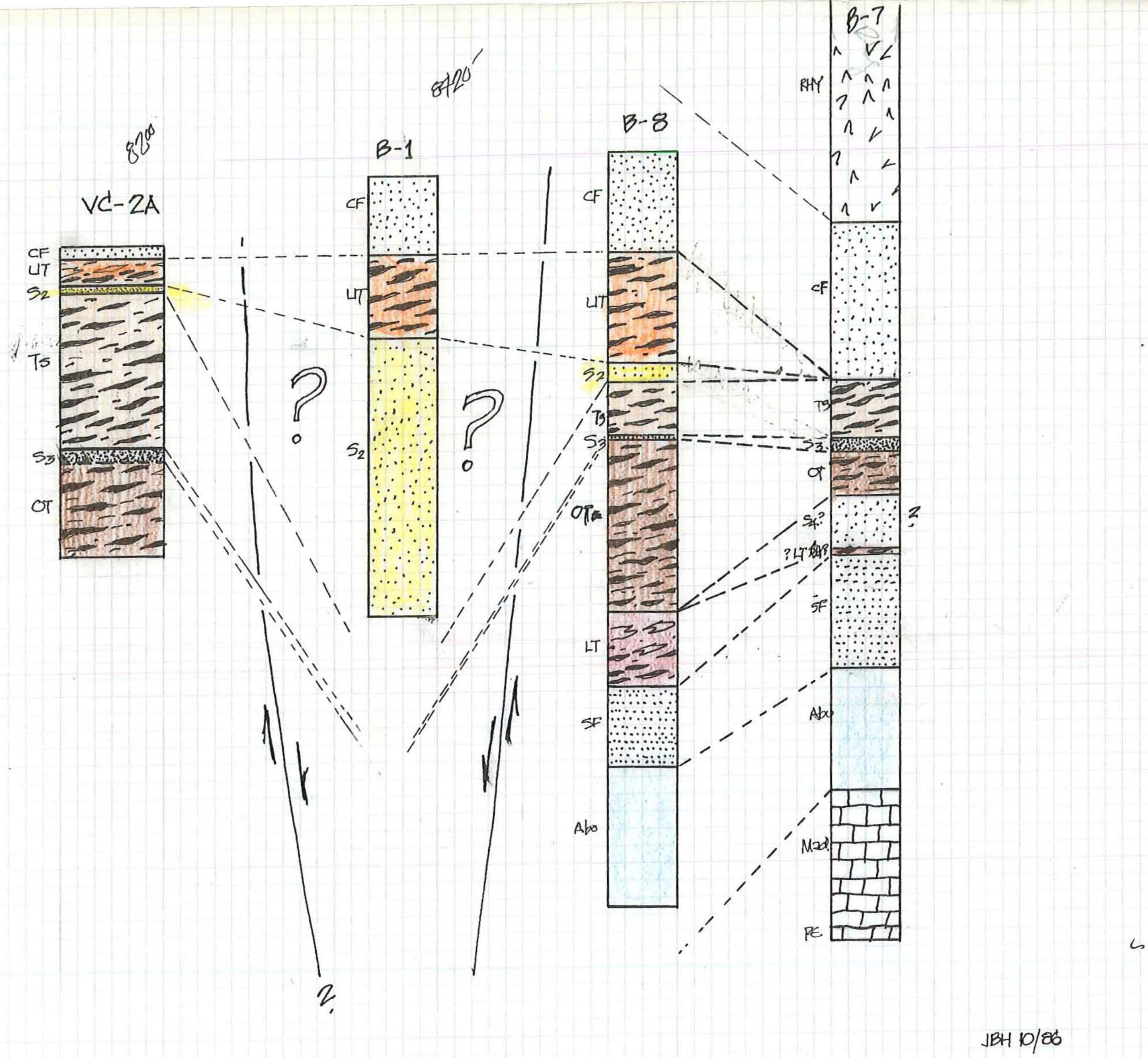
FROM NIELSON & HULEN, 1984



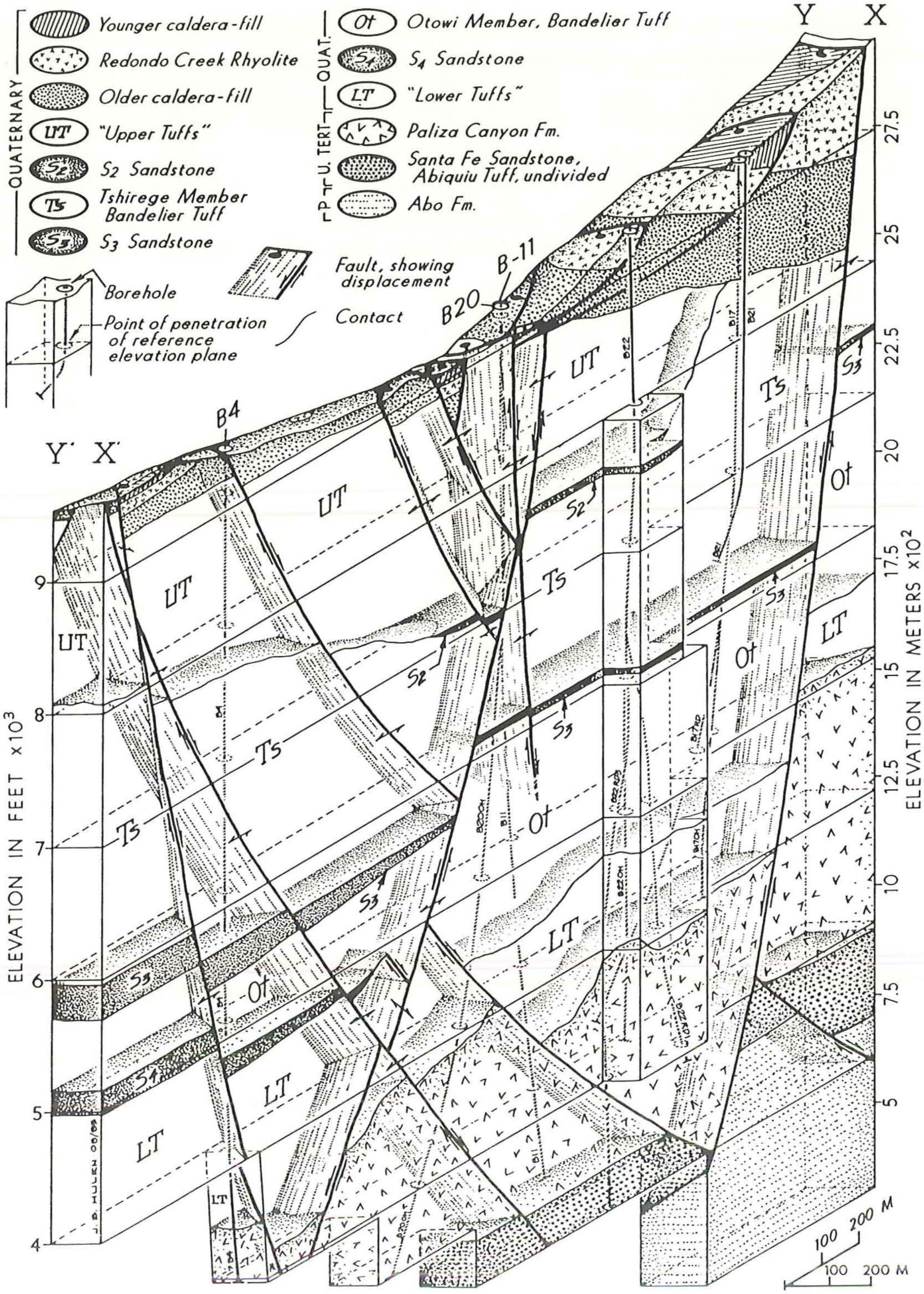
STRATIGRAPHIC CORRELATION
B2, B7, B8 & AC-1

S3 = DATUM

JBH MAY 1986
REVISED FROM
FEBRUARY 1986

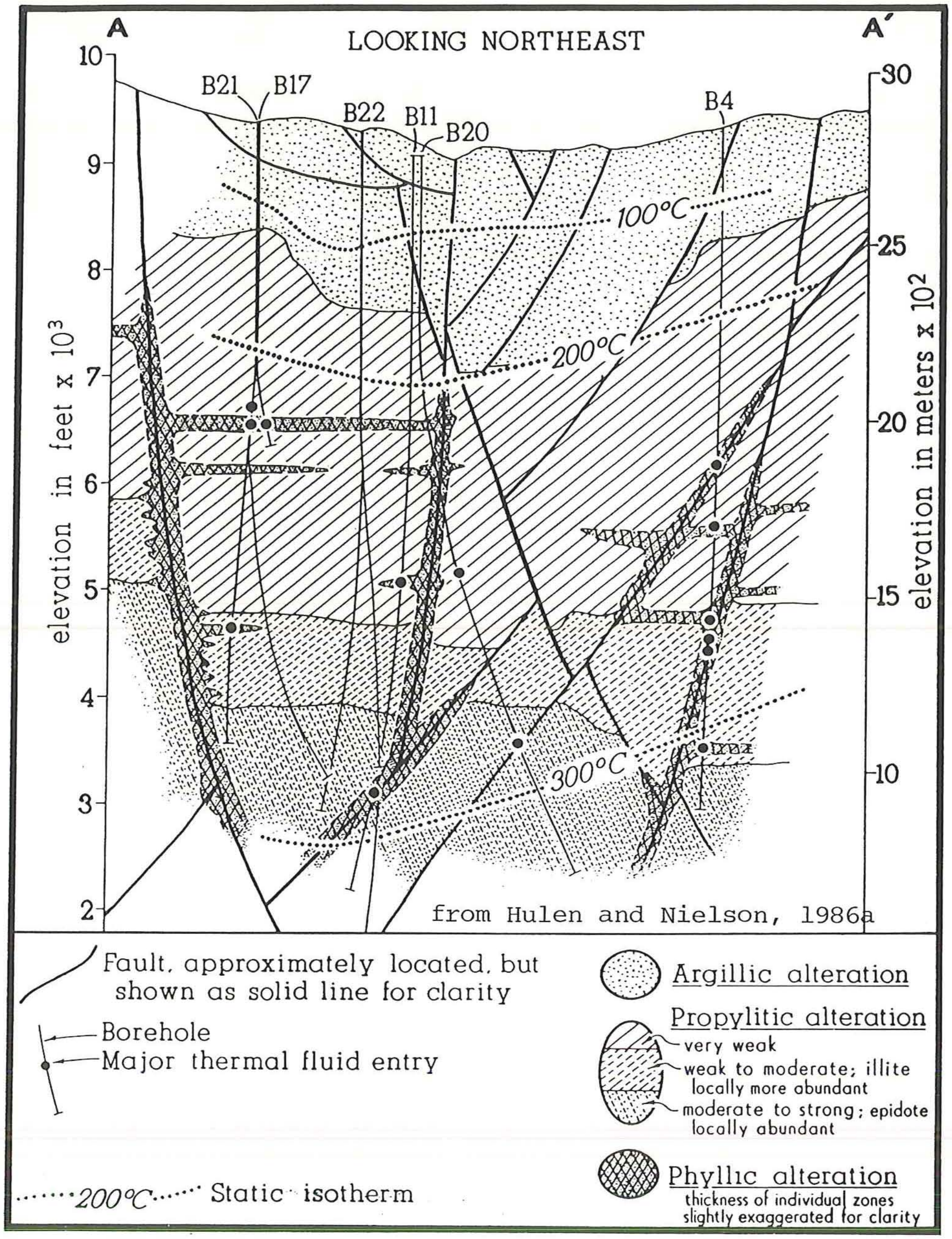


VC-2A: PRELIMINARY STRATIGRAPHIC CORRELATION, SULPHUR SPRINGS AREA.



(Looking Southwest)

Southeast (left) to northwest (right) geologic section through the medial graben of the Valles caldera's resurgent dome, with control provided by UOC geothermal wells. Section shows most of the major stratigraphic units intersected in the explored portion of the caldera as well as major structures.



Generalized northwest-southeast hydrothermal alteration cross-section through the medial graben of the Valles caldera's resurgent dome (Redondo Creek area) with control provided by UOC geothermal wells. Corresponds to geologic cross-section of Figure 5, except viewed from the southwest.

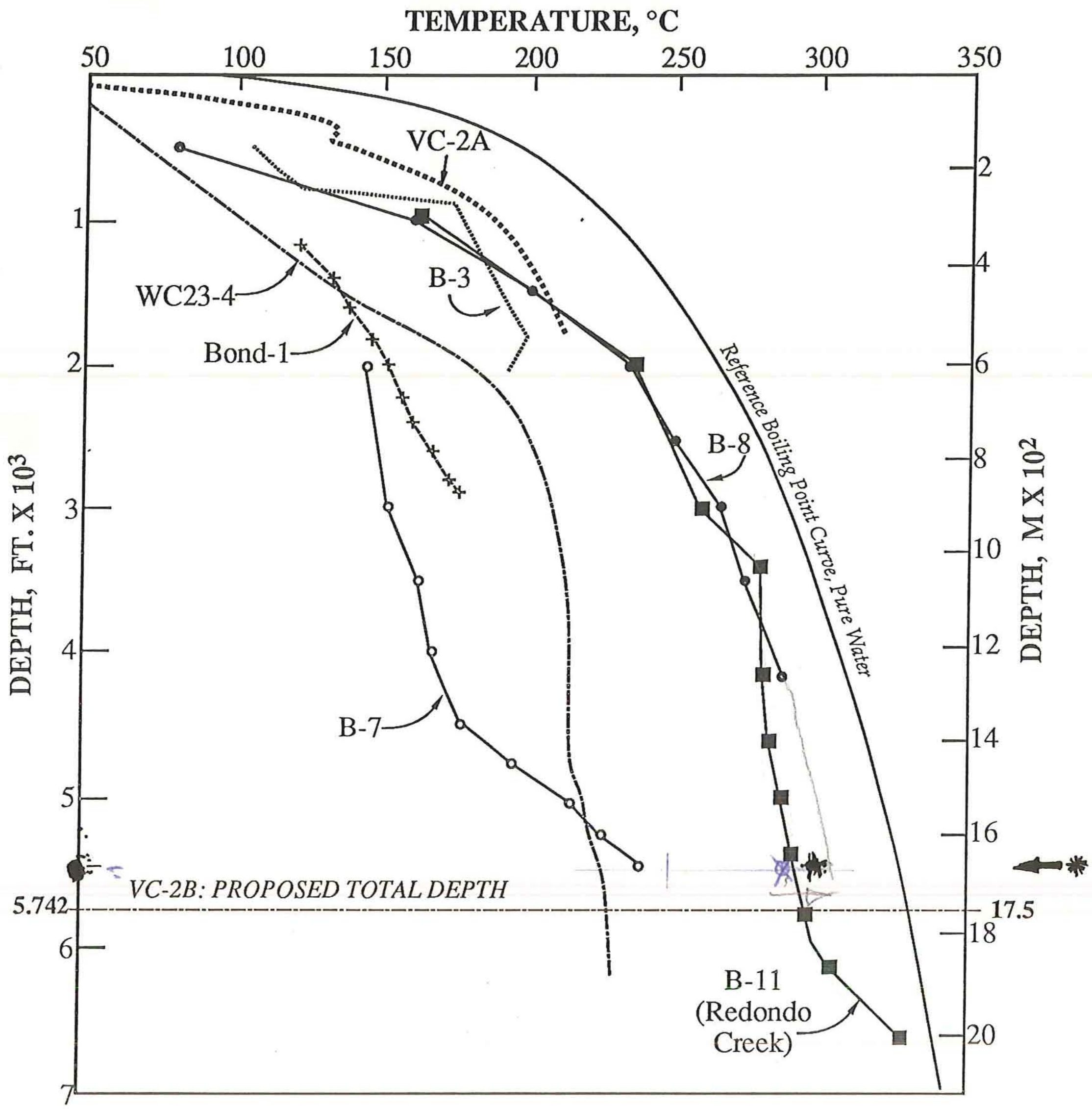


Figure 10: Temperature surveys for geothermal wells and CSDP corehole VC-2A, Sulphur Springs area. Shown for comparison is a temperature survey for well B-11, in the Redondo Creek area. Data from UOC (1982) and Dondanville (1971)(B-1 to B-11, Bond-1); Goff et al. (1987)(VC-2A); Shevenell et al. (1987)(WC-23-4).

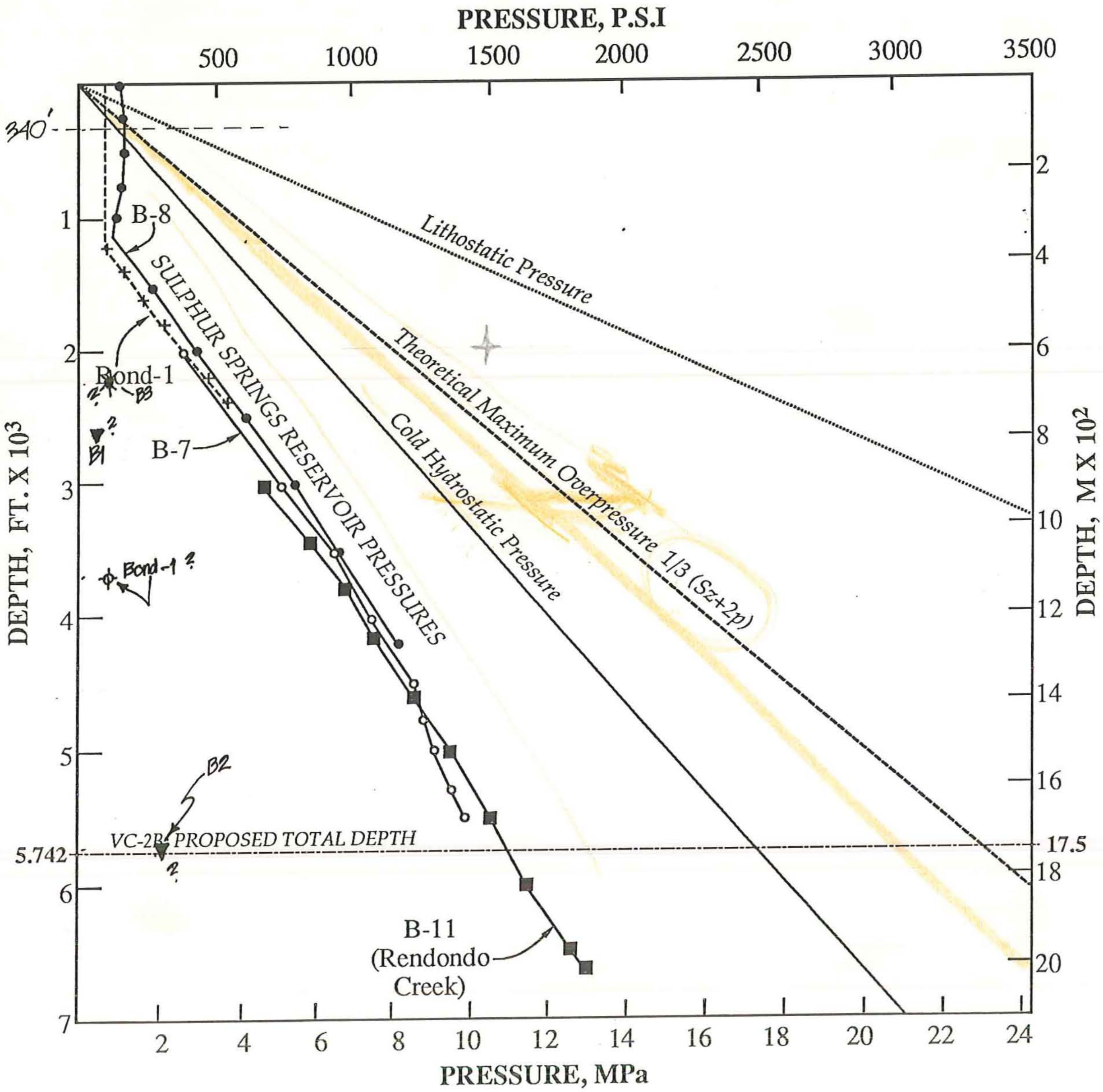
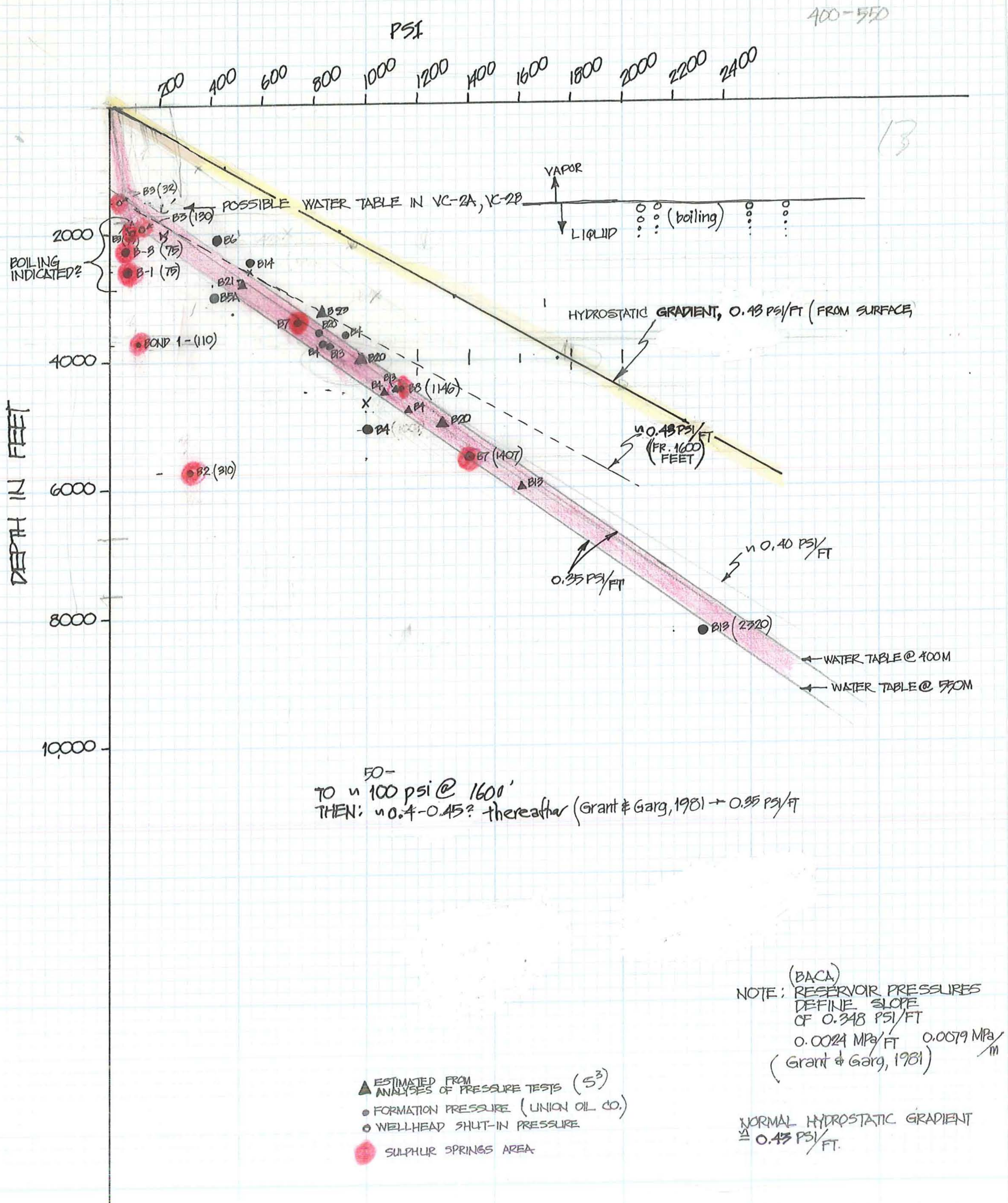


