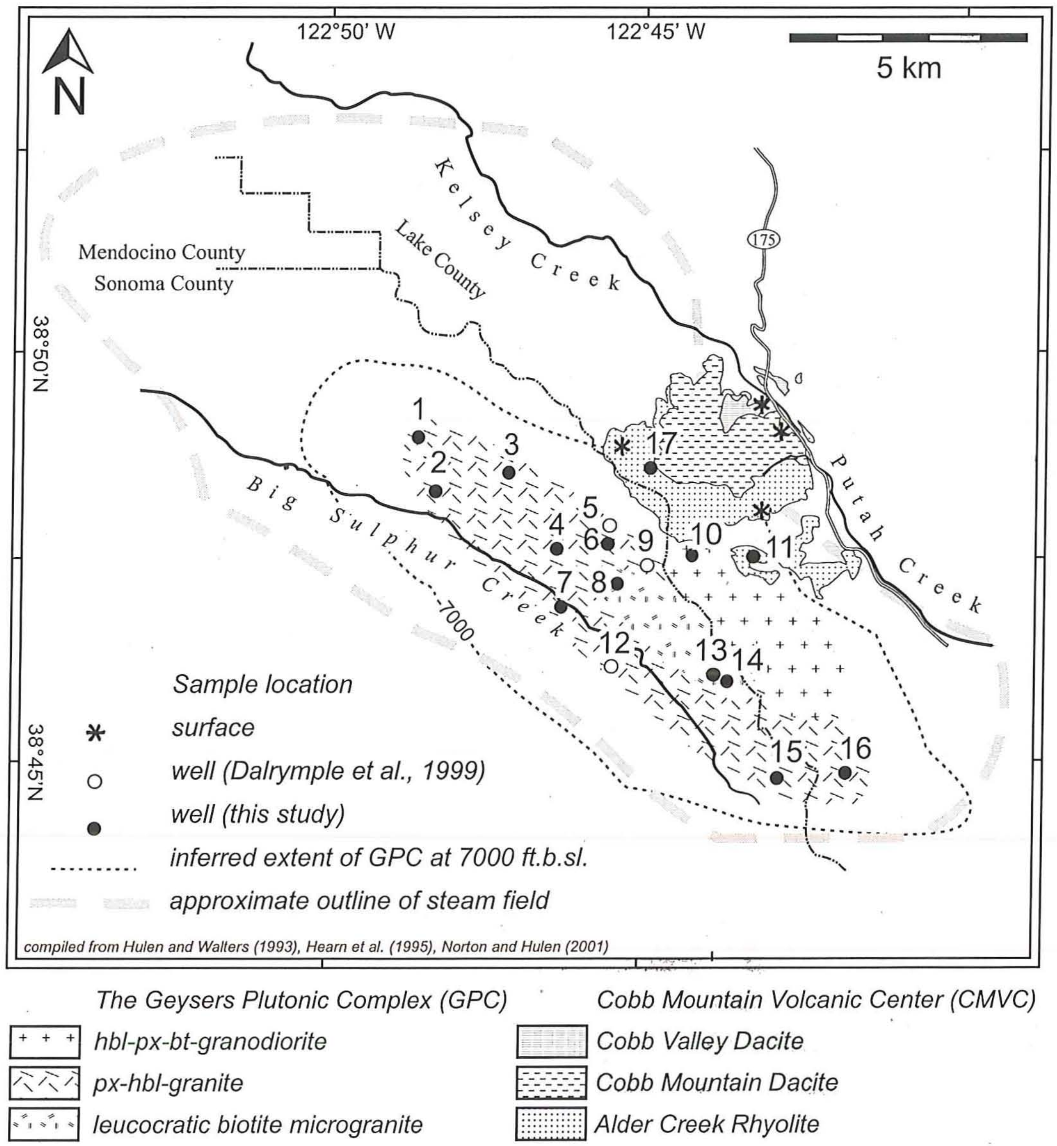
FELSITE, GENERAL



	well	*sampled depth (m.b.sl.)*					*sampled depth (m.b.sl.)*		
1	**OF21C-12**	1793-1885			9	**ANG-1**	2425-2428		
2	**SB24**	1691-1795			10	**SF74F-21**	2130-2140	2469-2479	2835-2845
3	**DX84**	2434-2446			11	**PDC2**	1250-1256		
4	**GDCF 123-19**	1049-1110	1781-1842		12	**FF52**	1930-1933		
5	**LF23**	2058-2061			13	**DV2**	195-198	878-881	1566-1569
6	**LF40-ST3**	1793-1827			14	**DV- 25 ST2**	614-1133		
7	**GDC-5**	1813-1839			15	**NCPA J5**	1983-2227		
8	**LF48**	1585-1588			16	**NCPA J4**	1931-1989		
					17	**NEGU 2**	1272-1315		

Intrusive emplacement and thermal history of the Geysers Plutonic Complex, northern California: New insights from in-situ U-Pb zircon dating

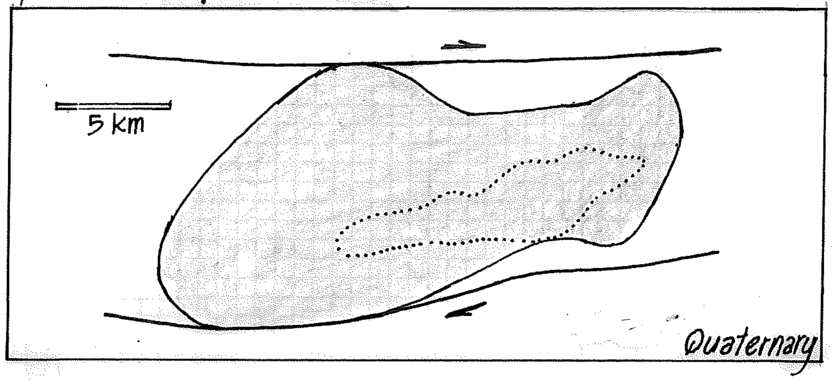
Axel K. Schmitt, Marty Grove, T. Mark Harrison, Jeffrey Hulen, Mark Walters

The Geysers Plutonic Complex (GPC) is a unique example of a Quaternary intrusion that is exposed at shallow subsurface levels (~0.7 km depth). It spatially overlaps with a major surface heat-flow anomaly that is associated with one of the world's largest geothermal fields, known as The Geysers. Based on drill hole penetration, the GPC appears as an elongated northwest-trending keel shaped body which has an areal extent of ~50 km^2. It has been petrographically subdivided into microgranite porphyry, granite and granodiorite and compositional similarities of these subunits linked them to the extrusive rhyolites and dacites from the Cobb Mountain Volcanic field (CMVF) that overly the GPC at its eastern margin, but little is known about the relative timing of the intrusive and related volcanic activities. Age determination of the GPC requires in-situ techniques due to xenocrystic contamination of drill cuttings that are generally the only available materials from the GPC. Meaningful ages reported in the literature are limited to four samples from the GPC granite unit that range from 1.13 to 1.25 Ma ($^{238}U/^{206}Pb$ ages uncorrected for initial ^{230}Th-deficit). Here we present U-Pb zircon ages for an extended sample set that covers all subunits of the GPC and the CMVF. These ages provide new constraints on the onset and duration of intrusive emplacement of and eruptive tapping from a shallow magma body.

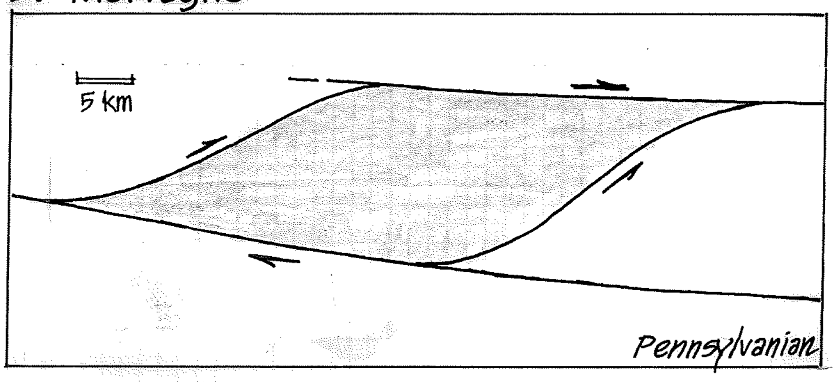
Apparent $^{238}U/^{206}Pb$ ages (1.52 – 1.74 Ma, 1σ uncertainty typically <5 % relative) for five samples of microgranite porphyry including a microgranitic dike rock exceed the ages determined for the granite and granodiorite units (1.13 – 1.25 Ma, 14 samples total). One well at the eastern margin of the GPC penetrated 0.8 km of previously unidentified biotite-orthopyroxene-hornblende granite that yielded slightly younger $^{238}U/^{206}Pb$ ages between 1.05 and 1.08 Ma (three samples). U-Pb ages from the CMVF (1.20 – 1.24 Ma, four samples) closely overlap with the age range of the granite and the granodiorite. Initial ^{230}Th deficit in zircon results in radiogenic ^{206}Pb contents that are on average by 5-10 % too low, and therefore an average +0.10 m.y. age correction is required. After applying this correction, we obtain an average zircon crystallization age for the CMVF that is about 0.20 m.y. older than the eruption ages implied by Ar-Ar sanidine ages (1.15 ± 0.01 to 1.01 ± 0.06 Ma). The eruption ages are close to the corrected zircon crystallization ages of the biotite-orthopyroxene-hornblende granite.

The data indicate a complex intrusive history for the GPC and a time span of at least 0.8 m.y. for its formation. Volcanic activity is temporally and spatially linked to the last intrusive phase but the erupted magmas appear to consist of remobilized older materials of previous intrusions. Intrusive activity within the main body of the GPC ceased at ~1.0 Ma which suggests that the GPC at its presently known extent is unlikely to be the heat source for the present-day heat-flow anomaly at the Geysers steam field.

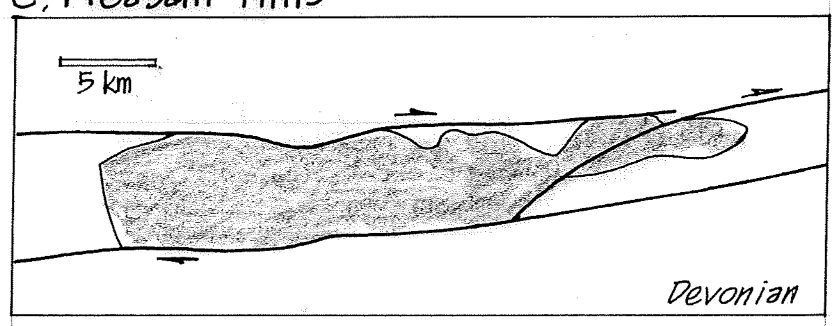
A. The Geysers



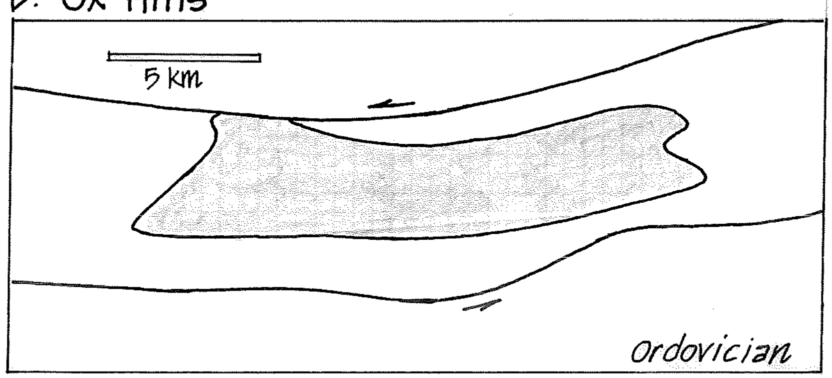
B. Mortagne



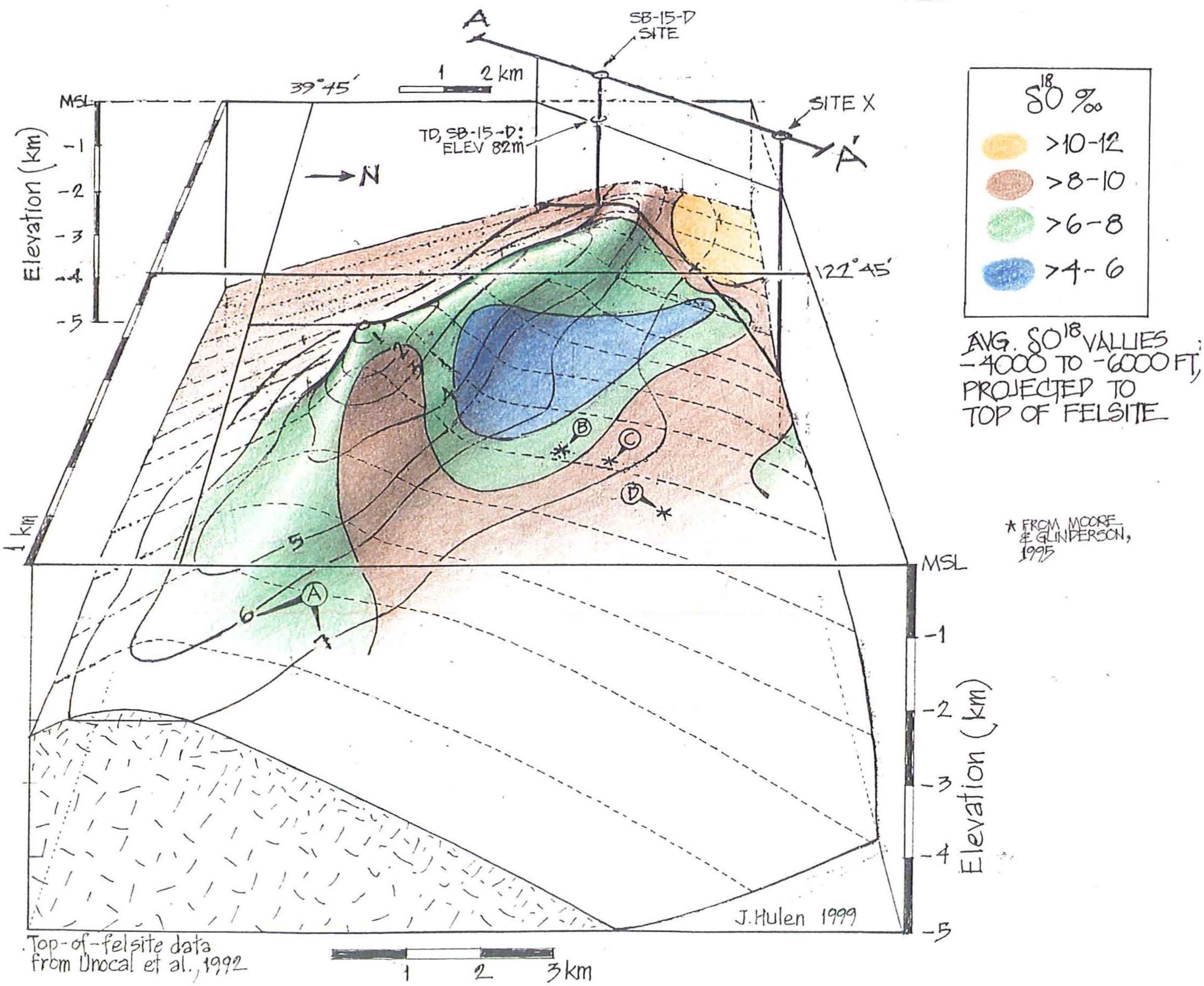
C. Pleasant Hills



D. Ox Hills



DRAFT



Top-of-felsite data from Unocal et al., 1992

Ⓐ ELEVATION CONTOUR, FT × 10^3 BELOW MEAN SEA LEVEL (MSL)

* VENT LOCATIONS, COBB MTN. VOLCANIC CENTER, PROJECTED VERTICALLY DOWNWARD TO TOP OF FELSITE

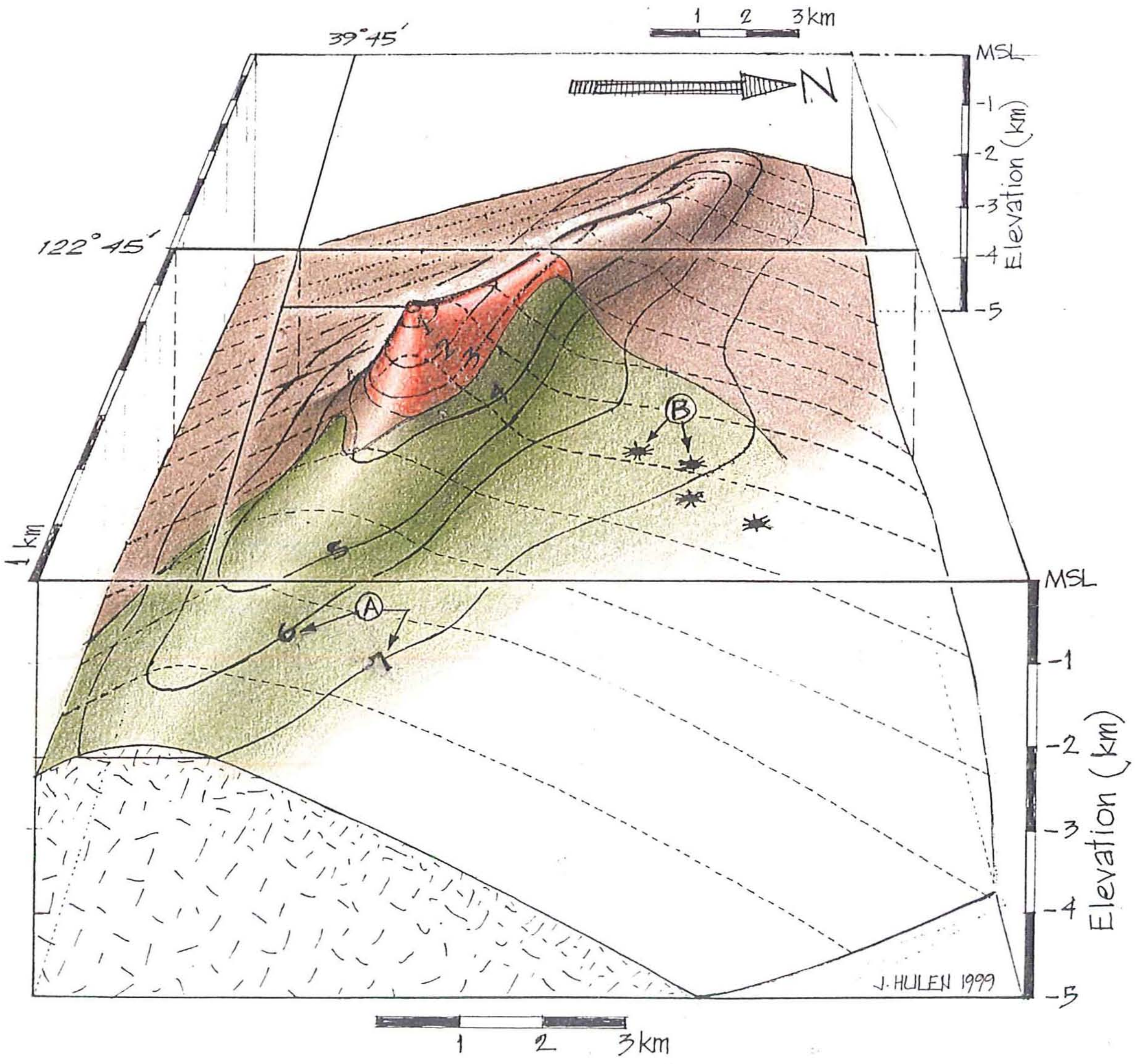
Ⓑ Rhyolite of Alder Creek (1.2 Ma), elev. 1390 m

Ⓒ Dacite of Cobb Mtn. (1.1 Ma), elev. 1430 m

Ⓓ Dacite of Cobb Valley (1.1 Ma), elev. 1100 m

FIGURE 1 PERSPECTIVE 3-D BLOCK DIAGRAM OF THE UPPER SURFACE OF THE GEYSERS FELSITE. SECTION A-A′, WHICH PASSES THROUGH COREHOLE SB-15-D, WAS CHOSEN FOR NUMERICAL THERMAL HISTORY MODELING TO APPROXIMATE PEAK PALEOTEMPERATURES OBTAINED FROM FLUID-INCLUSIONS AND VITRINITE REFLECTANCE.

DRAFT
2



3-D PERSPECTIVE DIAGRAM SHOWING TOPOGRAPHY AND INTRUSIVE ROCK TYPES AT THE UPPER SURFACE OF THE GEYSERS FELSITE. BROWN — Biotite-orthopyroxene granite (probably porphyritic). SCARLET — Biotite-pyroxene(?) microgranite porphyry. GREEN — Biotite-hornblende-orthopyroxene granodiorite. Ⓐ Elevation contours in feet x 10³ below sea level. Ⓑ Vent locations, Cobb Mtn. volcanic center, projected vertically downward to top of felsite.

Lotus file Hulen.wk3

sample	descriptio.	_ymbol	code	age (Ma)	volume (km3)	SiO2	TiO2	Al2O3	Fe2O3	FeO	MnO
H75.1a	andes. Ford Flat	aff	a	1.71		58.5	0.72	16.80	1.60	3.50	0.07
CL440	andes. Ford Flat	aff	a	1.71		60.0	0.74	16.90	0.97	4.10	0.08
H72.51a	dac. Cobb	dc	d	1.05	0.37	68.0	0.52	15.80	1.90	1.10	0.06
F92-34	dac. Cobb	dc	d	1.05	0.37	66.84	0.716	15.89	3.88		0.060
H75.09b	dac. Cobb Valley	dcv	d	1.08	0.04	65.3	0.53	15.70	0.67	2.70	0.05
F91-17	dac. Cobb Valley	dcv	d	1.08	0.04	65.79	0.615	17.47	4.1	0	0.055
H72.5	dac. Cobb Valley	dcv	d	1.08	0.04	64.7	0.50	16.80	1.80	1.90	0.05
F92-33	rhy. Alder Ck.	ra	r	1.10	4.1	69.97	0.355	14.35	2.72		0.046
H72.44c	rhy. Alder Ck.	ra	r	1.10	4.1	72.4	0.18	15.30	1.50	0.32	0.01
H76.59	rhy. Alder Ck.(?)	ra/dc	d	1.11	4.1	66.4	0.48	16.60	2.20	1.20	0.06
H76.17	rhy. Alder Ck.	ra	r	1.10	4.1	74.1	0.22	14.20	1.10	0.52	0.03
H73.75d	rhy. Alder Ck.	ra	r	1.10	4.1	71.6	0.25	14.80	1.50	0.60	0.00

sample	MgO	CaO	Na2O	K2O	[illegible]+	H2O-	P2O5	Total	Total*
H75.1a	4.80	7.40	3.20	1.40	0.59	0.14	0.19	98.91	98.18
CL440	4.70	7.80	3.30	1.30	0.31	0.02	0.18	100.40	100.07
H72.51a	0.72	2.50	3.50	3.20	1.50	0.82	0.15	99.77	97.45
F92-34	1.14	3.69	3.71	2.97			0.161	99.06	99.06
H75.09b	3.10	3.50	3.80	2.50	0.49	0.05	0.19	98.58	98.04
F91-17	2.57	1.74	3.085	2.78	0	0	0.13	98.335	98.335
H72.5	2.50	3.20	3.40	2.40	1.40	0.78	0.17	99.40	97.22
F92-33	1.27	2.52	3.24	3.91			0.094	98.47	98.47
H72.44c	0.25	1.00	2.80	4.00	1.40	0.33	0.04	99.53	97.80
H76.59	1.50	3.30	3.20	2.90	0.52	0.58	0.10	99.04	97.94
H76.17	0.50	1.20	3.60	4.20	0.67	0.15	0.03	100.52	99.70
H73.75d	0.77	1.60	3.30	3.40	1.20	0.51	0.11	99.64	97.93

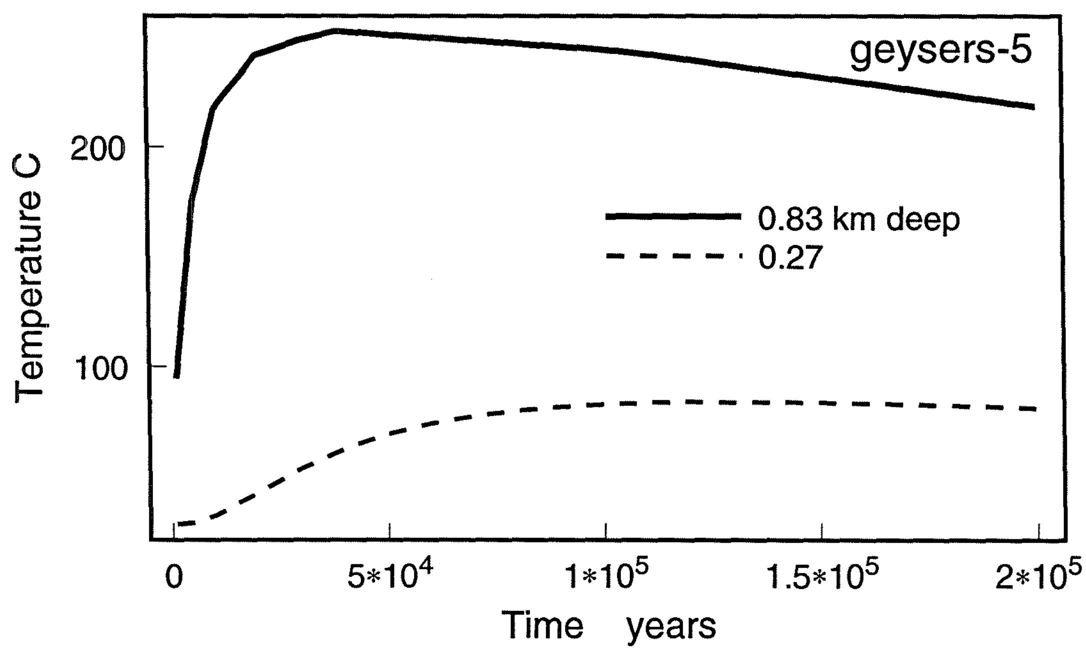
sample	SiO2*N	TiO2*N	Al2O3*N	Fe2O3*N	FeO*N	MnO*N	MgO*N	CaO*N	Na2O*N	K2[illegible]	[illegible]O*N	FeOT
H75.1a	59.58	0.73	17.11	1.63	3.56	0.07	4.89	7.54	3.26	1.43	0.19	5.03
CL440	59.96	0.74	16.89	0.97	4.10	0.08	4.70	7.79	3.30	1.30	0.18	4.97
H72.51a	69.78	0.53	16.21	1.95	1.13	0.06	0.74	2.57	3.59	3.28	0.15	2.88
F92-34	67.48	0.72	16.04	3.92	0.00	0.06	1.15	3.72	3.75	2.99	0.16	3.53
H75.09b	66.61	0.54	16.01	0.68	2.75	0.05	3.16	3.57	3.88	2.55	0.19	3.37
F91-17	66.90	0.63	17.77	4.17	0.00	0.06	2.61	1.77	3.14	2.83	0.13	3.75
H72.5	66.55	0.51	17.07	1.85	1.95	0.05	2.57	3.29	3.50	2.47	0.17	3.62
F92-33	71.06	0.36	14.57	2.76	0.00	0.05	1.28	2.56	3.29	3.97	0.10	2.48
H72.44c	74.03	0.18	15.64	1.53	0.33	0.01	0.26	1.02	2.86	4.09	0.04	1.71
H76.59	67.80	0.49	16.95	2.25	1.23	0.06	1.53	3.37	3.27	2.96	0.10	3.25
H76.17	74.32	0.22	14.24	1.10	0.52	0.03	0.50	1.20	3.61	4.21	0.03	1.51
H73.75d	73.11	0.26	15.11	1.53	0.61	0.00	0.79	1.63	3.37	3.47	0.11	1.99