Figure 11. Pressure surveys for various geothermal wells in the Sulphur Springs area and, for comparison, for well B-11 in the Redondo Creek area. Also shown are cold hydrostatic and lithostatic (2.5g/cm) pressure profiles and a profile corresponding to theoretical pressure required for hydraulic rock rupture (from Hubbert and Willis, 1957). Well data from UOC (1982) and Dondanville (1971).



400-550
PSI
200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400
DEPTH IN FEET
2000
4000
6000
8000
10,000
B3 (32)
B3 (130)
POSSIBLE WATER TABLE IN VC-2A, VC-2B
VAPOR
LIQUID
(boiling)
BOILING INDICATED?
B-3 (75)
B-1 (75)
B6
B14
B21
B5A
B20
B7
BOND 1-(110)
B13
B8 (1146)
B4
B7 (1407)
B2 (310)
HYDROSTATIC GRADIENT, 0.43 PSI/FT (FROM SURFACE
~0.43 PSI/FT (FR. 1600 FEET)
~0.40 PSI/FT
0.35 PSI/FT
B13 (2320)
WATER TABLE @ 400M
WATER TABLE @ 550M
TO ~ 100 psi @ 1600' (50-)
THEN: ~0.4-0.45? thereafter (Grant & Garg, 1981 → 0.35 PSI/FT
NOTE: (BACA) RESERVOIR PRESSURES DEFINE SLOPE OF 0.348 PSI/FT
0.0024 MPa/FT 0.0079 MPa/M
(Grant & Garg, 1981)
ESTIMATED FROM ANALYSES OF PRESSURE TESTS (S³)
FORMATION PRESSURE (UNION OIL CO.)
WELLHEAD SHUT-IN PRESSURE
SULPHUR SPRINGS AREA
NORMAL HYDROSTATIC GRADIENT ≅ 0.43 PSI/FT.

GOFF ET AL., 1985

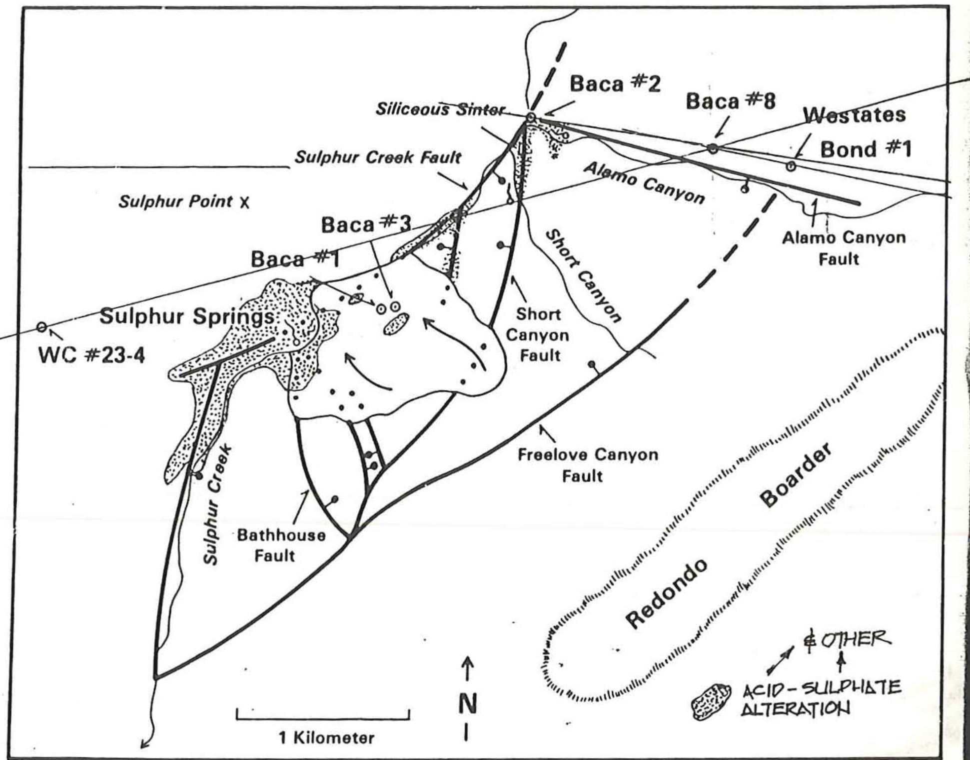
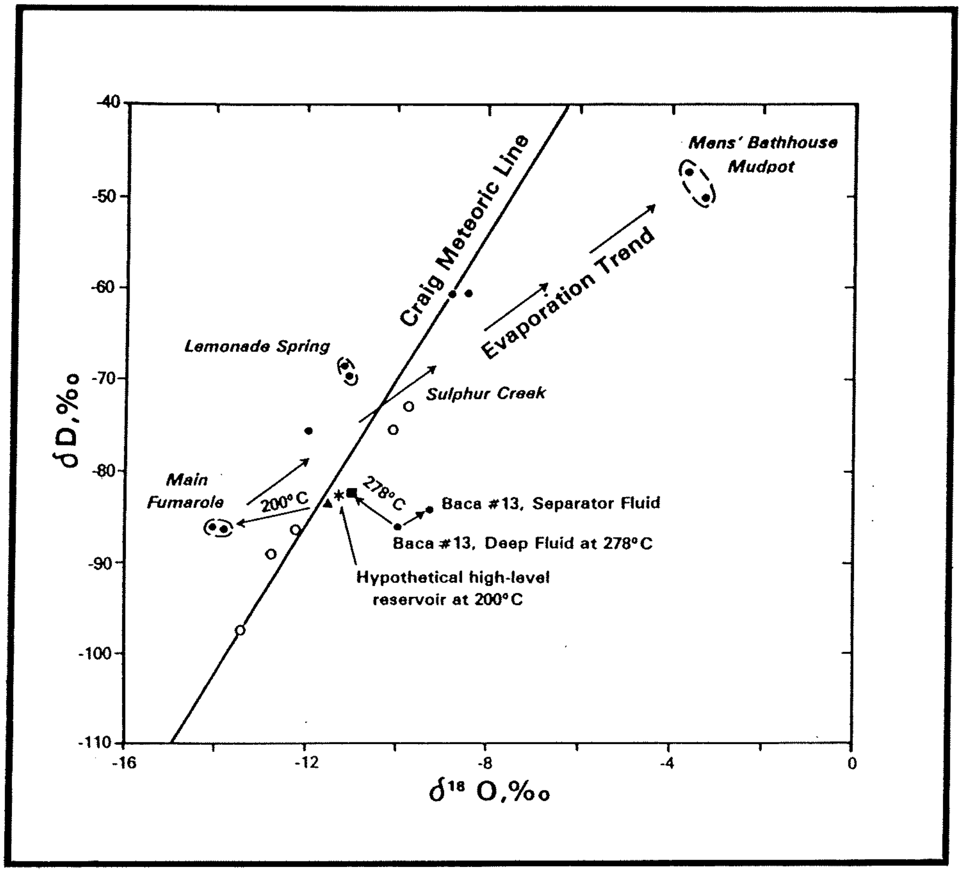


Fig. 2. Fault map of Sulphur Springs area, New Mexico (Goff and Gardner, 1980) showing positions of thermal areas and nearby geothermal wells. Redondo Boarder denotes

(DOWNHOLE PRESSURE IN SHUT-IN WELLS)

PRESSURES, BACA

BOND 1	1130 m / 3707.5′	0.76 MPa / 110 PSI
B1	790 m / 2592.0′	0.52 MPa / 75 PSI
B2	1740 m / 5,708.9′	2.14 MPa / 310 PSI
B3	680 m / 2,231.1′	0.76 MPa / 75 PSI
B7	1687 m / 5,535.1′	9.7 MPa / 1407 PSI
B8	1350 m / 4,429.4′	7.9 MPa / 1146 PSI
B4	1350 m / 5095.4′	6.9 MPa / 1001 PSI
B13	2515 / 8251.7′	~16 / ~ 2320 PSI



Plot of deuterium vs. oxygen-18 from geothermal and surface meteoric waters, Sulphur Springs area. Open circles denote meteoric fluids; dots denote thermal fluids; square represents composition of steam produced by single-stage boiling of reservoir fluid from well B-13 (Fig. 2) at 278°C; triangle represents composition of parent water that produces fumarole steam by single-stage boiling at 200°C; star represents a hypothetical, high-level reservoir at 200°C beneath Sulphur Springs. (From Goff et al., 1985)

NOTES ON DRILLING CHARACTERISTICS OF ROCKS TO BE PENETRATED BY VC-2B

1. High-level volcaniclastic rocks and debris-flow deposits

   B-1: "ash altered to clay", "powdery", "very friable" to 900, but silicified below that depth.

2. Intracaldera ignimbrite sequence (Lower Tuffs, Bandelier Tuff, Upper Tuffs

   These rocks are highly variable in terms of both primary texture and hydrothermal alteration characteristics. Densely welded tuffs are flinty, hard, and if unfractured should provide no real drilling problems. Non- to poorly-welded varieties could be very soft even if unaltered, and might slough or cave into the borehole; these tuffs are also commonly intensely altered, further promoting instability. Volcaniclastic rocks interbedded with these ignimbrites would respond to drilling much like their high-level counterparts.

3. Santa Fe Group sandstones (including the Abiquiu "Tuff")

   General: "wells which have penetrated this unit have had sloughing problems"; caused severe lost circulation problem, "ran into holes"; commonly only very poorly cemented (Union Oil Company log).

   B-8: "Hard, silicified, epidotized' (Union Oil Company, 1982); Silicified, large, coherent, well-cemented chips (Hulen and Nielson, 1986).

   B-10: "Loose sandstone, drilled without returns" (UOC Log).

   B-16: "Unconsolidated to cemented with calcite and/or clay" (UOC log).

4. Abo Formation -- generally red, hematitic shales siltstones and sandstones

   General: Prone to slumping and caving where exposed at the surface in the Jemez Mountains (for example, where the road to Jemez Springs crosses the Abo near La Cueva, it is frequently broken by landslides). However, this is probably due to a fairly high percentage of expandable clay interlayers in mixed-layer illite smectite. In VC-2B, present and past temperatures at the depth range spanned by the Abo should have eliminated these expandable interlayers, and the formation is therefore probably more competent.

B-8: "Large pieces indicate much caving" (UOC log).

B-12: "Some lost circulation" (UOC log)

B-22
RD-3: Dominantly "soft, friable", locally unconsolidated, but variable characteristics (locally dense, firm, well-cemented).

5. Madera Limestone -- mostly massive limestone with minor interbedded calcareous shale, siltstone, and sandstone

General: The Madera apparently drilled with few problems in corehole VC-1 (L. Pisto, personal communication).

B-22-
RD-3: Described as "massive limestone", but cuttings samples are >95% lost circulation material (UOC log; obs. of cuttings samples)

6. Sandia Formation -- mixed clastic and carbonate strata; drilling characteristics probably intermediate between those of the Madera and Abo.

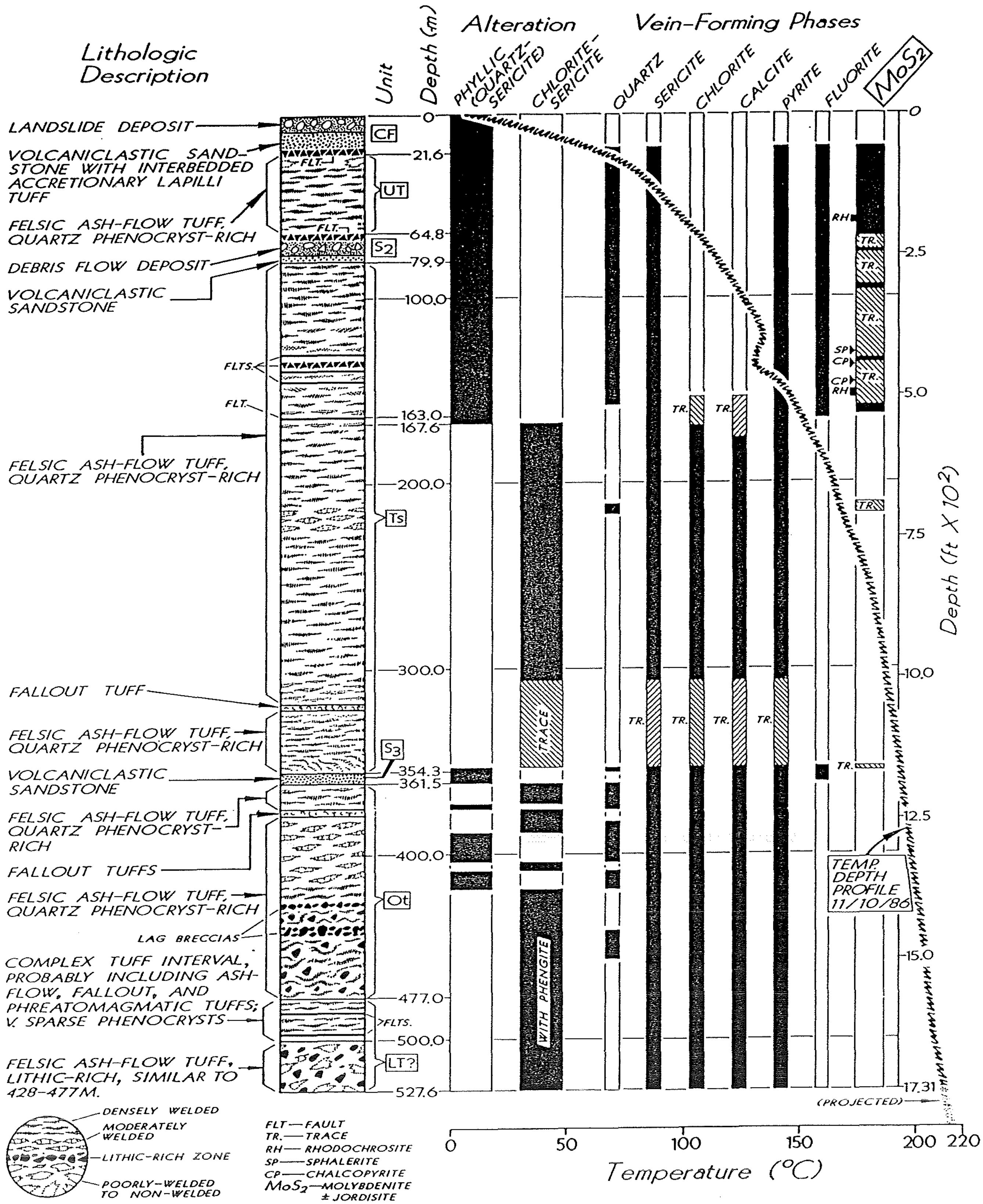


Figure 8. Generalized lithologic, structural, alteration, and vein mineralization log for CSDP corehole VC-2A (modified from Hulen et al., 1987).

APPENDIX A

DETAILED LITHOLOGIC, STRUCTURAL, HYDROTHERMAL ALTERATION AND VEIN MINERALIZATION LOG FOR CSDP COREHOLE VC-2A, SULPHUR SPRINGS AREA, VALLES CALDERA, N. MEXICO

by

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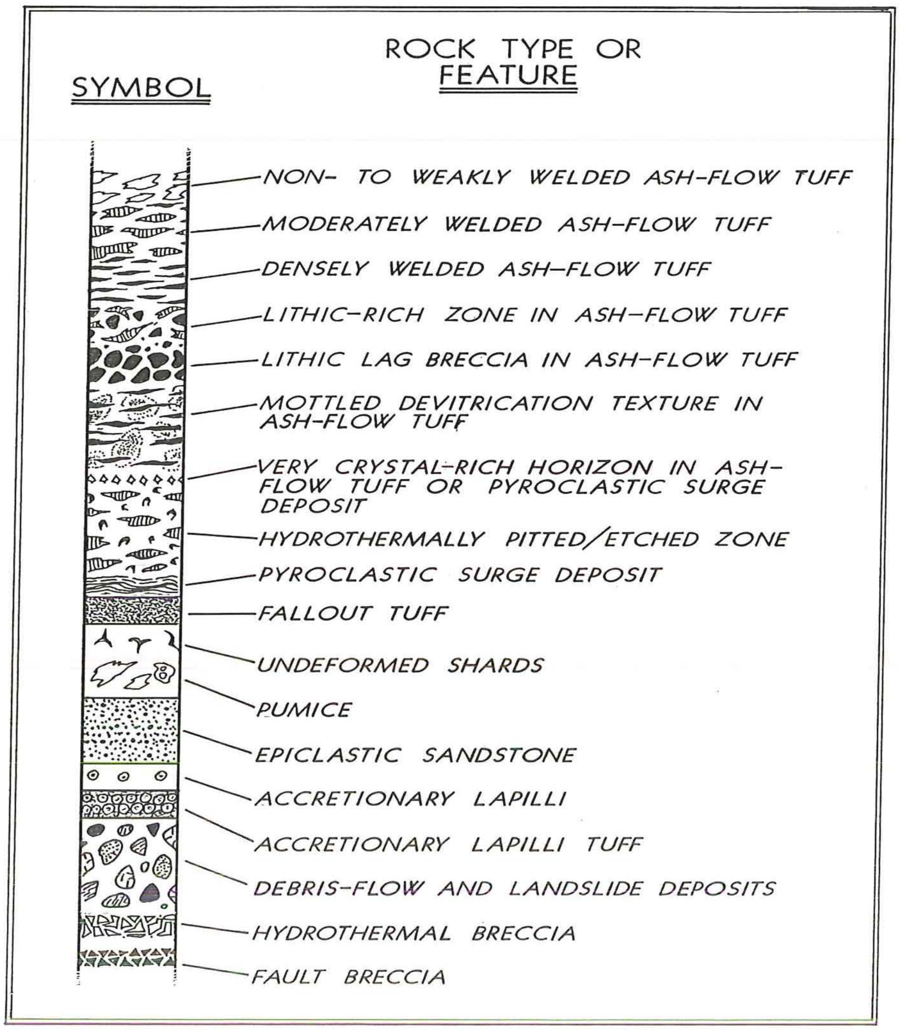

VC-2A: EXPLANATION OF LITHOLOGIC SYMBOLS

SEPT.-OCT. 1986
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FOR U.S. DEPARTMENT OF ENERGY—OFFICE OF BASIC ENERGY SCIENCES
AGREEMENT NO. DE-FG02-86ER13555

CATEGORY	INTENSITY		
	WEAK (W)	MODERATE (M)	STRONG (S)
QUARTZ—SERICITE (PHYLLIC) ALTERATION	ORIGINAL PLAGIOCLASE PARTIALLY SERICITIZED. ORIGINAL K-FELDSPAR ≤10% SERICITIZED. GROUNDMASS <10% ALTERED TO MICROCRYSTALLINE QUARTZ—SERICITE AGGREGATE.	ORIGINAL PLAGIOCLASE >50% SERICITIZED. ORIGINAL K—FELDPAR 10—50% SERICITIZED GROUNDMASS 10—50% ALTERED TO MICROCRYSTALLINE QUARTZ—SERICITE AGGREGATE.	ORIGINAL PLAGIOCLASE COMPLETELY SERICITIZED. ORIGINAL K—FELDSPAR >50% SERICITIZED. GROUNDMASS >50% ALTERED TO MICROCRYSTALLINE QUARTZ—SERICITE AGGREGATE.
SILICIFICATION	GROUNDMASS ≤10% ALTERED TO ESSENTIALLY MONOMINERALIC MICROCRYST. QUARTZ.	GROUNDMASS >10—50% ALTERED TO ESSENTIALLY MONOMINERALIC MICROCRYSTALLINE QTZ.	GROUNDMASS >50% ALTERED TO ESSENTIALLY MONOMINERALIC MICROCRYSTALLINE QTZ.
CHLORITE—SERICITE ALTERATION	ORIGINAL PLAGIOCLASE <10% ALTERED TO SERICITE, MINOR CHLORITE AND PHENGITE. ORIGINAL K—FELDSPAR UNALTERED. ORIGINAL MAFICS ALTERED TO CHLORITE ± CALCITE, PHENGITE, LEUCOXENE. GROUNDMASS < 10% ALTERED TO MICROCRYSTALLINE AGGREGATE OF SERICITE WITH CHLORITE, PHENGITE, CALCITE, AND (BELOW 420M) ALBITE.	SAME AS WEAK COUNTERPART EXCEPT PLAGIOCLASE 10—50% ALTERED, GROUNDMASS 10—50% ALTERED, ORIGINAL K—FELDSPAR FRESH OR <10% SERICITIZED.	SAME AS WEAK COUNTERPART EXCEPT PLAGIOCLASE >50% ALTERED, GROUNDMASS >50% ALTERED, ORIGINAL K FELDSPAR <20% SERICITIZED.
CALCITE AFTER PLAGIOCLASE	≤10% OF ORIGINAL PLAGIOCLASE ALTERED TO CALCITE.	10—50% OF ORIGINAL PLAGIOCLASE ALTERED TO CALCITE.	>50% OF ORIGINAL PLAGIOCLASE ALTERED TO CALCITE.
DISSEMINATED PYRITE	≤1%	1—5%	>5%
FRACTURING	≤10 FRACTURES/M	10—30 FRACTURES/M	>30 FRACTURES/M
VEINING AND VUG—FILLING	≤10 VEINLETS/M ± ≤1% (VOL.) VUG—FILLING* PHASES	10—30 VEINLETS/M ± 1—5% VUG—FILLING* PHASES.	>30 VEINLETS/M ± >5% VUG—FILLING* PHASES

* HYDROTHERMAL

VC—2A: EXPLANATION OF ALTERATION, FRACTURING, AND VEINLET INTENSITY LOGS.

VG-2A: ABBREVIATIONS

AB--albite
ACCR--accretionary
ACC--accessory
AF--ash-flow
AGG--aggregate
ALT--altered
ALTN--alteration
AND--andesite
ANH--anhedral
APP--apparently
AVG--average
BX--breccia(s)
CAL--calcite
CALC--calcite
CH--chlorite
CHL--chlorite
CHLTZD--chloritized
CM--centimeter(s)
COMP FOL--compaction foliation
CPY--chalcopyrite
CRS--coarse
DEF--definitely
DIA--diameter
DISS--disseminated
DK--dark
DW--densely welded
E G.--for example
ESP--especially
EUH--euhedral
EXC--except
F--fine
FL--fluorite
FLUOR--fluorite
FLD--fluid
FM--formation
FSP--feldspar
GEN--generally
GR--grained
HYD--hydrothermal
HYDROVOLC--hydrovolcanic
IL--illite
INC--inclusion(s)
INTM--intermediate
IRREG--irregular
K--potassium
KF--potassium feldspar
KFSP--potassium feldspar
LAP--lapilli
LEUC--leucoxene
LIMEST--limestone
LST--least
LT--light
M--meter(s)
MED--medium
MICROXLN--microcrystalline
MM--millimeter(s)
MO--molybdenite
MOLYBD--molybdenite
MoS_2--molybdenite
MOD--moderate
PH--phengite
PHENG--phengite
PL--plagioclase
PLAG--plagioclase
POSS--possible,possibly
PPY--porphyry
PPYTIC--porphyritic
PR--primary
PY--pyrite
Q--quartz
QTZ--quartz
REL--relatively
RH--rhodochrosite
RHODOCHR--rhodochrosite
RHY--rhyolite
SEC--section
SEQ--sequence
SER--sericite
SL--slightly
SLTST--siltstone
SP--sphalerite
SPH--sphalerite
SPHALER--sphalerite
SS--sandstone
SUBH--subhedral
TRANSL--translucent
TR--trace
V--very
VAP--vapor
VNLT--veinlet
W/--with
WO/--without
WT--weight
XL--crystal
XLINE--crystalline
XLN--crystalline

SYMBOLS

& --and
~ --about
∡ --angular
$>$ --greater than
$<$ --less than
$\pm$ --with or without
$\perp$ --perpendicular

VC-2A: DEFINITIONS

Illite--White or nearly white, clay-grade, essentially non-expandable potassium mica-like mineral similar to muscovite but with less potassium, more silica, and more bound water; may contain up to 5% interstratified smectite, an amount not readily detectable by routine X-ray diffraction.

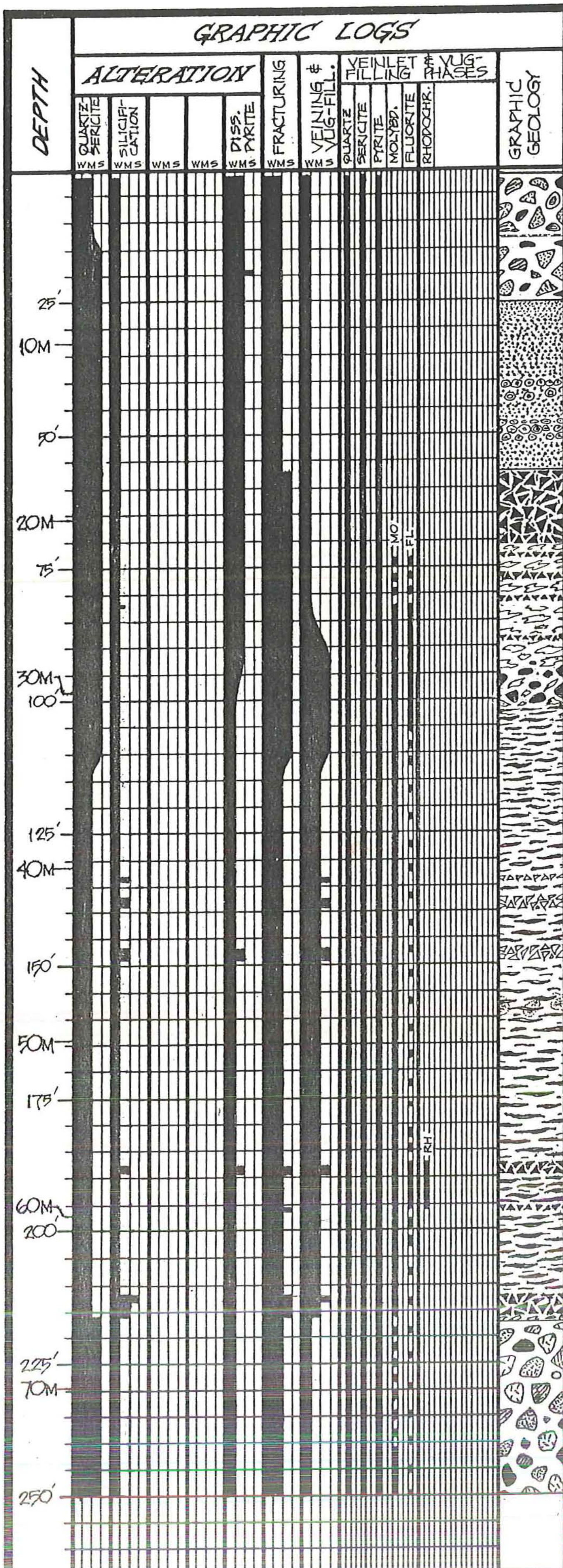
Phengite--Brown to (characteristically) vivid gray-green, iron-rich illite analogue

Sericite--A general term encompassing both illite and illite-rich, mixed-layer illite/smectite

Smectite--Fully expandable, mica-like sheet silicate with charge deficiency of 0.2-0.6 per formula unit balanced by various interlayer cations (typically calcium and sodium) which readily adsorb water or polar organic molecules (such as ethylene glycol) to produce the characteristic expansion; commonly interstratified with illite to form partially expandable mixed-layer clay.

Leucoxene--White to light grayish-yellow, microcrystalline aggregate of sphene and anatase in various proportions with or without minor rutile.

GRAPHIC LOGS



NOTES, COMMENTS

- 0.61M (2')
- CLAY-RICH (GOUGE?)
- 7.92M (26')
- APP. DIP 10-15°
- ACCRETION. LAPILLI TUFF
- 17.37M (57')
- 21.64M (71'), 22.19M (72.8')
- FLT.
- 24.9M (81.7')
- FLT.
- 28.2M (92.5')
- 31.1M (102')
- APP. DIP 15°
- HYD. BX
- HYD. BX
- 42.7M (140')
- 45M (147.5')
- HYD. BX.
- 47.7M (156.5 FT)
- 57.2M (187.8')
- FLT. BX
- APP. DIP 10°
- 63.5M (208.5')
- 64.8M (212.6')
- 65.8M (216')
- 66.1M (217')
- 68.6M (225 FT.)
- 76.2M (250')

DESCRIPTIONS

0-0.61 M: NO CORE

0.61-7.92M: LANDSLIDE BRECCIA, SOFT, PUNKY, POROUS, LT. GRAY TO WHITE; HETEROLITHOLOGIC CLASTS, SUBANGULAR TO ANGULAR, UP TO 20 CM. DIA., COMPRISING MED.-GR. ARKOSE & EPICLASTIC SS, FLOW-BANDED RHYOLITE, RHY. ASH-FLOW TUFF, FINE-MED.-XLN. LIMESTONE; SEVERAL LIMEST. & SS. CLASTS HAVE PY-RICH CORES & SURROUNDING PYRITIC BANDS; MATRIX IS CLAYEY SILT, SAND & GRIT, PROBABLY TUFFACEOUS, NOW EXTENSIVELY ALTERED TO QUARTZ - SERICITE ± PYRITE AGGREGATE; CLAY (SERICITE) SEAM FROM 4.12-4.27 M (POSSIBLE GOUGE ZONE)

7.92-17.37 M: EPICLASTIC SEDIMENTS, SOFT, PUNKY, LT. GRAY TO WHITE; DISTINCTLY BEDDED (APPARENT DIP 10-15°); ALTERNATING COARSE & FINE-MED. SAND; GRIT BEDS (COARSE SAND) ARE UP TO 5 CM. THICK, FINER-GR. SS BEDS GEN. < 15 MM THICK; GRIT BEDS LOCALLY CONTAIN LARGER (UP TO 25 MM) ANGULAR FRAGMENTS; CLASTS CONSIST OF QTZ, FSP, & ABUNDANT LITHICS (FELSIC VOLCANICS MOSTLY); ACCRETIONARY LAPILLI PRESENT -- THESE BECOME CONSPICUOUS AT 12.8 M. ACCRETIONARY LAPILLI TUFF 14.63-15.39 M. MIXED ACCR. LAP. TUFF & CRS. SS 15.39-15.85 M. V. STRONG PHYLLIC (QUARTZ-SER.-PYRITE) ALTERATION THROUGHOUT THIS UNIT -- V. SIMILAR TO 0.61-7.92 M. FELDSPARS BOTH PARTIALLY TO COMPLETELY DISSOLVED, ALTERED TO F. XLN. SERICITE.

17.37-21.64 M FAULT BRECCIA; ANGULAR CLASTS UP TO AT LEAST 10 CM. DIA., MOSTLY WELDED ASH-FLOW TUFF; ALTN. AS ABOVE EXCEPT QTZ, SER. & PYRITE START TO APPEAR IN VEINLETS & VUGS.

21.64-22.19 M: NON-WELDED ASH-FLOW TUFF; ALTN. AS ABOVE

22.19-24.9 M: ALTERNATING ZONES OF FAULT BRECCIA & NON-POORLY WELDED ASH-FLOW TUFF; ALTN. AS ABOVE.

24.9-28.2 M: HIGHLY FRACTURED, INTENSELY ALTERED, NON- TO POORLY-WELDED ASH-FLOW TUFF; TR. FLUORITE & QTZ IN VUGS. SOOTY MoS_2 "PAINT" APPEARS.

28.2-31.1 M: LITHIC-RICH, NON-POORLY WELDED ASH-FLOW TUFF; POSS. LAG BRECCIA; QTZ-SER., SILICIFD., W/ QTZ, SER., FL., & SOOTY GRAY MOLYBDENITE IN VEINS & VUGS; MINERALIZATION IS DISTINCTLY EPITHERMAL IN CHARACTER.

31.1-64.8 M: DENSELY WELDED, XL-RICH, RHYOLITE ASH-FLOW TUFF, FRACTURED, QTZ-SERICITIZED, MINERALIZED W/ MoS_2; PHENOCRYSTS ARE QTZ & K-FELDSPAR, THE LATTER COMMONLY PARTIALLY DISSOLVED, PARTIALLY ALTERED TO FINE-XLN. SERICITE; ROCK IS LOCALLY DISRUPTED BY HYDROTHERMAL BRECCIA, MATRIX OF WHICH IS SILICIFIED & SELECTIVELY ENRICHED IN MoS_2; QTZ VNLTS W/O PY LOCALLY PRESENT & POST-DATE QTZ-SER. ALTN.; DISSOLVED VUGS IN K-FELDSPAR PHENOCRYSTS COMMONLY LINED WITH EUHEDRAL QUARTZ CRYSTALS. SERICITE REPLACES BOTH PUMICE & FSP. AS WELL AS MATRIX & OCCURS AS VEINLETS.

39.3-39.5 M, 41.9-42.7 M, 45-45.6 M } SILICIFIED, QTZ-SER, HYDROTHERMAL BX. ENRICHED IN MoS_2.

(BX AT 45 M. COULD ALSO BE LAG BX)

- XRD, 47.7M (%): Q-63, KF-19, PY-2, IL-15

48.2-49.1 M BLOTCHY DEVITRIFICATION TEXTURE APPARENT EVEN THROUGH ALTERATION OVERPRINT

50.9 M: FINE-XLN PYRITE COATING EUH. QTZ. XL. IN VEINLET.

57.2-57.6 M: MoS_2-RICH, SILICFD., SER. BX W/ ABUNDANT, LATE-STAGE FLUORITE. ALSO LOCAL, DELICATE LIGHT PINK RHODOCHROSITE ROSETTES & IRREGULAR AGGREGATES -- BETWEEN 57.2M & 59.7 M.

- XRD, 63.5M (%) Q-53, KF-24, PY-3, IL-19

64.8-65.8 M ALTERED FAULT BRECCIA

65.8-66.1': ALTERED, PUMICE-RICH TUFF, POSS. SOME ACCRETIONARY LAPILLI. THIS MAY BE A CLAST IN THE UNDERLYING DEBRIS FLOW.

66.1-76.2 M: DEBRIS FLOW, POROUS, PUNKY, INTENSELY QUARTZ-SERICITIZED (MOST ORIGINAL FELDSPAR EITHER DISSOLVED OR ALTERED TO SERICITE); ROCK CONSISTS OF > 50% CLASTS, UP TO 0.6 M (AVG. ~ 2 CM.) DIA., COMPRISING BLEACHED, REDDISH SANDSTONE (ABO FM.), PORPHYRITIC ANDESITE, PORPHYRITIC RHYOLITE (W/ & W/O BIOTITE), WELDED ASH-FLOW TUFF & MINOR GRANITE EMBEDDED IN A SILTY TO SANDY, ALTERED TUFFACEOUS MATRIX; SOME CLASTS SELECTIVELY PYRITIZED.

- XRD, 68.6M (%): Q-53, PY-2, ANATASE-2, ILLITE-44

DRILL HOLE VC-2A

LOCATION VALLES CALDERA, N. MEXICO

LOGGED BY J.B. HULEN AND J.N. GARDNER

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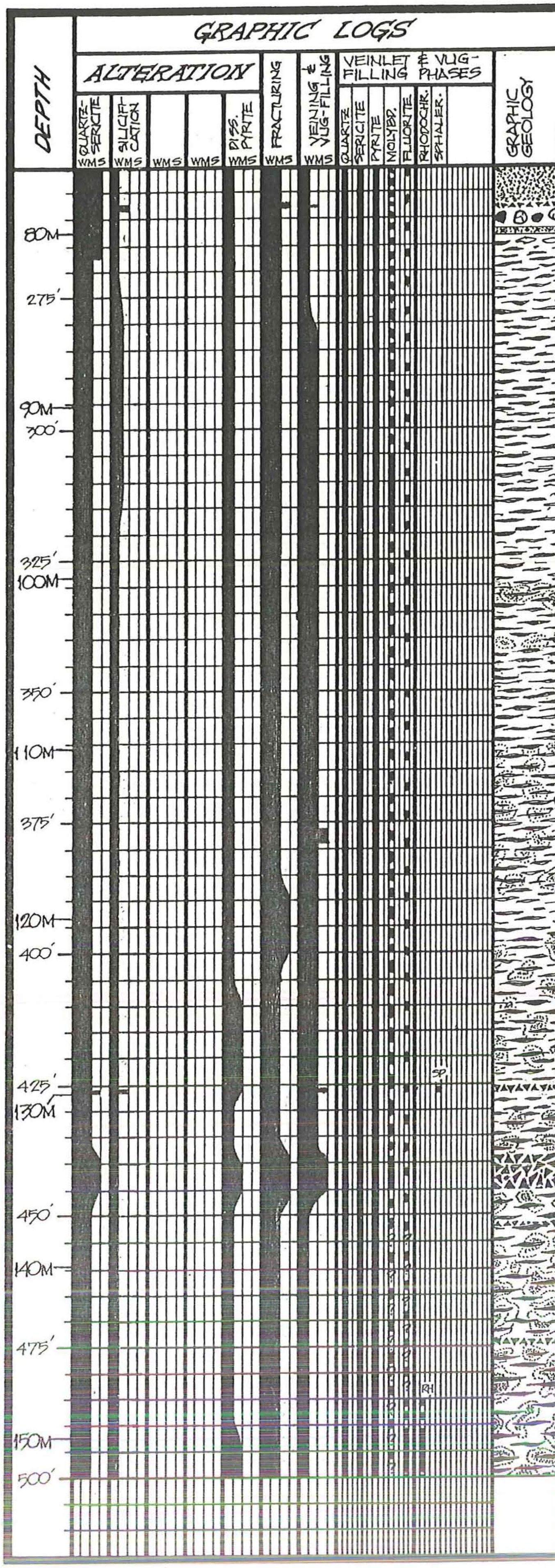
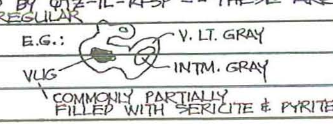