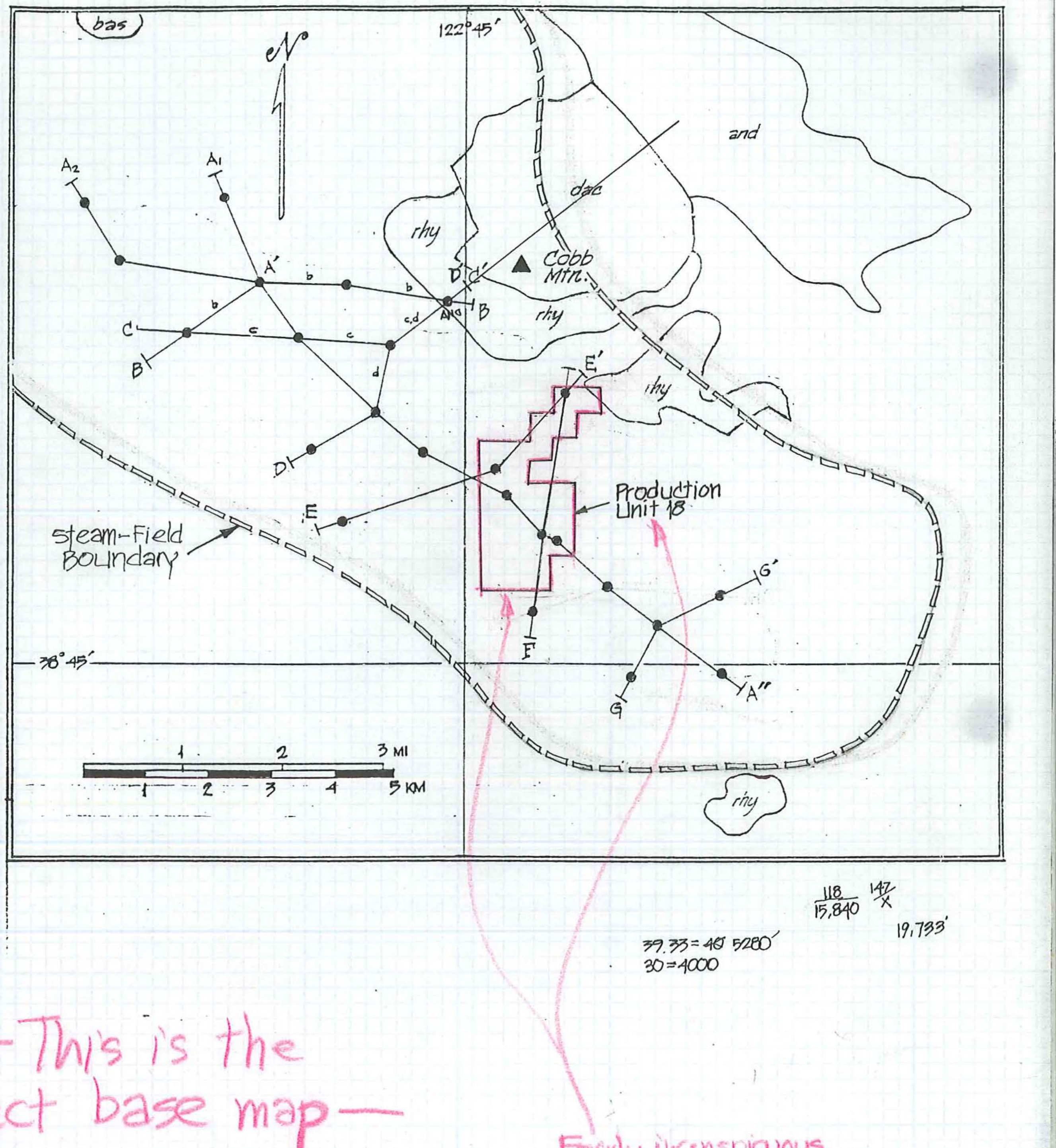
CLEAR LAKE VOLCANICS							
	Sample#		Description	symbol	code	age	volume
B	1952	ft.	Republic Core Boggs 1	rbp	r		
H	72.52		obsid, Borax L	rb	r	0.09	0.087
H	73.09	A	rhy, Bonanza Spgs tuff	rbp	r	1.02	1.6
H	75.39		rhy, Hildebrand	rh	r	0.55	0.001
*			Carmichael Bottle R. obsid	ro	r		
RLS			obsid, Manning Flat	ro	r	0.50	6.2
B	1756	ft.	Republic Core Boggs 1	rbp	r		
H	75.47		obsid, Napa Glass Mtn	sv	sv		
H	72.73	D-1	obsid, Camelback Ridge	ro	r	0.55	
H	73.4	B	obsid vent ENE McIntire	rh	r		
H	72.53	C	bi rhy, Cole Ck	rcc	r	0.50	0.93
H	73.69	C	bi rhy E Kelsey-Cobb Fire	rr	r		
H	73.31	A	rhy pum, N of McIntyre Cr	rh	r		
H	75.32	B	rhy, Bonanza Spgs, obsid	rbp	r	1.02	
RG	173	75	rhy, welded tuff, Sonoma V.	sv	sv		
H	76.17		rhy, Alder Ck	ra	r	1.10	
CL	216		bi rhy, Red Hills Rd.	rrp	r	0.50	0.066
H	74.61	B	bi rhy, NE Mt. Olive	rpo	r	0.55	0.013
CL	181		rhy, Milky Ck	rm	r	0.60	0.27
H	74.65	A	bi rhy, Honeycutt	rps	r	0.54	
H	72.44	C	rhyolite, Cobb Mt	ra	r	1.10	
H	73.75	D	rhy, Cobb Mt	ra	r	1.10	4.1
H	73.66	E	bi rhy 1mi E Mt. Olive	rcl	r	0.50	0.016
B	1437	ft.	Republic Core Boggs 1	dhf	r		
CL	486		rhy, Pine Mtn	rpm	r	2.06	0.02
CL	520		rhy pum nr. Steinhart Lakes	rsl	d		
H	73.48		dac, Kelsey Ck gorge	dkc	r	0.55	0.47
H	73.64	C	dac, Mt. Olive	do	r	0.53	0.58
H	75.21	F	dac, N of Camel's Hump	dch	d	0.59	
H	77.01	B	sandstone, GV seq under aph	gv	gv		
H	76.46	A	dac, Sugarloaf	dsl	d	0.60	0.31
H	74.63	C	dac, Shaul Spg	dss?	d		0.7
H	73.18	A	dac, Sulphur Mound Mine	dsm	d	0.57	0.78
61	WCL	1	dac, Horseshoe Bend, by CW	dh	d	0.35	1.55
CL	540		dac, xl-rich, NNE Wright Pk	dk	d	0.35	0.097
H	72.51	A	dac of Cobb Mt	dc	d	1.05	0.37
H	74.45		dac, Camel's Hump	dch	d	0.59	0.29
CL	85		pyx dac, Loch Lomond	dd	d	0.92	0.47
MH	1006		core, dac, Harrington Flat?	dhm	d	0.90	
CL	118	gl	rhy, Anderson I, glass sep.	dh	d	0.40	
MH	860		core, dac, Mt. Hannah	dhc	d	0.90	
H	73.52		dac, Seigler Mt	ds	d	0.61	0.47
H	72.1	C-1	dac, Loch Lomond, H73-10C	dl	d	0.90	0.58
H	75.05	A	dac, Rockledge	dr	d	1.20	0.001
CL	485		dac, Turner Flat	dtf	d	2.10	
H	72.7	B	dac, Seigler Mt	ds	d	0.61	
H	72.24		dac, Wright Pk	dwp	d	0.35	0.2
B	1427	ft.	Republic Core Boggs 1	dhm	d	0.90	
H	72.22	A	dac, South Pk., Konocti	dbr	d	0.35	
CL	480		dac, Appletree Ck	da	d	2.10	0.002
H	72.46	B	dac, Soda Bay	dsb	d	0.40	
H	74.62	D	dac, Peacock Point	dpp	d	0.60	0.027
H	72.27	B	dac, NE Split-Top Ridge	dd	d	0.92	
CL	203		dac, Soda Bay dome	dsb	d	0.41	5.1
H	76.26	B	dac, Ely Ridge	dko	d	0.45	0.41
H	76.59		rhy, SE Cobb Mt	ra	d	1.11	
H	73.57	A	dac, Henderson Pt.	dhp	d	0.40	0.7
CL	493		dac, Cache Ck	dcc	d	0.40	0.12
CL	383		coarse-gr dac, Mt. Hannah	dhc	d	0.90	
CL	407		dacite of Plum Flat	dpf	d	0.45	1.05
H	73.9146		pyx dac, Boggs L	db	d	0.98	0.039

CLEAR LAKE VOLCANICS							
	Sample#		Description	symbol	code	age	volume
CL	543		dacite, Grizzly Pk	dg	d		
CL	386		dac, Harrington Flat	dhf	d	0.90	0.25
H	74.74	A	dac E. of Shaul V.	dsv	d	0.45	0.31
H	74.9119		dac, Pinkeye Lake	dpl	d	0.48	0.19
H	75.09	B	dac, glassy, Cobb V.	dcv	d	1.08	0.04
H	72.5		dac, Cobb Valley	dcv	d	1.08	
H	76.23	B	dac, Benson Ridge?	dbr	d	0.35	
CL	268		Thurston Dac=Cl 15	dt	d	0.45	1.7
H	76.18		dac, Buckingham Bluffs	dbb	d	0.40	2.7
H	72.57	A	dac, Chalk Mt	dcm	d	0.90	0.009
CL	269		dac, Cache Ck	dhi	d	0.52	0.12
H	76.17	D	dac, xl-poor, NNE Wright Pk	dk	d	0.35	
H	77.01	A	incl, schist, Perini	aph	i		
H	72.55	D	dac, Mt. Hannah	dhm	d	0.90	
H	75.4		dac, Clearlake Park	dcp	d	0.10	0.027
H	75.01	B	dac, Tyler Valley	dtv	a	0.84	0.003
H	74.46	C	dac in diatreme, Camel's Hu	ddb	d		
H	72.55	J	dac, Mt. Hannah	dhm	d	0.90	0.093
CL	267		dac, Konocti Bay	dkb	d	0.45	1.6
H	74.5		dac, Vulture Rock	dv	d	0.44	0.16
CL	266		dac, Fraser Pt.	df	d	0.40	3.7
H	73.8	A	dac, Wheeler Pt.	dw	d	0.45	0.35

CLEAR LAKE VOLCANIC													
			Normalized analyses, volatile-free										
	Sample#		SiO2*N	TiO2*N	Al2O3*N	Fe2O3*N	FeO*N	MnO*N	MgO*N	CaO*N	Na2O*N	K2O*N	P2O5*N
B	1952	ft.	77.6	0.09	13.28	0.21	0.66	0.03	0.10	0.90	2.78	4.32	0.00
H	72.52		76.7	0.03	12.96	0.31	0.72	0.00	0.45	0.67	3.62	4.52	0.03
H	73.09	A	75.9	0.05	13.75	0.53	0.89	0.03	0.12	0.81	3.64	4.25	0.03
H	75.39		75.9	0.27	13.75	0.51	0.71	0.02	0.22	1.04	2.94	4.62	0.00
*			75.5	0.26	13.17	0.19	1.06	0.03	0.22	1.10	3.55	4.86	0.03
RLS			75.5	0.24	13.28	0.28	1.04	0.03	0.22	1.02	3.53	4.85	0.03
B	1756	ft.	75.5	0.09	13.83	0.30	1.00	0.04	0.20	0.92	3.91	4.21	0.05
H	75.47		75.4	0.13	13.29	0.65	0.85	0.02	0.26	0.63	4.36	4.36	0.05
H	72.73	D-1	75.1	0.21	13.82	0.10	1.20	0.00	0.29	1.00	3.61	4.61	0.06
H	73.4	B	75.1	0.25	13.55	0.31	1.22	0.02	0.33	1.12	3.46	4.59	0.05
H	72.53	C	75.0	0.27	14.29	0.48	0.79	0.01	0.15	1.04	3.21	4.76	0.01
H	73.69	C	74.8	0.30	13.80	0.10	1.41	0.00	0.35	1.21	3.63	4.33	0.09
H	73.31	A	74.7	0.25	14.73	0.52	0.96	0.00	0.25	1.04	3.13	4.39	0.05
H	75.32	B	74.7	0.07	14.87	0.25	1.00	0.02	0.16	0.84	3.72	4.32	0.07
FG	173	75	74.6	0.26	14.33	1.32	0.24	0.03	0.11	0.59	4.17	4.27	0.08
H	76.17		74.3	0.22	14.24	1.10	0.52	0.03	0.50	1.20	3.61	4.21	0.03
CL	216		74.3	0.26	14.59	0.41	0.95	0.04	0.12	1.55	3.21	4.55	0.04
H	74.61	B	74.3	0.23	13.97	0.80	0.96	0.03	0.50	1.50	3.39	4.29	0.07
CL	181		74.1	0.14	14.82	0.77	0.40	0.05	0.27	1.51	3.63	4.24	0.04
H	74.65	A	74.1	0.28	14.96	1.32	0.57	0.00	0.34	1.02	2.85	4.58	0.01
H	72.44	C	74.0	0.18	15.64	1.53	0.33	0.01	0.26	1.02	2.86	4.09	0.04
H	73.75	D	73.1	0.26	15.11	1.53	0.61	0.00	0.79	1.63	3.37	3.47	0.11
H	73.66	E	72.9	0.36	14.93	0.93	1.24	0.00	0.58	1.54	3.09	4.33	0.09
B	1437	ft.	72.3	0.35	15.17	0.72	1.23	0.04	0.92	2.46	3.28	3.49	0.05
CL	486		72.3	0.32	14.43	0.57	1.56	0.03	0.84	1.77	3.53	4.57	0.10
CL	520		72.3	0.27	15.68	1.02	1.03	0.03	0.28	2.26	3.44	3.65	0.08
H	73.48		72.2	0.31	14.20	1.41	0.77	0.04	1.61	2.42	3.42	3.53	0.08
H	73.64	C	71.7	0.35	14.16	2.04	0.57	0.05	1.73	2.55	3.26	3.46	0.12
H	75.21	F	71.3	0.37	14.36	1.54	0.90	0.04	2.77	3.38	3.69	1.54	0.11
H	77.01	B	71.1	0.49	12.90	1.42	1.42	0.25	1.02	7.11	2.51	1.64	0.16
H	76.46	A	70.8	0.45	15.10	2.53	0.41	0.04	1.11	2.03	3.55	3.85	0.10
H	74.63	C	70.8	0.41	14.77	2.04	0.73	0.05	1.32	2.44	3.46	3.87	0.11
H	73.18	A	70.8	0.41	15.82	2.19	0.92	0.02	1.25	1.87	3.12	3.54	0.11
61	WCL	1	70.5	0.35	15.90	1.44	1.13	0.05	1.13	2.67	3.49	3.28	0.11
CL	540		70.2	0.43	15.28	0.79	1.86	0.05	1.34	2.79	3.30	3.82	0.15
H	72.51	A	69.8	0.53	16.21	1.95	1.13	0.06	0.74	2.57	3.59	3.28	0.15
H	74.45		69.7	0.43	14.44	0.82	1.84	0.03	2.36	3.07	3.48	3.69	0.11
CL	85		69.7	0.69	15.20	0.40	2.21	0.04	1.61	3.02	3.62	3.42	0.10
MH	1006		69.4	0.41	15.51	0.94	1.84	0.04	1.53	3.37	3.47	3.37	0.13
CL	118	gl	69.3	0.40	15.89	0.41	2.24	0.04	1.53	3.36	3.26	3.46	0.15
MH	860		69.2	0.42	15.27	1.51	1.51	0.03	2.01	3.52	3.31	3.11	0.12
H	73.52		69.1	0.52	15.57	1.02	2.15	0.05	1.64	3.18	3.18	3.38	0.17
H	72.1	C-1	69.1	0.47	15.49	1.41	1.71	0.03	1.41	3.32	3.62	3.32	0.12
H	75.05	A	69.0	0.49	15.65	3.15	0.69	0.02	0.84	3.15	3.76	3.05	0.18
CL	485		68.8	0.44	15.61	0.28	2.45	0.04	2.04	3.57	3.47	3.16	0.19
H	72.7	B	68.5	0.55	16.01	1.94	1.43	0.06	1.73	3.16	3.26	3.16	0.18
H	72.24		68.5	0.50	15.88	1.42	1.62	0.04	1.92	3.44	3.34	3.24	0.15
B	1427	ft.	68.4	0.47	15.84	0.71	2.52	0.06	2.22	3.63	3.23	2.82	0.09
H	72.22	A	68.4	0.44	16.35	1.23	1.75	0.02	1.54	3.91	3.29	2.88	0.22
CL	480		68.3	0.51	15.59	0.64	2.46	0.05	2.36	3.28	3.49	3.08	0.21
H	72.46	B	68.2	0.39	16.56	1.20	1.61	0.02	1.91	3.81	3.31	2.81	0.15
H	74.62	D	68.1	0.52	14.94	1.64	1.84	0.02	2.76	3.68	3.38	2.97	0.17
H	72.27	B	68.0	0.43	15.72	0.61	2.33	0.01	1.72	3.45	4.36	3.25	0.16
CL	203		67.9	0.43	17.32	0.82	1.84	0.05	1.54	3.48	3.07	3.38	0.13
H	76.26	B	67.9	0.49	15.10	0.78	2.30	0.06	2.90	3.80	3.50	3.00	0.19
H	76.59		67.8	0.49	16.95	2.25	1.23	0.06	1.53	3.37	3.27	2.96	0.10
H	73.57	A	67.5	0.61	15.16	0.95	2.44	0.04	2.75	3.87	3.15	3.36	0.19
CL	493		67.4	0.48	15.66	0.68	2.46	0.05	2.46	4.09	3.27	3.27	0.15
CL	383		67.4	0.52	16.60	1.64	1.74	0.05	1.84	3.38	3.48	3.18	0.15
CL	407		67.3	0.54	15.76	1.12	2.03	0.04	2.64	3.56	3.46	3.46	0.10
H	73.9146		67.3	0.40	14.69	0.40	2.90	0.00	3.80	4.20	3.50	2.70	0.15

CLEAR LAKE VOLCANIC													
			Normalized analyses, volatile-free										
	Sample#		SiO2*N	TiO2*N	Al2O3*N	Fe2O3*N	FeO*N	MnO*N	MgO*N	CaO*N	Na2O*N	K2O*N	P2O5*N
CL	543		67.0	0.26	14.76	1.00	2.09	0.05	5.19	2.69	4.29	2.49	0.14
CL	386		66.8	0.59	15.85	0.71	2.74	0.05	2.24	4.06	3.15	3.66	0.10
H	74.74	A	66.8	0.46	16.29	1.22	2.14	0.06	2.85	3.87	3.36	2.85	0.13
H	74.9119		66.7	0.65	15.67	1.33	2.46	0.04	3.07	3.28	3.48	3.18	0.15
H	75.09	B	66.6	0.54	16.01	0.68	2.75	0.05	3.16	3.57	3.88	2.55	0.19
H	72.5		66.6	0.51	17.07	1.85	1.95	0.05	2.57	3.29	3.50	2.47	0.17
H	76.23	B	66.4	0.55	16.66	0.86	2.44	0.05	2.03	4.27	3.56	2.95	0.19
CL	268		66.2	0.44	15.35	1.81	2.51	0.06	3.51	3.81	3.21	2.91	0.18
H	76.18		65.8	0.59	16.68	1.42	2.12	0.05	2.83	4.25	3.44	2.63	0.18
H	72.57	A	65.7	0.39	14.93	1.52	2.64	0.08	5.58	3.15	3.86	2.03	0.12
CL	269		65.5	0.48	14.86	0.61	3.05	0.06	5.09	4.48	3.05	2.54	0.22
H	76.17	D	65.4	0.54	16.96	0.67	2.71	0.05	2.71	4.82	3.41	2.51	0.17
H	77.01	A	65.4	0.76	17.06	3.86	2.13	0.11	2.44	4.98	1.83	1.22	0.19
H	72.55	D	65.4	0.47	17.11	1.42	2.43	0.04	3.04	4.25	3.04	2.63	0.18
H	75.4		64.9	0.86	14.23	0.59	4.44	0.08	3.43	5.05	3.43	2.83	0.18
H	75.01	B	64.9	0.50	16.92	0.80	2.68	0.06	2.78	5.16	3.61	2.48	0.13
H	74.46	C	64.9	0.71	15.75	0.79	3.47	0.07	3.37	5.05	3.57	2.18	0.17
H	72.55	J	64.7	0.58	16.13	1.22	2.84	0.06	3.04	5.17	3.45	2.64	0.15
CL	267		64.7	0.62	15.83	0.60	3.33	0.07	3.83	5.14	3.33	2.32	0.22
H	74.5		64.7	0.55	14.72	0.60	3.61	0.06	4.91	5.31	3.20	2.20	0.15
CL	266		64.5	0.49	16.99	1.01	2.81	0.04	3.42	5.03	3.22	2.31	0.15
H	73.8	A	64.0	0.55	15.65	0.80	3.11	0.05	4.92	4.61	3.41	2.71	0.18


geysers-5
0.83 km deep
0.27
Temperature C
200
100
0
5*10^4
1*10^5
1.5*10^5
2*10^5
Time years



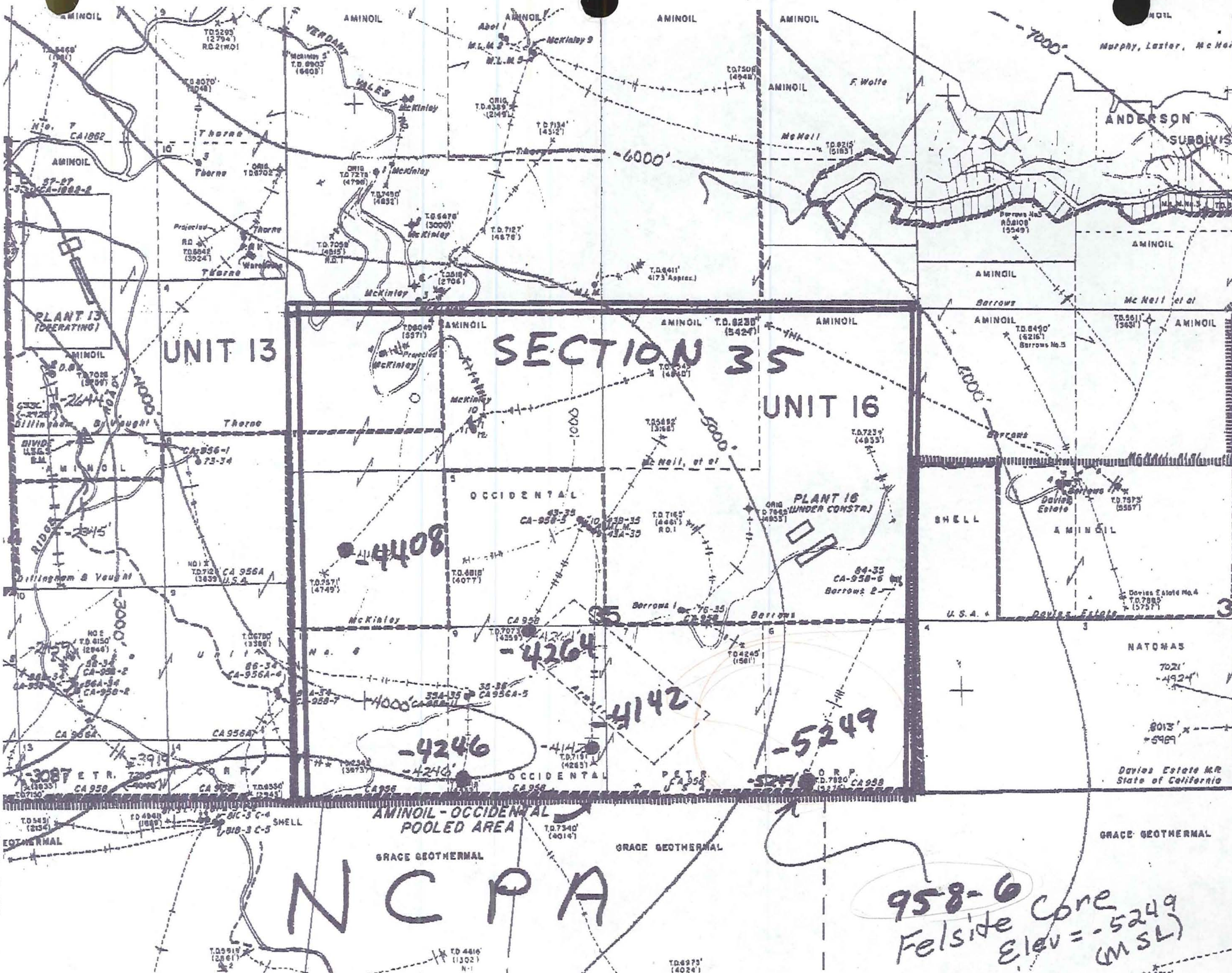
$\frac{118}{15,840}$ $\frac{147}{x}$

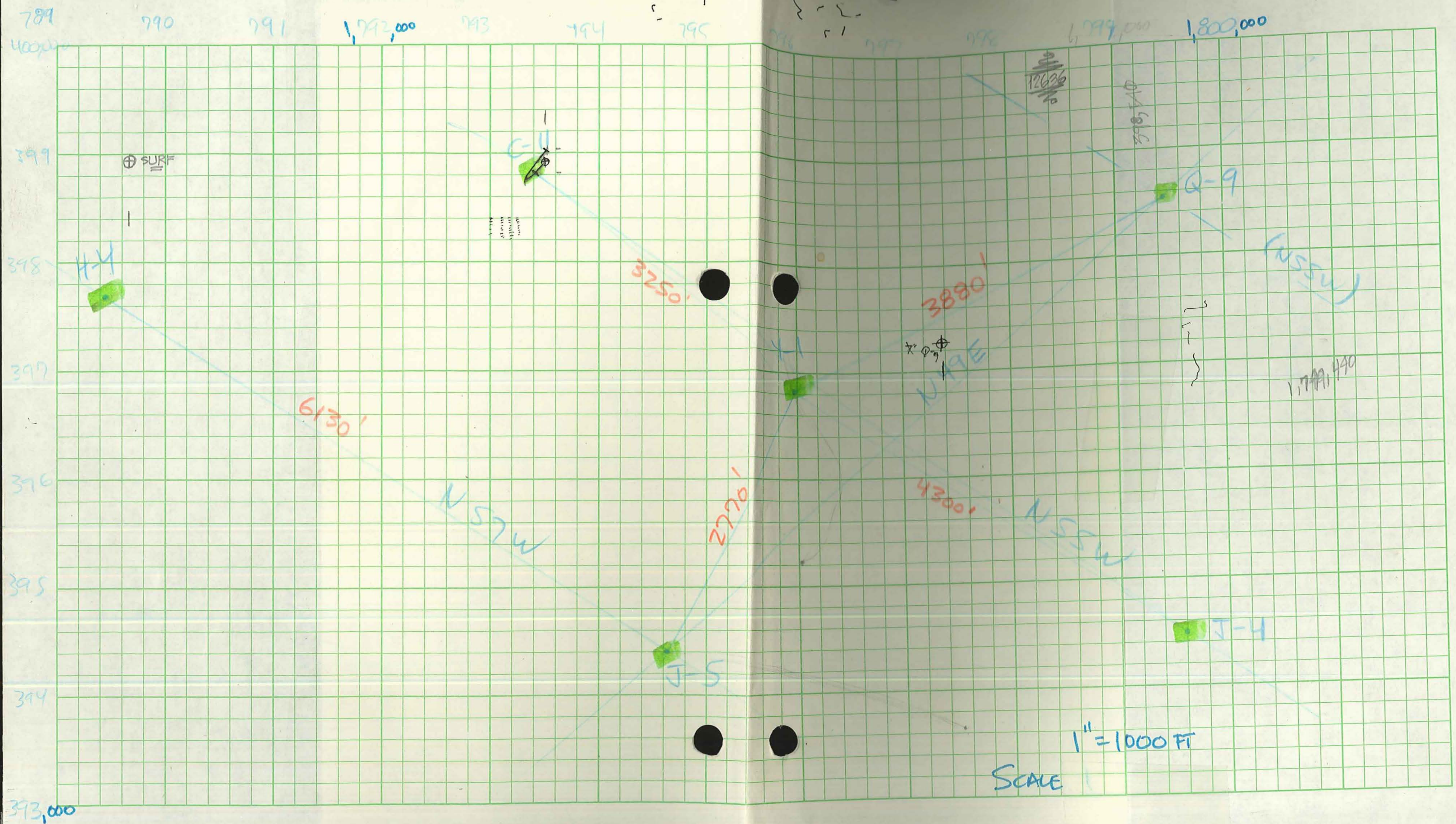
19,733′

39.33 = 40 5280′
30 = 4000

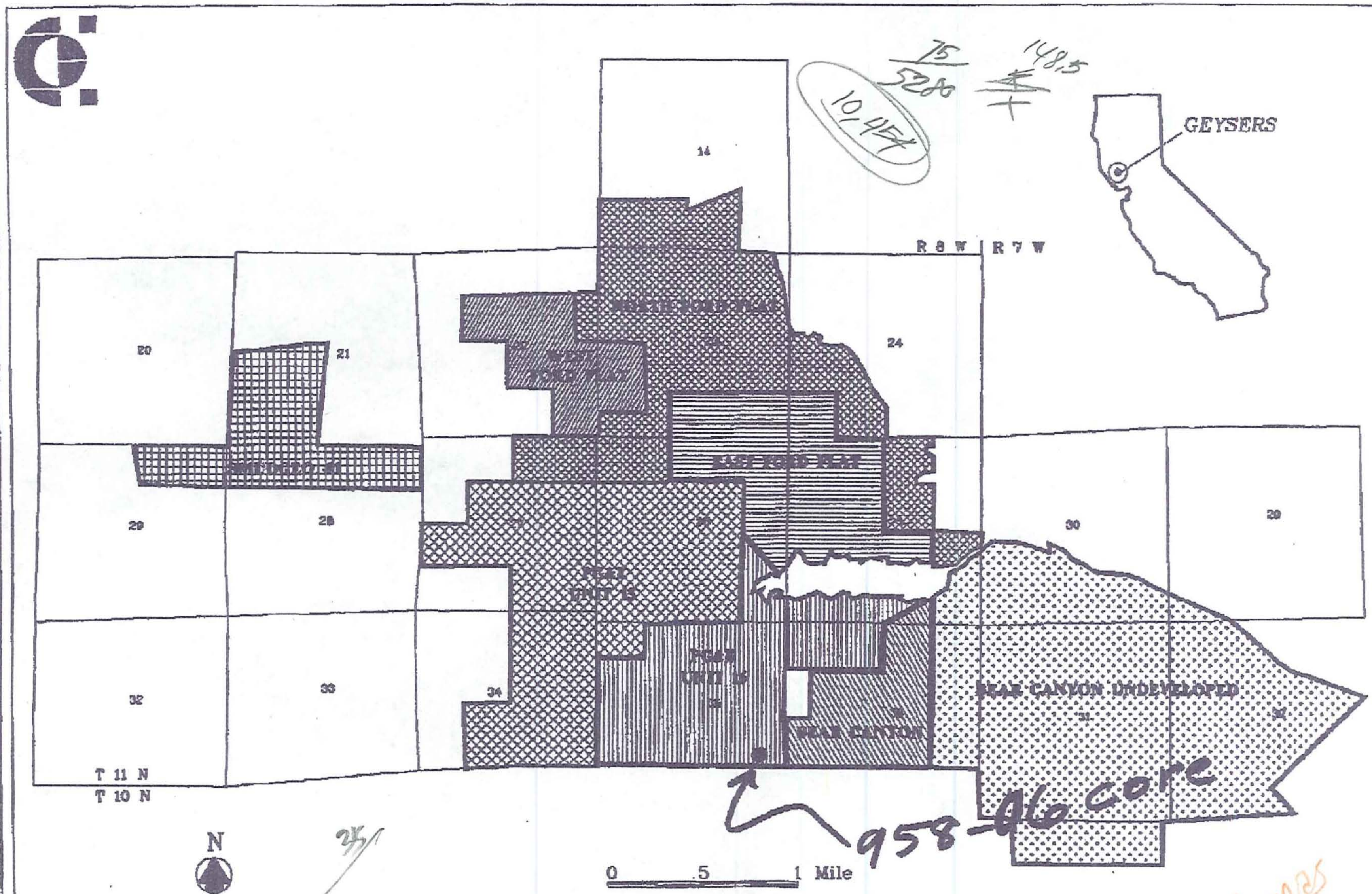
Bob – This is the correct base map –

CALPINE – FELSITE CORE LOCATIONS FROM JOE BEALL



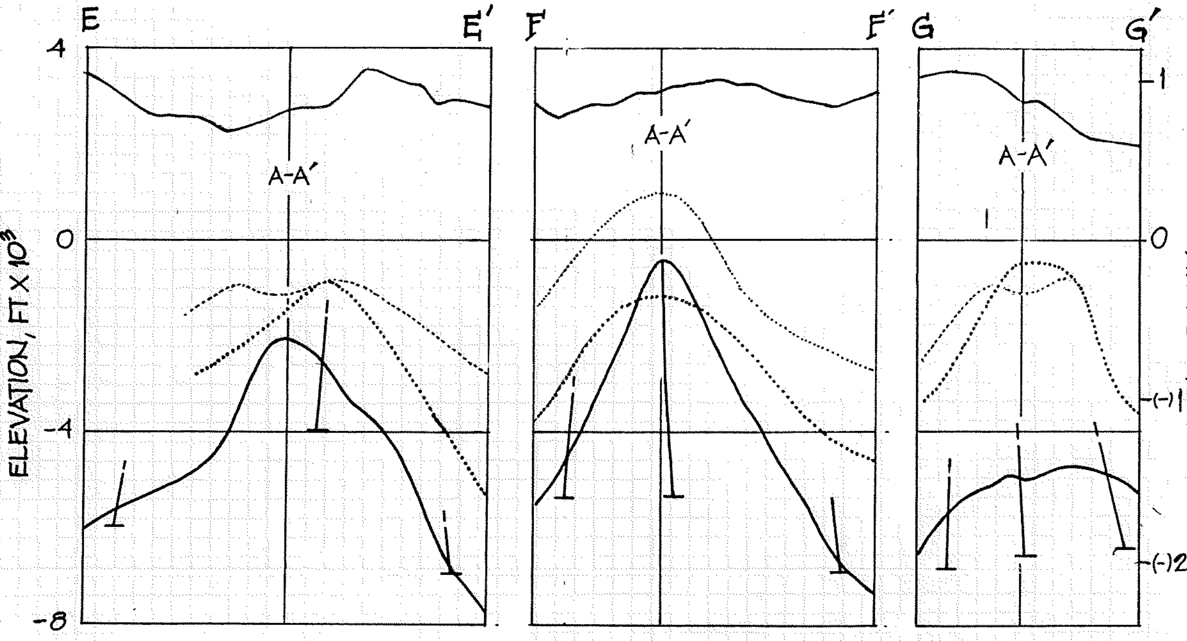


789
790
791
1,792,000
793
794
795
1,799,000
1,800,000
400,000
399
398
397
396
395
394
393,000
SURF
C-11
H-4
3250'
6130'
N57W
2770'
J-5
X-1
3880'
N49E
4300'
N55W
Q-9
(N55W)
J-4
1" = 1000 FT
SCALE