NOTES COMMENTS	DESCRIPTIONS
76.2M (250')	76.2-78.6M MASSIVE, FINE-MED. GR. EPICLASTIC SS., BLEACHED, PUNKY, INTENSELY QTZ-SERICITIZED
78.6M (258')	78.6-79.8M: DEBRIS FLOW, SAME AS 66.1-76.2M.
79.8M (262') 80.2M (263.2')	79.8-80.2M: EPICLASTIC SANDSTONE, AS ABOVE; CONTACT W/TUFF AT BASE - DIP 45°
	80.2-80.7M: MOD-WELDED, XL-RICH RHY. ASH-FLOW TUFF
• DIP ~ 45° (COMP. FOL.)	80.7-215.5 M: DENSELY WELDED, CRYSTAL-RICH RHYOLITE ASH-FLOW TUFF, VARIABLY ALTERED, FRACTURED & MINERALIZED, BUT IN GENERAL LT.-MED. GRAY & SOMEWHAT FLINTY-APPEARING; AVG. 30-35% PHENOCRYSTS-- QUART & K-FELDSPAR (POSS. ORIGINALLY MICROPERTHITE NOW WITH ALBITE ALTERED TO SER.; AVG. 5-7% LITHIC FRAGMENTS -- MOSTLY PORPHYRITIC INTERMEDIATE VOLCANIC ROCK; MINOR COLLAPSED PUMICE COMMONLY VUGGY & ALTERED TO SERICITE. ROCK IS CUT BY NUMEROUS QTZ ± SER ± PY VNLTS -- THESE SAME THREE MINERALS ALSO OCCUR SINGLY & IN VARIOUS COMBINATIONS AS VUG LINING/FILLING PHASES. DEPARTURES FROM THESE GENERALITIES NOTED BELOW. GROUNDMASS ORIGINALLY QTZ, ORTHOCLASE, ALBITE -- LATTER NOW COMPLETELY SERICITIZED (THIS ACCOUNTS FOR THE TEXTURAL CONTRAST W/ ROCK ABOVE 81.4M; NOTE, THEN, ALBITE & KSPAR ARE EARLY
	95.4-96M: VEIN UP TO 1 CM WIDE (QTZ-SER.) ALSO VUGS UP TO 15X10X5 MM
100.5M (330') 101.6M (333.3')	• XRD, 101.6M (%): Q-59, KF-23, PY-2, IL-15
	100.5-101.8 M: ROCK TAKES ON MOTTLED APPEARANCE (DEVITRIFICATION TEXTURES)
103.6M (340')	103.6-105M: AS ABOVE
	105-105.5 M: POWDERY GOUGE ZONE, DIP ~ 80°
109.7M (360')	
	• XRD, 112.3M (%): Q-54, KF-29, PY-5, IL-10, GYPSUM-1
• DIP ~ 42° (COMP. FOL.)	113.4-114M: SPARSE, IRREGULAR VUGS, BUT THESE
112.3M (368.3')	ARE UP TO 30X12 MM -- LINED W/QUARTZ, THEN PYRITE, THEN PARTIALLY INFILLED WITH ILLITE.
	109.7-118.3M: MOTTLED, DEVITRIFIED DENSELY WELDED ASH-FLOW TUFF, AS ABOVE
118.3M (388')	118.3-121.6M: >100 FRACTURES/METER
121.6M (399')	123.1-129.6 M: IRREGULAR, ILLITE-LINED VUGS UP TO 50X15 MM -- W/QTZ & PYRITE; ILLITE ALSO MASSIVELY REPLACES SCATTERED FIAMME.
	129.6-129.9 M: POWDERY, DARK GRAY, FINELY GROUND FAULT BRECCIA W/HONEY-COLORED, LATE-STAGE SPHALERITE CRYSTALS.
SPHALERITE	
129.6M (425.3') MIN. FLT. BX	• XRD, 129.6M (%): Q-47, PY-4, IL-46, SPHAL-2
133.8M (439')	133.8-135.6 M: FAULT BRECCIA, RUBBLE STAINED
MINERALIZED FAULT BX	& COATED SOOTY DARK GRAY W/ MICROCRYSTALLINE PYRITE, MOLYBDENITE.
135.6M (445')	
FLT (137.8M 452')	135.6-150.6': BELOW THE ABOVE-MENTIONED RUBBLE ZONE, THE BLOTCHY DEVITRIFICATION TEXTURE IS ESPECIALLY PROMINENT, W/ LARGE (UP TO 5 CM. DIA.) "EYES" CORED W/ILLITE/PYRITE, MANTLED BY QTZ-IL-KFSP -- THESE ARE VERY IRREGULAR
• DIP ~ 43° (COMP. FOL.)	E.G.: 
FAULT	
149.8M (491.5')	147.4 M: 2.5X1.5MM. CPY BLEB IN GRANOPHYRIC MATRIX OF DENSELY WELDED ASH-FLOW TUFF
RHODOCHR.	149.8-152.1 M: MINOR RHODOCHROSITE, SAME TEXTURE AS 57.2-59.7 M.
152.4M	

DRILL HOLE VC-2A
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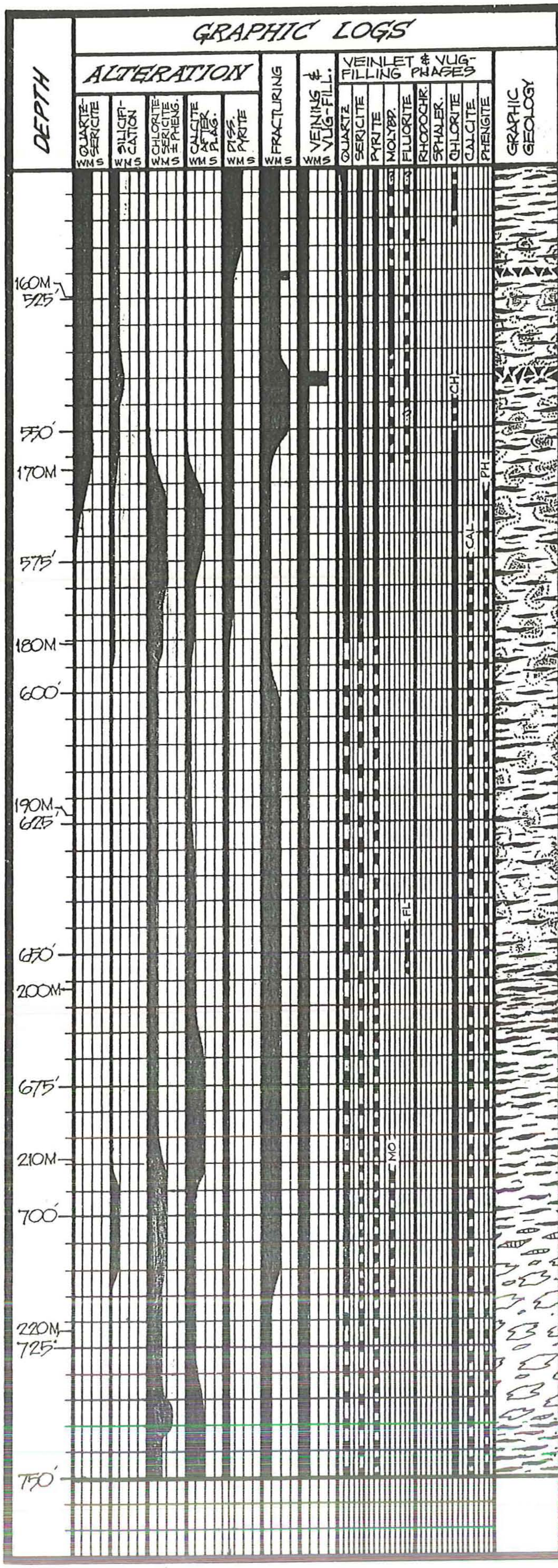

NOTES COMMENTS	DESCRIPTIONS
	DENSELY WELDED, XL-RICH RHY. ASH-FLOW TUFF CONTINUES
	● XRD, 156.8M (%): Q-55, KF-22, PY-4, IL-18
RHODOCHR. 156.7M (514')	156.7M → RHODOCHROSITE, AS ABOVE
158.5M (520')	158.5-159.1 M: RUBBLIZED FAULT ZONE W/ SOOTY MoS_2
● DIP ~45° (COMP. FOL.)	
	BLOTCHY DEVITRIFICATION TEXTURE STILL PROMINENT (SEE PRECEDING PAGE)
164M (538.2')	● XRD, 164M (%): Q-54, KF-28, PY-2, IL-15
164.3M (539')	164.3-165.1 M: FAULT ZONE: CONTAINS TRANSL. APPLE GREEN FLUOR.-- ONE OCTAHEDRON 15 18 mm. DIA.
LARGE GREEN FLUOR. XLS.	
167.8M (550.6') (CHL. APPEARS)	167.8M: CHLORITE APPEARS AS A VEIN-FORMING MINERAL (POSS. TRACES FOR A FEW M ABOVE).
● DIP 30-40° (COMP. FOL.)	(VISIBLE IN HAND-SPECIMEN)
	IRREGULAR SERICITE CLOTS UP TO AT LEAST 90X40 MM IN X-SECTION; ALSO BLOTCHY DEVITRIFICATION TEXTURE AS ABOVE.
(VEINLET) CALCITE APPEARS 175.6M (576.1')	175.6M: CALCITE APPEARS IN VEINLETS; SOME CAL. APPARENTLY POST-DATES CHL
177.5M (582.4 FT)	FIAMME HERE & BELOW ARE WHITE TO LIGHT GRAY GREEN DUE TO ALTN. TO CHLORITE & SERICITE.
	● XRD, 177.5M (%): Q-53, PL-8, KF-14, CAL-3, PY-1, IL-16, CH-5
	BLOTCHY, MOTTLED DEVITRIFICATION TEXTURE BECOMING LESS CONSPICUOUS.
● DIP 35-40° (COMP. FOL.)	
	● XRD, 198.1M (%): Q-42, PL-23, KF-12, PY-1, IL-10, CH-4
198.1M (650 FT)	MOTTLED DEVITRIFICATION TEXTURE DIES OUT
198.5 M (651.3') (FL)	198.5 M: QTZ-CAL-CHL-SER-FLUORITE VEIN
● DIP 37° (COMP. FOL.)	
	● XRD, 209.6M (%): Q-46, PL-2, KF-26, CAL-3, PY-2, IL-10, CH-5
209.6M (687.6 FT)	211.6-215.8 M: SERICITIZATION STRONGLY INCREASES.
211.6M (694.2')	
212.4M (697') QTZ-AB	212.4 M: 2MM WIDE QTZ-AB-CHL-SER. VEINLET AB IN DISTINCTIVE FAN-LIKE SHEAVES
	AB IN MICROPERTHITE LOCALLY REPLACED W/ CHL
216.2M (709.4')	
	216.2-225.8M: NON-WELDED TO POORLY WELDED RHYOLITE ASH-FLOW TUFF, LT. GREENISH-GRAY TO WHITE, BLEACHED-APPEARING, LOCALLY POROUS; ~7% QTZ. PHENOS., 10-12% FELDSPAR PHENOS, 15% (?) PUMICE, LARGELY UNCOLLAPSED. AB LOCALLY REPL. W/ CHL. ROSETTES; WIDELY-SCATTERED CHL ± SER ± QTZ ± CAL ± PY MICROVEINLETS; FIAMME SERICITIZED ± CHL. ± CAL.
225.6M (740.1 FT)	
225.8M (740.9')	● XRD, 225.6M (%): Q-35, PL-3, KF-28, CAL-4, PY-1, IL-17, CH-11
● DIP ~40° (COMP. FOL.)	225.8-~237.7M: DENSELY WELDED, XL. RICH, RHY. ASH-FLOW TUFF (SEE FOLLOWING PAGE)

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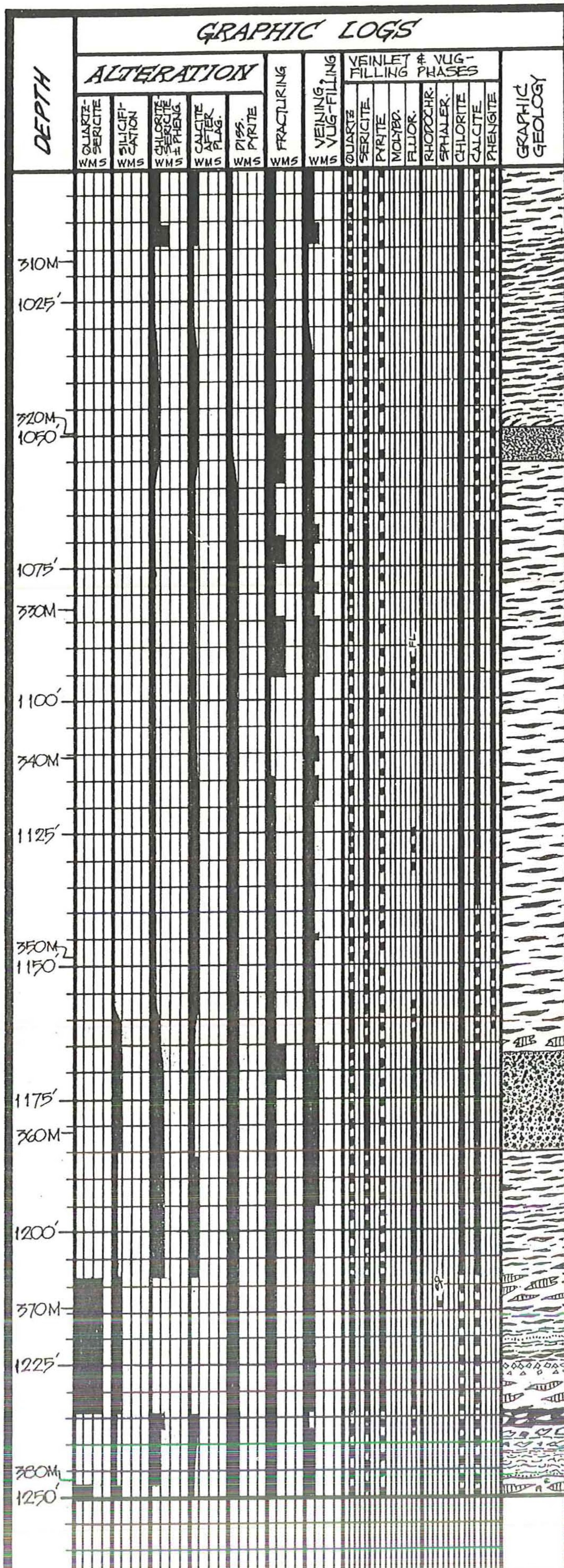

NOTES, COMMENTS	DESCRIPTIONS
	DENSELY WELDED, XL-RICH RHY. ASH-FLOW TUFF CONTINUES
306.6M (1006')	306.6 M: BEGIN TO SEE MINOR GLASS -- SOME SHARDS STILL SHINY DARK GRAY
● DIP ~ 40° (FIAMME)	
309.1M (1014')	309.1-317M: DENSELY WELDED, CRYSTAL-RICH, PARTIALLY STILL GLASSY, RHYOLITE ASH-FLOW TUFF; MED., SLIGHTLY PURPLISH-GRAY WITH DARK GRAY-PURPLISH-GRAY FIAMME; 35-37% PHENOCRYSTS, AVG. 1.5-2 MM. DIA., 10-12% QTZ, 20-25% MICROPERTHITE (KF & AB -- REPLACEMENT & EXSOLUTION?); 0.3-0.5% FORMER MAFICS, EQUANT TO STUBBY LATH-SHAPED, MOSTLY SUBHEDRAL, NOW ALT. TO CHL/PHENGITE/CALCITE/DK OPAQUE ± LEUC. AGGREGATES -- MANY OF THESE MAFICS RIMMED W/ DK. OPAQUE & INTERGROWN W/ MICROXLN. RELICT ZIRCON & APATITE ALSO: IRREG. AREAS IN MATRIX REL. CRS-XLINE (AVG. 0.15 MM
317M (1040')	CRYSTALS) QTZ-KF ± AB AGGREGATES UP TO AT LST 3 MM DIA. -- MANY FIAMME SIMILARLY COARSELY-XLN.
319.8M (1049')	317-319.8M: AS ABOVE, EXC. MORE BLEACHED-APPEARING.
FALLOUT TUFF *	319.8-321.9 M: FALLOUT TUFF; V. LT., SL. GREENISH-GRAY, DENSE, VERY F. GR., BUT CONTAINING A FEW, SCATTERED PUMICE LAPILLI & LITHICS, BOTH SELECTIVELY CHLTZD. -- THESE
321.9M (1056')	CONCENTRATED TOWARD TOP OF UNIT; AT UPPER CONTACT, FIAMME ARE DISCORDANT, SUB-⊥, BUT CHANGE RAPIDLY UPHOLE TO CONCORDANT
	321.9-355.7M: DENSE. WELDED, XL-RICH, RHY. ASH-FLOW TUFF AS ABOVE, EXC. GENERALLY A BIT MORE (THOUGH STILL WEAKLY) ALTERED; SOME FORMER MAFICS UP TO 0.5 MM. DIA. DEF. SOME FORMER PYROXENE, NOW ALT. TO CHL-CAL-PHENG.-LEUCOX.
	NOTE: THROUGHOUT THIS UNIT ARE BEAUTIFULLY DEVELOPED SPHERULITIC, AXIOLITIC & "SHELL WITHIN SHELL" DEVITRIFICATION TEXTURES.
	QTZ-CHL-CAL-PHENGITE-FLUORITE VEINLETS. THESE CONTAIN ABUNDANT VAPOR-RICH PRIMARY FLUID INCLUSIONS (BOILING INDICATED)
	342-347.2 M: MOD. CAL-CHL VEINING; WHERE VNLTS. COALESCE LOCALLY, FORM IRREG. MASSES UP TO
342M (1122 FT)	3CM. IN DIAMETER.
	DISS. DK OPAQUES, AS ABOVE, SOME RIMMED W/LEUC.
	● XRD: Q-37, KF-16, PL-24, CAL-3, PY-1, IL-2, CH-2 (APP. WT. %, 343.9 M)
347.2M (1139 FT)	
	AT 349.1 M, GLASS DISAPPEARS, FIAMME BECOME LT. GREENISH-GRAY, & MATRIX CHANGES FROM
349.1M (1145.5')	LT. PURPLISH-GRAY TO LT. GRAY
	● XRD, 354.1 M: Q-36, KF-15, PL-25, CAL-3, PY-1, FL-3, IL-7, CH-7 (%)
	FIAMME EXTENSIVELY REPLACED WITH CHL-QTZ ± SER. AGGREGATES
355.7M (1167 FT)	355.7-361.7M: EPICLASTIC SANDSTONE, V.V. LT. GREENISH-GRAY, MED.-GRAINED, MODERATELY SORTED, V. IMMATURE; ~30% MICROCRYSTALLINE MATRIX, ORIGINALLY ASH?, NOW: QUARTZ, ILLITE, CHL. AGG.; MINOR, SCATTERED, VUGGY PUMICE UP TO AT LEAST 20MM. DIA. (AVG. 2 MM.) --
SLIP PLANE	THESE ALTERED & INFILLED W/ VARIOUS COMBINATIONS OF CAL, SER, CHL, FLUOR., & QUARTZ; GRAINS ARE
361.7M (1186.7FT)	QTZ, KF MICROPERTHITE, VARIOUS LITHICS, POSS. LARGE, ALTERED GLASS SHARDS.
	361.7-371.5M: MODERATELY TO DENSELY WELDED, XL-RICH RHYOLITE ASH-FLOW TUFF, SIMILAR TO 321.9-355.7M, BLEACHED, PUNKY-APPEARING, V. LT. GREENISH-GRAY WITH MED. GREENISH-GRAY FIAMME.
	367.7': COMPLEX QTZ-CHL-CALC-FLUOR VEINLET ‡
367.7M (1206.3')	369.8-370.13M: QTZ-SER-PY-VEINLET W/TR. EUH. SPHALERITE CRYSTALS
	371M: QTZ-CHL-CAL-ADULARIA VEINLET
371.5M (1219 FT)	371.5-372.6M: SEQ. OF V. DISTINCTLY BEDDED DENSELY WELDED TUFFS (WELDED SURGES?); BEDS AVG 2 CM THICK
372.6M	372.6-373.5M: DW, XL-RICH, RHY. ASH-FLOW TUFF.
373.5M	← V. CRYSTAL-RICH (UP TO 70%) HORIZON (373.5-373.8M) MUST BE A SURGE DEPOSIT
376M (1233.8')	376-376.8M: MYSTERY TUFF BRECCIA; 30% ± TO SUBROUNDED
376.8M (1236.4')	CLASTS OF ASH-FLOW TUFF IN DARK GRAY GLASSY MATRIX. 376.8-377.4 M: LITHIC & PUMICE-RICH NON-WELDED A.F. TUFF
● DIP 27°	377.4-377.6 M: DISTINCTLY BEDDED, FINE-GR TUFF 377.6-378.3 M: SAME AS 376.8-377.6M
380.2M (1247.5 FT)	378.3-378.6 M: V. WELL-BEDDED FINE-GR. TUFF 378.6-380.2M: XL-RICH, BEDDED TUFF
	* SKETCH OF CONTACT OF FALLOUT TUFF W/ OVERLYING ASH-FLOW TUFF
	 → DOWN
	‡ THIS VEINLET SHOWS EVIDENCE OF BOILING (COEXISTING PR. VAP. & LIQUID-RICH FLD. INC