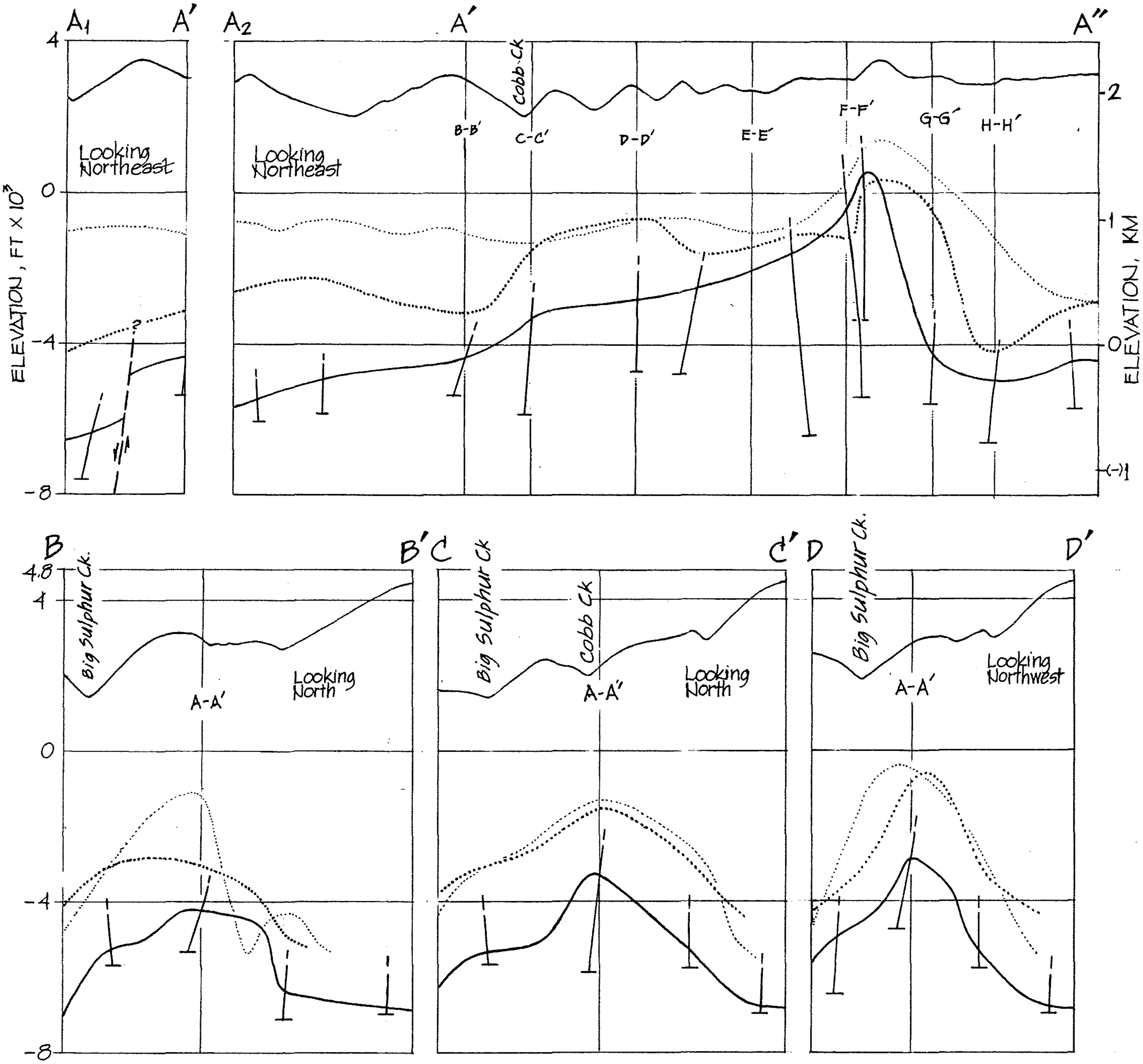


SANTA ROSA GEOTHERMAL COMPANY
GEYSERS LAND MAP

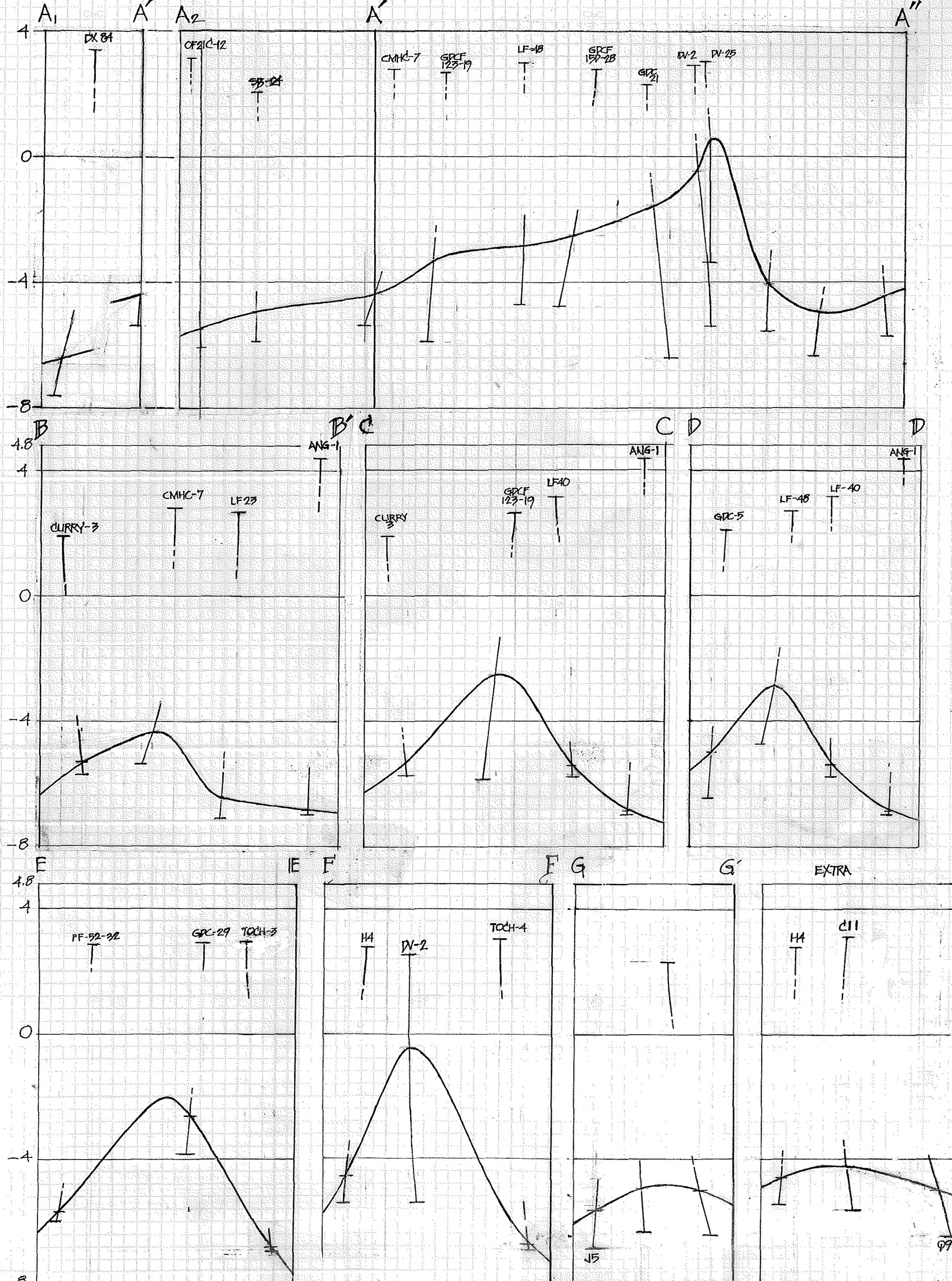
UNITS 3/28/93

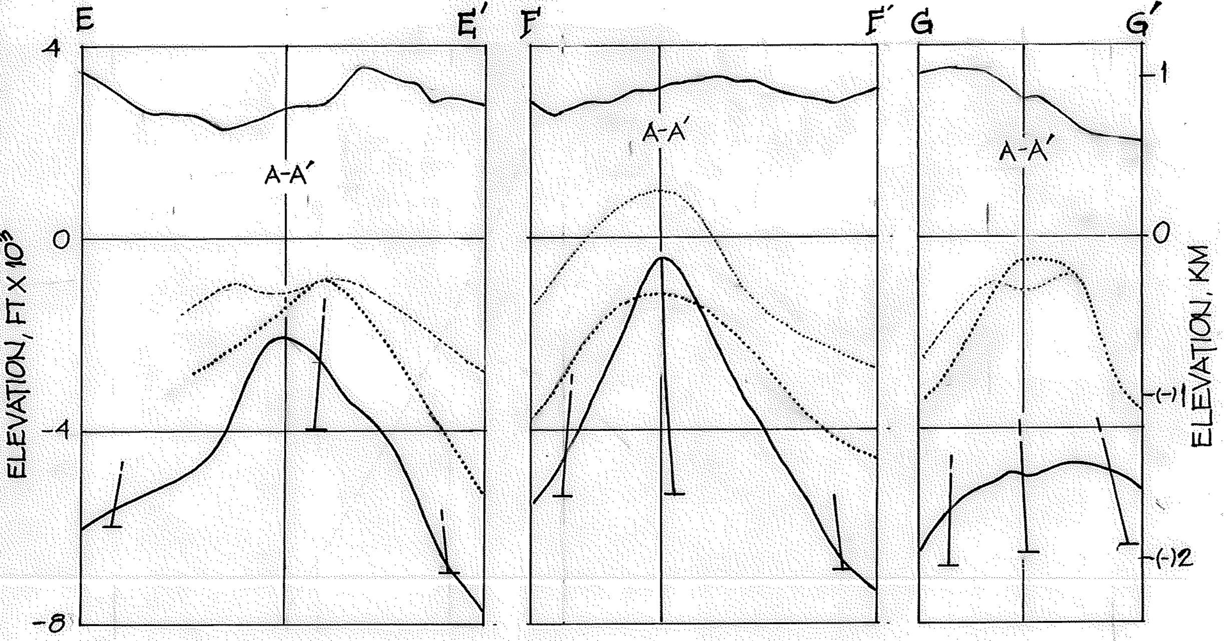


E
E′
F
F′
G
G′
4
0
-4
-8
1
0
(-)1
(-)2
A-A′
A-A′
A-A′
ELEVATION, FT X 10³
ELEVATION, KM

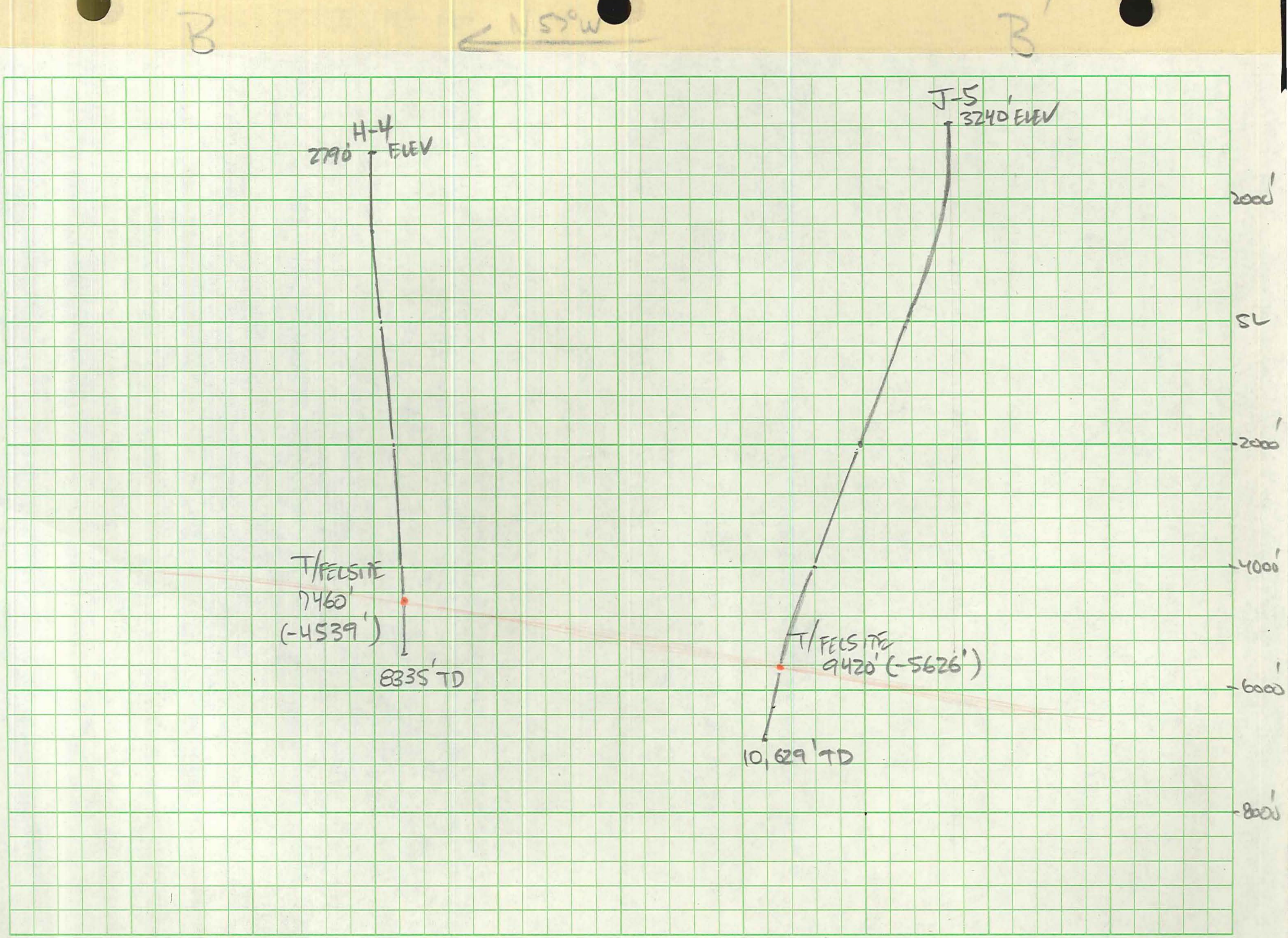


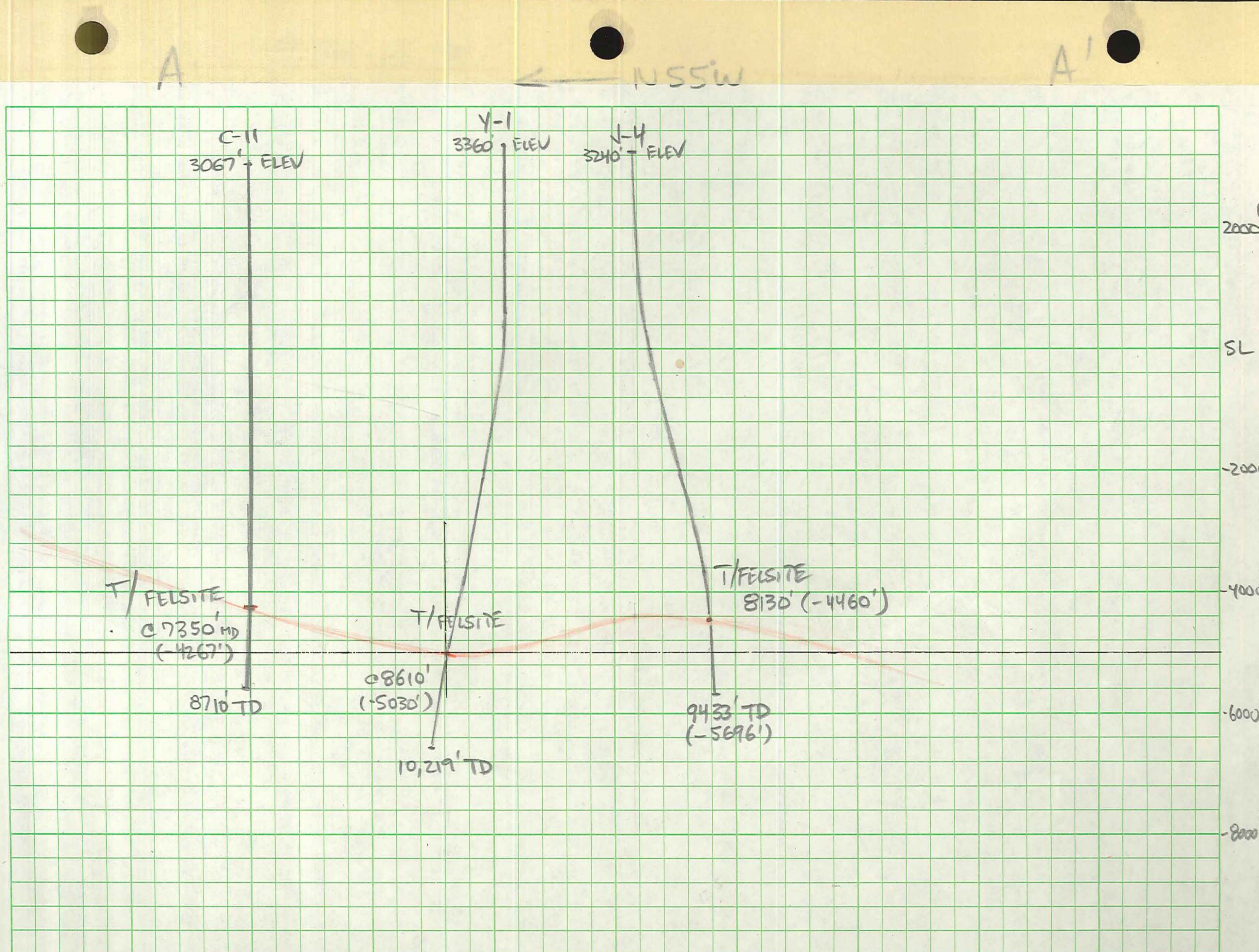
A1
A'
A2
A'
A''
Cobb Ck
B-B'
C-C'
D-D'
E-E'
F-F'
G-G'
H-H'
Looking Northeast
Looking Northeast
ELEVATION, FT X 10^3
ELEVATION, KM
4
0
-4
-8
2
1
0
(-)1
B
B'
C
C'
D
D'
4.8
Big Sulphur Ck.
Big Sulphur Ck
Cobb Ck
Big Sulphur Ck.
A-A'
A-A'
A-A'
Looking North
Looking North
Looking Northwest


A1
A'
A2
A'
A''
4
0
-4
-8
DX 84
OF21
C-12
CMHC-7
GDCF 123-19
LF-48
GDCF 150-28
GDC 21
DV-2
DV-25
B
B'
C
C
D
D
4.8
4
0
-4
-8
CURRY-3
CMHC-7
LF23
ANG-1
CURRY 3
GDCF 123-19
LF40
ANG-1
GDC-5
LF-48
LF-40
ANG-1
E
E
F
F
G
G'
EXTRA
4.8
4
0
-4
-8
FF-52-32
GDC-29
TOCH-3
H4
DV-2
TOCH-4
J5
H4
D9

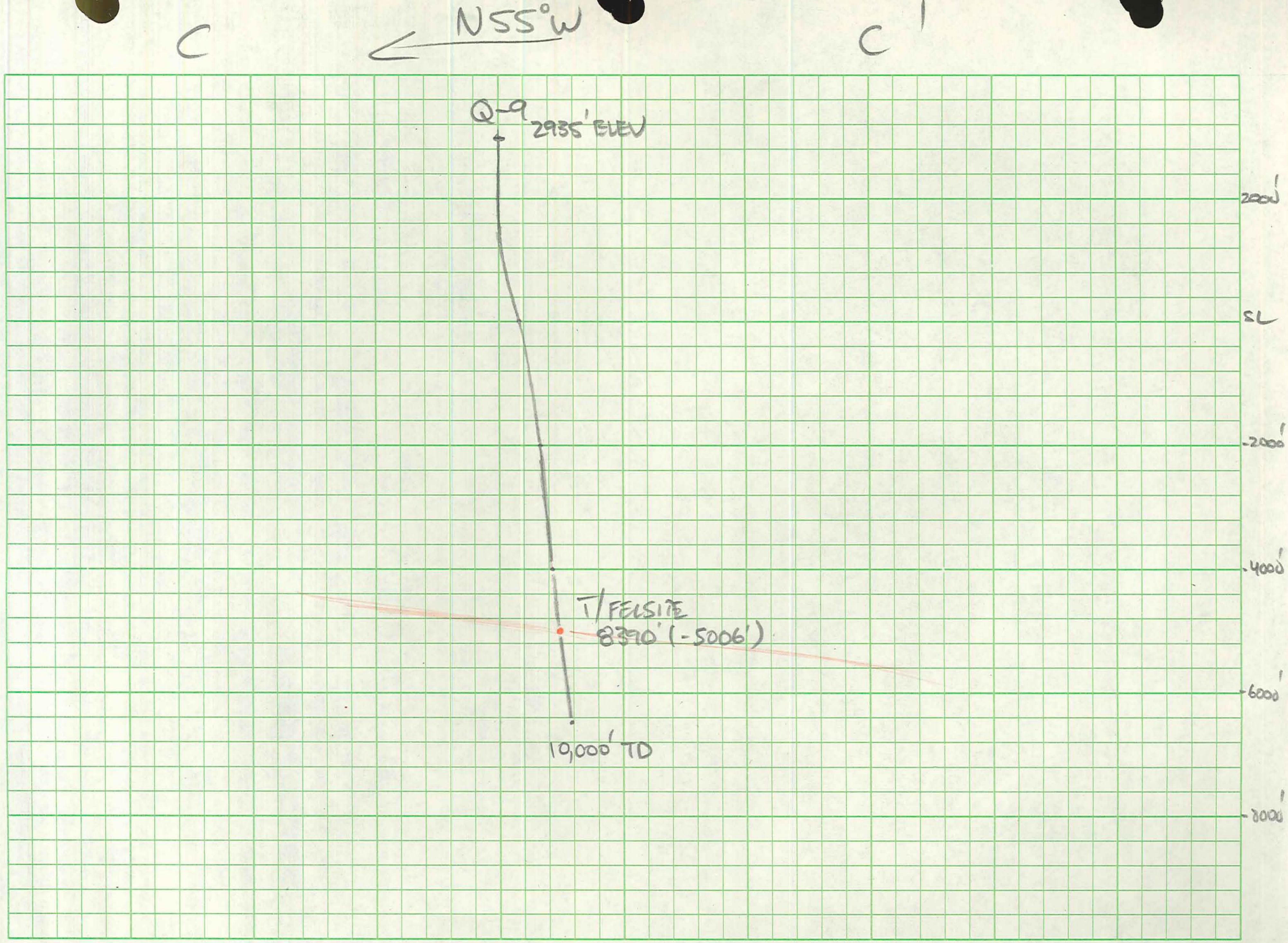


E
E'
F
F'
G
G'
A-A'
A-A'
A-A'
4
0
-4
-8
1
0
(-)1
(-)2
ELEVATION, FT X 10³
ELEVATION, KM

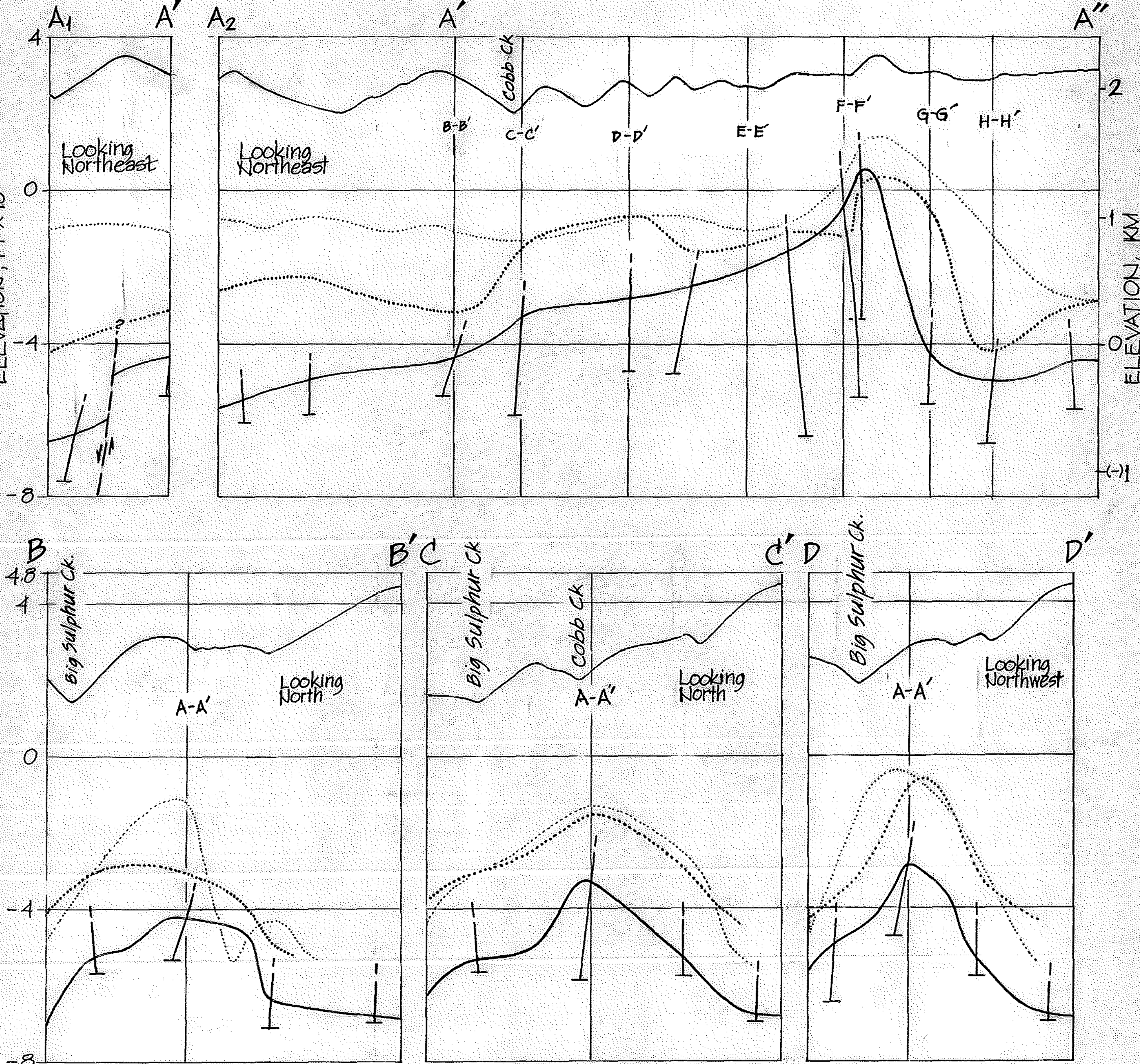

B
N 53°W
B'
H-4
2790' ELEV
T/FELSITE
7460'
(-4539')
8335' TD
J-5
3240' ELEV
T/FELSITE
9420' (-5626')
10,629' TD
2000'
SL
-2000'
-4000'
-6000'
-8000'



A
N55W
A'
C-11
3067' ELEV
Y-1
3360' ELEV
J-4
3240' ELEV
2000'
SL
-2000'
-4000'
-6000'
-8000'
T/ FELSITE
@ 7350' MD
(-4267')
8710' TD
T/FELSITE
@8610'
(-5030')
10,219' TD
T/FELSITE
8130' (-4460')
9433' TD
(-5696')



C
N55°W
C'
Q-9
2935' ELEV
2000'
SL
-2000'
-4000'
T/FELSITE
8390' (-5006')
-6000'
10,000' TD
-8000'



A1
A'
A2
A'
A''
4
0
-4
-8
ELEVATION, FT X 10^3
ELEVATION, KM
2
1
0
(-)1
Looking Northeast
Looking Northeast
Cobb Ck
B-B'
C-C'
D-D'
E-E'
F-F'
G-G'
H-H'
B
B'
C
C'
D
D'
4.8
Big Sulphur Ck.
Big Sulphur Ck
Big Sulphur Ck.
Cobb Ck
A-A'
A-A'
A-A'
Looking North
Looking North
Looking Northwest

COMPLETE SAMPLE INVENTORY FILED UNDER "GEYSERS, MISCELL." IN CABINET.

FELWELLS.XLS

FELSITE WELLS

	Well	Sidetrack?	Top	TD	ft drilled	footage in wells to study
1	ang1		11260	11440	180	180
2	bef4233	st2	5720	7021	1301	
3	bef4233		5780	7829	2049	
4	bef42a33		5560	7250	1690	
5	bef42b33		4380	9113	4733	
6	bef5333		5360	9010	3650	
7	bef85a28		7680	8446	766	
8	bg12	st1	5900	8183	2283	
9	bg13		5780	8230	2450	
10	cmhc2	rd1	7740	9520	1780	
11	cmhc3	rd1	8700	9603	903	
12	cmhc6	st1	7400	8077	677	
13	cmhc6		7520	9150	1630	
14	cmhc7		7460	8713	1253	1253
15	curry3		8260 ?	8338	78	78
16	dv1		5040	5113	73	
17	dv11	st1	4760	5932	1172	
18	dv12		5100	5740	640	
19	dv13		5900	8765	2865	
20	dv16		5740	6264	524	
21	dv2	st1	3440	8623	5183	5183
22	dv2		3380	4255	875	
23	dv23		4960	8366	3406	
24	dv24		5040	8685	3645	
25	dv25	st1	2860	8831	5971	
26	dv25	st2	2560	6849	4289	4289
27	dv3	st1	4160	7406	3246	
28	dv3	st2	3760	7111	3351	
29	dv3		4160	4455	295	
30	dv4		3560	9581	6021	
31	dv5	st1	6240	7287	1047	
32	dv5		5240	8619	3379	
33	dv6		5250	8015	2765	
34	dx26		9500	10281	781	
35	dx71	st1	8040	8392	352	
36	dx84	st1	9880	10606	726	
37	dx84		10080	11483	1403	1403
38	ff5232	st2	8840	9155	315	315
39	ff5232		7100	8392	1292	
40	gdc1		6380	7375	995	
41	gdc11		5440	7338	1898	
42	gdc18		5480	8525	3045	
43	gdc19		5980	7602	1622	
44	gdc2	st2	6600	7722	1122	
45	gdc2029	dpn	5760	8133	2373	
46	gdc21		3840	8915	5075	5075
47	gdc23		5340	5481	141	
48	gdc24		5500	7305	1805	
49	gdc25		5840	6128	288	

FELWELLS.XLS

50	gdc26		6060	6442	382	
51	gdc29		5620	7056	1436	1436
52	gdc3618	rd1	7200	9700	2500	
53	gdc5	st1	7160	8086	926	
54	gdc5		6880	8667	1787	1787
55	gdc6	dpn	6260	7579	1319	
56	gdc7230		6620	8317	1697	
57	gdc8		5000	6757	1757	
58	gdcf	st3	7180	8437	1257	
59	gdcf117a19		7960	8501	541	
60	gdcf12319		6200	8817	2617	2617
61	gdcf1427	st1	6860	8960	2100	
62	gdcf1427	st2	6540	8991	2451	
63	gdcf15a28		5100	7658	2558	
64	gdcf15b28	st1	6740	8475	1735	
65	gdcf15b28		7220	8532	1312	
66	gdcf15c28		6200	6266	66	
67	gdcf15d28		5460	7939	2479	2479
68	gdcf3628	st1	4100	6753	2653	
69	gdcf3628	st2	3960	9000	5040	
70	gdcf3628	st4	4160	8654	4494	
71	gdcf4428	st1	5360	7459	2099	
72	gdcf4428		5240	9468	4228	
73	gdcf44a28	st1	5780	6090	310	
74	gdcf44b28		5100	6083	983	
75	gdcf6329		5220	7147	1927	
76	gdcf63a29		5640	8910	3270	
77	gdcf63b29		5620	8336	2716	
78	gdcf9419	st1	6440	6520	80	
79	gdcf9419	st2	6370	8249	1879	
80	gdcf9419		6680	9083	2403	
81	gdcf94a19	st1	6100	7207	1107	
82	gdcf94a19		5900	7289	1389	
83	gdcf94b19	st1	5940	7307	1367	
84	gdcf94b19		6300	6361	61	
85	1f12	rd1	7140	7354	214	
86	1f20		6500	6568	68	
87	1f23	st1	9180	9912	732	732
88	1f30	st1	8680	8826	146	
89	1f35		5960	8623	2663	
90	1f36		6000	8074	2074	
91	1f37		8500	9000	500	
92	1f39		8160	8228	68	
93	1f4		8240	9029	789	
94	1f40	st2	9380	9478	98	
95	1f40	st3	8700	9120	420	420
96	1f42		6850	8035	1185	
97	1f48		6300	8096	1796	1796
98	1f49		7540	7902	362	
99	1f6	dpn	6300	6769	469	
100	1f7	rd1	8360	9840	1480	
101	1f8	dpn	7840	8113	273	
102	modini2		5180	8112	2932	
103	negu2*	st1	7610	7840	230	230
104	negu2*	st1	6160	6220	60	60
105	negu8*		8740	8820	80	80

? dike?

FELWELLS.XLS

106	ocf9618	st1	7160	8114	954	
107	ocf9618		7540	8428	888	
108	of21c12		8760	9341	581	581
109	of4512	rd1	8920	9231	311	
110	of4512	rd2	7660	8807	1147	
111	of4512		7680	8131	451	
112	of45a12		8200	9500	1300	
113	os23	rd1	7980	9005	1025	
114	sb24		6740	7977	1237	1237
115	sb25	dpn	6780	7350	570	
116	sb30		7040	7316	276	
117	sb31		6840	7040	200	
118	tocher3		9220	9415	195	
119	tocher4		9840	9942	102	102

Total felsite drilled = 188,205 feet

Average felsite drilled = 1,582 feet/well

Total felsite studied = 29,994 feet
or 15.9 % of all felsite drld

Unocal Geothermal Division
Unocal Corporation
3576 Unocal Place, P.O. Box 6854
Santa Rosa, California 95406
Telephone (707) 545-7600

WIL

UNOCAL 76

I acknowledge receipt of the following Geysers cuttings samples on behalf of the University of Utah Research Institute from Unocal Geothermal. The samples are subject to the conditions of the Unocal/UURI research agreement dated April 26, 1991.

I also acknowledge receipt of a 50% split of Unocal's Geysers NEGU-17 core on behalf of the U.S. Department of Energy. The U.S. Department of Energy is now full owner of this core split.

CUTTINGS SAMPLES

Well	Depth Interval	
ANG-1	11,000-11,440	440
LF-48	6000-8080	2080
LF-40 ST3	8400-9120	720
DX-84	9140-11,460	2320
FF 52-32 ST2	8600-9135	535'
CURRY-3	8000-8320	320'
DV-2	3200-8600	5400'
DV-25 ST2	2300-6800	4500'
GDC-21	3600-8915	5315'
TOCH-4	9500-9942	442'
NEGU-2 ST1 (dikes)	6000-8060	2060'
GDCF 123-19	6000-8800	2800'
NEGU-8	8600-8840	240'
OF21C-12	8600-9300	700'
CMHC-7	7200-8713	1513'
GDC-29	5340-7056	1716
GDCF 15D-28	4440-7920	3480
GDC-5	6640-8086	1446
LF-23 RD1	8800-9912	1112
SB-24	6500-7940	1440
20		42,679

2 per 100 ft

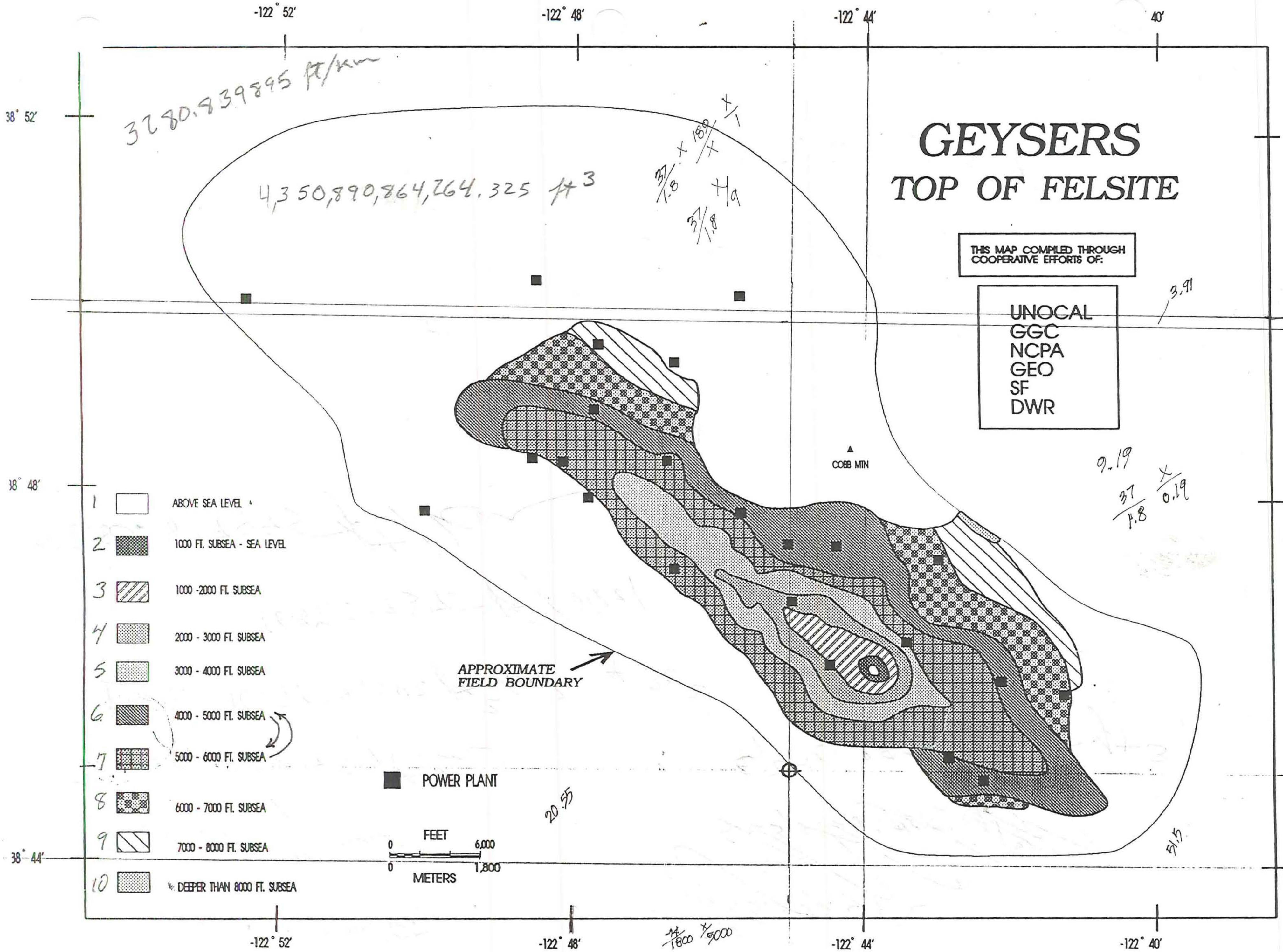
427

850 T.S.

~~42,679~~
÷ 10' 42
100) 42679
400
267

Signed Jeffrey B. Hulen

Title Geologist



GEYSERS
TOP OF FELSITE
THIS MAP COMPILED THROUGH COOPERATIVE EFFORTS OF:
UNOCAL
GGC
NCPA
GEO
SF
DWR
-122° 52'
-122° 48'
-122° 44'
40'
-122° 40'
38° 52'
38° 48'
38° 44'
COBB MTN
APPROXIMATE FIELD BOUNDARY
ABOVE SEA LEVEL
1000 FT. SUBSEA - SEA LEVEL
1000 -2000 FT. SUBSEA
2000 - 3000 FT. SUBSEA
3000 - 4000 FT. SUBSEA
4000 - 5000 FT. SUBSEA
5000 - 6000 FT. SUBSEA
6000 - 7000 FT. SUBSEA
7000 - 8000 FT. SUBSEA
DEEPER THAN 8000 FT. SUBSEA
POWER PLANT
FEET
0
6,000
0
1,800
METERS
3280.839895 ft/km
4,350,890,864,264.325 ft³

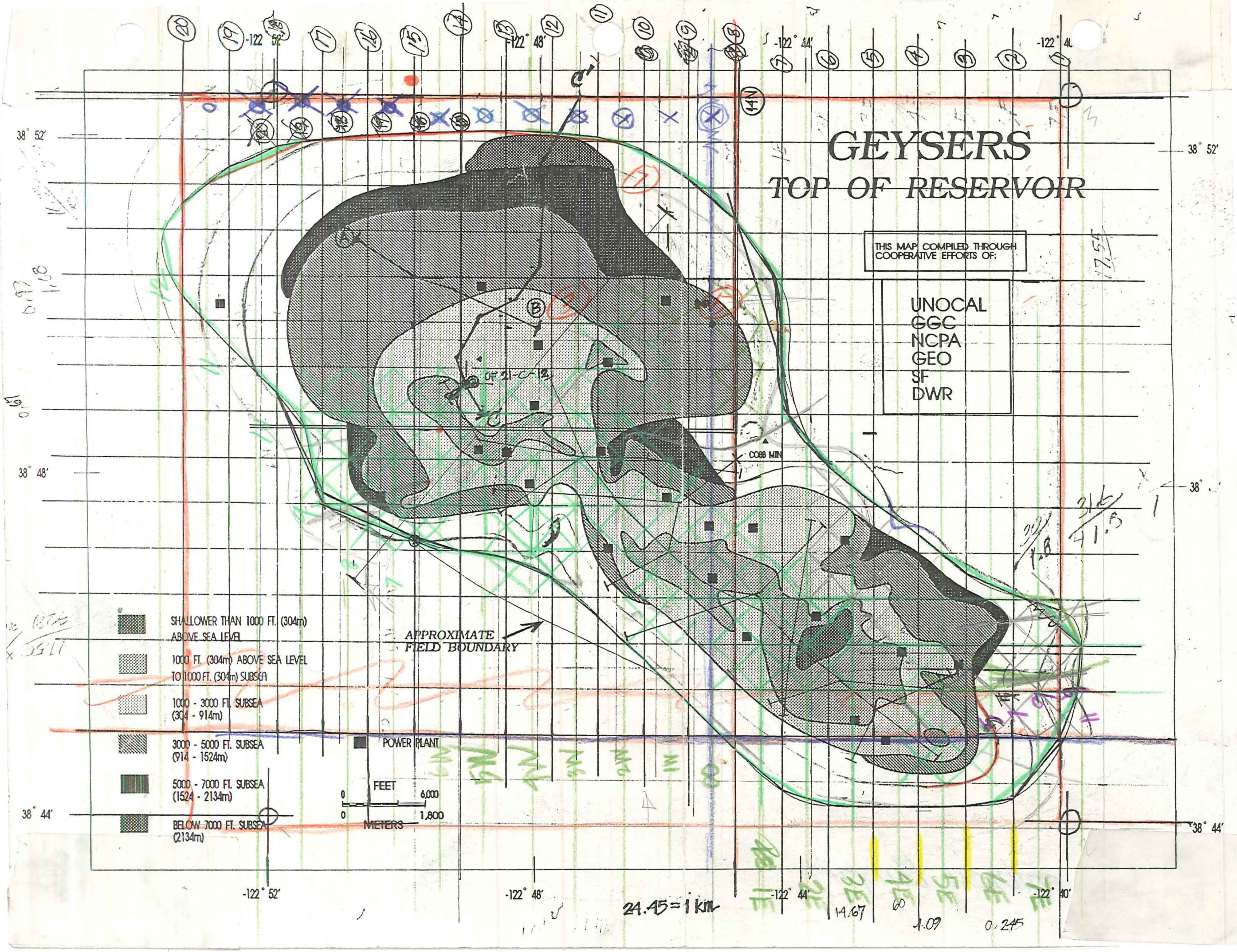
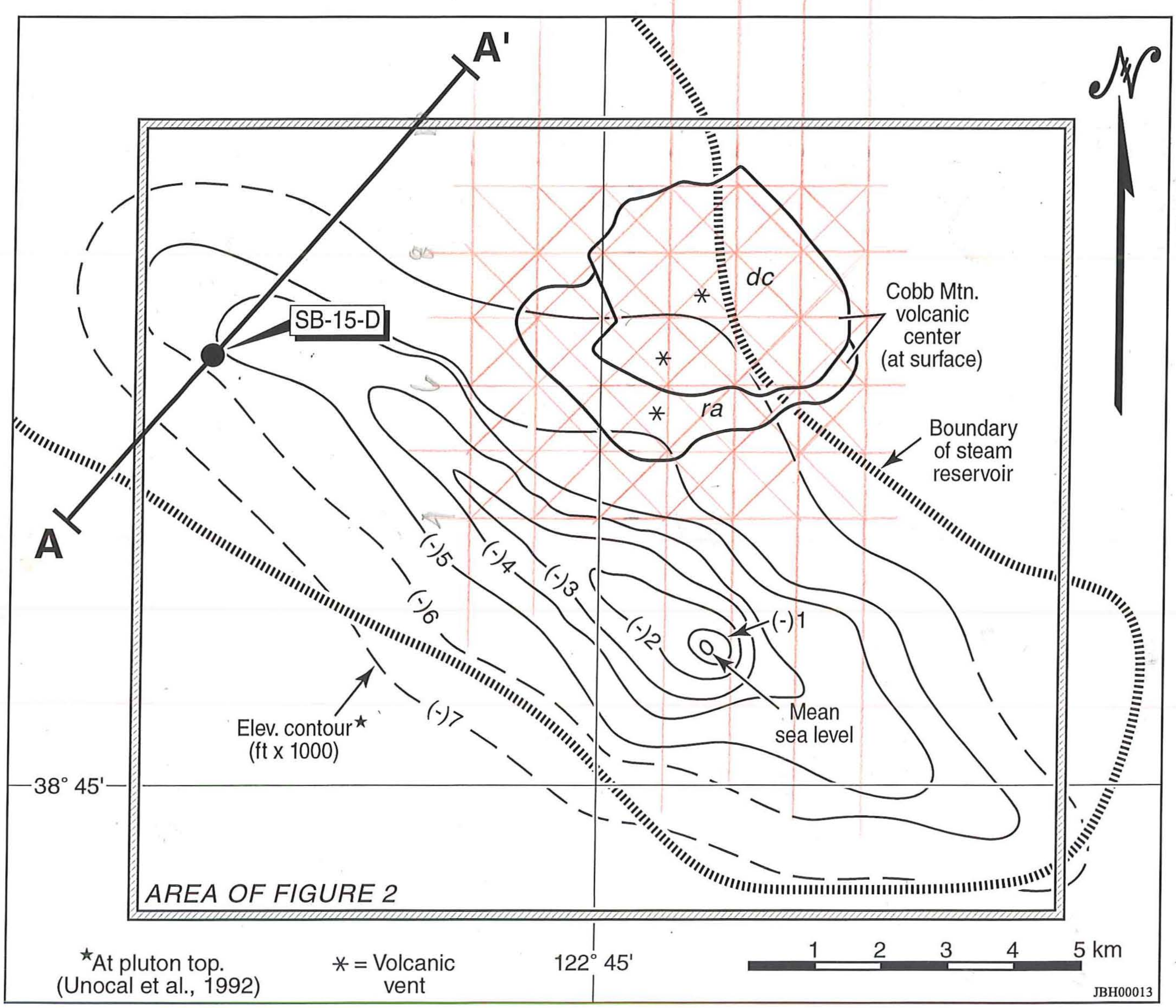
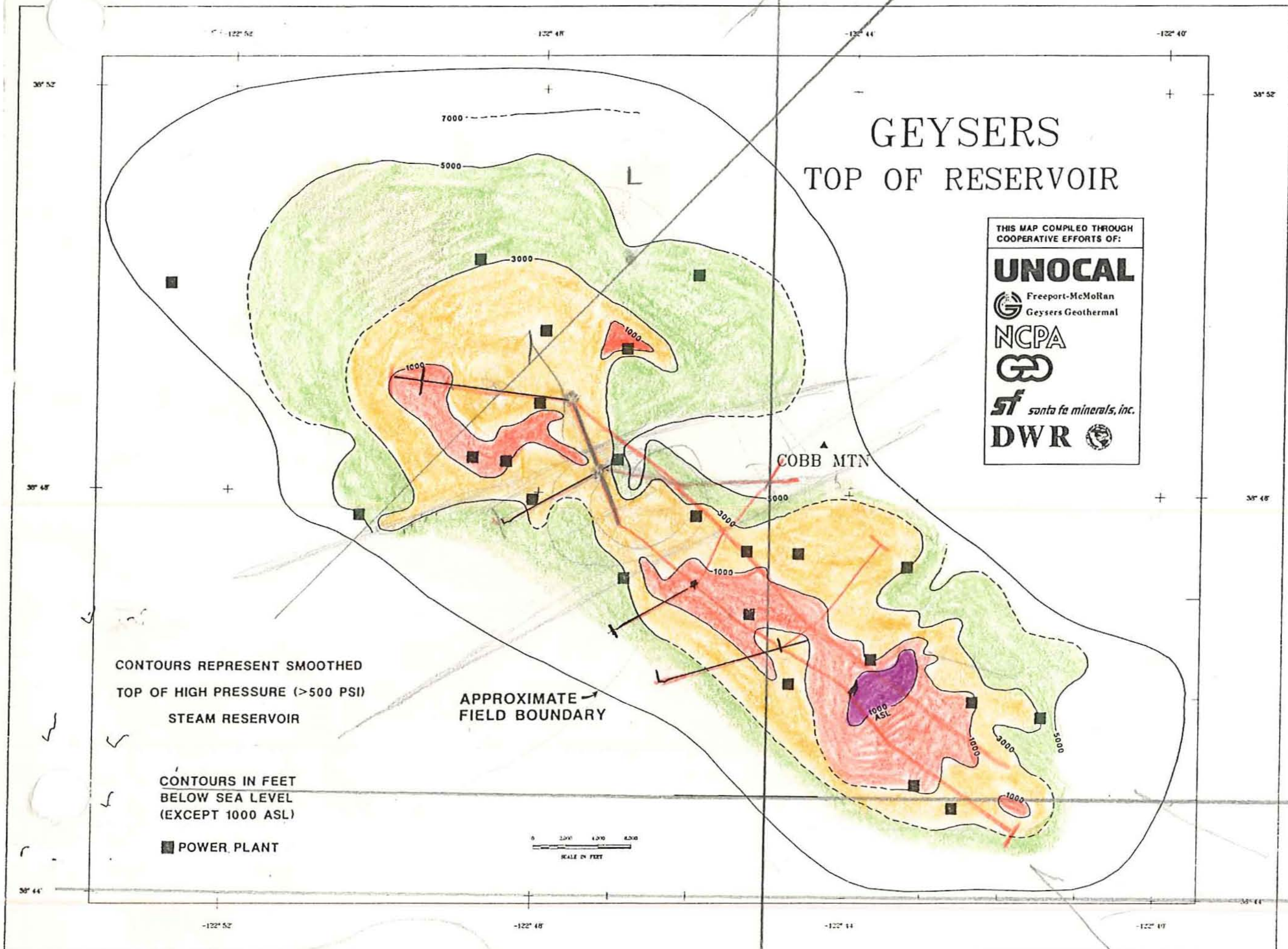

GEYSERS
TOP OF RESERVOIR
THIS MAP COMPILED THROUGH COOPERATIVE EFFORTS OF:
UNOCAL
GGC
NCPA
GEO
SF
DWR
SHALLOWER THAN 1000 FT. (304m) ABOVE SEA LEVEL
1000 FT. (304m) ABOVE SEA LEVEL TO 1000 FT. (304m) SUBSEA
1000 - 3000 FT. SUBSEA (304 - 914m)
3000 - 5000 FT. SUBSEA (914 - 1524m)
5000 - 7000 FT. SUBSEA (1524 - 2134m)
BELOW 7000 FT. SUBSEA (2134m)
POWER PLANT
FEET 0 6,000
METERS 0 1,800
APPROXIMATE FIELD BOUNDARY
COBB MTN
38° 52'
38° 48'
38° 44'
-122° 52'
-122° 48'
-122° 44'
-122° 40'
24.45 = 1 km

Fig. 1


A'
A
SB-15-D
dc
ra
Cobb Mtn. volcanic center (at surface)
Boundary of steam reservoir
(-)1
(-)2
(-)3
(-)4
(-)5
(-)6
(-)7
Mean sea level
Elev. contour★ (ft x 1000)
38° 45'
AREA OF FIGURE 2
★At pluton top. (Unocal et al., 1992)
⚹ = Volcanic vent
122° 45'
1 2 3 4 5 km
JBH00013



(80)

31.5 = 6000
X = 3281

17.22 = 1 km

PROPRIETARY

Figure 2a: Key for figures 2b, 3 and 4

FRANCISCAN UNITS

Unit 1:	Tocher Serpentine
Unit 3:	MUM-metamorphosed ultramafic
Unit 2: Unit 6:	Cobb Mountain Frandsen Federal Graywacke/minor Greenstone
Unit 2,6:	Greenstone
Unit 4:	Little Geysers Basin Unit Semischistose Graywacke/Greenstone

FELSITE

	A	Biotite granite porphyry
	B	Biotite granite
	C	Biotite + clinopyroxene microgranite
	D	Biotite + clinopyroxene granodiorite
BSC FZ	I, II	Big Sulphur Creek Fault Zone I: Franciscan II: Recent fracture zone
AC FZ		Anderson Creek Fault Zone (McLaughlin, 1974)
•		Wellhead locations
●		Wells included in study
		Wellcourse with steam entry locations

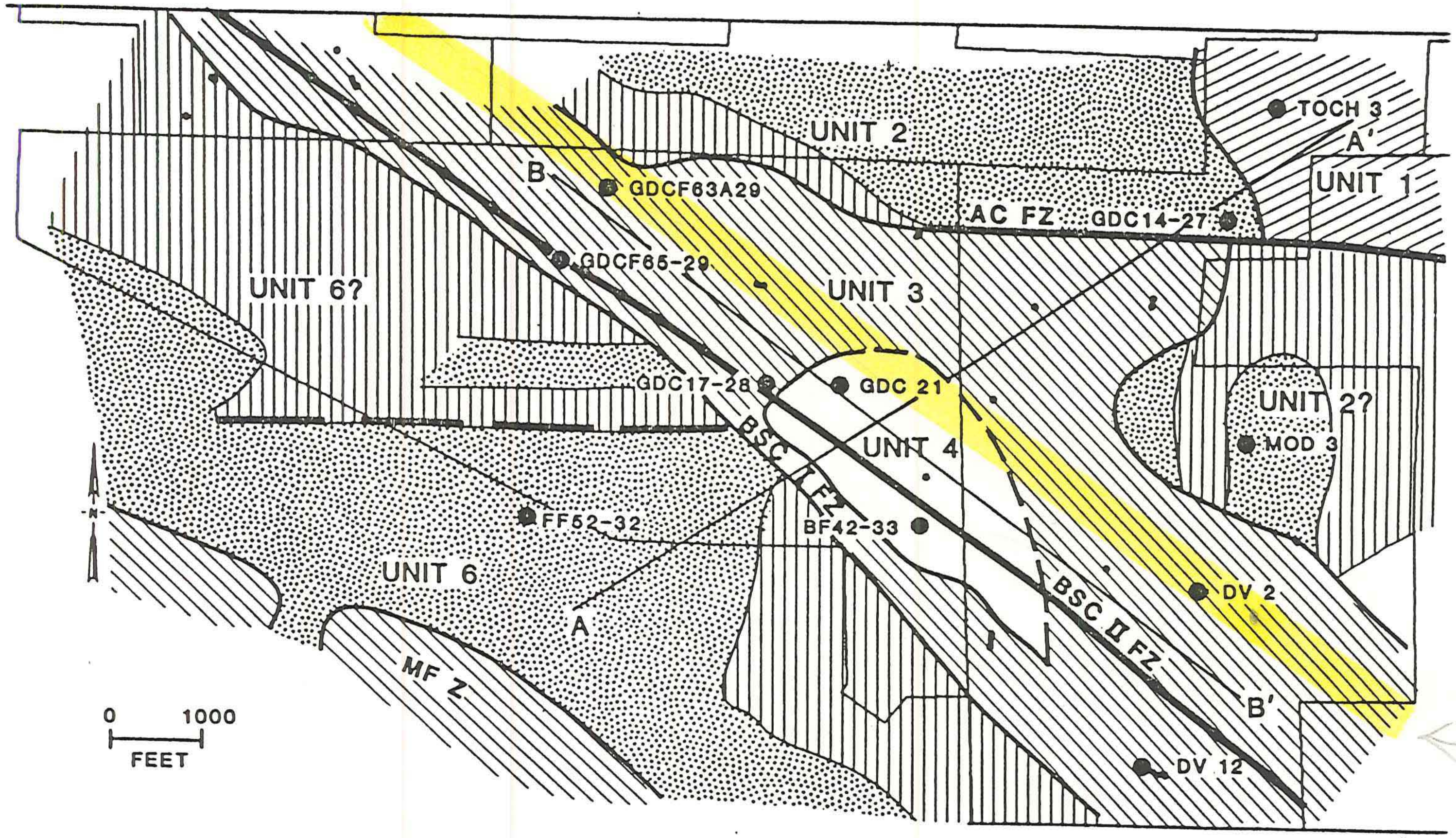


Figure2b Unit 18 & 20 Simplified Geology (from Tepper & Horning, 1984)