DRILL HOLE VC-2A

LOCATION VALLES CALDERA, N. MEXICO

LOGGED BY J. B. HULEN AND J.N. GARDNER

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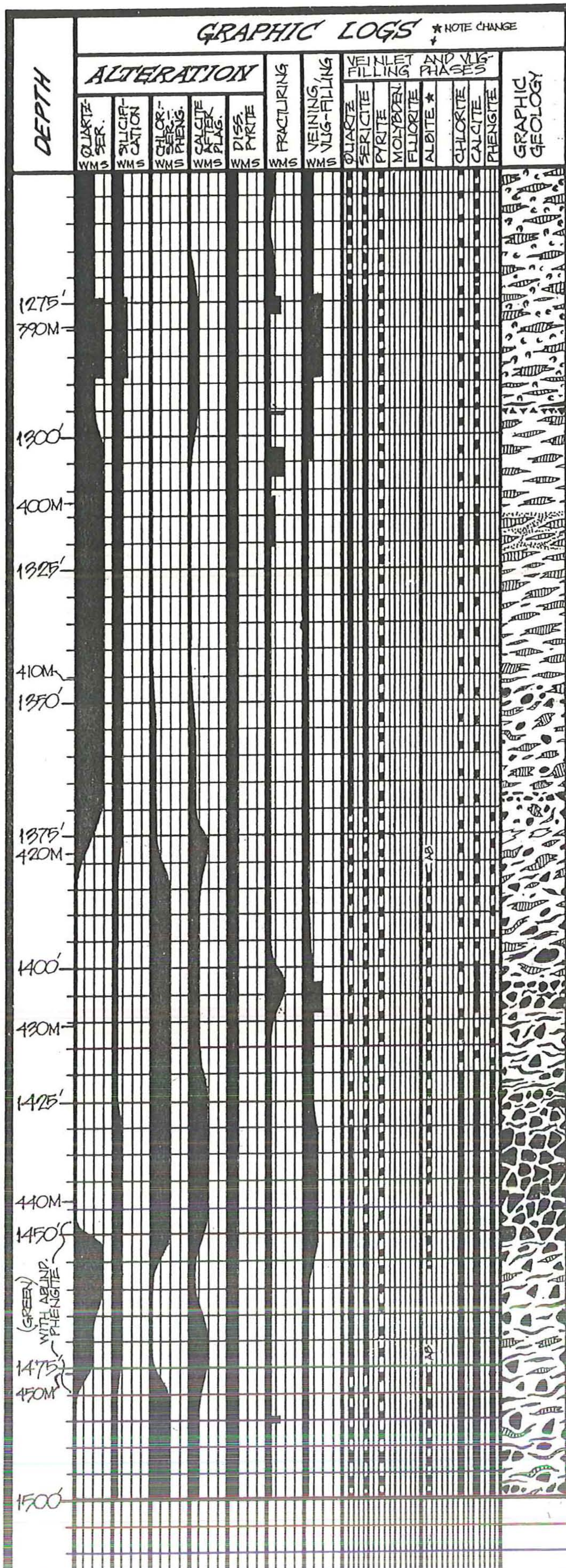

NOTES, COMMENTS	DESCRIPTIONS
● DIP 45° (FIAMME)	380.2-402.8M: MODERATELY WELDED CRYSTAL-RICH, RHYOLITE ASH-FLOW TUFF, V. LT. GRAY TO LOCALLY GREENISH-GRAY, DISTINCTIVELY PITTED DUE TO ETCHING & COMPLETE DISSOLLITION OF FSP. PHENOCRYSTS; AVG. ~ 0.5% DISS. PY, 0.5-0.7% DISS. LEUCOXENE; MINOR LITHICS.
388.3M (1274 FT)	388.3-392.6M: V. STRONG PHYLLIC (QTZ-SER) ALTN., V. SPONGY, PITTED ASPECT--ETCHED FSP. CAVITIES LOCALLY LINED W/ TINY (<0.2 MM) EUH. QTZ. XLS.-- RARELY EUH. CALCITE XLS. IN THESE VUGS. TR. CHL. MICROVEINLETS ± CAL, SER., PY
392.6M (1288 FT)	● XRD, 388.6M (%): Q-64, KF-1?, PY-1, IL-33
	394.8M: RUBBLE ZONE W/5 MM CALCITE XLS.
394.8M (1295.4')	
401.1M (1316')	● XRD, 402.5M (%): Q-53, PY-2, ANH-8, IL-35
ANHYDRITE ZONE?	402.5 M (THIN-SEC.): FELDSPARS WIDELY REPLACED WITH ANHYDRITE--THIS MAY CORRESPOND WITH A PINKISH ZONE BETWEEN 401.1 M AND 402.8 M. (VERY DENSE); TR. QTZ. XLS. IN ETCHED FSP. CAVITIES
402.8M (1321.6FT)	
SPHALER. (404.2 M)	
● DIP ~ 40° (FIAMME)	402.8-427.6 M: MODERATELY WELDED, XL-RICH, RHY. ASH-FLOW TUFF, SAME AS 380.2-401.1 M, EXC. SLIGHTLY LESS PITTED/ETCHED; ALTERATION REMAINS STRONG; A FEW FIAMME HAVE BEEN ETCHED, THEN SPARSELY LINED WITH MICROCRYSTALLINE PYRITE.; A FEW LARGER PUMICES SEEM QUITE UNDEFORMED; RARE, SCATTERED CHL. MICROVEINLETS
410.9M (1348') LITHIC-RICH	404.2 M: 50° FRACTURE BEARING RESINOUS-APPEARING, GREENISH-YELLOW SPH. XLS. <0.5 MM. DIA.
	410.9-411.7M: LITHIC-RICH ZONE W/ 10-15% ∡ TO ROUNDED LITHICS UP TO 75 MM. DIA.; INCL. PPYTIC ANDESITE, ABO FM. REDBEDS, DW ASH-FLOW TUFF; LITHICS REMAIN 5-7% OF THE ROCK BELOW THIS INTERVAL.
416.9M (1367.8')	416.9-417.4M: LITHIC-RICH ZONE, AS ABOVE, EXC. CLASTS ARE < 20 MM. DIA.
419.3M (1375.8') COOLING BREAK	419.3M: BEAUTIFUL UNCOLLAPSED SHARDS; 5-7% QTZ. PHENOCRYSTS, 12-15% FSP. PHENOS
	420.5-427.6M: ROCK BECOMES MODERATELY TO DENSELY WELDED W/ PUMICE DISTINCTLY MED. GRAY-GREEN IN A WHITISH, PUNKY MATRIX; CONT. 5-7% LITHIC FRAGMENTS, MANY W/ 0.5-7 MM. GREEN "ENDO-HALOS" (COLOR SIMILAR TO FIAMME); DISS. PYRITE CONTINUES; LITHIC MOSTLY PORPHYRITIC ANDESITE W/LESSER ASH-FLOW TUFF, RED SILTST., SS., RHY?
● DIP ~ 30° (FIAMME)	10 CM. DIA. ∡ LITHIC (AND. PPY.) AT 426.5 M.
427.6M (1403 FT)	
429.8M (1408.5')	427.6-429.3M: MOD. WELDED, ASH-FLOW TUFF LAG BRECCIA; 20-60% (VARIABLE W/ DEPTH) ∡ TO SUBROUNDED LITHICS; COMPOSITION OF THESE AS ABOVE (SEE 410.9 M); HIGHLY FRACTURED, INFILLED W/ CALCITE; GRAY-GREEN COLOR; MANY CLASTS HAVE DARKER GRAY-GREEN PHENGITE RIMS
● DIP ~ 45° (FIAMME)	
434M (1424 FT)	429.3-434.0 M: DW, LITHIC RICH, FELSIC-INTM. ASH-FLOW TUFF; V. LT. GRAY-GREEN W/ MED. GRAY-GREEN FIAMME; LITHICS INCREASE DOWNWARD; MATRIX IS PREDOMINANTLY QUARTZ (+) ALBITE (MICROCRYSTALLINE) - KFELDSPAR CONCENTRATED IN LITHICS AND PHENOCRYSTS; IRREG., REL. CRS.-XLN ALBITE CLOTS OCCUR LOCALLY
	434-442.6M: MOD. WELDED, FELSIC-INTM. ASH-FLOW TUFF LAG BRECCIA, LT.-MED. GREENISH-GRAY; PUNKY, EARTHY TEXTURE; 30-40% CLASTS TO 436.6M--80%+ CLASTS BELOW THAT DEPTH; CLASTS MOSTLY VARIOUS TEXTURAL VARIETIES OF PORPHYRITIC ANDESITE, W/ MINOR WELDED RHY ASH-FLOW TUFF, PINKISH SLTST. & SANDSTONE (PERMIAN ABO FM.); MANY CLASTS HAVE BRIGHT GREEN PHENGITE RIMS--THESE ESP. WELL-DEVELOPED AROUND ABO CLASTS; CLASTS COMMONLY SELECTIVELY PYRITIZED; SOME CLASTS CONTAIN PRE-BRECCIA CHL-CAL VEINLETS; QTZ. PHENOCRYSTS PERSIST, BUT APPEAR SPARSE DUE TO LOW BX-MATRIX PERCENTAGE.
442.6M (1452.3')	
448.2M (1470.4')	442.6-477M: MOD. TO DENSELY WELDED, FELSIC-INTM. ASH-FLOW TUFF, LT. GRAY-GREEN W/ DARKER GRAY-GREEN LITHICS & PUMICE; ROCK V. SIMILAR TO 429.3-434M.; LITHIC-RICH (10-15%); ROCK HAS COMPACT BUT PUNKY AND EARTHY ASPECT
	● XRD, 448.2M (%): Q-52, KF-17, CAL-3, PY-1, IL-25 (CHL <1)

SKETCH OF ALBITIZED KFSP. PHENOCRYST AT 433 M.

DRILL HOLE VC-2A
LOCATION VALLES CALDERA, N. MEXICO

LOGGED BY J. B. HULEN AND J. N. GARDNER
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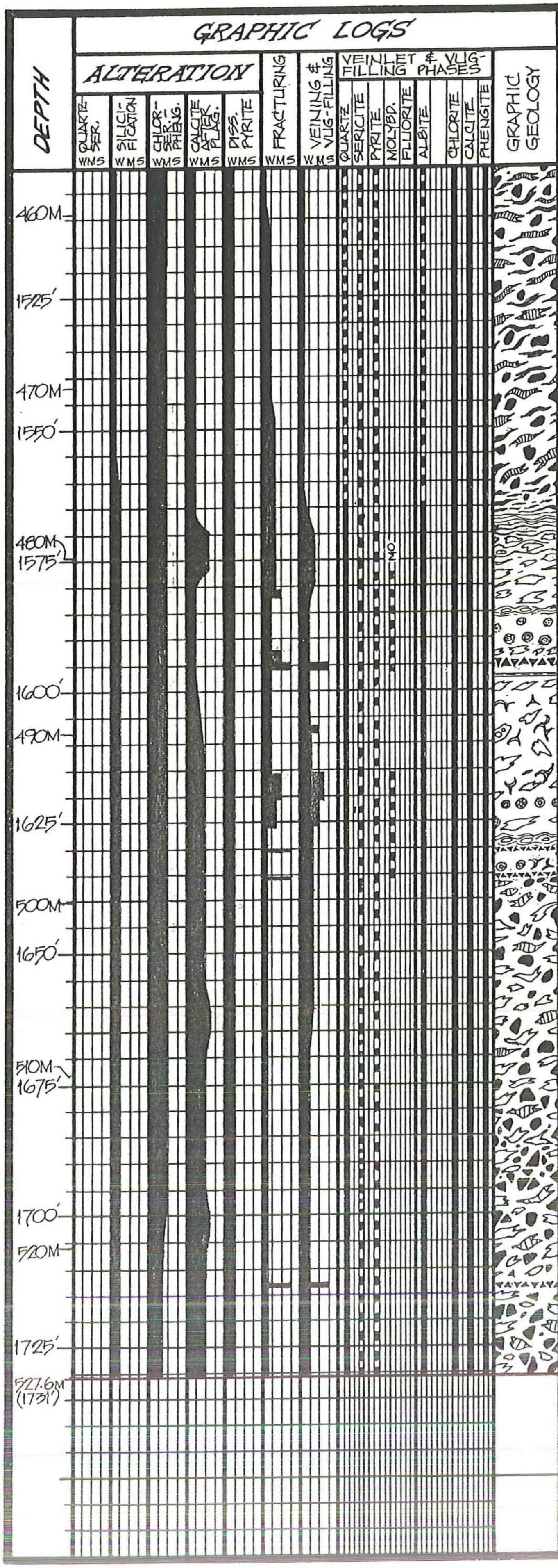

NOTES, COMMENTS

- • DIP 35-40°
- 477M (1565')
- ← WELDED SURGE?
- 480M (1575 FT)
- MoS_2 "PAINT" ON FRACS.?
- 483.1M (1585')
- 486M (1594.5')
- FAULT 486.7M
- • DIP ~ 40°
- UNDEFORMED SHARDS
- UNDEFORMED SHARDS
- 494.7M (1623 FT)
- "PSEUDO-MYLONITE"
- FAULTS
- 498.6M (1636FT.)
- • DIP ~ 40°
- 515.1M (1690FT.) (POINT COUNT)
- 516.3M (1694 FT) (HYDROTH. RUTILE) & SP
- 522.1M (1713 FT.)
- FAULT
- 527.6M (1731 FT)

DESCRIPTIONS

MOD. TO DENSELY WELDED, FELSIC-INTM., ASH-FLOW TUFF CONTINUES TO 477 M; QUITE COHERENT BUT HAS A PUNKY EARTHY TEXTURE; DISTINCTIVE LT. GRAY-GREEN COLOR DUE TO PHENGITE W/MINOR CHLORITE; AVG. 12-15% ANGULAR TO SUBROUNDED LITHIC FRAGS., UP TO AT LEAST 40 MM. IN DIAMETER; LITHICS ARE ABT. 50% PPYTIC. INTM. VOLCANICS W/LESSER DW RHY. ASH-FLOW TUFF, MINOR ABO FM. PINKISH SILTST. & SANDSTONE; MANY CLASTS HAVE BRIGHT GRAY-GREEN PHENGITE RIMS; FELSIC WELDED TUFF CLASTS ARE WHITISH IN CONTRAST TO MATRIX.

NOTE: SCATTERED OTHER CLASTS INCLUDE QTZ. LATITE & FINE-XLN QTZ. MONZONITE (PRECAMBRIAN?)

• XRD 466.1 M Q-42, KF-11, PL-13, CAL-5, PY-1, IL-23, CH-3

476.4-477M: FAINT "BEDDING" DEFINED BY LAYERS OF COMPACTED GREENISH-GRAY PUMICE

477-477.8 M: AS ABOVE BUT WELL-DEFINED "BEDDING"-- POSS. A WELDED SURGE DEPOSIT

477.8-498.6M: ALTERED, V. WEAKLY TO NON-WELDED (FUSED?) PUMICE-RICH TUFF; RX. IS BASICALLY A DENSE, V. LT. GREENISH-GRAY, MICROCRYSTALLINE QTZ-ALBITE-SER-CHL-PHENG. AGGREGATE W/ABUNDANT PUMICE UP TO AT LST 30MM. DIA. (AVG. 1.5 MM DIA.) & SCATT., LOCAL, WELL-FORMED, ROUND TO SUBROUND ASH BALLS 0.1-0.7MM (AVG. 0.2 MM.) DIAMETER-- SOME OF THESE HAVE VAGUE "SHELLS" & MAY BE ACCRETIONARY LAPILLI; ALSO AVG. 5-7% SUBRND-ANGULAR LITHICS UP TO AT LEAST 20 MM (AVG. 7 MM) DIAMETER-- THESE AND. PPY, PPYTIC. DACITE, RHY. ASH-FLOW TUFF; ONLY ABOUT 0.5-1% QTZ, FSP. PHENOCRYSTS, ONLY AVG 0.3-0.5 MM. DIAMETER; QTZ-ALBITE VUG-FILLING AS ABOVE;

NOTE: THIS COULD BE IN PART PHREATOMAGMATIC, BUT WHATEVER ITS ORIGIN, HAS BEEN SLIGHTLY COMPACTED & DEFORMED (WHILE WET?) TO YIELD A LOCAL "PSEUDOMYLONITIC" TEXTURE W/PUMICE & LITHIC "AUGEN" (PARTICULARLY 496.2-497.1M, 477.8-480M, 483.1M)

486.7M: 0.2M DK. GRAY-GREEN, F.XLN. SHALE-LIKE ROCK

494.7 M: ABUNDANT COARSELY VESICULAR PUMICE & COMPLETE, DELICATE BUBBLE SHARDS (THIN-SEC.)

• XRD, 498.3M (%): Q-40, PL-15, KF-9, CAL-5, PY-1, IL-25, CH-4

498.3 M: AS ABOVE, EXC. SCATTERED ASH BALLS, SAME (?) AS IN MAIN DESCRIPTION

498.6-527.6M: LITHIC-RICH, NON- TO WEAKLY WELDED (OVERALL), MODERATELY ALTERED, ASH-FLOW TUFF, LT. GRAY-GREEN DUE TO PHENGITE & CHL. ALTERATION; EARTHY, PUNKY TEXTURE, BUT VERY COHERENT; PUMICES REL. DARKER GRAY-GREEN; MATRIX IS MICROXLN AGG. OF AB, QTZ, ILLITE, PHENGITE & MINOR CHL.-- KFSP STAIN SHOWS NO KFSP IN MATRIX-- ALL KFSP APPARENTLY IN CLASTS; CLASTS PREDOMINANTLY PORPHYRITIC, INTERMEDIATE-COMPOSITION VOLCANIC ROCKS (ANDESITE-RHYODACITE), W/ SUBORDINATE RHYOLITE ASH-FLOW TUFF (COMMONLY GRANOPHYRICALLY DEVITRIFIED/RECRYSTALLIZED W/ MICROPEGMATITIC TEXTURES; MANY CLASTS HAVE PARTIAL, DARK, BRIGHT GRAY-GREEN, PHENGITE RIMS; MANY CLASTS SELECTIVELY PYRITIZED (DISS.); OVERALL 0.5-1% PYRITE -- SOME CLASTS 2-3% PYRITE; 0.1% DISS. V. F. XLN HEMATITE (REDDISH) PARTIALLY REPLACING PRIMARY DARK OPAQUES (PRINCIPALLY IN INTM.-COMPOSITION VOLCANIC CLASTS)

ALSO TR. <1MM. EUH. SP. XLS

516.3 M: FRACTURE SURFACE SPARSELY COVERED W/<1MM CALCITE & RUTILE CRYSTALS.

• XRD, 515.1 M (%): Q-33, PL-19, KF-17, CAL-4, PY-1, IL-18, CH-5 (THIN-SEC. 2% LEUCOXENE)

522.1-522.4M: FAULT GOUGE & BRECCIA W/ABUND. CALCITE; ONE 5 X 2 CM. VUG CALCITE-FILLED

• XRD, 527.6 M (%): Q-41, PL-22, KF-17, CAL-4, PY-1, IL-10, CH-2 (THIN-SEC 2% LEUC)

POINT COUNT, 515.1 M:	%	LITHIC-FREE BASIS:	%
• QTZ. PHENOCRYSTS	3.2	• QTZ. PHENOCRYSTS	4.8
• K-FELDSPAR PLUS MICROPERTHITE PHENOCRYSTS	5.3	• K-FELDSPAR PLUS MICROPERTHITE PHENOCRYSTS	7.9
• PLAGIOCLASE PHENOCRYSTS	0.7	• PLAG. PHENOCRYSTS	1.0
• PUMICE	12.3	• PUMICE	18.4
• LITHIC FRAGMENTS	41.3	• GROUNDMASS	67.9
• GROUNDMASS	37.2		