Approx. Axis of Felsite Intrusion

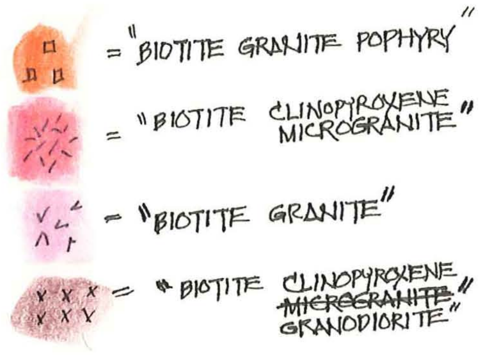
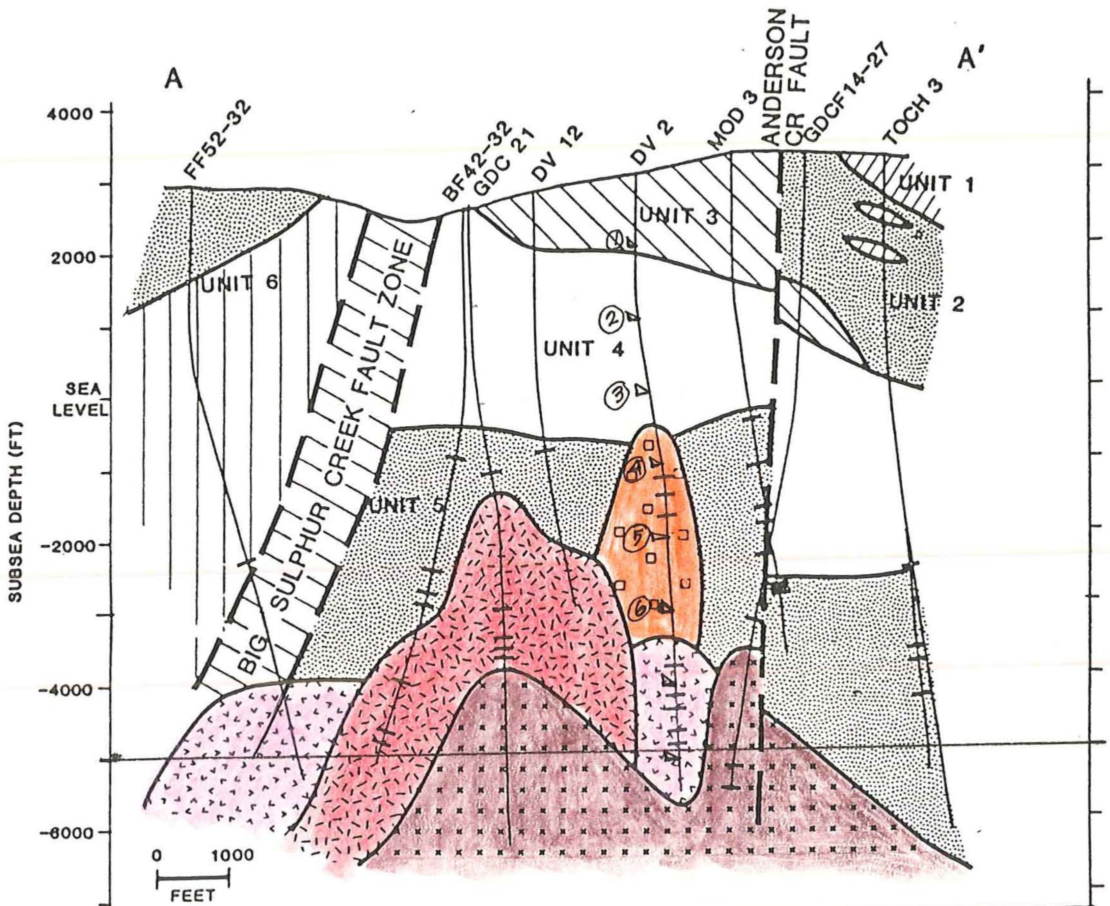
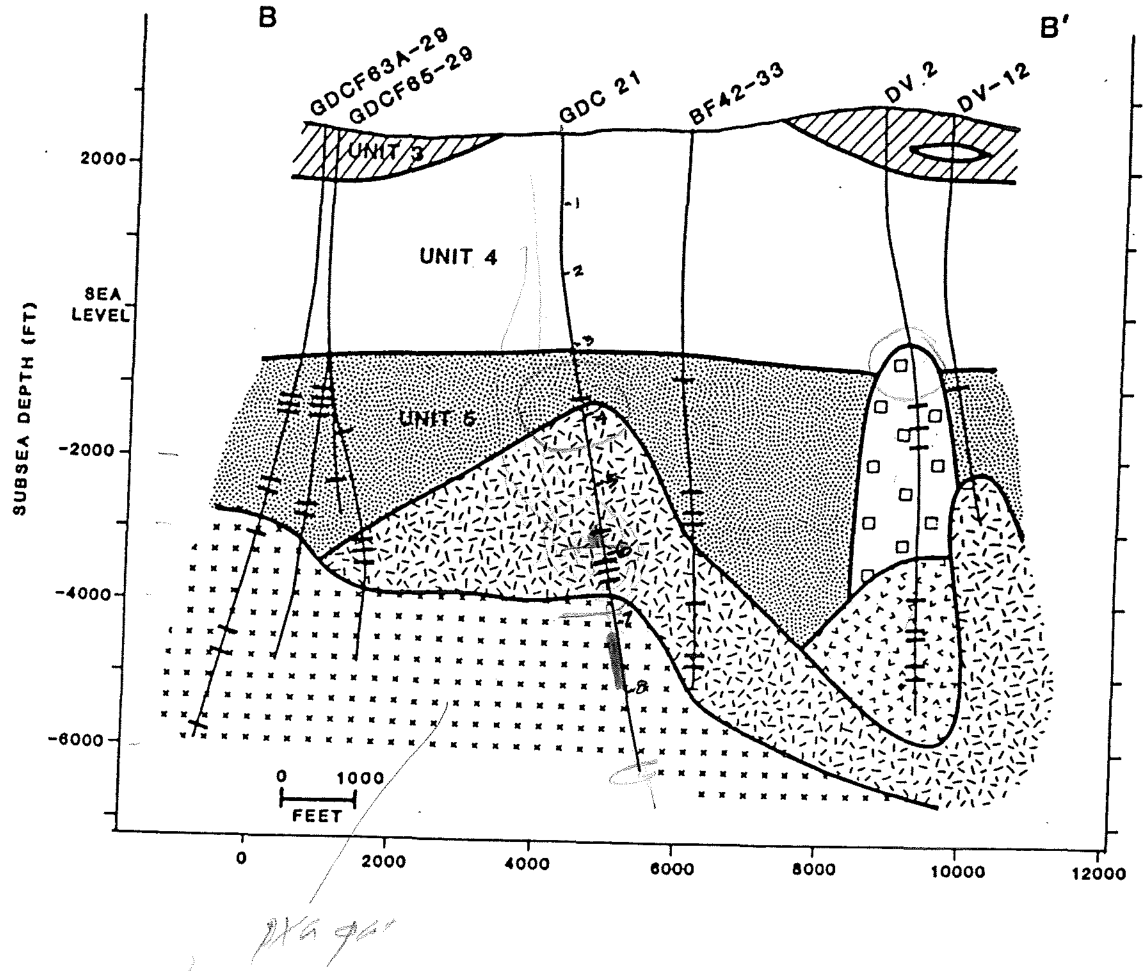


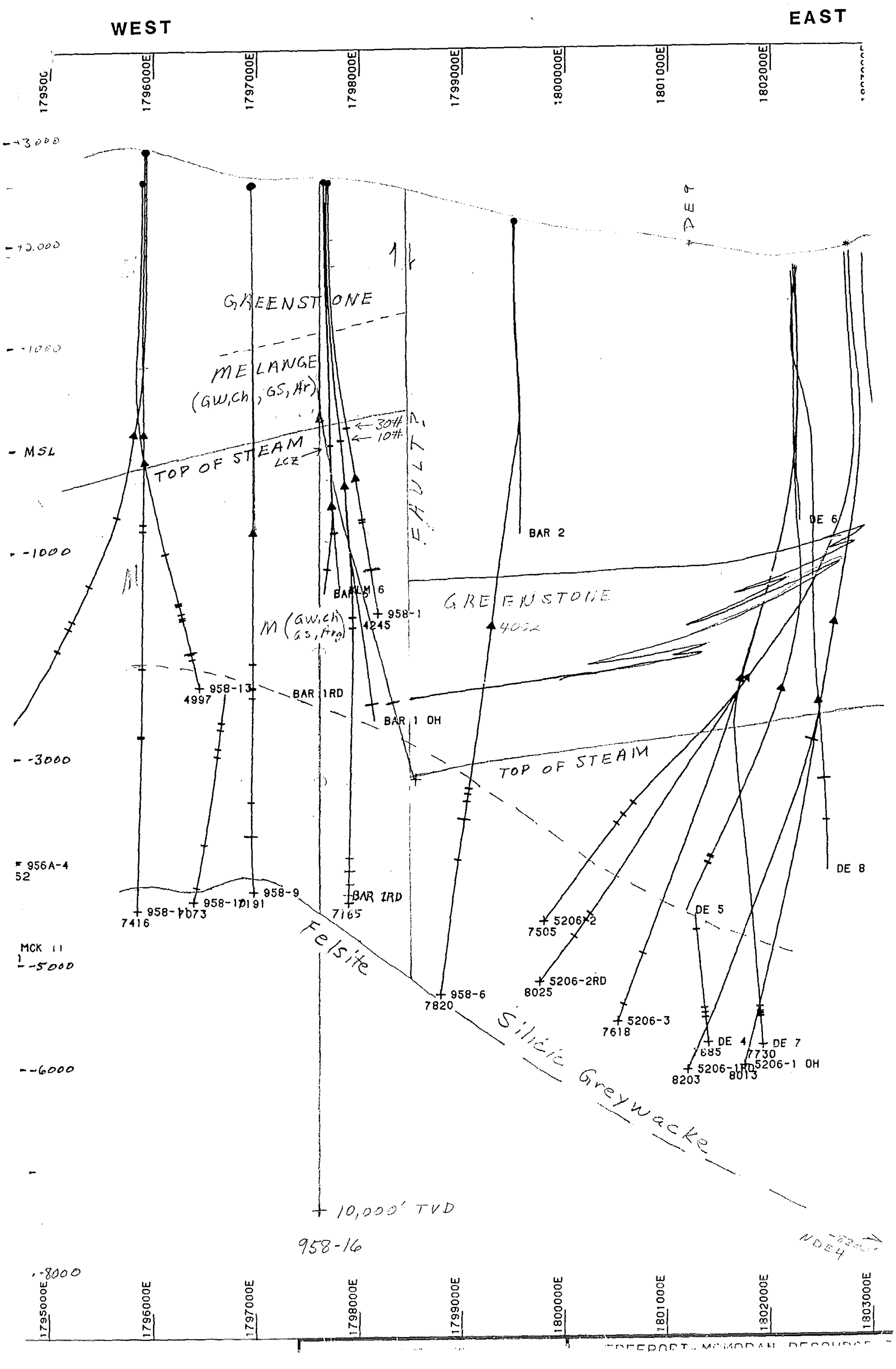
Figure 3 : UNIT 20 MINERALOGY PROJECT



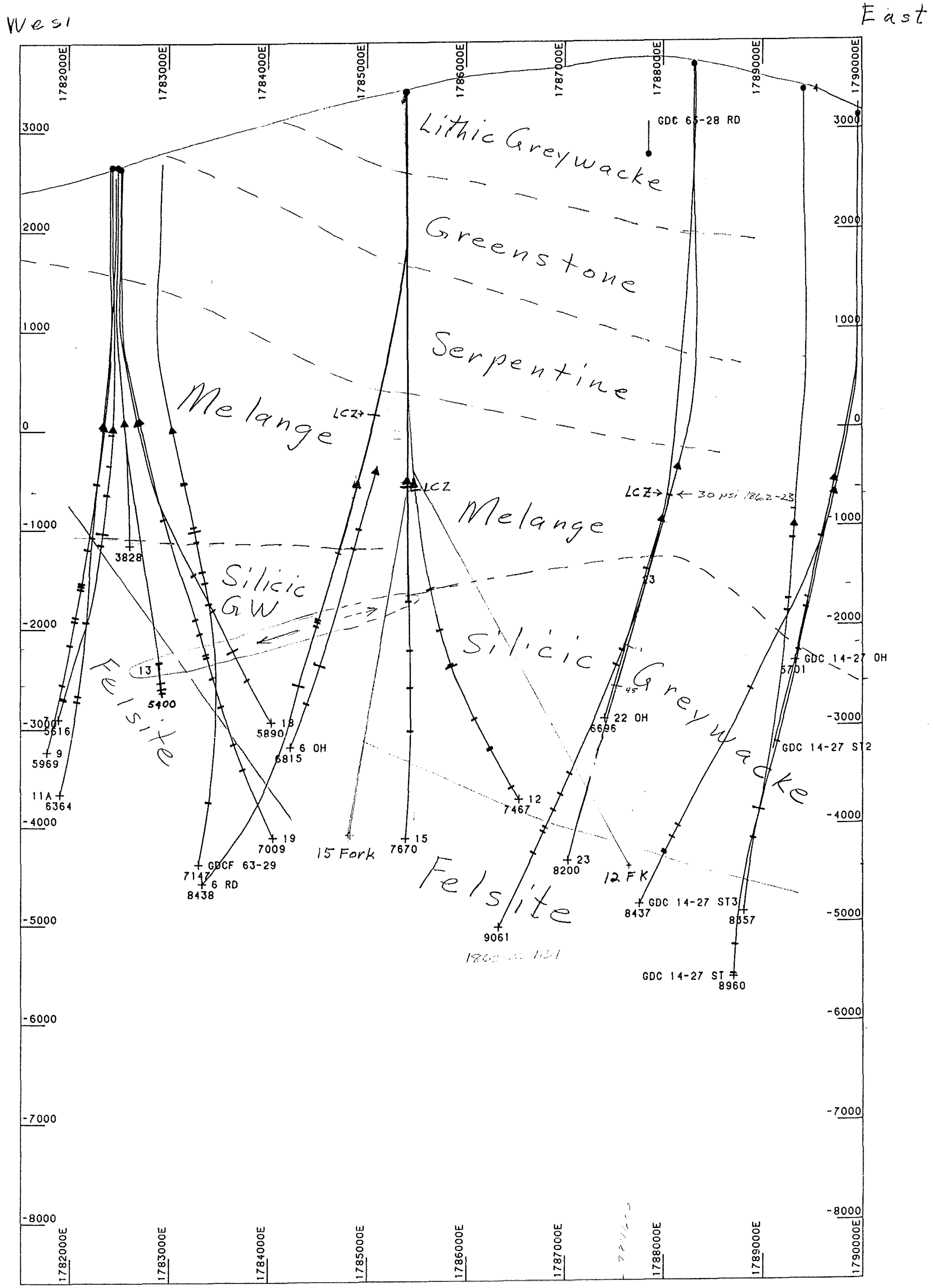
Some of the apparent topography in the felsite is related to projection of the wells into the plane of the x-section. Ditto in Figure 4.

Figure 4 : UNIT 20 MINERALOGY PROJECT



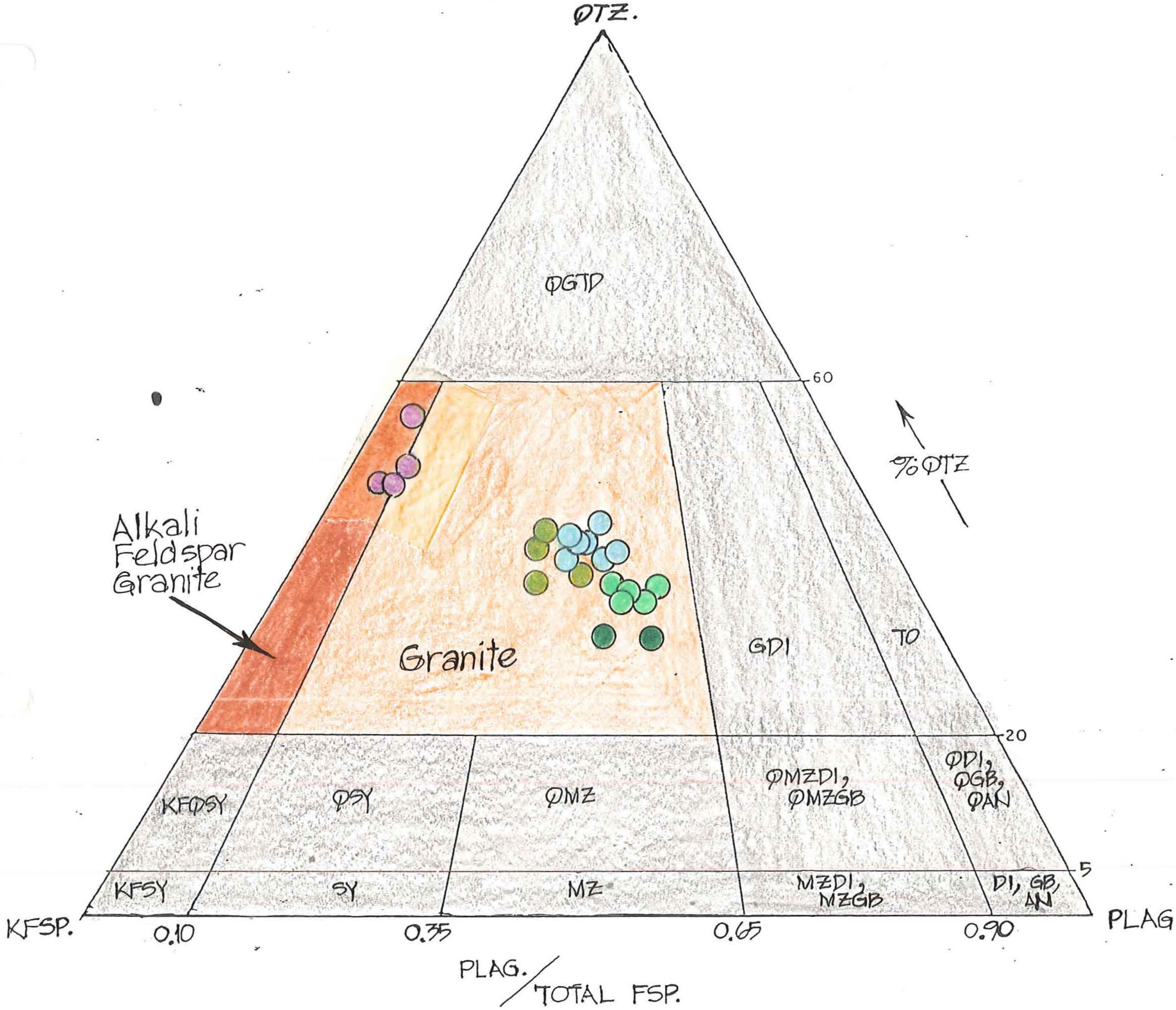


WEST
EAST
1795000E
1796000E
1797000E
1798000E
1799000E
1800000E
1801000E
1802000E
1803000E
+3000
+2000
+1000
MSL
-1000
-3000
-5000
-6000
-8000
GREENSTONE
MELANGE
(GW, Ch, GS, Ar)
TOP OF STEAM
LCZ
30#
10#
FAULT
BAR 2
DE 6
GREENSTONE
M (GW, Ch, GS, Arg)
958-1
4245
BAR 6
958-13
4997
BAR 1RD
BAR 1 OH
TOP OF STEAM
956A-4
52
958-9
958-1
7416
7073
958-10
7191
BAR 1RD
7165
Felsite
958-6
7820
Siliceous Greywacke
5206-2
7505
5206-2RD
8025
5206-3
7618
DE 5
DE 4
7685
DE 7
7730
5206-1RD
8203
5206-1 OH
8013
DE 8
MCK 11
10,000' TVD
958-16
NDE4
FREEPORT-McMORAN RESOURCE



West
East
1782000E
1783000E
1784000E
1785000E
1786000E
1787000E
1788000E
1789000E
1790000E
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
Lithic Greywacke
Greenstone
Serpentine
Melange
Melange
Silicic GW
Silicic Greywacke
Felsite
Felsite
LCZ
LCZ
LCZ
← 30 psi
GDC 65-28 RD
GDC 14-27 OH
5701
GDC 14-27 ST2
GDC 14-27 ST3
8437
8557
GDC 14-27 ST
8960
3828
13
5400
5616
9
5969
11A
6364
18
5890
6 OH
6815
19
7009
GDCF 63-29
7147
6 RD
8438
15 Fork
15
7670
12
7467
23
22 OH
6696
23
8200
12 FK
9061

Figure 2



UPPER FELSITE COMPOSITIONS

- DV-2, ST2
- GDC-21
- LF-48
- OF21C-12
- FF52-32, ST2

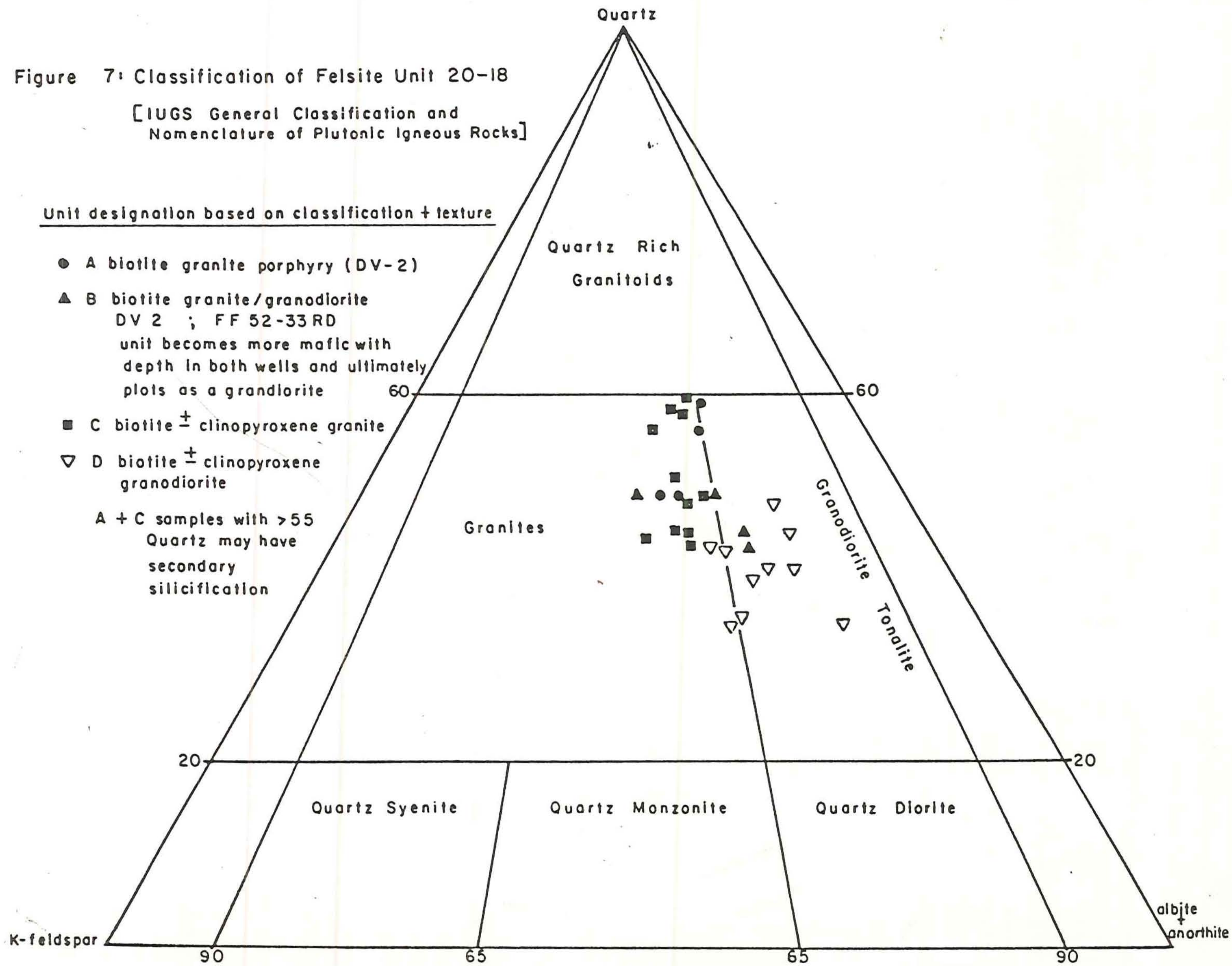
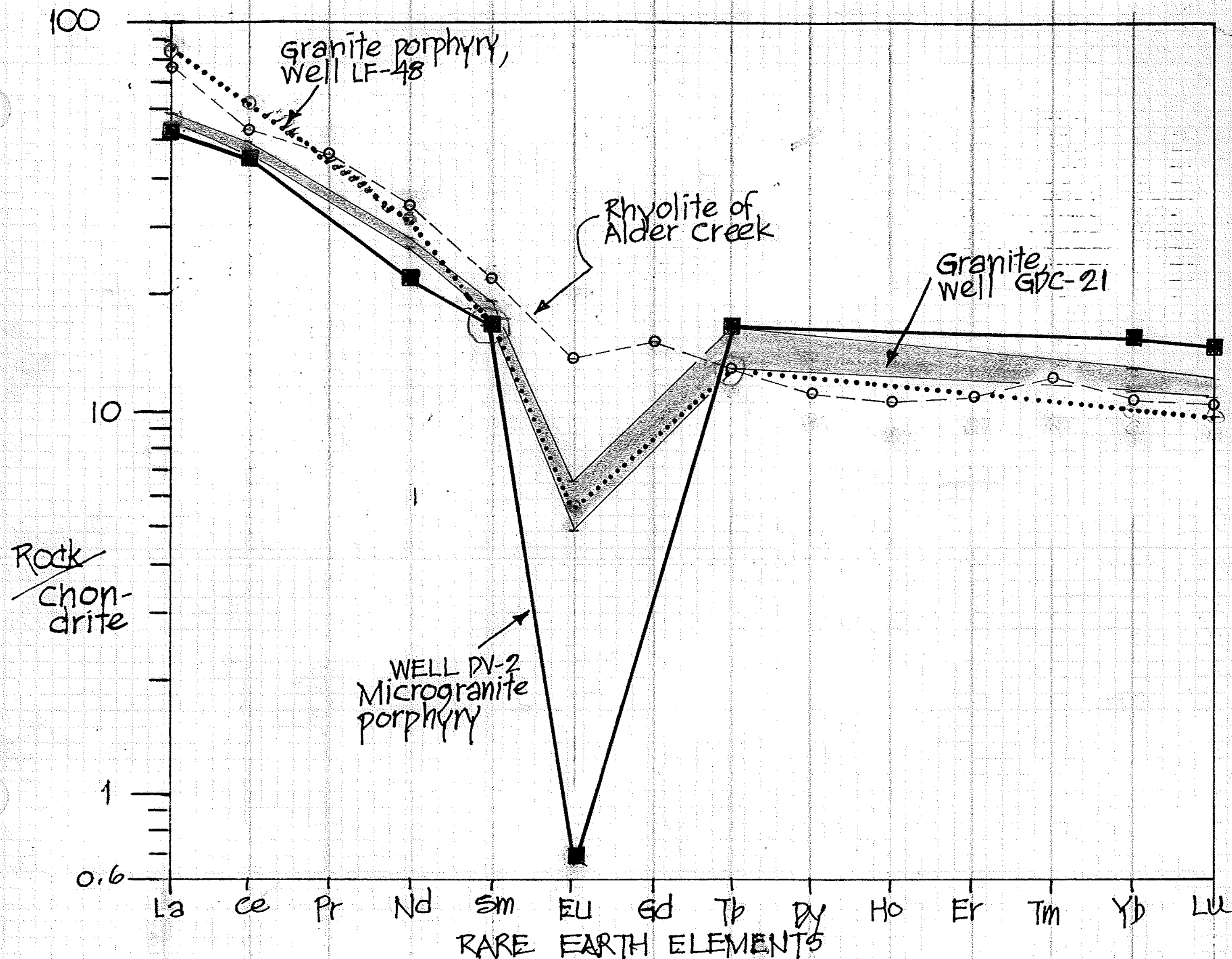
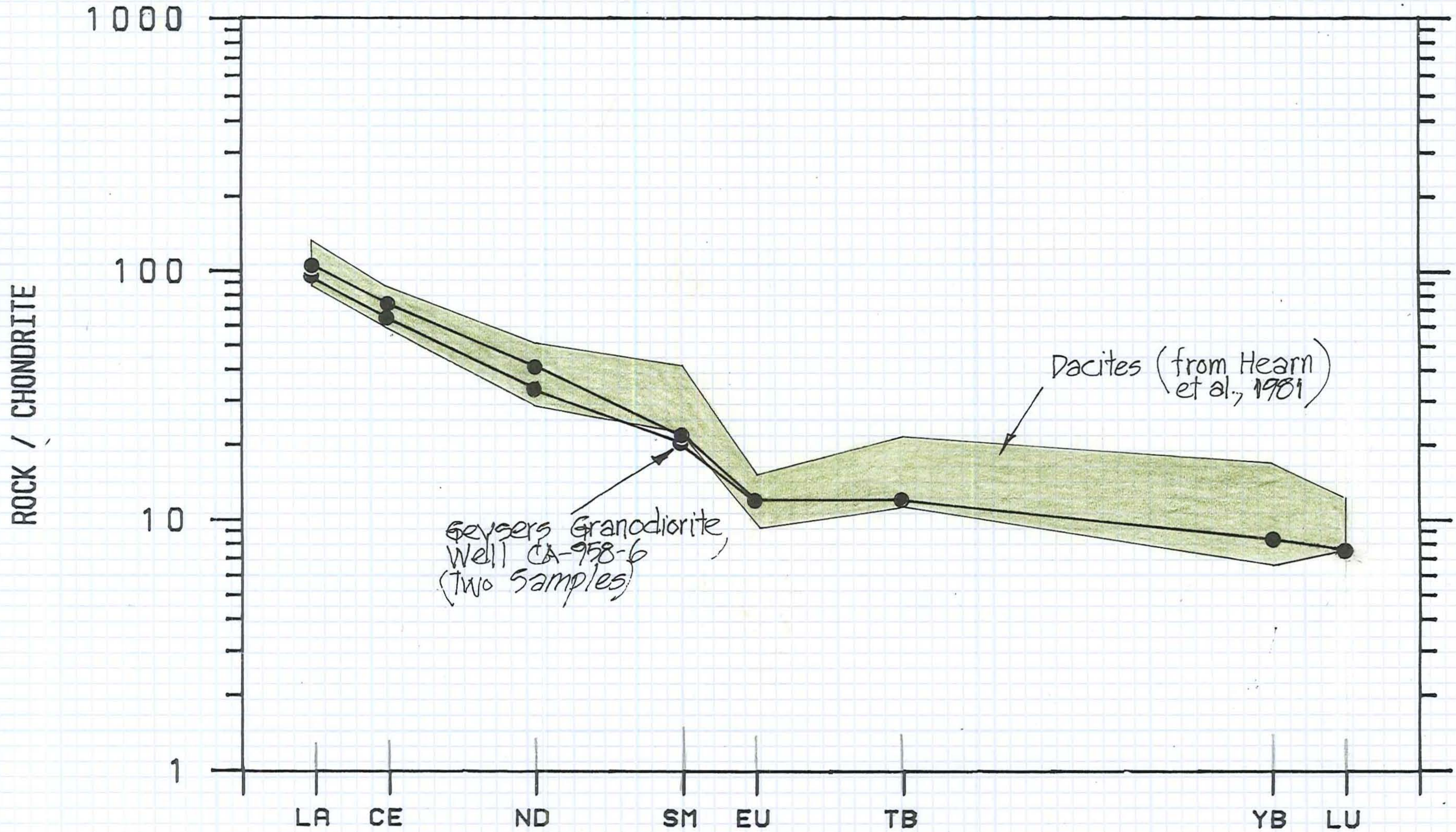