LOGGED BY J.B. HULEN AND J.N. GARDNER

SEPT.-OCT. 1986
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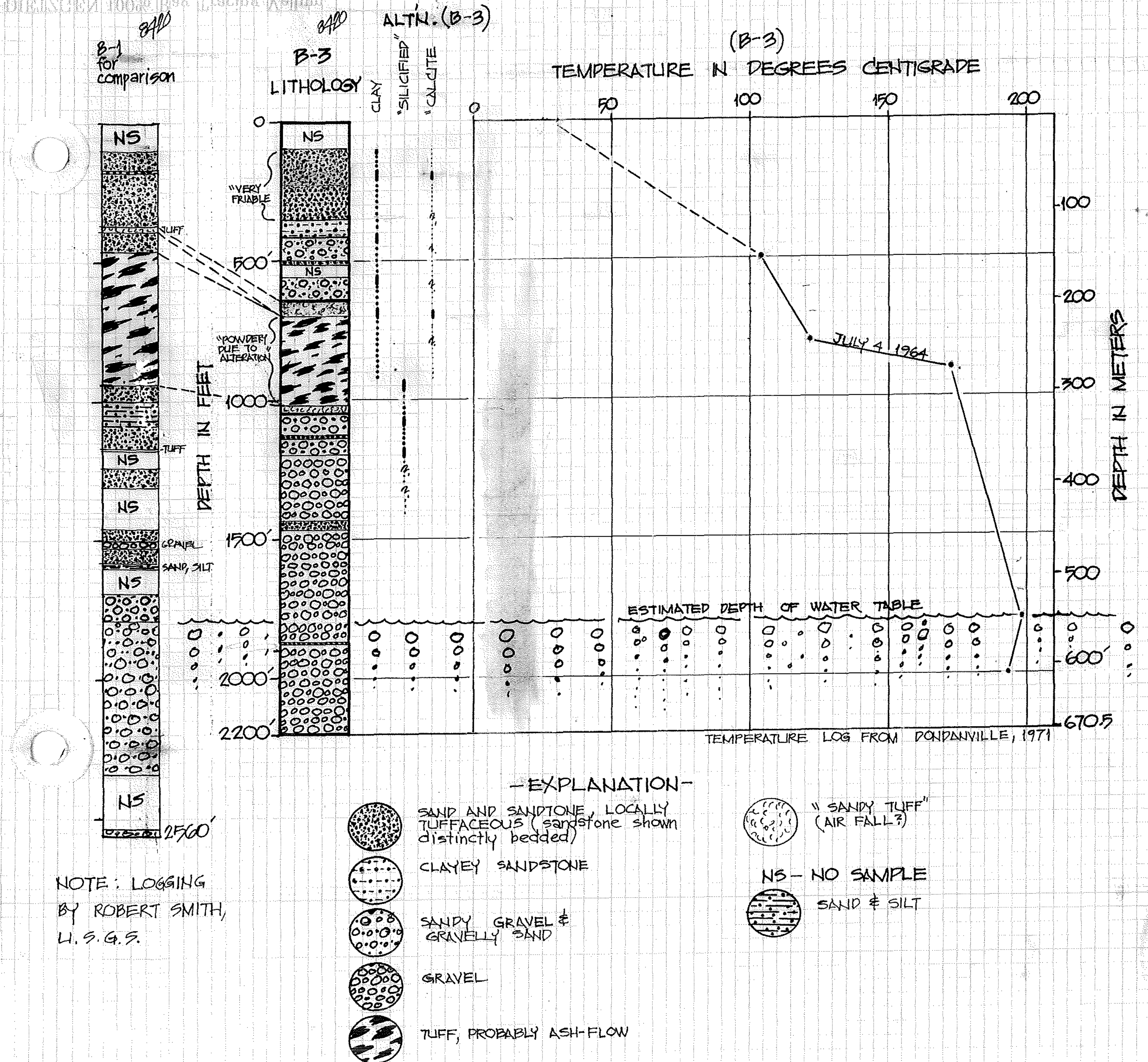
DRILL HOLE VC-2A

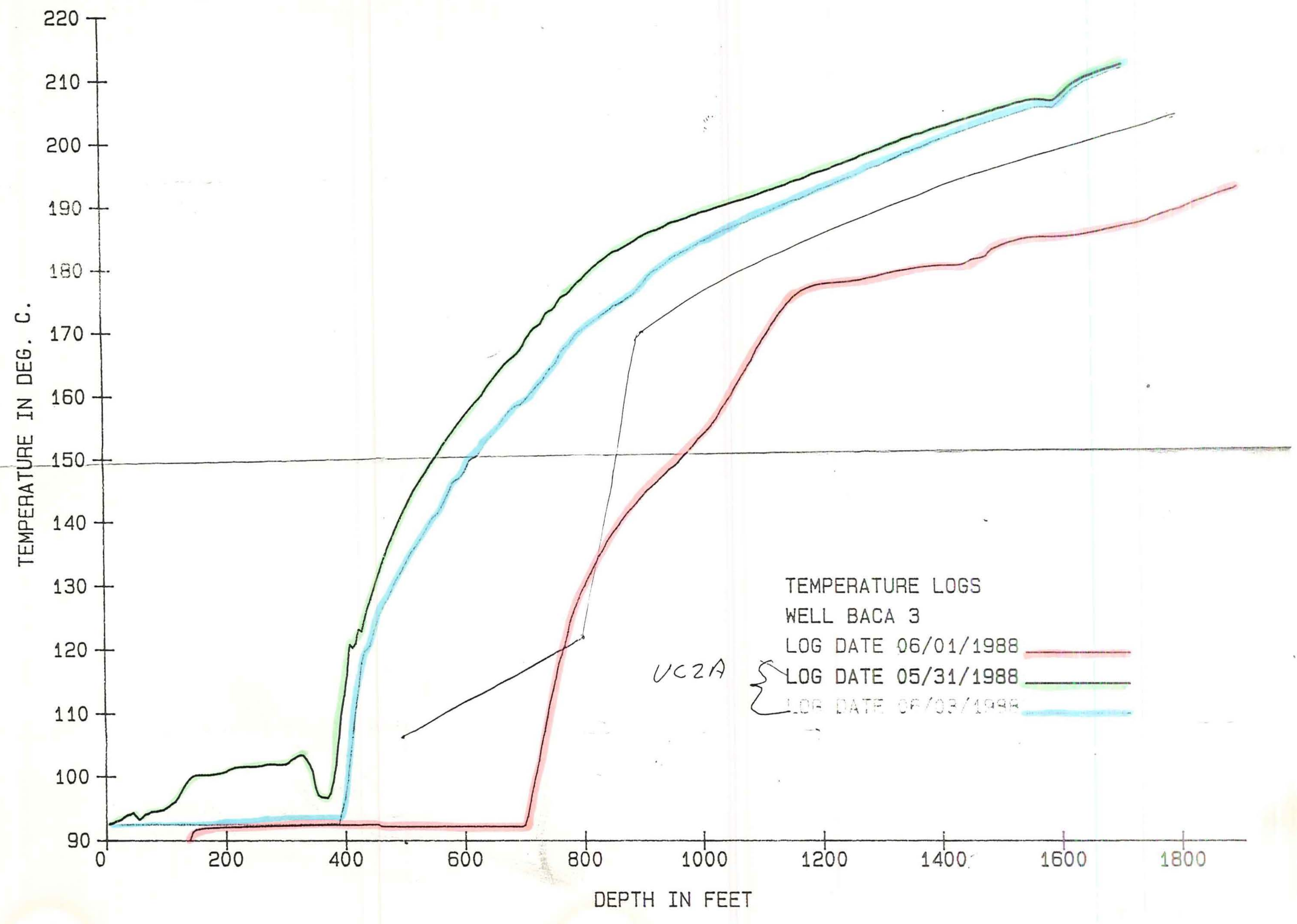
LOCATION VALLES CALDERA, N. MEXICO



Lithologic, "alteration" and temperature log for well Baca 3, Sulphur Springs area, Valles caldera, New Mexico.

(ABSTRACTED FROM LOG BY BACA LAND & CATTLE CO.)
LOGGED BY BOB SMITH, U.S.G.S.

JBH 07/12/86



TEMPERATURE IN DEG. C.
90
100
110
120
130
140
150
160
170
180
190
200
210
220
DEPTH IN FEET
0
200
400
600
800
1000
1200
1400
1600
1800
TEMPERATURE LOGS
WELL BACA 3
LOG DATE 06/01/1988
LOG DATE 05/31/1988
LOG DATE
UC2A

FROM DONDANVILLE, 1971

for the temperature surveys show that some of the test fluid was coming from below 2900 feet, but pressures appear too high and temperatures too low to allow a vapor-phase separation.

It is concluded that the rocks penetrated by the Bond #1 well contain liquid water at elevated temperature, and significantly less than hydrostatic pressure.

Baca #1, T.D. 2560 feet
2. Baca #3, T.D. 2200(?) feet

The Baca #1 well is the first well in Valles Caldera drilled to establish geothermal steam production. With 13-3/8 inch casing emplaced to 461 feet, the well encountered steam zones at 1441 - 1500 feet. As measured by Rogers Engineering Company, the zones flowed 85,000 pounds of steam per hour with less than 5% liquid water content. Their estimate of reservoir conditions was 310° - 320°F. and 65 psig reservoir pressure, a saturated steam zone. Rogers' estimate of the formation temperature is in good agreement with the temperature calculated from the sodium-potassium content of the effluent water: 338°F. The well was deepened to 2560 feet and the hole was lost while attempting to run casing.

The Baca #3 well, a twin to the Baca #1, was drilled to re-establish production from the steam zones discovered in the Baca #1 well. At a total depth of 1983 feet, with 1179 feet of 9-5/8 inch casing, the well had a flow of 11% steam and 89% water, chiefly from zones below 1900 feet. The water zone apparently was depleted rapidly, for one day later the well was flowing 50% steam. After tests, 7 inch casing was hung from 1000 feet to 1983 feet and the well was drilled to total depth, about 2200 feet. A down-hole temperature survey recorded a maximum temperature of 390°F. at 1800 feet and a water level between 800 feet and 900 feet.

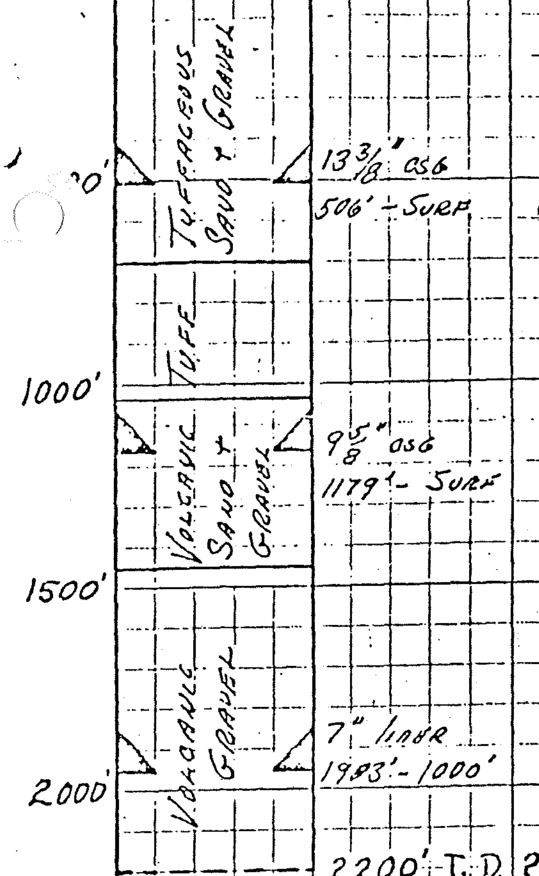
The Baca #1 and #3 wells establish that low pressure-high temperature conditions are available in the Valles Caldera suitable for formation of saturated steam reservoirs. Although the wells, as drilled, did not discover commercial production, data from the Baca #4 well indicates the Baca #1 - #3 location is probably on the fringe of a saturated steam reservoir and may be prospective for dry steam production from greater depths.

3. Baca #2, T.D. 5658 feet

The Baca #2 well is the deepest geothermal test in the Valles Caldera, and is the only well to penetrate Paleozoic sediments and Pre-Cambrian granite. The well was drilled with mud to a depth of 3445 feet with lost circulation

BACA LAND AND CATTLE CO.
BACA # 3 (TWIN TO BACA #1)

ELEVATION: 8350'
T.D.: 2200' (?)
DRILLED WITH AIR, SUMMER, 1964



T.D. 1555' WHSIP 32 psig

T.D. 1944' WHSIP 130 psig

T.D. 1983' W.HSIP 99 psig @ 306°F

6/27/64 ROGER'S ENG. CALORIMETER TEST INDICATES 10.6% STEAM

6/28/64 CALORIMETER IND. 50% STEAM

AFTER TESTS, 7" liner hung 1000' - 1983', WELL Drilled to T.D.

7/4/64 BZM TEMPERATURE SURVEY

DEPTH	TEMP	
500'	220°F	
800'	250°	← LOG NOTES TOP-OF-H_2O
900'	342°	
1800'	390°	
2000'	380°	

PERFORATE 1880'-1936' FLOW STEAM + WATER
" 1780-1840 " " " "

Na/K in PRODUCED WATER = 11:1
INDICATES EQUILIBRIUM WITH 410°-428°F

RAD 1977

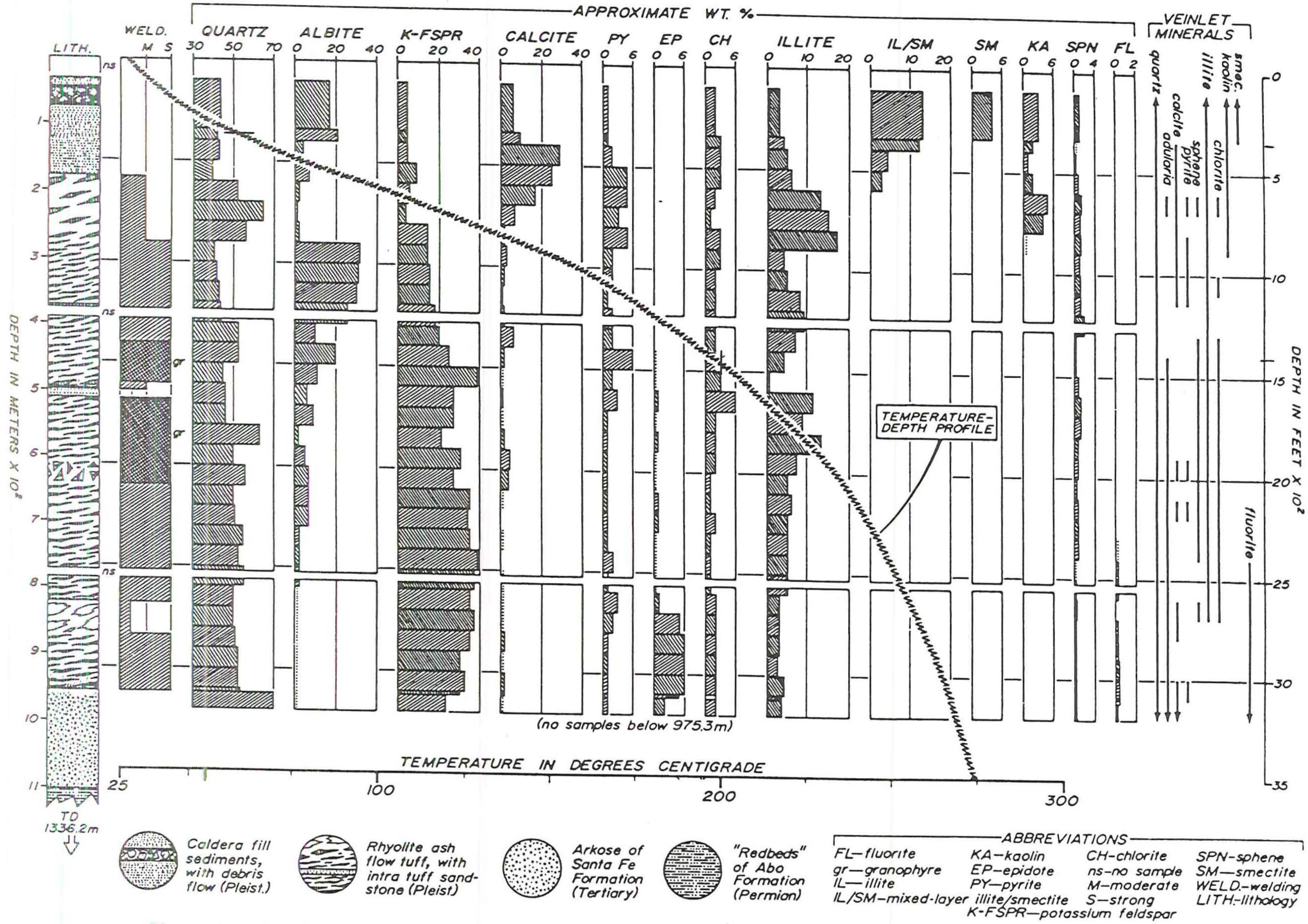


Figure 2. Lithology and distribution of rock-forming and hydrothermal alteration minerals, borehole B-8.

Hulen and Nielson, 1986

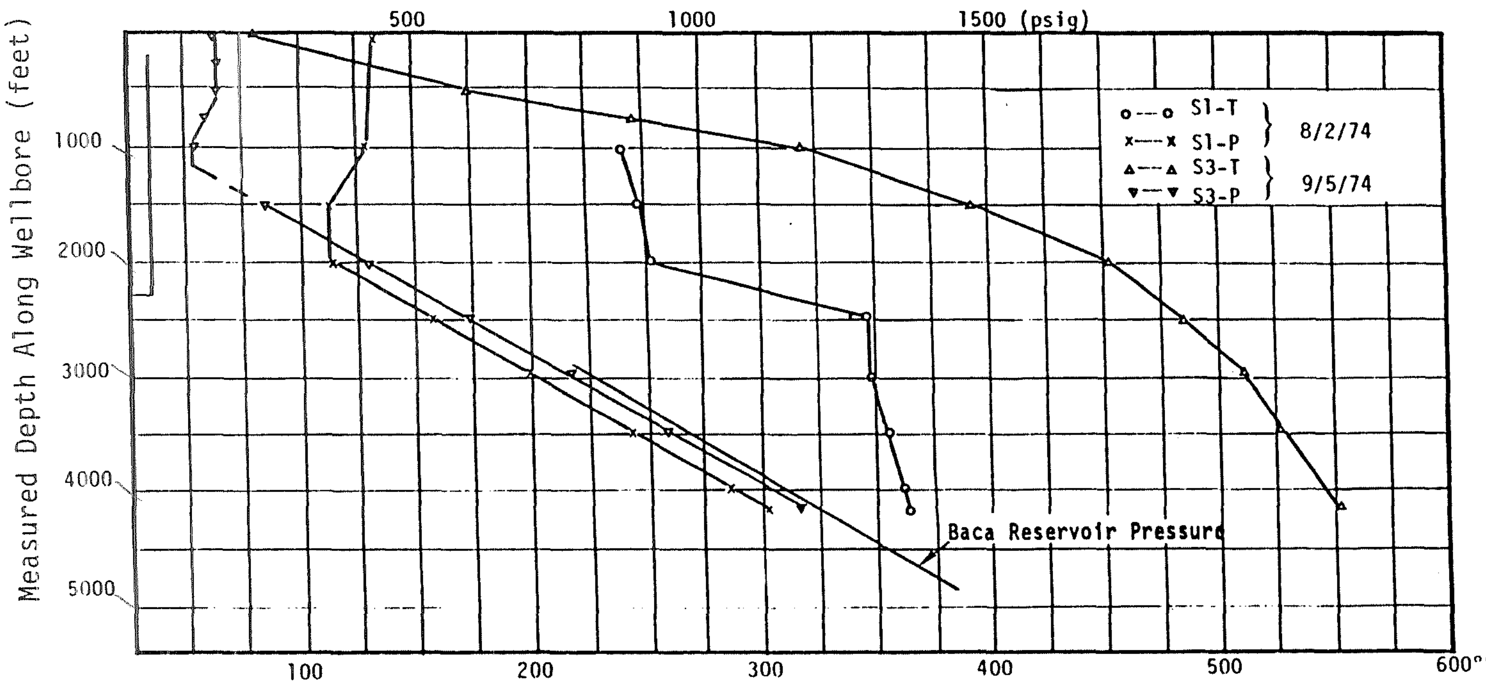


Figure 3.8. B-8 Pressure and Temperature.

FROM: GRANT & GARG, 1981

Casing Data:
1. Bottom of 9-5/8" casing: 2908 ft
2. 7" liner from 2697 to 5515 ft; liner slotted from 3202 to 5512 ft

Formation Encountered During Drilling:
1. Valles Rhyolite: 0 - 1400 ft
2. Caldera Fill: 1400 - 2300 ft
3. Bandelier Tuff: 2300 - 3300 ft
4. Tertiary Sediments: 3300 - 3960 ft
5. Permian Redbeds: 3960 - 4840 ft
6. Pennsylvanian Limestones: 4840 - 5460 ft
7. Granite: below 5460 ft

Only one pressure/temperature survey is available for this well (see Figure 3.7). Baca reservoir pressure, as deduced from Redondo Creek Wells, is also shown in Figure 3.7. Both the downhole pressure and temperature surveys show a change in gradient at approximately 4500 ft; since the fluid in the well is liquid, this change in pressure gradient is most easily explained by a measurement error. Above 4000 ft, the measured pressure in B-7 is similar to the Baca reservoir pressure.

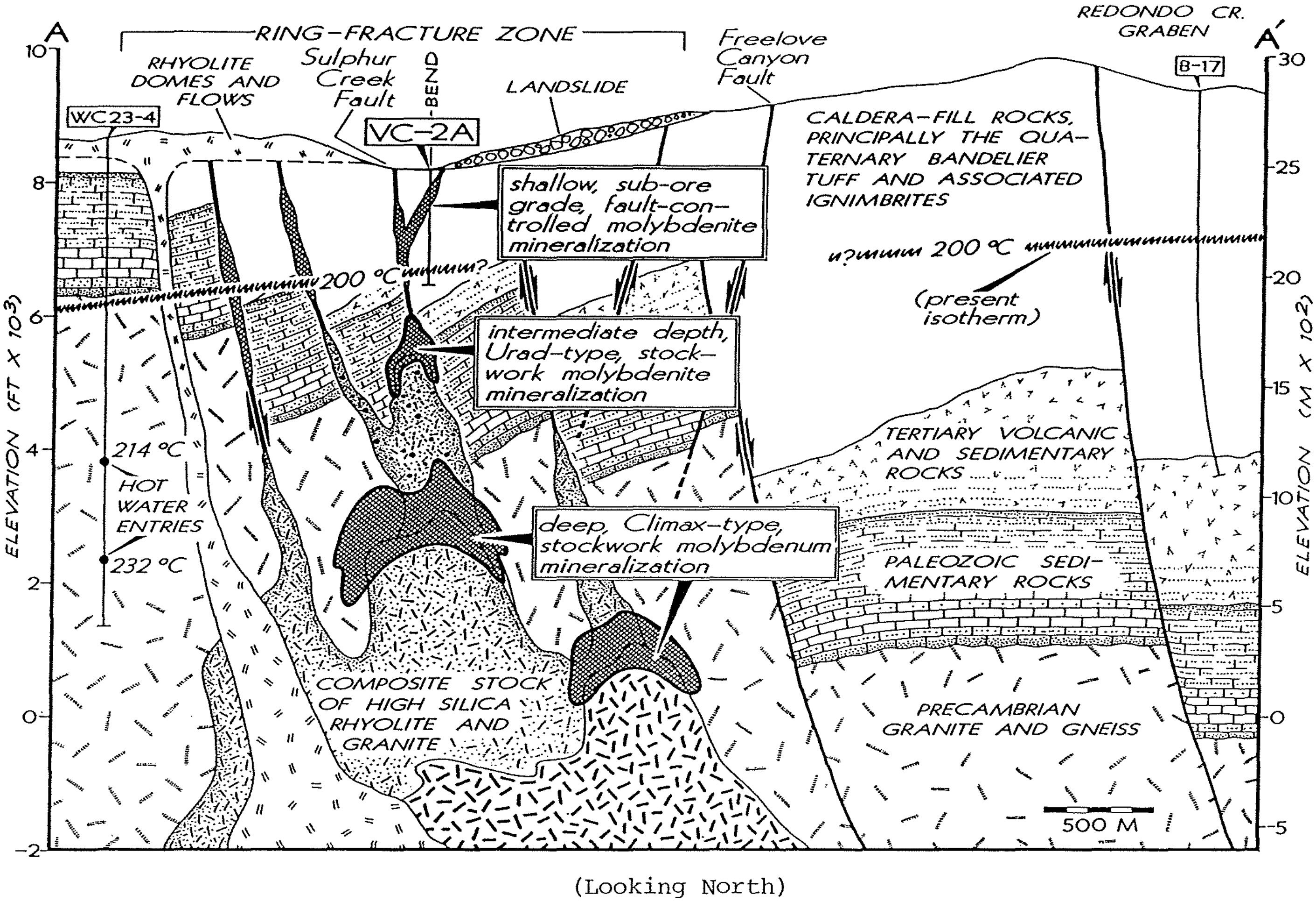
3.12 Well Baca No. 8 (Sulphur Creek Area)

Ground Surface Elevation: 8631 ASL
Zero Point for Downhole Surveys: 8637±1 ASL
Date Completed: 9/13/72
Total Depth of Well: 4384 ft
Deviation Data: Unavailable

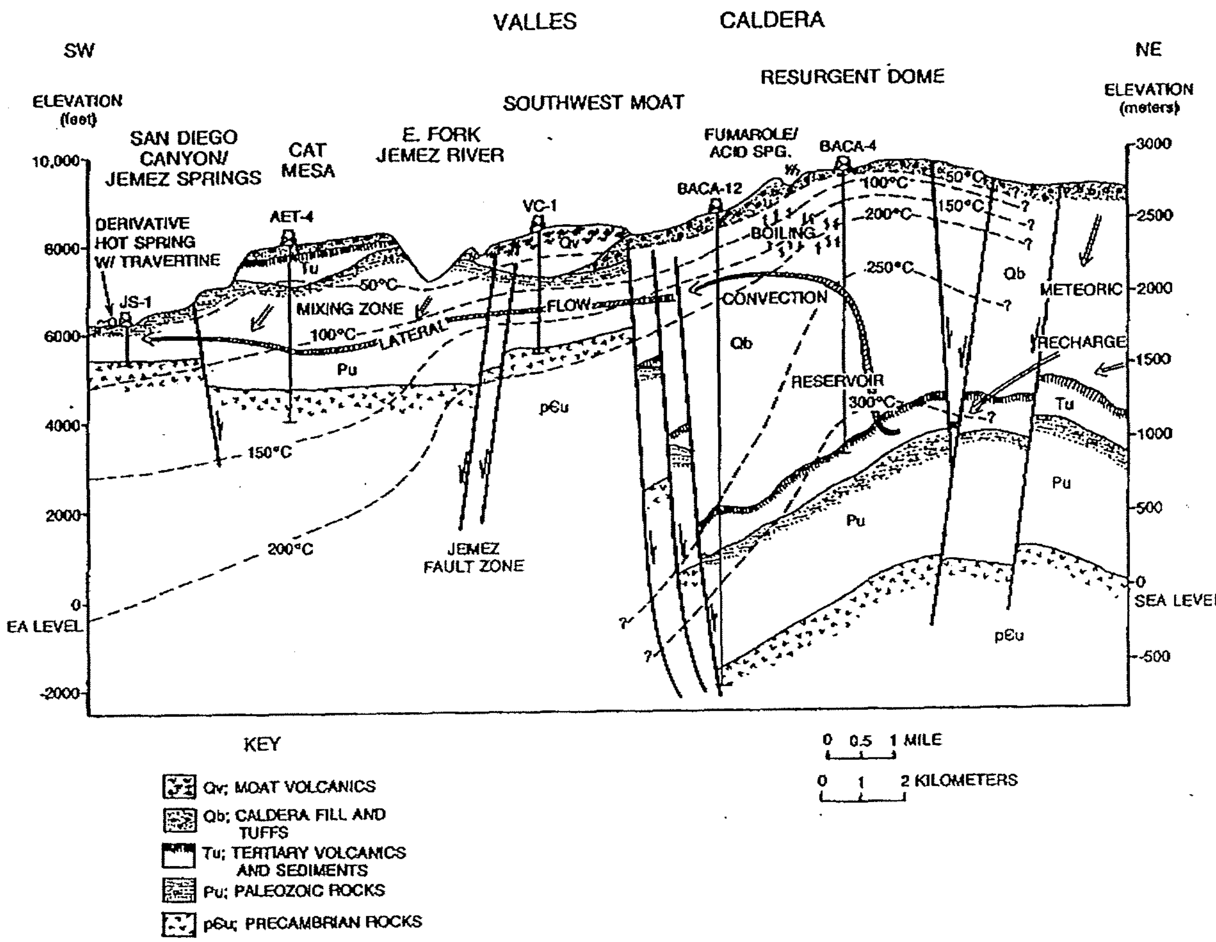
Casing Data:
1. Bottom of 9-5/8" casing: 2281 ft
2. 2-3/8" tubing: 0 - 4225 ft

Formations Encountered During Drilling:
1. Caldera Fill: 0 - 580 ft
2. Bandelier Tuff: 580 - 3100 ft
3. Tertiary Sediments: 3100 - 4000 ft
4. Permian Redbeds: 4000 - 4384 ft

The available pressure/temperature surveys for B-8 are shown in Figure 3.8. Temperature survey S3-T in B-8 is a nice boiling-point profile, indicating that boiling water is entering and flowing up the well. It, therefore, appears that B-8 penetrates two-phase conditions toward bottomhole, with no information available about conditions elsewhere.



. West-east conceptual geologic cross-section through the Sulphur Springs area and the west-central Valles caldera complex (see Fig. 7 for location). Control provided by geothermal wells along and north of the section, by CSDP corehole VC-2A, and by the geologic mapping of Goff and Gardner (1980). Section shows position of hypothetical Urad- and Climax-type stockwork molybdenum mineralization relative to the low-temperature, high-level molybdenite occurrence of VC-2A. Also shown is a hypothetical composite stock of high-silica rhyolite and granite genetically related to the molybdenum mineralization. From Hulen et al., 1987.



Southwest-northeast cross-section showing stratigraphy, structure, isotherms, and conceptual fluid pathline in the Valles hydrothermal system.

Table Aspects of tectonic, volcanic and magmatic evolution of the Valles caldera complex addressed by collaborating investigators.

TOPIC OF INVESTIGATION	INVESTIGATOR(S)	METHOD OF INVESTIGATION
Facies within caldera-fill units and their relationship to hydrothermal systems	Heiken, Broxton, Krier, Wohletz (LANL)	Geologic mapping, core logging, stratigraphic correlation, various petrographic techniques
Vertical variation in rock composition, VC-2B (as a guide to magmatic evolution	Goff (LANL)	Major/minor/trace element geochemistry and isotopic analysis of whole-core samples
	Wolff (UTA), Gardner, (LANL), Sykes (UTA), Self (UTA)	(Bandelier Tuff) petrographic study; geochemical analysis of whole-pumice and matrix in rhyolitic ignimbrite cores; correlation with outflow-sheet characteristics; integration of these data to model magmatic evolution
Pre- and post-eruptive volatile distributions in intracaldera rhyolites (as a guide to magmatic evolution)	Stix (UT), Gorton (UT), Williams (LSU)	Analysis of H_2O, CO_2, F, S, and Cl in melt inclusions in phenocrysts and in coexisting matrix glass
Paleomagnetic stratigraphy	Geissman (UNM)	Measurement of intensity, orientation, and polarity of paleomagnetism in core samples
Comparison of intracaldera ignimbrites with corresponding outflow sheets	Wolff (UTA), Gardner (LANL), Sykes (UTA), Self (UTA)	(Bandelier Tuff) integration of results of past field studies with petrographic, geochemical, and isotopic characterization of the Bandelier Tuff in cores from VC-2A and VC-2B
Geometry, caldera-fill characteristics, and evolution of the pre-Bandelier-age Lower Tuffs caldera	Hulen and Nielson (UURI)	(Lower Tuffs) detailed logging, petrographic examination, geochemical and isotopic analysis of cuttings from UOC geothermal wells and core from VC-2A and 2B; 3-D reconstruction of caldera
Petrography and composition of a hypothetical, subvolcanic, rhyolitic pluton beneath the VC-2B site	Musgrave (NMIMT)	Petrography, XRD
	Goff (LANL)	Major/minor/trace element geochemical and isotopic analysis of core

*numbers refer to research objectives listed on pages

Table Aspects of evolution of the Sulphur Springs hydrothermal system addressed by collaborating investigators.

TOPIC OF INVESTIGATION	INVESTIGATOR(S)	METHOD OF INVESTIGATION
Variation in fluid composition with depth and time	Musgrave (NMIMT)	Geochemical and light stable isotopic analysis of secondary phases and inclusion fluids; fluid-inclusion microthermometry; gas analysis of fluid inclusions.
	Bohlke (ANL)	Halogens and noble gas isotopes in fluid inclusions
	W-Gabriel (LANL)	Oxygen isotopes in sericite
	McKibben and Williams (UCR)	Gas analysis of fluid inclusions
	Sasada (GSJ)	Fluid inclusion microthermometry
Variation in temperature/ pressure with depth and time	Sasada (GSJ)	Fluid-inclusion microthermometry
	Musgrave (NMIMT)	Fluid-inclusion microthermometry
	Geissman (UNM)	Determination of past maximum temperatures by progressive demagnetization of rock
Sources of fluids at different stages of the system's evolution	Bohlke (ANL) and Irwin (UCB)	Halogens and noble gas isotopes in fluid inclusions
	Musgrave (NMIMT)	Light stable isotopic, helium isotopic, and Pb/Sr isotopic analysis of inclusion fluids
Relative ages of alteration/ mineralization events	Musgrave (NMIMT)	Surface geologic and alteration mapping, core logging, petrography
	Geissmann (UNM)	Measurement of intensity and polarity of secondary magnetism acquired during hydrothermal events
Absolute ages of alteration/ mineralization events; distinguishing present (active) from past alteration and mineralization	W-Gabriel (LANL)	K-Ar dating of hydrothermal sericites
	Sturchio and Bohlke (ANL)	U-series isotopic geochronology
Metamorphic and contact-metasomatic mineralogy, zoning, paragenesis; active metamorphic and metasomatic reactions (conductive/convective heat transfer zone)	Elston and Grambling (UNM)	Geochemical and light stable isotopic analysis of secondary phases and inclusion fluids; petrography, XRD

*numbers refer to research objectives listed on pages

Table continued. Aspects of evolution of the Sulphur Springs hydrothermal system addressed by collaborating investigators.

TOPIC OF INVESTIGATION	INVESTIGATOR(S)	METHOD OF INVESTIGATION
Sources and migration of sulphur in the Sulphur Springs hydrothermal system	McKibben (UCR) and Eldridge (ANU)	Sulphur isotopic analysis of sulfides, sulfates, and fluids
Sources of metals in the Sulphur Springs hydrothermal system	Musgrave (UNM)	Pb and Sr isotopic analysis of inclusion fluids and metallic minerals of hydrothermal origin
Mechanisms of alteration and metallic mineralization	Bohlke (ANL) and Irwin (UCB)	Halogens and noble gas isotopes in fluid inclusions
	Sasada (GSJ) Musgrave (NMIMT)	Phase relations in fluid inclusions
Clay mineral geothermometry	Ballantyne and Moore (UURI)	Sericite geochemistry and expandability as correlated with past and present temperatures
Compositions of unaltered lithologies (protoliths) as references for studies of alteration and fluid-rock interaction	Wolff (UTA), Gardner (LANL), Sykes (UTA), Self (UTA)	Major/minor/trace element and isotopic analysis of unaltered caldera-fill lithologies or their proximal-facies, outflow-sheet equivalents
	Elston and Grambling (UNM)	Major/minor/trace element and isotopic analysis of unaltered, pre-caldera lithologies.

*numbers refer to research objectives listed on pages

Table continued. Aspects of the active Sulphur Springs hydrothermal system addressed by collaborating investigators.

TOPIC OF INVESTIGATION	INVESTIGATOR(S)	METHOD OF INVESTIGATION
Subsurface configuration of fluid regimes	Wannamaker (UURI)	Controlled-source audiomagnetotelluric survey
Physical/chemical controls on contemporary hydrothermal alteration and metallic mineralization	Musgrave (NMIMT)	Combining geochemical and isotopic analyses of fluids and secondary phases with which they are in contact; computer modeling
	Sturchio and Bohlke (ANL)	U-series disequilibrium studies
	Laul and Gosselin (BPNWL)	Measurement of radionuclide abundance patterns, correlations, and activity ratios; REE geochemistry, relative abundances
Rates of mass transport	Laul and Gosselin (BPNWL)	U-series disequilibrium studies
	Sturchio and Bohlke (ANL)	U-series disequilibrium studies
Contemporary fluid sources	Kennedy (UCB)	Measurement of elemental and isotopic compositions of noble gases in fluids
	McKibben (UCR) and Eldridge (ANU)	Sulphur isotopic analysis of reservoir fluid
	Goff (LANL)	Geochemical and isotopic analysis of reservoir fluids
	Laul and Gosselin (BPNWL)	REE geochemistry of reservoir fluids
Physical/chemical controls on contemporary isochemical thermal metamorphism and contact metasomatism	Elston and Grambling	Geochemical and isotopic analysis of fluids, solutes, and the secondary minerals with which they are in contact

*numbers refer to research objectives listed on pages

Table Aspects of the active Sulphur Springs hydrothermal system addressed by collaborating investigators.

TOPIC OF INVESTIGATION	INVESTIGATOR(S)	METHOD OF INVESTIGATION
Thermal conductivity of reservoir rocks; heat flux at Sulphur Springs and throughout the Valles caldera complex	Sass (USGS), Morgan (NAU), Lachenbruch (USGS), Christensen (PU)	Thermal conductivity measurements of water-saturated VC-2B core at simulated reservoir pressures and temperatures; computer modeling
Variation in fluid composition with depth	Goff (LANL)	Geochemical and isotopic analysis of fluids collected both at the wellhead and at specific sites down the borehole
Current state-of-stress	Sattler (SNL)	Differential strain-curve analysis and/or waveform analysis; petrographic characterization of microcracking in oriented core; sonic wave amplitude and relative to core diameter and orientation
Nature of permeability and porosity	Owen and Little (TTR)	Measurement of permeability at simulated overburden pressure; 3-D reconstruction of porosity network from computerized X-ray tomography (CT) scans; measurement of visible fracture orientation using computerized goniometer
	Heiken, Broxton, Krier, Wohletz (LANL)	Characterization of primary permeability (nature and distribution) intracaldera volcanic and volcaniclastic units)
Electrical properties of reservoir rocks	Owen (TTR)	Measurement of dielectric permittivity and electrical resistivity of core at various simulated reservoir pressures and temperatures
Thermal conductivity of reservoir rock during drilling	Lee (NMIMT)	Mathematical modeling of effective thermal conductivity, theoretically removing effects of drilling fluid and its circulation