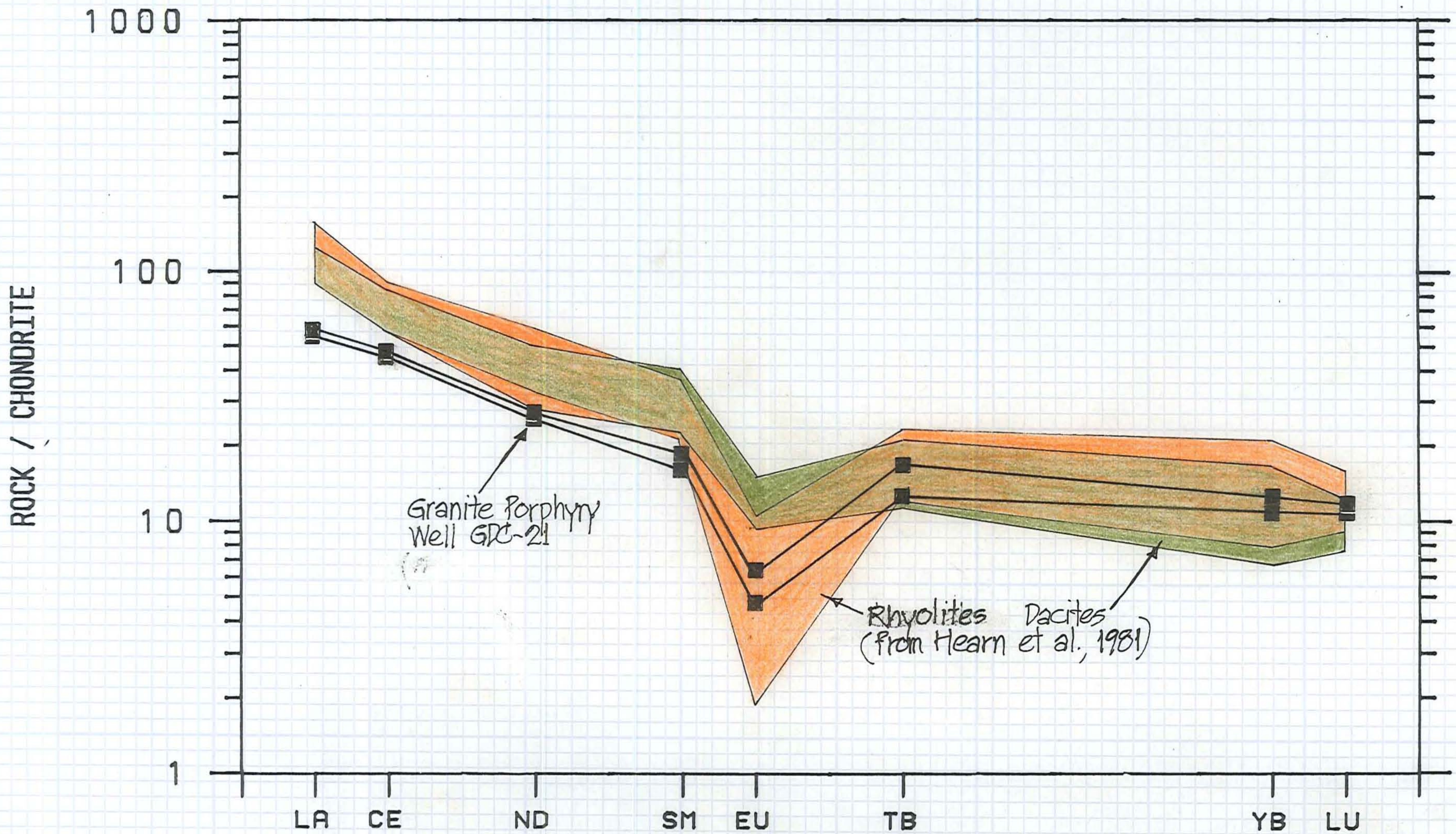
Figure 7: Classification of Felsite Unit 20-18
[IUGS General Classification and Nomenclature of Plutonic Igneous Rocks]



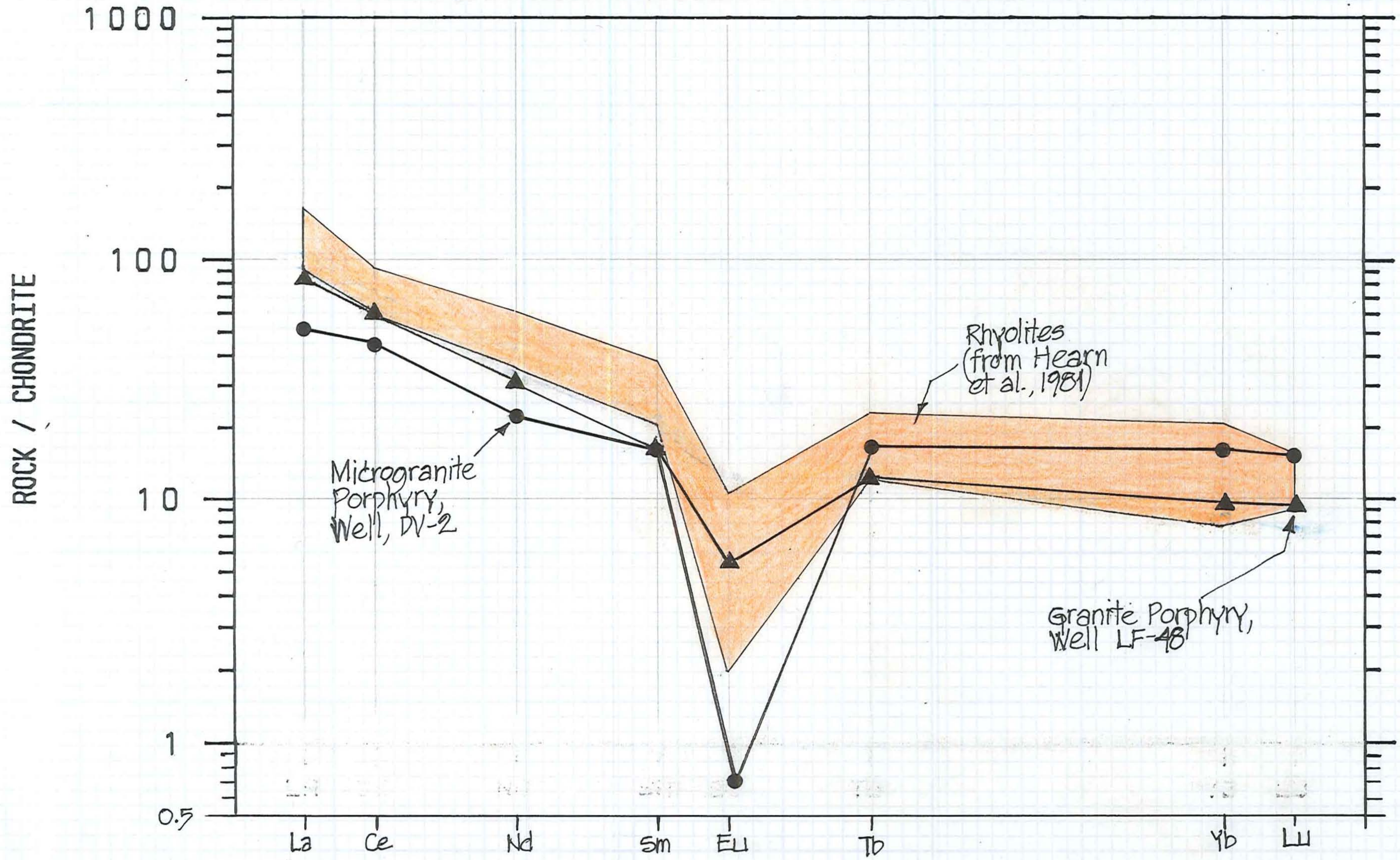
100
10
1
0.6
Rock/chondrite
Granite porphyry, well LF-48
Rhyolite of Alder Creek
Granite, well GDC-21
WELL DV-2 Microgranite porphyry
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu
RARE EARTH ELEMENTS



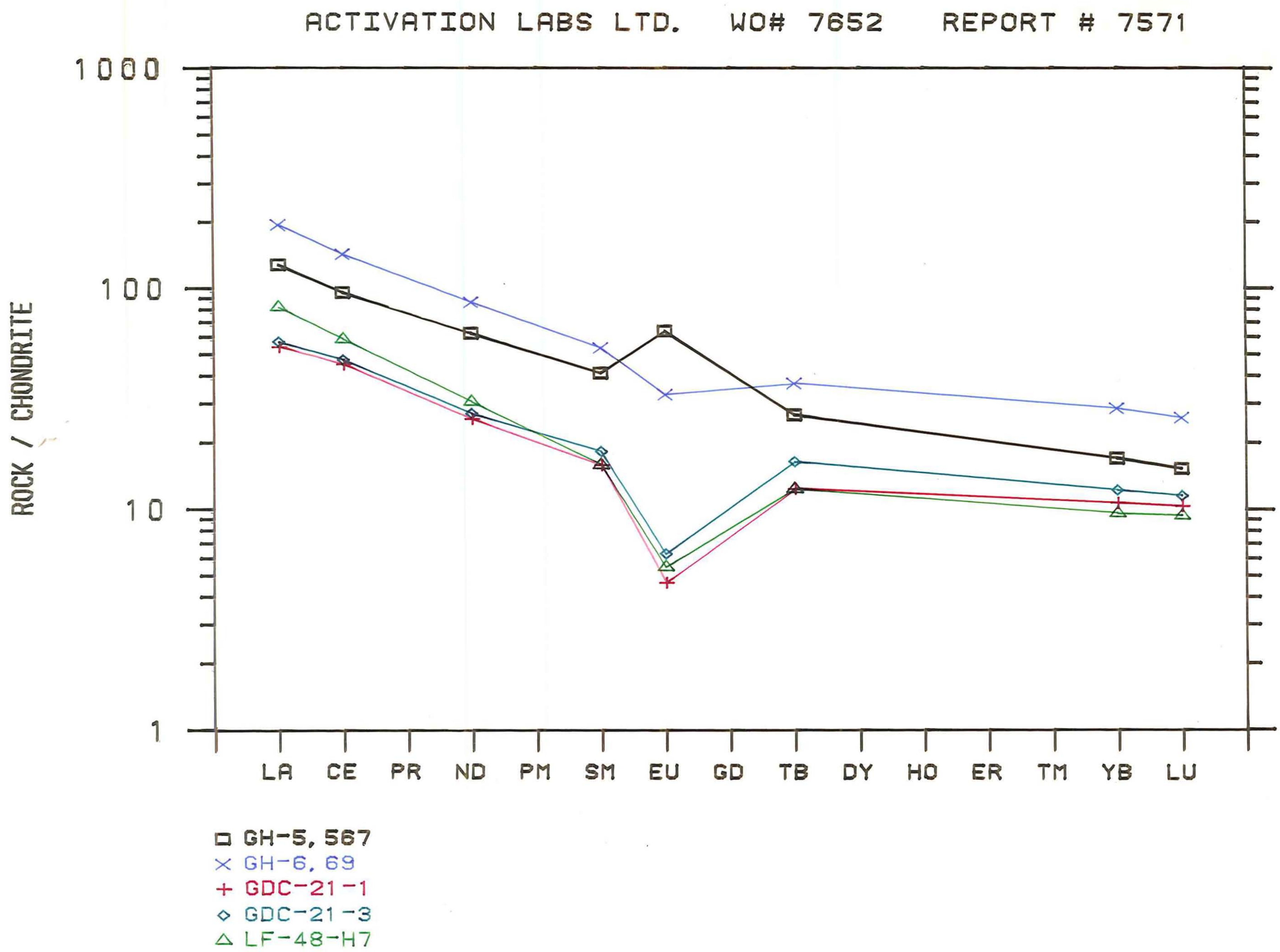
CHONDRITE-NORMALIZED RARE-EARTH ELEMENT PATTERNS, GEYSERS GRANODIORITE VS. DACITE OF THE CLEAR LAKE VOLCANICS

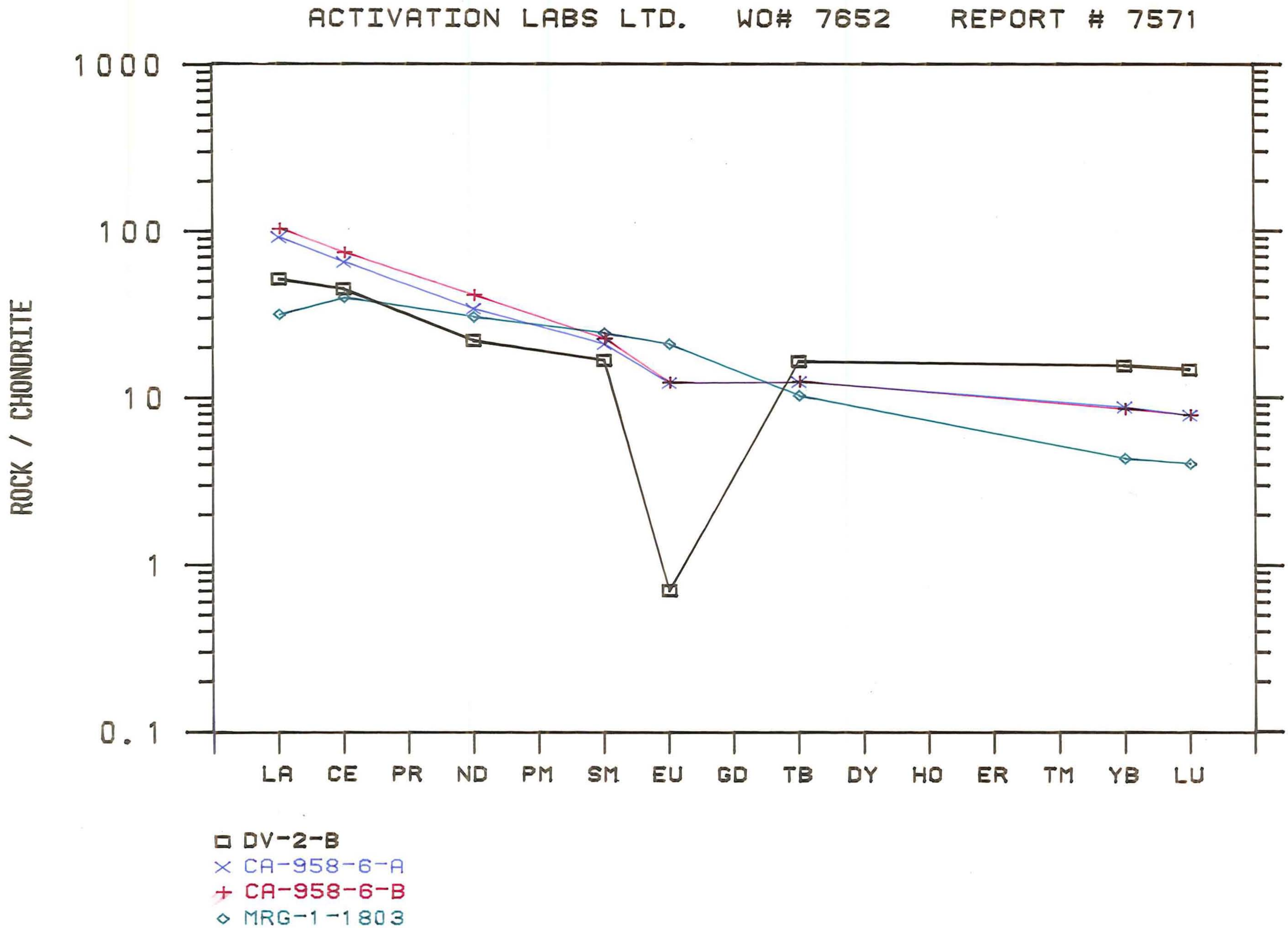


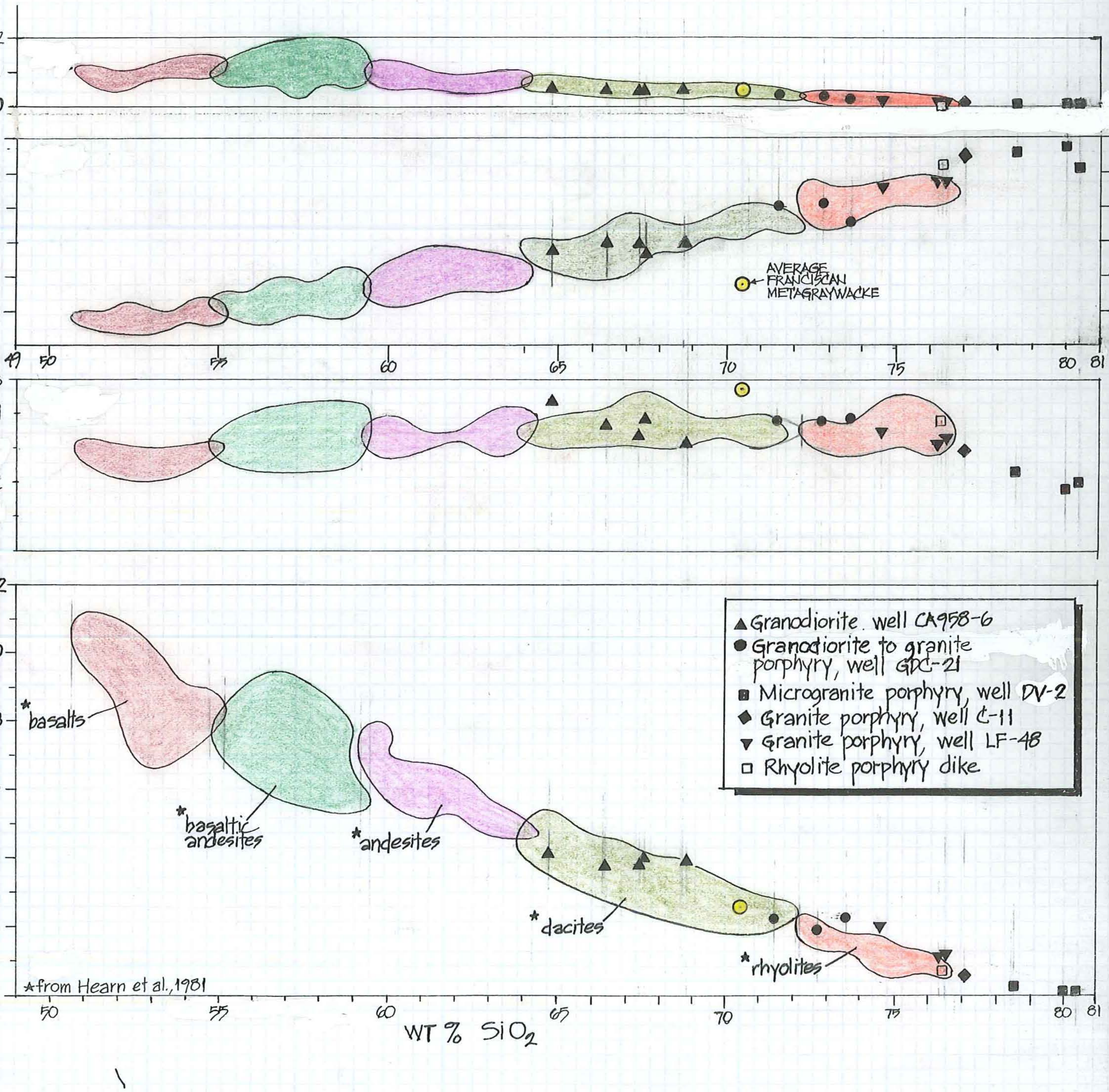
CHONDRITE-NORMALIZED RARE-EARTH ELEMENT PATTERNS
"HYBRID" GEYSERS GRANITE PORPHYRY VS. RHYOLITE AND
DACITE OF THE CLEAR LAKE VOLCANICS



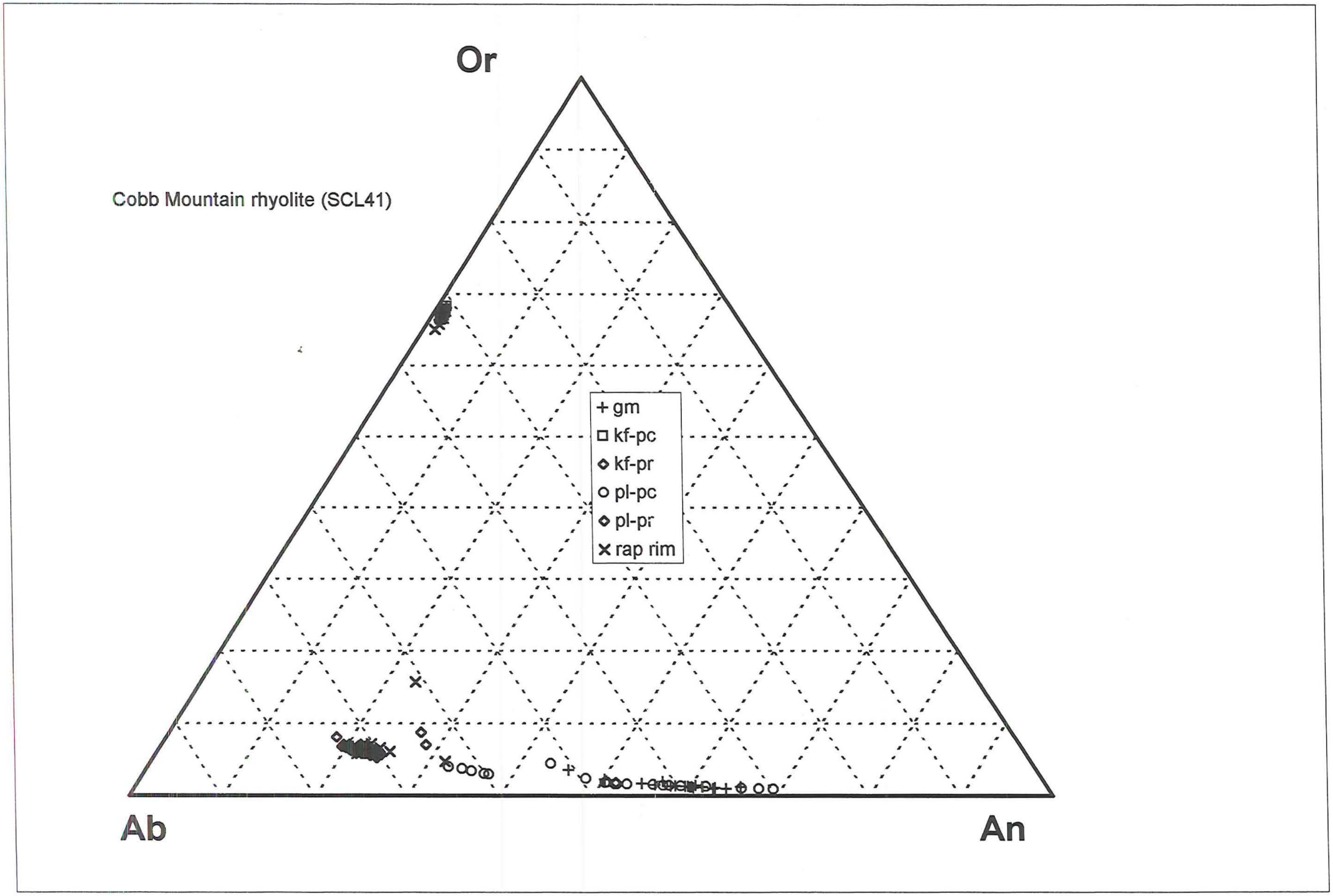
CHONDRITE-NORMALIZED RARE-EARTH ELEMENT PATTERNS, GEYSERS GRANITES VS. RHYOLITES OF THE CLEAR LAKE VOLCANIC FIELD

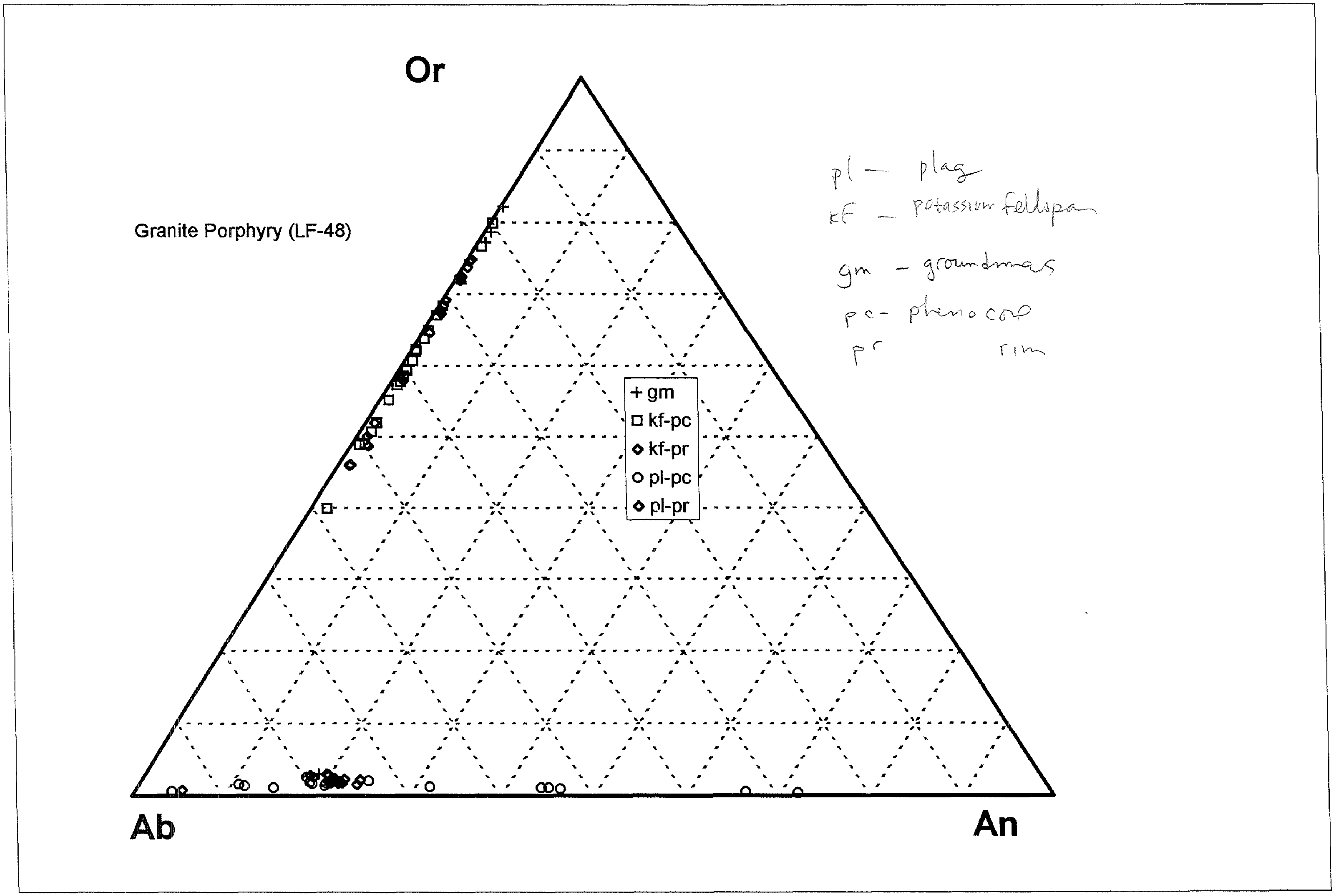

ACTIVATION LABS LTD. WO# 7652 REPORT # 7571
ROCK / CHONDRITE
1000
100
10
1
LA
CE
PR
ND
PM
SM
EU
GD
TB
DY
HO
ER
TM
YB
LU
GH-5, 567
GH-6, 69
GDC-21-1
GDC-21-3
LF-48-H7


ACTIVATION LABS LTD.   WO# 7652   REPORT # 7571
1000
100
10
1
0.1
ROCK / CHONDRITE
LA
CE
PR
ND
PM
SM
EU
GD
TB
DY
HO
ER
TM
YB
LU
DV-2-B
CA-958-6-A
CA-958-6-B
MRG-1-1803



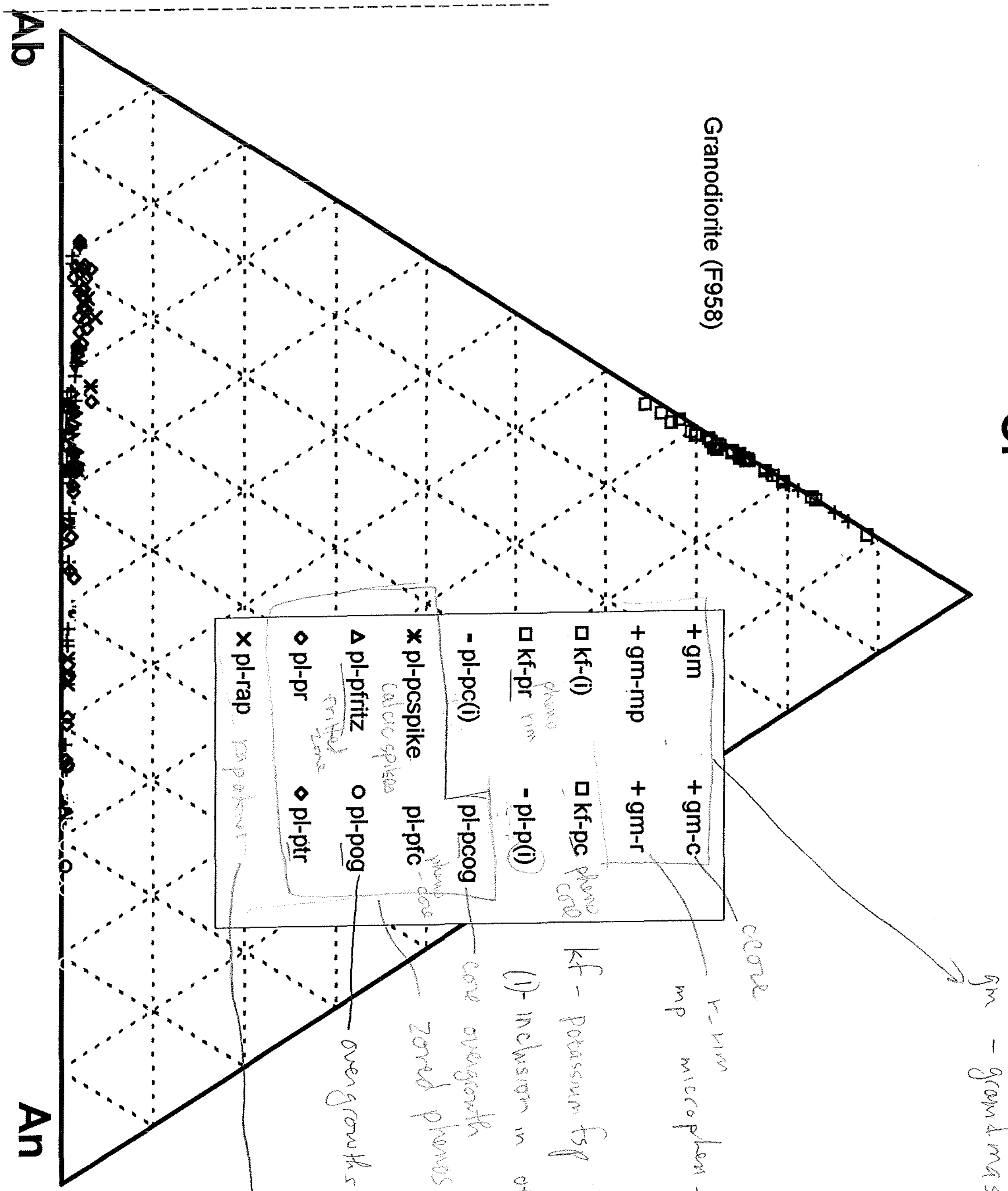
VARIATION OF MAJOR ELEMENTS WITH SILICA FOR THE GEYSERS PLUTON VS. CLEAR LAKE VOLCANICS