*numbers refer to research objectives listed on pages

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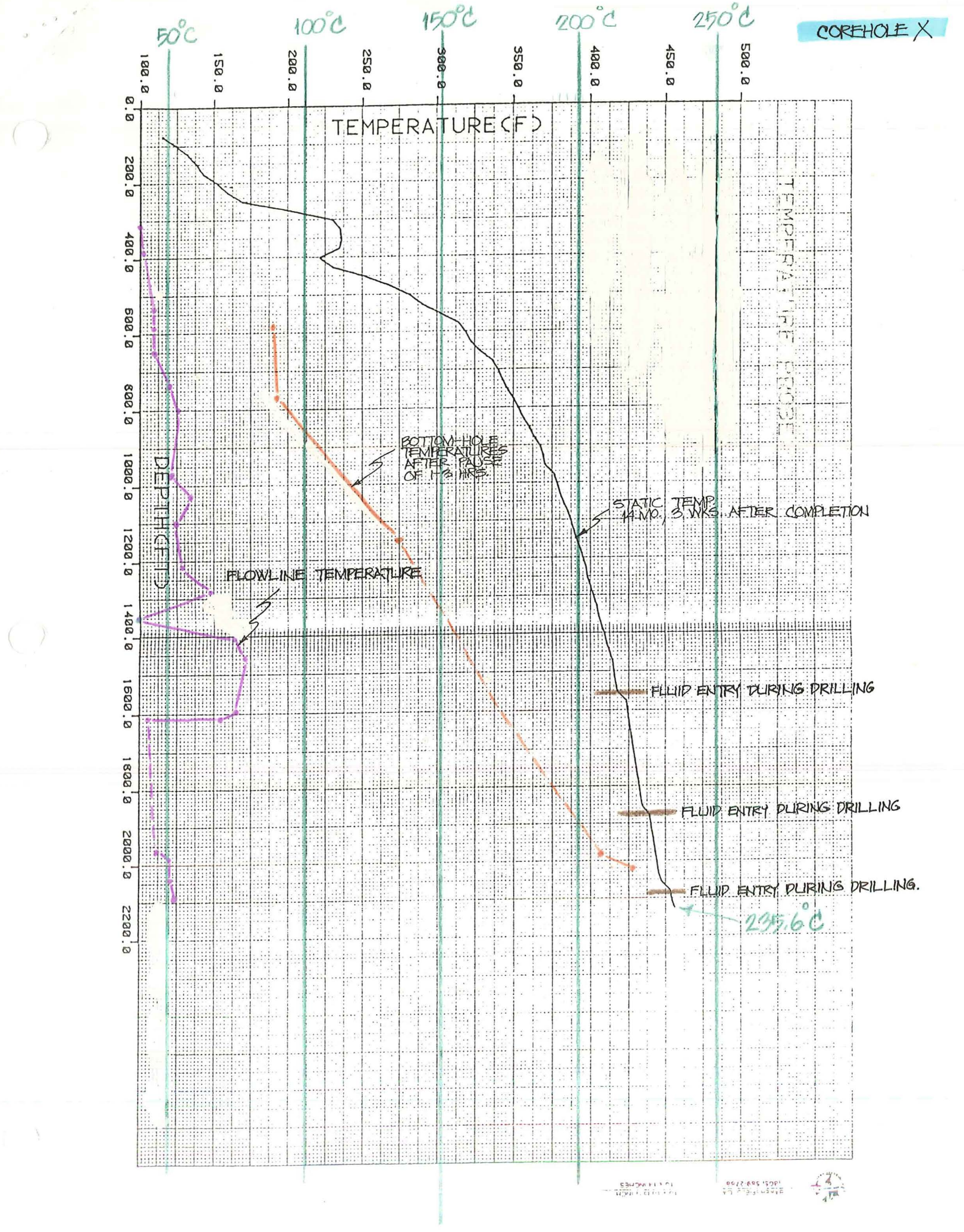
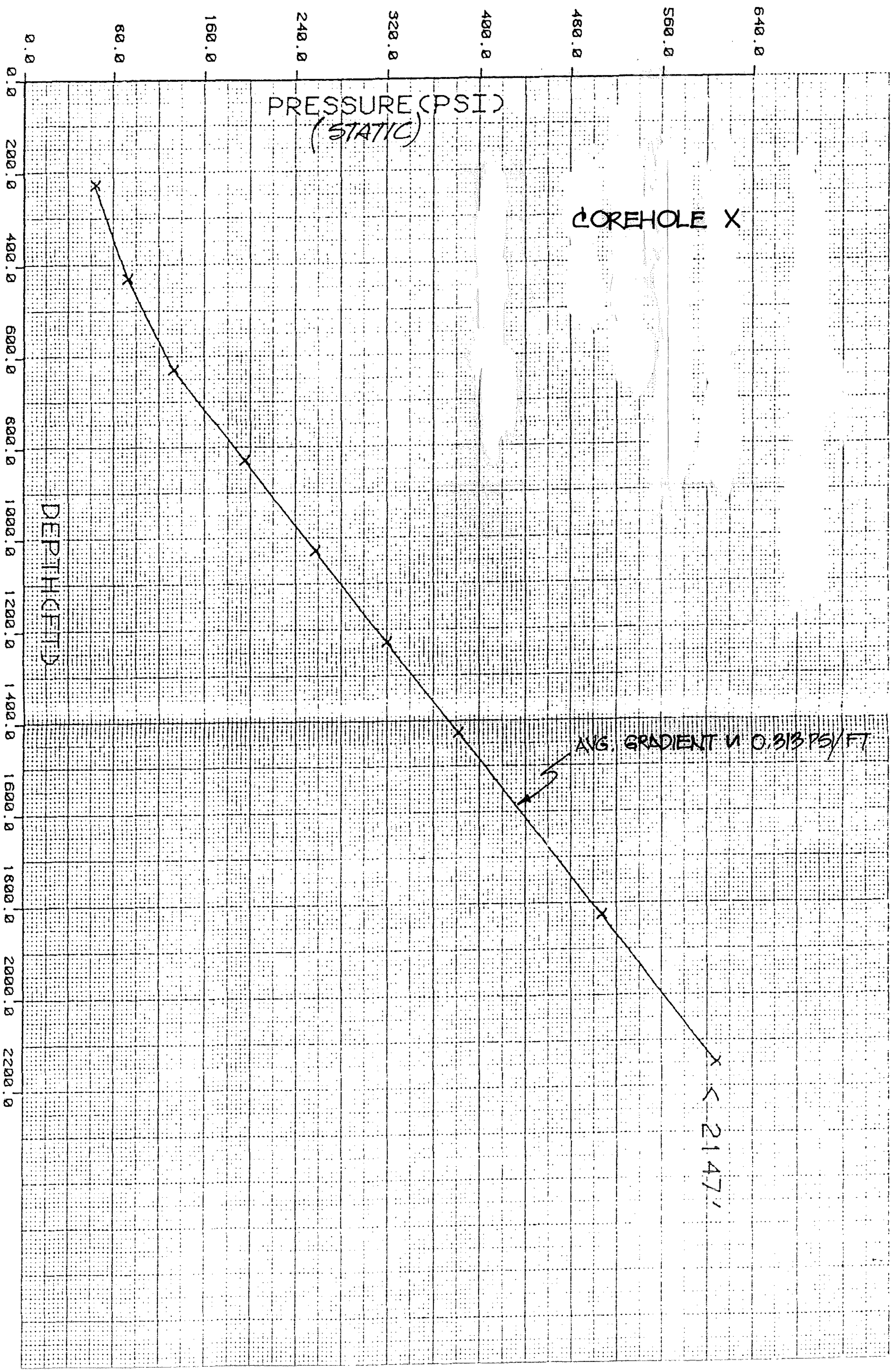
DAILY DRILLING SUMMARY, COREHOLE X

DATE	INTERVAL	BIT WEIGHT	RPM	MUD: CAKE	MUD: WT.	MUD: VIS	MUD: W/L	MUD: pH	COMPONENTS	FLOWLINE TEMP.	COMMENTS
05/21	314-319'								2 GEL 1 LIGNITE 1 SODA ASH		ROTARY TO 314'
05/22	319-475'	—	—	1/32"	8.4	30	15cc	11	1 GEL 1 POLYCORE 1 CMC	38.9°C @ 385'	
05/23	475-594'	—	—	—	—	—	—	—	3 GEL 1 SODA ASH	43.4°C @ 532', 588'	100% RECOVERY
05/24	594-696'	—	—	—	8.5	38	—	—	5 GEL 5 GAL POLYCORE L	43.4°C @ 650'	– BIT #2 @ 690' (LY HOWL) – CONDITION HOLE – WORK THRU BRIDGES @ 580'
05/25	696-732'	3000	600-800	—	8.4	40	—	—	3.5 GEL	48.9°C @ 730'	WORKING THROUGH BRIDGES AT 575'
05/26	732-908'	3500	"	—	8.5	40	—	—	3 GEL 1 CM (C?) 5 GAL. POLYCORE L	51.7°C @ 850'	– BIT #3 @ 859' (LY HOWL) – 100% RECOVERY
05/27	908-1079'	5000	"	—	—	36	—	—	5 GEL, 1 CMC 5 GAL POLYCORE L 1 SODA ASH	48.9°C @ 977', 56.7°C @ 1030'	– 100% RECOVERY
05/28	1079-1216'	"	"	—	—	36	—	—	4 GEL 1 SODA ASH 1 CAUSTIC	51.7°C @ 1100', 53.3°C @ 1215'	"
05/29	1216-1367'	"	"	—	9.4	50	—	12	5 GEL, 1? MON-PACK #50 5 GAL DRILLING DETERGENT 1 CAUSTIC 5 GAL VAN-FLAK 1 STA-FLO #50	64.4°C @ 1280', 37.8°C @ 1360'	"
05/30	1367-1448'	"	"	—	—	—	—	—	5 GEL 5 GAL. STA-FLO 1 SACK LIGNITE 2 SACKS CAUSTIC	73.3°C @ 1405', 76.7°C @ 1458'	BIT #4 @ 1386' ? LY HOWL
05/31	1448-1599'	5000	—	2/32	9.3	37	8.8	—	4 GEL, 5 GAL. STA-FLO 1 VAN-FLOCK 1 LIGNITE	73.9°C @ 1599'	MUD THICK W/SOLIDS; DUMPED, MIXED NEW BATCH
06/01	1599-1619'	"	—	1/32	8.4	40	6.4	—	25 SACKS GEL 2 STA-FLO 50# 2 CAUSTIC 50# 5 GAL VON FLOCK 1 SACK LIGNITE	68.3°C, then 40.6°C @ 1610'	HOLE "CAME IN" WHILE MUD WAS BEING CHANGED; SPENT 21 of 24 HRS. CONDITIONING HOLE.
06/03	1619-1695'	—	—	—	8.4	33	8.0	10	1 GEL, 1 CAUSTIC	—	BIT #7 @ 1652' (NO MENTION OF #5,6)
06/04	1695-1838'	2000	300-600	1/32	8.4	33	8.0	10	11 GEL, 5g. STA-FLO.	—	BIT #8 @ 1714' 100% RECOVERY
06/05	1838-1996'	2000	300-600	1/32	8.4	33	8.0	10	10 GEL, 5 (g?) STA-FLO 1 CAUSTIC	44.4°C @ 1961', 48.9°C @ 1985'	—
06/06	1996-2090'	2000	"	1/32	8.5	34	11.2	11	10 GEL ("W/POLYMERS")	49.4°C @ 2041', 51.1°C @ 2090'	BIT #9 @ 2013' (LY NOWL) 100% RECOVERY
06/07	2090-2146'	"	"	—	8.5	42	—	—	10 GEL 5 GAL POLYCORE "L"	—	CONDITION HOLE TO RUN TUBING; REMOVE BOP & CUT H ROD CASING @ 600'; RUN 66 JTS. 1½" TUBING TO 2146'. WELD TUBING TO 4½" CASING HEAD W/ DONUT; WELD 2" COLLAR BELOW HEAD TO 4½" CASING; CIRCULATE MUD FROM HOLE W/CLEAR WATER FOR 4 HRS.



CORHOLE X
50°C
100°C
150°C
200°C
250°C
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
TEMPERATURE (F)
TEMPERATURE PROBE
DEPTH (FT)
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
1600.0
1800.0
2000.0
2200.0
BOTTOM-HOLE TEMPERATURES AFTER PAUSE OF 1-1/3 HRS.
STATIC TEMP. 14 MO., 3 WKS. AFTER COMPLETION
FLOWLINE TEMPERATURE
FLUID ENTRY DURING DRILLING
FLUID ENTRY DURING DRILLING
FLUID ENTRY DURING DRILLING.
235.6°C


PRESSURE (PSI)
(STATIC)
DEPTH (FT)
COREHOLE X
AVG. GRADIENT ≈ 0.313 PSI/FT
< 2147'
0.0
80.0
160.0
240.0
320.0
400.0
480.0
560.0
640.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
1600.0
1800.0
2000.0
2200.0

COREHOLE X — ADDITIONAL NOTES

FLUID ENTRIES

FLUID ENTRY ~ 1550-1552': BRECCIA ZONE W/ FSP. CLASTS IN CALCITE MATRIX

" ~ 1875': (1868') → "QUARTZ VEINS W/UP TO 2" OPEN SPACE"
(1880') → "DOGTOOTH CALCITE, CHLORITE, EPIDOTE VEINLETS"

" ~ 2090': (2082'—2084') → "BROKEN, W/OPEN-SPACE CALCITE VEINLETS, SOME DOGTOOTH CALCITE."

MUD CHARACTERISTICS

	1996'	2110'	1848'	1704'	1599'	1448
WT.	8.5	8.5	8.6	8.3	9.3	8.8
FUNNEL VISC., SEC./QT.	? 34 ? (3?)	31	46	30 (6?)	37	34
APP. VIS	5	5	18	5	5	10
PLAST. VIS	3	4	12	4	10	?
YIELD PT.	5	2	3	2	10	10
GEL STRENGTH	3/4	3/5	4/5	3/4	6/7	5/8
pH	10	10	10	10?	8	8
API FLUID LOSS, CC/30m	11.2	12.6	8.0	16.4	8.8	8.8
FILTER CAKE THICKNESS	1/32	1/32	1/32	2/32	2/32	2/32
ALK. of FILTRATE	11.2?	?	.1/.2?	.1/.2?	.1/.2?	?
Cl, PPM	1400	1500	1600	1800	1700	1500
Ca, PPM	87	100	85	100	100	75
SAND, %	TR	TR	0.5%	TR	2%	2.5%
SOLIDS, %			4%		7%	6%

EOS, v. 69, p. 697 (1988)

Third Hole Planned at Valles Caldera

Valles caldera, N. Mex., is the culmination of more than 13 million years of volcanism in the Jemez volcanic field and is an excellent model for resurgent calderas and for the high-temperature geothermal systems found with them. This month one of the biggest diamond drills in the world will start the third research core hole in the caldera. Valles Caldera 2B will be the tenth core hole in the Department of Energy's Continental Scientific Drilling Program.

CSDP drilling in the 1.1-million-year-old caldera began in 1984 in the southwest moat zone when the research hole Valles Caldera 1 was continuously cored to 856 m. VC-1 intersected a hydrothermal outflow plume from the deep geothermal system. Data indicate multiple episodes of hydrothermal activity in the volcanic field's history, as well as multiple episodes of rhyolite magma generation during evolution of the caldera. The June 10, 1988 (vol. 63), issue of *Journal of Geophysical Research—Solid Earth and Planets* carried a special section on results from VC-1.

Core hole Valles Caldera 2A was drilled in 1986 to a depth of 528 m, into the shallow vapor cap of the Sulphur Springs hydrothermal system on the west flank of the resurgent dome. Research is still underway on VA-2A; preliminary results include production of superheated fluids from the top of the neutral chloride liquid-dominated zone of the hydrothermal system and identification of suboregrade molybdenite deposition at shallow depths from an earlier configuration of the evolving hydrothermal system (see *Eos*, July 28, 1987, cover and p. 649).

VC-2B will penetrate vapor and liquid zones of the active Sulphur Springs system and will bottom at about 1.75 km and 300°C in Precambrian granitic rocks. The core hole will be sited near the junction of the caldera's resurgent dome with the main ring fracture and will continuously sample Quaternary caldera-fill tuffs and sedimentary rocks, Miocene-Pliocene arkosic sandstones, Permian red beds, Pennsylvanian limestone, and Precambrian rocks. All will exhibit effects of young caldera-related hydrothermal activity and thermal metamorphism. The hole will be kept open for 4 years following drilling so researchers can do experiments and log or sample fluids.

Prime scientific objectives for VC-2B are to study

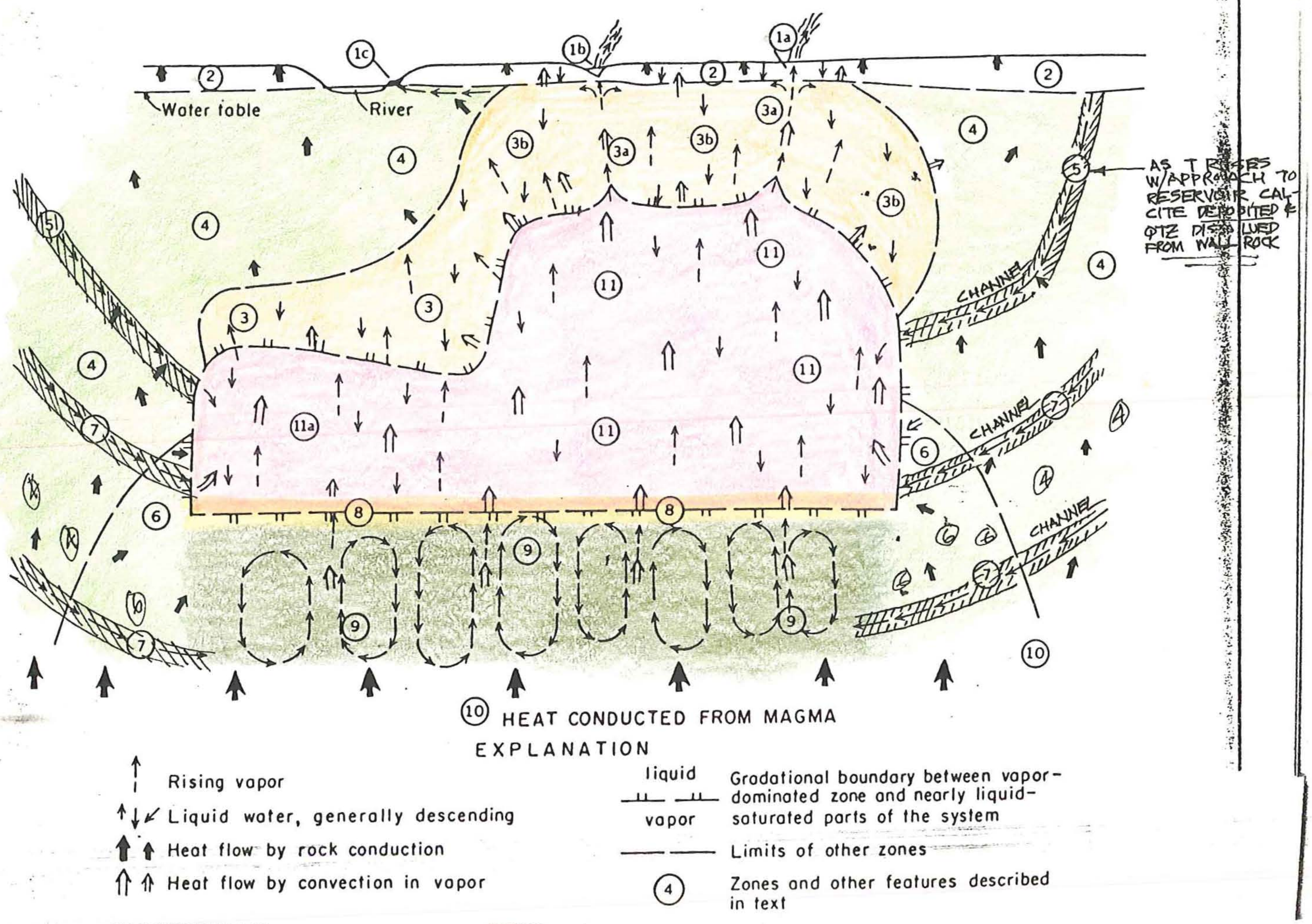
- structural and geochemical evolution of hydrothermal systems
- active ore deposition in geothermal systems
- development of vapor-dominated geothermal systems
- structural and magmatic development of large calderas
- physical chemistry of fluids and mineralization
- nature of boiling transition between vapor and liquid zones of the hydrothermal system
- structural settings and facies models for caldera-hosted natural resources
- heat transfer and active metamorphism in a conductive-convective thermal regime transition zone

Scientists interested in participating in the project, obtaining core or fluid samples, or conducting downhole experiments should contact Jamie Gardner or Fraser Goff (Los Alamos National Laboratory, MS D462, Los Alamos, NM 87545; tel. 505-667-1799) and Jeff Hulen (Earth Science Laboratory, University of Utah Research Institute, 391-C Chipeta Way, Salt Lake City, UT 84108; tel. 801-524-3446). Following completion of drilling and digestion of preliminary results, there will be an open workshop in spring 1989 to coordinate research activities and to evaluate and revise the long-range plan for continental scientific drilling at Valles caldera.

The VC-2B coring, logging, and associated logistics operations will be paid for by DOE's Office of Basic Energy Sciences. Most associated scientific studies will be supported by the U. S. Geological Survey, National Science Foundation, or DOE. Interested scientists should solicit research support by independent proposals to their customary funding agencies. After submission of proposals, coordination of proposal reviews and selection will be handled by the Interagency Coordination Group under the USGS/NSF/DOE Accord for Continental Scientific Drilling.

This news was contributed by Jamie Gardner, *Los Alamos National Laboratory, New Mexico.*

MODEL OF A TRUE VAPOR-DOMINATED SYSTEM. FROM WHITE ET AL., 1971



(8) DEEP SUBSURFACE WATER TABLE

(3) CONDENSATE ZONE – Nearly saturated with liquid water condensed from steam. Rich in clays (kaolin & montmorillonite). Pressure slightly above hydrostatic because may be major channels of upflowing steam from (11), w/

"CAP" impeding free escape of rising vapor

(11) VAPOR-DOMINATED RESERVOIR – Vapor & Liquid Water Co-exist

LIQUID-DOMINATED