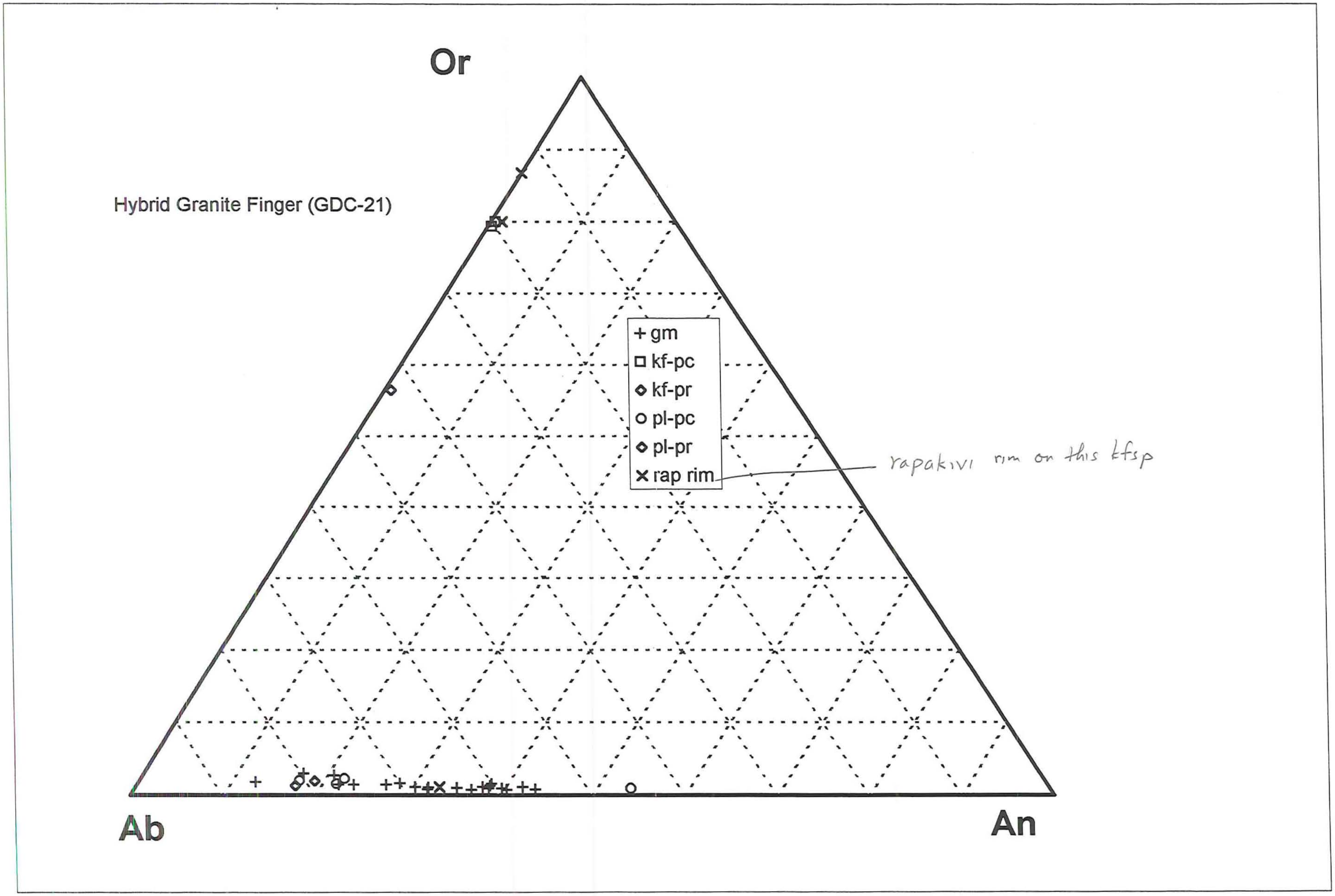

Or
Cobb Mountain rhyolite (SCL41)
+ gm
kf-pc
kf-pr
pl-pc
pl-pr
rap rim
Ab
An

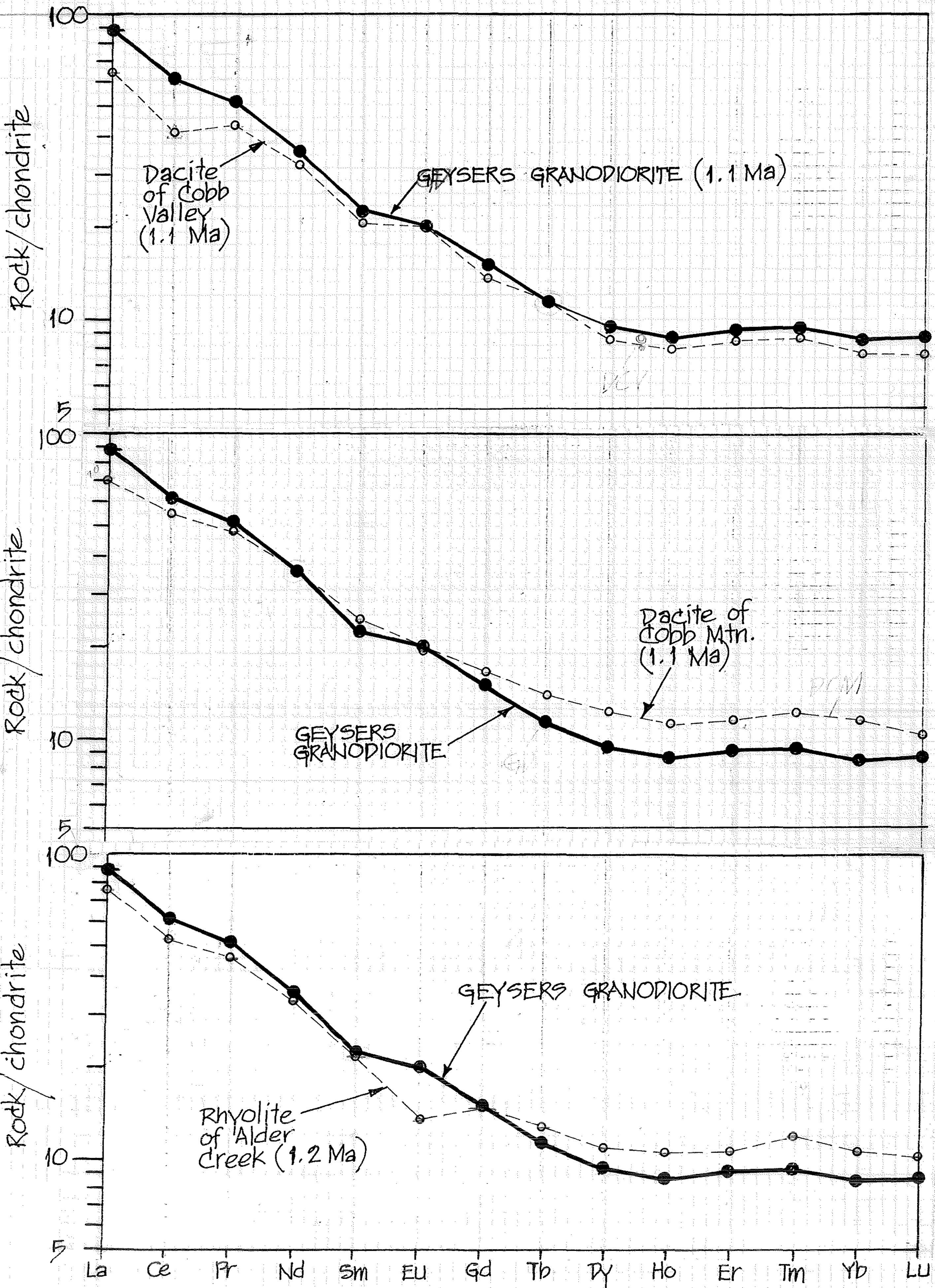

Granite Porphyry (LF-48)
Or
Ab
An
+ gm
kf-pc
kf-pr
pl-pc
pl-pr
pl — plag
kf — potassium feldspar
gm — groundmass
pc — pheno core
pr rim

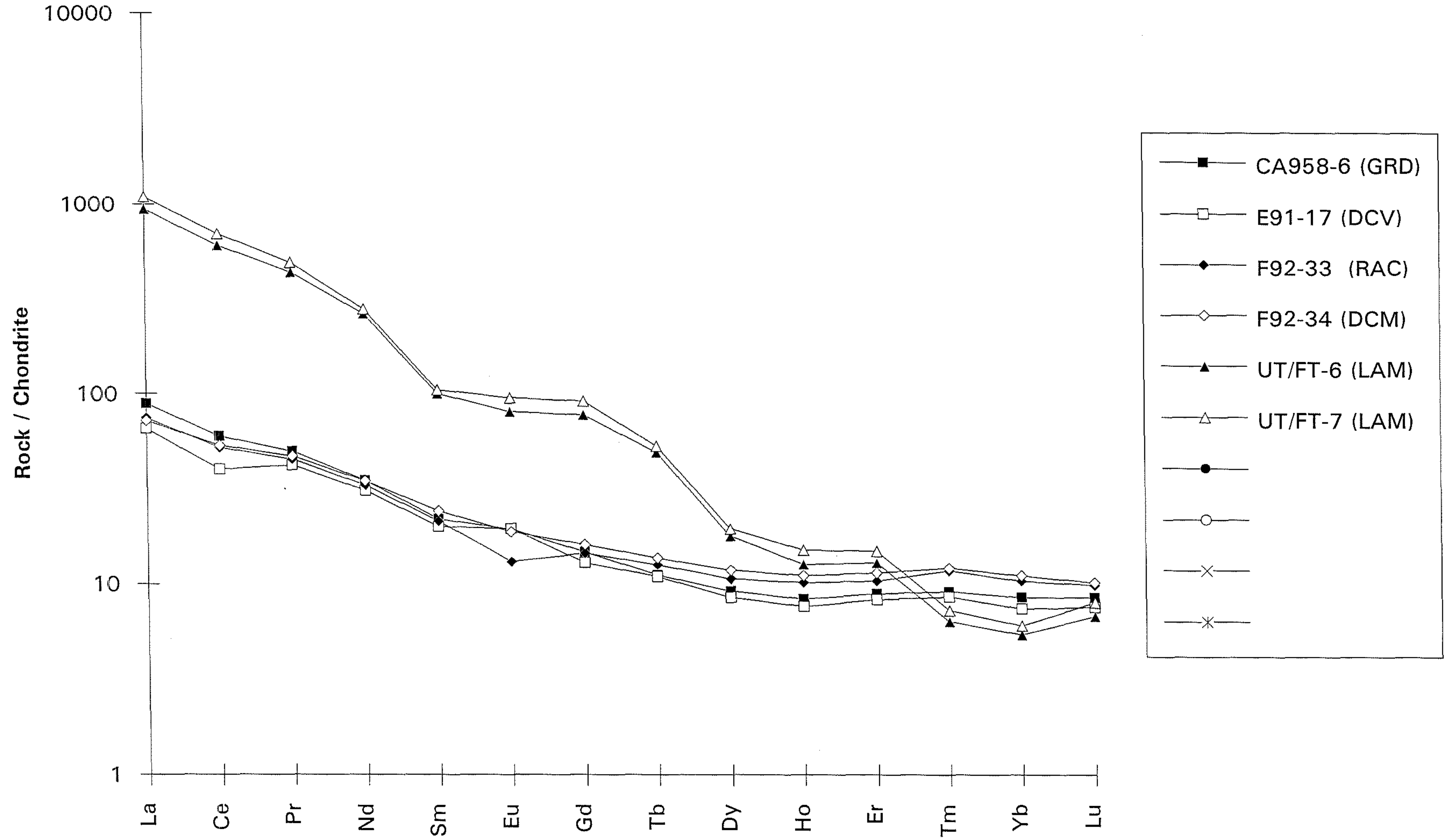
University of Leeds
Leeds LS2 9JT
UK

Tel. 0113 233 5200 Fax 0113 233 5259




Hybrid Granite Finger (GDC-21)
Or
Ab
An
+ gm
kf-pc
kf-pr
pl-pc
pl-pr
rap rim
rapakivi rim on this kfsp


100
10
5
Rock/chondrite
Dacite of Cobb Valley (1.1 Ma)
GEYSERS GRANODIORITE (1.1 Ma)
100
10
5
Rock/chondrite
Dacite of Cobb Mtn. (1.1 Ma)
GEYSERS GRANODIORITE
100
10
5
Rock/chondrite
GEYSERS GRANODIORITE
Rhyolite of Alder Creek (1.2 Ma)
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu


10000
1000
100
10
1
Rock / Chondrite
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu
CA958-6 (GRD)
E91-17 (DCV)
F92-33 (RAC)
F92-34 (DCM)
UT/FT-6 (LAM)
UT/FT-7 (LAM)

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

September 8, 1997
EES-1, Geology/Geochemistry
MS D462
(505) 667-8060
FAX (505) 665-3285

Jeffrey B. Hulen
ESRI
1515 E. Mineral Square, Room 109
Salt Lake City, UT 84112

Dear Jeff:

Enclosed at long last are some analyses of "volatile" elements from some of your favorite rocks. I hope you can use these in some future publication.

		B	Br	Cl	F	Li	S
F91-17	Cobb Va Dacite	26.5	1.3	54.7	301	29.5	10
F92-33	Cobb Mtn Rhyo	71.2	1.5	476	340	49.2	15
F92-34	Cobb Mtn Dacite	30.2	<0.5	60.5	349	29.6	7
CA-9586	The Felsite	25.4	1.6	466	745	33.9	58

Hi to Renata. Ciao for now.

As always,

Fraser Goff

Cy: BUS-4, MSA190
EES-1 Files

Subject: **13465.csv**
Date: Tue, 29 Jul 1997 14:47:40 -0400
From: Activation Laboratories <actlaba@ibm.net>
Organization: Activation Laboratories
To: "Univ. of Utah-hulen" <jhulen@egi.utah.edu>

```
Sample ID,,F %

CA958-6 (GRD),,0.130
F91-17 (DVC),,0.068
F92-33 (RAC),,0.049
F92-34 (DCM),,0.055
UT/FT-6 (LAM),,0.430
UT/FT-7 (LAM),,0.430
```

ACTLABS ACTIVATION LABORATORIES LTD

Invoice No.: 13244
Work Order: 13271
Invoice Date: 30-JUN-97
Date Submitted: 02-JUN-97
Your Reference: 25075
Account Number: 1161

UNIVERSITY OF UTAH
ENERGY AND GEOSCIENCE INSTITUTE
423 WAKARA WAY, SUITE 300
SALT LAKE CITY, UTAH
USA 84108
ATTENTION: JEFFREY B. HULEN

CERTIFICATE OF ANALYSIS

6 ROCK SAMPLES were submitted for analysis.

The following analytical packages were requested. Please see our current fee schedule for elements and detection limits.

..PORT 13244 PKG 4B-MAJOR ELEMENTS FUSION ICP/FEO-TITRATION/H20+- GAVIMETRIC
REPORT 13244 B PKG 4F- S - LECO

REPORT 13244 RPT.XLS PKG 4B2RE-TRACE ELEMENTS FUSION ICP/MS
REPORT 13244 BRP.XLS PKG 4B OPT3 FUSION ICP/MS

This report may only be reproduced in its entirety without the express consent of ACTIVATION LABS. If no instructions were received or will be received within 90 days from the date of this report, excess material will be discarded. Our liability is limited solely to the analytical cost of these analyses.

CERTIFIED BY :

DR. E. L. HOFFMAN

1336 SANDHILL DRIVE, ANCASTER, ONTARIO, CANADA L9G 4V5 • TEL: 905-648-9611 • FAX: 905-648-9613
E-MAIL: ACTLABA@IBM.NET or 102040.700 @ COMPUSERVE.COM

Lithogeochem (Research Package) Job #: 13271

Trace Element Values Are in Parts Per Million. Negative Va

Sample ID:	Sb	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm
CA958-6 (GRD)	0.97	10.0	1,005.6	27.98	48.71	5.142	20.88	4.20	1.403	3.81	0.55	2.98	0.58	1.89	0.274
E91-17 (DCV)	1.42	6.0	850.1	20.59	32.64	4.341	18.49	3.85	1.416	3.34	0.54	2.77	0.53	1.76	0.257
F92-33 (RAC)	1.17	16.2	694.6	23.42	42.53	4.670	19.74	4.12	0.946	3.76	0.62	3.46	0.71	2.21	0.353
F92-34 (DCM)	0.95	5.6	657.0	22.75	43.60	4.834	20.71	4.65	1.356	4.17	0.67	3.85	0.78	2.44	0.365
UT/FT-6 (LAM)	1.46	7.5	15,786.6	296.49	492.79	45.227	157.39	19.19	5.832	20.09	2.42	5.80	0.89	2.76	0.191
UT/FT-7 (LAM)	1.83	5.9	22,051.1	344.96	571.37	50.832	167.72	20.10	6.882	23.71	2.61	6.35	1.06	3.18	0.219

	p.335		p.326		p.327	p.323		p.323
	La/Yb	Sm	Nb	Zr	Th	Ba	Sr	Zr/Hf
UT/FT-6	264.72	19.19	165.5	355.2	25.54	15,786.6	2,229.71	111 (?)
UT/FT-7	275.97	20.10	221.2	854.1	33.48	22,051.1	4,679.28	45.2

poss.: Minette
Micaceous kimberlite

Lithogeochem (Research Package) Job #: 13271

Trace Element Values Are in Parts Per Million. Negative Va

Sample ID:	Yb	Lu	Hf	Ta	W	Tl	Pb	Bi	Th	U
CA958-6 (GRD)	1.76	0.274	3.1	0.44	0.5	0.59	17	-0.05	11.61	3.47
E91-17 (DCV)	1.54	0.244	3.7	0.54	21.9	0.75	34	-0.05	8.06	3.50
F92-33 (RAC)	2.16	0.319	2.7	0.73	2.4	1.39	24	0.13	13.89	6.10
F92-34 (DCM)	2.30	0.328	3.4	0.69	1.4	0.68	39	-0.05	10.48	4.56
UT/FT-6 (LAM)	1.12	0.218	3.2	9.57	1.1	0.57	37	0.12	25.54	3.95
UT/FT-7 (LAM)	1.25	0.258	18.9	12.92	2.0	1.19	49	0.16	33.48	6.95

Lithogeochem (Halogen Package) Job #: 13271 Report#: 13244B Company: University of Utah Contact: Jeffrey B. Hulen

Trace Element Values Are in Parts Per Million. Negative Values Equal Not Detected at That Lower Limit.

Sample ID:	Cl	Br	I
CA958-6 (GRD)	1,651	7	1
F91-17 (DCV)	1,775	7	-1
F92-33 (RAC)	2,697	9	-1
F92-34 (DCM)	2,593	7	-1
UT/FT-6 (LAM)	3,754	17	-1
UT/FT-7 (LAM)	4,624	17	-1

Certified By:

David D'Anna

D. D'Anna, Dipl. T.
ICPMS Technical Manager, Actlabs Ltd.

Date: 30 June 97

Lithogeochem (Research Package) Job #: 13271 Report#: 13244 Client:University of Utah Contact: Jefferey Hulen

Trace Element Values Are in Parts Per Million. Negative Values Equal Not Detected at That Lower Limit.

Sample ID:	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	As	Rb	Sr	Y	Zr	Nb	Mo	Ag	In	Sn
CA958-6 (GRD)	71	42	8.1	26	35	54	18	1.2	-5	137.1	333.16	17.7	133.6	5.3	0.3	-0.5	-0.1	2.1
E91-17 (DCV)	64	120	13.6	82	116	78	20	1.3	32	113.2	327.54	16.8	144.1	6.3	0.7	0.5	-0.1	1.6
F92-33 (RAC)	42	40	4.3	23	21	37	16	1.4	9	186.9	270.16	22.2	92.9	4.7	1.3	-0.5	-0.1	3.5
F92-34 (DCM)	38	28	6.6	16	12	60	17	1.2	10	129.9 ✱	328.39	23.8	132.5	6.9	0.5	0.6	-0.1	3.5
UT/FT-6 (LAM)	198	1,170	45.2	222	136	539	16	2.5	20	456.2	2,229.71	28.7	355.2	165.5	4.8	INT	0.9	9.3
UT/FT-7 (LAM)	222	853	52.8	231	170	910	18	2.3	27	546.3	4,679.28	32.2	854.1	221.2	1.9	INT	2.1	28.5

INT: Niobium interference on silver by ICPMS.

p. 339-340 →

✱ phlogopite lamproites fr. W. Kimberley mean Rb = 457 ppm.

5 locales: minettes Rb
30-258
96-237
31-60
117-313
64-239

Certified By:

Dario D'Anna

D. D'Anna, Dipl. T.
ICPMS Technical Manager, Actlabs Ltd.

Date: 30 June 97

1. compare w/ S.R. dike swarm ⇄ geochem / pet. > esp "microshonkinites"
2. search for others along "faults" of Flat Tops trend

SAMPLE DESCRIPTION	S %
CA958-6 (GRD)	0.005
F91-17 (DCV)	<0.003
F92-33 (RAC)	0.003
F92-34 (DCM)	<0.003
UT/FT-6 (LAN)	0.261
UT/FT-7 (LAN)	0.505

ACTLABS

ACTIVATION LABORATORIES LTD

Invoice No.: 13244
Work Order: 13271
Invoice Date: 30-JUN-97
Date Submitted: 02-JUN-97
Your Reference: 25075
Account Number: 1161

UNIVERSITY OF UTAH
ENERGY AND GEOSCIENCE INSTITUTE
423 WAKARA WAY, SUITE 300
SALT LAKE CITY, UTAH
USA 84108
ATTENTION: JEFFREY B. HULEN

466-9560

CERTIFICATE OF ANALYSIS

6 ROCK SAMPLES were submitted for analysis.

The following analytical packages were requested. Please see our current fee schedule for elements and detection limits.

REPORT 13244 PKG 4B-MAJOR ELEMENTS FUSION ICP/FEO-TITRATION/H20+- GAVIMETRIC
REPORT 13244 B PKG 4F- S - LECO

REPORT 13244 RPT.XLS PKG 4B2RE-TRACE ELEMENTS FUSION ICP/MS
REPORT 13244 BRP.XLS PKG 4B OPT3 FUSION ICP/MS

This report may only be reproduced in its entirety without the express consent of ACTIVATION LABS. If no instructions were received or will be received within 90 days from the date of this report, excess material will be discarded. Our liability is limited solely to the analytical cost of these analyses.

CERTIFIED BY :

DR. E. L. HOFFMAN

1336 SANDHILL DRIVE, ANCASTER, ONTARIO, CANADA L9G 4V5 • TEL: 905-648-9611 • FAX: 905-648-9613
E-MAIL: ACTLABA@IBM.NET or 102040.700 @ COMPUSERVE.COM

Lithogeochem (Halogen Package) Job #: 13271 Report#: 13244B Company: University of Utah Contact: Jeffrey B. Hulen

Trace Element Values Are in Parts Per Million. Negative Values Equal Not Detected at That Lower Limit.

Sample ID:	Cl	Br	I
CA958-6 [GRD]	1,651	7	1
F91-17 (DCV)	1,775	7	-1
F92-33 (RAC)	2,697	9	-1
F92-34 (DCM)	2,593	7	-1
UT/FT-6 [LAM]	3,754	17	-1
UT/FT-7 [LAM]	4,624	17	-1

Certified By:

David D'Anna

D. D'Anna, Dipl. T.
ICPMS Technical Manager, Actlabs Ltd.

Date: 30 June 97

Lithogeochem (Research Package) Job #: 13271

Trace Element Values Are in Parts Per Million. Negative Va

Sample ID:	Yb	Lu	Hf	Ta	W	Tl	Pb	Bi	Th	U
CA958-6 (GRD)	1.76	0.274	3.1	0.44	0.5	0.59	17	-0.05	11.61	3.47
E91-17 (DCV)	1.54	0.244	3.7	0.54	21.9	0.75	34	-0.05	8.06	3.50
F92-33 (RAC)	2.16	0.319	2.7	0.73	2.4	1.39	24	0.13	13.89	6.10
F92-34 (DCM)	2.30	0.328	3.4	0.69	1.4	0.68	39	-0.05	10.48	4.56
UT/FT-6 (LAM)	1.12	0.218	3.2	9.57	1.1	0.57	37	0.12	25.54	3.95
UT/FT-7 (LAM)	1.25	0.258	18.9	12.92	2.0	1.19	49	0.16	33.48	6.95

13244RPT.XLS

Lithogeochem (Research Package) Job #: 13271

Trace Element Values Are in Parts Per Million. Negative Va

Sample ID:	La/Yb	Sb	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm
CA958-6 (GRD)	15.9	0.97	10.0	1,005.6	27.98	48.71	5.142	20.88	4.20	1.403	3.81	0.55	2.98	0.58	1.89	0.274
E91-17 (DCV)	13.4	1.42	6.0	850.1	20.59	32.64	4.341	18.49	3.85	1.416	3.34	0.54	2.77	0.53	1.76	0.257
F92-33 (RAC)	20.01	1.17	16.2	694.6	23.42	42.53	4.670	19.74	4.12	0.946	3.76	0.62	3.46	0.71	2.21	0.353
F92-34 (DCM)	9.89	0.95	5.6	657.0	22.75	43.60	4.834	20.71	4.65	1.356	4.17	0.67	3.85	0.78	2.44	0.365
UT/FT-6 (LAM)		1.46	7.5	15,786.6	296.49	492.79	45.227	157.39	19.19	5.832	20.09	2.42	5.80	0.89	2.76	0.191
UT/FT-7 (LAM)		1.83	5.9	22,051.1	344.96	571.37	50.832	167.72	20.10	6.882	23.71	2.61	6.35	1.06	3.18	0.219

Lithogeochem (Research Package) Job #: 13271 **Report#: 13244** **Client:University of Utah** **Contact: Jefferey Hulen**

Trace Element Values Are in Parts Per Million. Negative Values Equal Not Detected at That Lower Limit.

Sample ID:	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	As	Rb	Sr	Y	Zr	Nb	Mo	Ag	In	Sn
CA958-6 (GRD)	71	42	8.1	26	35	54	18	1.2	-5	137.1	333.16	17.7	133.6	5.3	0.3	-0.5	-0.1	2.1
E91-17 (DCV)	64	120	13.6	82	116	78	20	1.3	32	113.2	327.54	16.8	144.1	6.3	0.7	0.5	-0.1	1.6
F92-33 (RAC)	42	40	4.3	23	21	37	16	1.4	9	186.9	270.16	22.2	92.9	4.7	1.3	-0.5	-0.1	3.5
F92-34 (DCM)	38	28	6.6	16	12	60	17	1.2	10	129.9	328.39	23.8	132.5	6.9	0.5	0.6	-0.1	3.5
UT/FT-6 (LAM)	198	1,170	45.2	222	136	539	16	2.5	20	456.2	2,229.71	28.7	355.2	165.5	4.8	INT	0.9	9.3
UT/FT-7 (LAM)	222	853	52.8	231	170	910	18	2.3	27	546.3	4,679.28	32.2	854.1	221.2	1.9	INT	2.1	28.5

INT: Niobium interference on silver by ICPMS.

Certified By:

D. D'Anna, Dipl. T.
ICPMS Technical Manager, Actlabs Ltd.

Date: 30 June 97

Activation Laboratories Ltd. **Work Order: 13271** **Report: 13244B**

SAMPLE DESCRIPTION	S %
CA95B-6 (GRD)	0.005
F91-17 (DCV)	<0.003
F92-33 (RAC)	0.003
F92-34 (DCM)	<0.003
UT/FT-6 (LAM)	0.261
UT/FT-7 (LAM)	0.505

Activation Laboratories Ltd. Work Order No. 13271 Report No.13244

SAMPLE	SiO2	Al2O3	Fe2O3	FeO	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	H2O-	H2O+	LOI	TOTAL	Ba	Sr	Y	Sc	Zr	Be	V
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
CA958-6 [GRD]	67.88	15.74	0.76	2.60	0.06	1.79	3.78	4.12	2.19	0.43	0.12	0.13	0.32	0.12	99.59	996	337	17	12	130	2	69
F91-17 [DCV]	64.72	17.40	1.77	2.00	0.05	2.41	1.70	3.19	2.83	0.58	0.13	0.22	2.66	1.77	98.59	869	337	16	12	146	2	61
F92-33 [RAC]	69.99	13.79	0.89	1.50	0.05	1.16	2.41	3.40	4.17	0.34	0.09	0.17	1.48	0.19	97.90	677	279	21	8	100	2	45
F92-34 [DCM]	66.71	15.36	2.09	1.50	0.07	1.15	3.69	3.90	3.28	0.70	0.18	0.11	0.6	0.41	99.04	659	342	23	11	133	1	38
UT/FT-6 [LAM]	28.55	8.32	5.20	3.10	0.14	5.50	18.60	0.13	7.44	3.30	1.81	0.14	0.96	13.87	95.98	14821	2110	27	32	682	4	204
UT/FT-7 [LAM]	30.14	8.43	5.53	2.40	0.17	4.60	16.96	0.15	7.23	3.85	1.70	0.16	0.66	12.78	93.94	20247	4282	29	29	894	5	227

Adrienne I. Rittau, B.Sc., C.Chem
ICP Technical Manager

Negative values indicate less than the detection limit

Activation Laboratories Ltd. Work Order No. 13271 Report No.13244

SAMPLE	SiO2	Al2O3	Fe2O3	FeO	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	H2O-	H2O+	LOI	TOTAL	Ba	Sr	Y	Sc	Zr	Be	V
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
CA958-6 (GRD)	67.88	15.74	0.76	2.60	0.06	1.79	3.78	4.12	2.19	0.43	0.12	0.13	0.32	0.12	99.59	996	337	17	12	130	2	69
F91-17 (DCV)	64.72	17.40	1.77	2.00	0.05	2.41	1.70	3.19	2.83	0.58	0.13	0.22	2.66	1.77	98.59	869	337	16	12	146	2	61
F92-33 (RAC)	69.99	13.79	0.89	1.50	0.05	1.16	2.41	3.40	4.17	0.34	0.09	0.17	1.48	0.19	97.90	677	279	21	8	100	2	45
F92-34 (DCM)	[illegible]	15.36	2.09	1.50	0.07	1.15	3.69	3.90	3.28	0.70	0.18	0.11	0.6	0.41	99.04	659	342	23	11	133	1	38
UT/FT-6 (LAM)	28.55	8.32	5.20	3.10	0.14	5.50	18.60	0.13	7.44	3.30	1.81	0.14	0.96	13.87	95.98	14821	2110	27	32	682	4	204
UT/FT-7 (LAM)	30.14	8.43	5.53	2.40	0.17	4.60	16.96	0.15	7.23	3.85	1.70	0.16	0.66	12.78	93.94	20247	4282	29	29	894	5	227

GRD 68.24 4.14 2.20
F91-17 DCV 66.85 3.30 2.92
RAC 71.63 3.48 4.27

Adrienne I. Rittau, B.Sc., C.Chem
ICP Technical Manager

Negative values indicate less than the detection limit

Activation Laboratories Ltd. Work Order No. 13271 Report No.13244

SAMPLE	SiO2 %	Al2O3 %	Fe2O3 %	FeO %	MnO %	MgO %	CaO %	Na2O %	K2O %	TiO2 %	P2O5 %	H2O- %	H2O+ %	LOI %	TOTAL %	Ba ppm	Sr ppm	Y ppm	Sc ppm	Zr ppm	Be ppm	V ppm
CA958-6 (GRD)	67.88	15.74	0.76	2.60	0.06	1.79	3.78	4.12	2.19	0.43	0.12	0.13	0.32	0.12	99.59	996	337	17	12	130	2	69
F91-17 (DCV)	64.72	17.40	1.77	2.00	0.05	2.41	1.70	3.19	2.83	0.58	0.13	0.22	2.66	1.77	98.59	869	337	16	12	146	2	61
F92-33 (RAC)	69.99	13.79	0.89	1.50	0.05	1.16	2.41	3.40	4.17	0.34	0.09	0.17	1.48	0.19	97.90	677	279	21	8	100	2	45
F92-34 (DCM)	66.71	15.36	2.09	1.50	0.07	1.15	3.69	3.90	3.28	0.70	0.18	0.11	0.6	0.41	99.04	659	342	23	11	133	1	38
UT/FT-6 (LAM)	28.55	8.32	5.20	3.10	0.14	5.50	18.60	0.13	7.44	3.30	1.81	0.14	0.96	13.87	95.98	14821	2110	27	32	682	4	204
UT/FT-7 (LAM)	30.14	8.43	5.53	2.40	0.17	4.60	16.96	0.15	7.23	3.85	1.70	0.16	0.66	12.78	93.94	20247	4282	29	29	894	5	227

10.49% CaO

30.09	8.77	5.48	3.27	0.15	5.80	19.60	0.14	7.84	3.48	1.91	0.15	14.62
32.37	9.05	5.93	2.58	0.18	4.94	18.21	0.16	7.76	4.13	1.83	0.17	13.72

1.47% SO4
0.82% H2O
.29

BaO

67.63   3.95   3.33

2.29

137.36
16.

98.63

BaO 64.4   65.2   58% Ba
SO3 34.3   34.8 SO3   42% SO3
98.7

14

2.03% Ba

58%

3.5%

93.12

94.88

Adrienne I. Rittau, B.Sc., C.Chem
ICP Technical Manager

Negative values indicate less than the detection limit

SAMPLE DESCRIPTION	S %
CA958-6 (GRD)	0.005
F91-17 (DCV)	<0.003
F92-33 (RAC)	0.003
F92-34 (DCM)	<0.003
UT/FT-6 (LAM)	0.261
UT/FT-7 (LAM)	0.505

Lithogeochem (Research Package) Job #: 13271 **Report#: 13244** **Client:University of Utah** **Contact: Jefferey Hulen**

Trace Element Values Are in Parts Per Million. Negative Values Equal Not Detected at That Lower Limit.

Sample ID:	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	As	Rb	Sr	Y	Zr	Nb	Mo	Ag	In	Sn
CA958-6 (GRD)	71	42	8.1	26	35	54	18	1.2	-5	137.1	333.16	17.7	133.6	5.3	0.3	-0.5	-0.1	2.1
E91-17 (DCV)	64	120	13.6	82	116	78	20	1.3	32	113.2	327.54	16.8	144.1	6.3	0.7	0.5	-0.1	1.6
F92-33 (RAC)	42	40	4.3	23	21	37	16	1.4	9	186.9	270.16	22.2	92.9	4.7	1.3	-0.5	-0.1	3.5
F92-34 (DCM)	38	28	6.6	16	12	60	17	1.2	10	129.9	328.39	23.8	132.5	6.9	0.5	0.6	-0.1	3.5
UT/FT-6 (LAM)	198	1,170	45.2	222	136	539	16	2.5	20	456.2	2,229.71	28.7	355.2	165.5	4.8	INT	0.9	9.3
UT/FT-7 (LAM)	222	853	52.8	231	170	910	18	2.3	27	546.3	4,679.28	32.2	854.1	221.2	1.9	INT	2.1	28.5

INT: Niobium interference on silver by ICPMS.

Certified By:

D. D'Anna, Dipl. T.
ICPMS Technical Manager, Actlabs Ltd.

Date: 30 June 97

Lithogeochem (Research Package) Job #: 13271

Trace Element Values Are in Parts Per Million. Negative Va

Sample ID:	Sb	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm
CA958-6 (GRD)	0.97	10.0	1,005.6	27.98	48.71	5.142	20.88	4.20	1.403	3.81	0.55	2.98	0.58	1.89	0.274
E91-17 (DCV)	1.42	6.0	850.1	20.59	32.64	4.341	18.49	3.85	1.416	3.34	0.54	2.77	0.53	1.76	0.257
F92-33 (RAC)	1.17	16.2	694.6	23.42	42.53	4.670	19.74	4.12	0.946	3.76	0.62	3.46	0.71	2.21	0.353
F92-34 (DCM)	0.95	5.6	657.0	22.75	43.60	4.834	20.71	4.65	1.356	4.17	0.67	3.85	0.78	2.44	0.365
UT/FT-6 (LAM)	1.46	7.5	15,786.6	296.49	492.79	45.227	157.39	19.19	5.832	20.09	2.42	5.80	0.89	2.76	0.191
UT/FT-7 (LAM)	1.83	5.9	22,051.1	344.96	571.37	50.832	167.72	20.10	6.882	23.71	2.61	6.35	1.06	3.18	0.219

Lithogeochem (Research Package) Job #: 13271

Trace Element Values Are in Parts Per Million. Negative Va

Sample ID:	Yb	Lu	Hf	Ta	W	Tl	Pb	Bi	Th	U
CA958-6 (GRD)	1.76	0.274	3.1	0.44	0.5	0.59	17	-0.05	11.61	3.47
E91-17 (DCV)	1.54	0.244	3.7	0.54	21.9	0.75	34	-0.05	8.06	3.50
F92-33 (RAC)	2.16	0.319	2.7	0.73	2.4	1.39	24	0.13	13.89	6.10
F92-34 (DCM)	2.30	0.328	3.4	0.69	1.4	0.68	39	-0.05	10.48	4.56
UT/FT-6 (LAM)	1.12	0.218	3.2	9.57	1.1	0.57	37	0.12	25.54	3.95
UT/FT-7 (LAM)	1.25	0.258	18.9	12.92	2.0	1.19	49	0.16	33.48	6.95

Lithogeochem (Halogen Package) Job #: 13271 **Report#: 13244B** **Company: University of Utah** **Contact: Jeffrey B. Hulen**

Trace Element Values Are in Parts Per Million. Negative Values Equal Not Detected at That Lower Limit.

Sample ID:	Cl	Br	I
CA958-6 (GRD)	1,651	7	1
F91-17 (DCV)	1,775	7	-1
F92-33 (RAC)	2,697	9	-1
F92-34 (DCM)	2,593	7	-1
UT/FT-6 (LAM)	3,754	17	-1
UT/FT-7 (LAM)	4,624	17	-1

Certified By:

David D'Anna

D. D'Anna, Dipl. T.
ICPMS Technical Manager, Actlabs Ltd.

Date: 30 June 97

ACTLABS

ACTIVATION LABORATORIES LTD

Invoice No.: 7571
Work Order: 7652
Invoice Date: 08-MAR-95
Date Submitted: 13-FEB-95
Your Reference: 67810
Account Number: U017

UNIVERSITY OF UTAH
EARTH SCIENCES AND RESOURCES INSTITUTE
391 CHIPETA WAY, SUTIE C
SALT LAKE CITY, UTAH
USA 84108
ATTENTION: JEFFREY B. HULEN

CERTIFICATE OF ANALYSIS

I A package, elements and detection limits:

AU	2.	PPB	AS	1.	PPM	BR	0.5	PPM	CO	0.1	PPM
CR	0.5	PPM	CS	0.2	PPM	HF	0.2	PPM	HG	1.	PPM
IR	1.	PPB	MO	2.	PPM	RB	10.	PPM	SB	0.1	PPM
SC	0.1	PPM	SE	0.5	PPM	TA	0.3	PPM	TH	0.1	PPM
U	0.1	PPM	W	1.	PPM	LA	0.1	PPM	CE	1.	PPM
ND	1.	PPM	SM	0.01	PPM	EU	0.05	PPM	TB	0.1	PPM
YB	0.05	PPM	LU	0.01	PPM						

REPORT 7571B - MAJOR ELEMENTS - FUSION - ICP
7571C - TOTAL DIGESTION - ICP

CERTIFIED BY :

Ingrid Hengemuhle
per DR. ERIC L. HOFFMAN

1336 SANDHILL DRIVE, ANCASTER, ONTARIO, CANADA L9G 4V5 • TEL: 905-648-9611 • FAX: 905-648-9613

Activation Laboratories Ltd. Work Order: 7652 Report: 7571

Sample description	AU PPB	AS PPM	BR PPM	CO PPM	CR PPM	CS PPM	HF PPM	HG PPM	IR PPB	MO PPM	RB PPM	SB PPM	SC PPM	SE PPM	TA PPM	TH PPM	U PPM	W PPM	LA PPM	CE PPM	ND PPM	SM PPM	EU PPM	TB PPM
AI-86-102	<2	<1	<0.5	0.7	<0.5	<0.2	14.4	<1	<1	2	66	0.1	9.5	<0.5	4.4	8.1	2.0	<1	58.8	111	49	9.67	2.31	1.8
AI-86-105	<2	3	4.8	0.8	<0.5	1.0	15.7	<1	<1	5	99	0.3	3.4	<0.5	7.1	11.8	3.3	<1	83.9	149	62	12.0	0.91	2.3
AI-86-107	<2	1	1.8	0.6	1.9	<0.2	13.7	<1	<1	2	62	0.1	5.1	<0.5	4.8	8.4	1.3	<1	61.9	115	49	9.36	1.85	1.5
AS-8	<2	2	1.2	0.7	<0.5	0.5	11.2	<1	<1	3	39	0.2	7.0	<0.5	4.6	6.9	2.1	<1	54.1	101	43	8.66	2.92	1.5
GH-1,353	<2	2	<0.5	0.6	<0.5	<0.2	14.3	<1	<1	<2	86	0.2	3.9	<0.5	5.8	12.0	3.9	<1	83.7	150	67	13.0	1.11	2.2
GH-5,567	<2	<1	<0.5	1.3	6.4	<0.2	7.2	<1	<1	<2	28	0.1	17.4	<0.5	2.6	3.8	1.0	<1	40.0	77	37	7.86	4.59	1.3
GH-6,69	2	<1	<0.5	0.6	<0.5	<0.2	14.7	<1	<1	2	69	<0.1	9.5	<0.5	4.2	8.4	2.0	<1	60.6	115	51	10.2	2.36	1.8
GDC-21-1	5	4	2.2	2.9	42.4	6.0	2.9	<1	<1	12	135	0.8	4.2	<0.5	0.9	17.5	9.0	10	16.8	36	15	2.99	0.33	0.6
GDC-21-3	4	5	2.3	4.8	36.5	9.5	2.8	<1	<1	10	168	0.9	5.8	<0.5	0.9	14.5	7.3	2	17.8	38	16	3.48	0.45	0.8
LF-48-H7	4	15	4.6	2.5	31.0	8.7	3.0	<1	<1	9	173	1.8	3.2	<0.5	0.7	18.2	7.2	8	25.4	47	18	3.01	0.39	0.6
DV-2-B	<2	8	1.1	0.8	11.3	6.8	3.1	<1	<1	<2	292	1.4	3.6	<0.5	1.2	22.6	12.9	<1	16.0	36	13	3.18	<0.05	0.8
CA-958-6-A	<2	2	1.4	8.2	26.4	8.9	3.4	<1	<1	2	112	0.4	11.4	<0.5	0.5	12.7	4.0	3	28.5	52	20	3.97	0.87	0.6
CA-958-6-B	<2	3	2.4	8.1	25.4	9.2	3.4	<1	<1	3	137	0.9	10.4	<0.5	0.5	14.9	4.2	<1	31.9	59	24	4.24	0.87	0.6
MRG-1-1803	8	<1	<0.5	88.6	460	<0.2	3.8	<1	<1	<2	25	0.6	53.1	<0.5	0.8	0.9	<0.1	<1	9.8	32	18	4.63	1.50	0.5

Activation Laboratories Ltd.   Work Order: 7652   Report: 7571

Sample description	YB PPM	LU PPM	Mass g
AI-86-102	5.82	0.77	1.522
AI-86-105	7.82	1.03	1.747
AI-86-107	4.91	0.70	1.828
AS-8	4.81	0.66	1.767
GH-1,353	7.25	0.98	1.641
GH-5,567	3.52	0.49	1.412
GH-6,69	5.89	0.83	1.547
GDC-21-1	2.20	0.33	1.319
GDC-21-3	2.53	0.37	1.398
LF-48-H7	1.98	0.30	1.332
DV-2-B	3.20	0.47	1.446
CA-958-6-A	1.80	0.25	1.769
CA-958-6-B	1.75	0.25	1.748
MRG-1-1803	0.90	0.13	0.6470

Activation Laboratories Ltd. Work Order: 7652 Report: 7571B

SAMPLE #	SiO2	Al2O3	Fe2O3	FeO	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	H2O+	H2O-	LOI	TOTAL
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
AI-86-102	66.28	15.37	4.74	-----	0.19	0.10	0.77	6.48	4.51	0.34	0.06	-----	-----	0.25	99.09
AI-86-105	66.45	14.14	3.62	-----	0.15	0.06	0.49	6.13	4.89	0.20	0.04	-----	-----	1.60	97.76
AI-86-107	68.80	13.52	4.50	-----	0.16	0.13	0.68	6.06	4.25	0.31	0.50	-----	-----	1.84	100.76
AS-8	65.86	15.68	5.13	-----	0.22	0.24	1.50	6.46	3.20	0.40	0.42	-----	-----	1.65	100.75
GH-1,353	71.55	14.08	3.23	-----	0.14	0.08	0.13	5.72	4.86	0.18	0.02	-----	-----	0.45	100.44
GH-5,567	64.43	14.71	7.11	-----	0.30	0.56	1.55	6.91	3.33	0.79	0.19	-----	-----	0.30	100.18
GH-6,69	67.34	15.41	4.74	-----	0.20	0.14	1.06	6.53	4.59	0.34	0.05	-----	-----	0.05	100.44
GDC-21-1	73.80	13.51	0.14	2.08	0.03	0.58	2.31	3.91	3.56	0.20	0.09	0.05	0.09	0.05	100.27
GDC-21-3	70.17	13.97	0.21	2.40	0.03	0.93	2.18	3.75	3.92	0.30	0.17	0.09	0.11	0.25	98.27
LF-48-H7	73.20	12.56	0.17	2.42	0.05	0.33	1.35	3.43	4.45	0.19	0.06	0.04	0.14	0.30	98.49
DV-2-B	76.77	11.71	0.19	0.85	0.01	0.09	0.19	2.27	5.45	0.07	0.03	0.09	0.10	0.55	98.19
CA-958-6-A	67.17	15.32	0.69	3.16	0.08	2.01	3.94	3.87	2.57	0.44	0.14	0.03	0.05	0.20	99.59
CA-958-6-B	68.51	14.99	0.55	3.20	0.08	1.85	3.73	3.71	2.94	0.43	0.13	0.17	0.03	0.40	100.52

Activation Laboratories Ltd. Work Order: 7652 Report: 7571BB

SAMPLE #	Ba PPM	Sr PPM	Y PPM	Sc PPM	Zr PPM
AI-86-102	1194	21	65	12	890
AI-86-105	72	2	90	4	861
AI-86-107	312	25	53	5	787
AS-8	828	163	61	9	708
GH-1,353	196	5	85	4	748
GH-5,567	2162	28	43	20	405
GH-6,69	1217	19	65	12	828
GDC-21-1	325	121	23	5	97
GDC-21-3	431	106	28	7	86
LF-48-H7	684	99	20	4	83
DV-2-B	208	32	33	4	54
CA-958-6-A	1110	352	20	13	147
CA-958-6-B	1123	338	21	12	143

Activation Laboratories Ltd.   Work Order: 7652   Report: 7571C

Sample description	CU PPM	PB PPM	ZN PPM	AG PPM	NI PPM	CD PPM	BI PPM	V PPM	BE PPM
AI-86-102	2.	5.	142.	0.5	3.	<0.5	6.	2.	4.
AI-86-105	4.	8.	139.	0.5	6.	0.5	6.	2.	6.
AI-86-107	3.	6.	95.	0.5	3.	<0.5	8.	3.	3.
AS-8	3.	5.	116.	0.5	3.	<0.5	10.	2.	3.
GH-1,353	5.	11.	135.	0.5	5.	<0.5	<5.	3.	5.
GH-5,567	2.	10.	117.	0.8	5.	<0.5	<5.	3.	2.
GH-6,69	2.	10.	128.	0.5	3.	<0.5	<5.	2.	3.
GDC-21-1	17.	16.	17.	0.5	37.	<0.5	6.	12.	2.
GDC-21-3	18.	12.	25.	0.5	31.	<0.5	<5.	18.	2.
LF-48-H7	52.	38.	45.	0.5	31.	<0.5	7.	10.	2.
DV-2-B	7.	16.	10.	0.5	10.	<0.5	10.	2.	3.
CA-958-6-A	43.	13.	62.	0.5	14.	<0.5	<5.	60.	<2.
CA-958-6-B	37.	17.	75.	0.5	16.	<0.5	<5.	57.	<2.

Activation Laboratories Ltd.   Work Order: 7652   Report: 7571D

SAMPLE DESCRIPTION	S	CO2	CL
	%	%	%
GDC-21-1	0.006	0.221	0.10
GDC-21-3	0.020	0.221	0.13
LF-48-H7	0.007	0.240	0.12
DV-2-B	0.005	0.259	0.03
CA-958-6-A	0.010	0.112	0.04
CA-958-6-B	0.008	0.095	0.06

Activation Laboratories Ltd. Work Order: 7652 Report: 7571

Sample description	AU PPB	AS PPM	BR PPM	CO PPM	CR PPM	CS PPM	HF PPM	HG PPM	IR PPB	MO PPM	RB PPM	SB PPM	SC PPM	SE PPM	TA PPM	TH PPM	U PPM	W PPM	LA PPM	CE PPM	ND PPM	SM PPM	EU PPM	TB PPM
AI-86-102	<2	<1	<0.5	0.7	<0.5	<0.2	14.4	<1	<1	2	66	0.1	9.5	<0.5	4.4	8.1	2.0	<1	58.8	111	49	9.67	2.31	1.8
AI-86-105	<2	3	4.8	0.8	<0.5	1.0	15.7	<1	<1	5	99	0.3	3.4	<0.5	7.1	11.8	3.3	<1	83.9	149	62	12.0	0.91	2.3
AI-86-107	<2	1	1.8	0.6	1.9	<0.2	13.7	<1	<1	2	62	0.1	5.1	<0.5	4.8	8.4	1.3	<1	61.9	115	49	9.36	1.85	1.5
AS-8	<2	2	1.2	0.7	<0.5	0.5	11.2	<1	<1	3	39	0.2	7.0	<0.5	4.6	6.9	2.1	<1	54.1	101	43	8.66	2.92	1.5
GH-1,353	<2	2	<0.5	0.6	<0.5	<0.2	14.3	<1	<1	<2	86	0.2	3.9	<0.5	5.8	12.0	3.9	<1	83.7	150	67	13.0	1.11	2.2
GH-5,567	<2	<1	<0.5	1.3	6.4	<0.2	7.2	<1	<1	<2	28	0.1	17.4	<0.5	2.6	3.8	1.0	<1	40.0	77	37	7.86	4.59	1.3
GH-6,69	2	<1	<0.5	0.6	<0.5	<0.2	14.7	<1	<1	2	69	<0.1	9.5	<0.5	4.2	8.4	2.0	<1	60.6	115	51	10.2	2.36	1.8
GDC-21-1	5	4	2.2	2.9	42.4	6.0	2.9	<1	<1	12	135	0.8	4.2	<0.5	0.9	17.5	9.0	10	16.8	36	15	2.99	0.33	0.6
GDC-21-3	4	5	2.3	4.8	36.5	9.5	2.8	<1	<1	10	168	0.9	5.8	<0.5	0.9	14.5	7.3	2	17.8	38	16	3.48	0.45	0.8
LF-48-H7	4	15	4.6	2.5	31.0	8.7	3.0	<1	<1	9	173	1.8	3.2	<0.5	0.7	18.2	7.2	8	25.4	47	18	3.01	0.39	0.6
DV-2-B	<2	8	1.1	0.8	11.3	6.8	3.1	<1	<1	<2	292	1.4	3.6	<0.5	1.2	22.6	12.9	<1	16.0	36	13	3.18	<0.05	0.8
CA-958-6-A	<2	2	1.4	8.2	26.4	8.9	3.4	<1	<1	2	112	0.4	11.4	<0.5	0.5	12.7	4.0	3	28.5	52	20	3.97	0.87	0.6
CA-958-6-B	<2	3	2.4	8.1	25.4	9.2	3.4	<1	<1	3	137	0.9	10.4	<0.5	0.5	14.9	4.2	<1	31.9	59	24	4.24	0.87	0.6
MRG-1-1803	8	<1	<0.5	88.6	460	<0.2	3.8	<1	<1	<2	25	0.6	53.1	<0.5	0.8	0.9	<0.1	<1	9.8	32	18	4.63	1.50	0.5

Activation Laboratories Ltd.   Work Order: 7652   Report: 7571

Sample description	YB PPM	LU PPM	Mass g
AI-86-102	5.82	0.77	1.522
AI-86-105	7.82	1.03	1.747
AI-86-107	4.91	0.70	1.828
AS-8	4.81	0.66	1.767
GH-1,353	7.25	0.98	1.641
GH-5,567	3.52	0.49	1.412
GH-6,69	5.89	0.83	1.547
GDC-21-1	2.20	0.33	1.319
GDC-21-3	2.53	0.37	1.398
LF-48-H7	1.98	0.30	1.332
DV-2-B	3.20	0.47	1.446
CA-958-6-A	1.80	0.25	1.769
CA-958-6-B	1.75	0.25	1.748
MRG-1-1803	0.90	0.13	0.6470

ACTLABS
ACTIVATION LABORATORIES LTD

Invoice No.:	7571
Work Order:	7652
Invoice Date:	08-MAR-95
Date Submitted:	13-FEB-95
Your Reference:	67810
Account Number:	U017

UNIVERSITY OF UTAH
EARTH SCIENCES AND RESOURCES INSTITUTE
391 CHIPETA WAY, SUTIE C
SALT LAKE CITY, UTAH
USA 84108
ATTENTION: JEFFREY B. HULEN

CERTIFICATE OF ANALYSIS

IN[illegible] package, elements and detection limits:

AU	2.	PPB	AS	1.	PPM	BR	0.5	PPM	CO	0.1	PPM
CR	0.5	PPM	CS	0.2	PPM	HF	0.2	PPM	HG	1.	PPM
IR	1.	PPB	MO	2.	PPM	RB	10.	PPM	SB	0.1	PPM
SC	0.1	PPM	SE	0.5	PPM	TA	0.3	PPM	TH	0.1	PPM
U	0.1	PPM	W	1.	PPM	LA	0.1	PPM	CE	1.	PPM
ND	1.	PPM	SM	0.01	PPM	EU	0.05	PPM	TB	0.1	PPM
YB	0.05	PPM	LU	0.01	PPM						

REPORT 7571B - MAJOR ELEMENTS - FUSION - ICP
7571C - TOTAL DIGESTION - ICP

CERTIFIED BY :

Ingrid Hengemuhle
pr DR. ERIC L. HOFFMAN

ACTLABS

ACTIVATION LABORATORIES LTD

Invoice No.: 7571
Work Order: 7652
Invoice Date: 08-MAR-95
Date Submitted: 13-FEB-95
Your Reference: 67810
Account Number: U017

UNIVERSITY OF UTAH
EARTH SCIENCES AND RESOURCES INSTITUTE
391 CHIPETA WAY, SUTIE C
SALT LAKE CITY, UTAH
USA 84108
ATTENTION: JEFFREY B. HULEN

CERTIFICATE OF ANALYSIS

INAA package, elements and detection limits:

AU	2.	PPB	AS	1.	PPM	BR	0.5	PPM	CO	0.1	PPM
CR	0.5	PPM	CS	0.2	PPM	HF	0.2	PPM	HG	1.	PPM
IR	1.	PPB	MO	2.	PPM	RB	10.	PPM	SB	0.1	PPM
SC	0.1	PPM	SE	0.5	PPM	TA	0.3	PPM	TH	0.1	PPM
U	0.1	PPM	W	1.	PPM	LA	0.1	PPM	CE	1.	PPM
ND	1.	PPM	SM	0.01	PPM	EU	0.05	PPM	TB	0.1	PPM
YB	0.05	PPM	LU	0.01	PPM						

REPORT 7571B - MAJOR ELEMENTS - FUSION - ICP
7571C - TOTAL DIGESTION - ICP

CERTIFIED BY :

Ingrid Hengemuller
DR. ERIC L. HOFFMAN
for

Total of 7 pages

1336 SANDHILL DRIVE, ANCASTER, ONTARIO, CANADA L9G 4V5 • TEL: 905-648-9611 • FAX: 905-648-9613

Activation Laboratories Ltd. Work Order: 7652 Report: 7571B

SAMPLE #	SiO2 %	Al2O3 %	Fe2O3 %	FeO %	MnO %	MgO %	CaO %	Na2O %	K2O %	TiO2 %	P2O5 %	H2O+ %	H2O- %	LOI %	TOTAL %
AI-86-102	66.28	15.37	4.74	-----	0.19	0.10	0.77	6.48	4.51	0.34	0.06	-----	-----	0.25	99.09
AI-86-105	66.45	14.14	3.62	-----	0.15	0.06	0.49	6.13	4.89	0.20	0.04	-----	-----	1.60	97.76
AI-86-107	68.80	13.52	4.50	-----	0.16	0.13	0.68	6.06	4.25	0.31	0.50	-----	-----	1.84	100.76
AS-8	65.86	15.68	5.13	-----	0.22	0.24	1.50	6.46	3.20	0.40	0.42	-----	-----	1.65	100.75
GH-1,353	71.55	14.08	3.23	-----	0.14	0.08	0.13	5.72	4.86	0.18	0.02	-----	-----	0.45	100.44
GH-5,567	64.43	14.71	7.11	-----	0.30	0.56	1.55	6.91	3.33	0.79	0.19	-----	-----	0.30	100.18
GH-6,69	67.34	15.41	4.74	-----	0.20	0.14	1.06	6.53	4.59	0.34	0.05	-----	-----	0.05	100.44
GDC-21-1	73.80	13.51	0.14	2.08	0.03	0.58	2.31	3.91	3.56	0.20	0.09	0.05	0.05	0.05	100.27
GDC-21-3	70.17	13.97	0.21	2.40	0.03	0.93	2.18	3.75	3.92	0.30	0.17	0.09	0.11	0.25	98.27
LF-48-H7	73.20	12.56	0.17	2.42	0.05	0.33	1.95	3.43	4.45	0.19	0.06	0.04	0.14	0.30	98.49 ✓
DV-2-B	76.77	11.71	0.19	0.85	0.01	0.09	0.19	2.27	5.45	0.07	0.03	0.09	0.10	0.55	98.19
CA-958-6-A	67.17	15.32	0.69	3.16	0.08	2.01	3.94	3.87	2.57	0.44	0.14	0.03	0.05	0.20	99.59
CA-958-6-B	66.51	14.99	0.55	3.20	0.08	1.85	3.73	3.71	2.94	0.43	0.13	0.17	0.03	0.40	100.52

GDC 21-1	~~73.70~~ 73.64	~~13.49~~ 13.48	0.14	2.08	0.03	~~0.58~~ 0.58	2.30	3.90	3.55	0.20	0.09	~~0.05~~	~~0.05~~	~~0.05~~
GDC 21-3	71.48	14.25	0.21	2.45	0.03	0.95	2.23	3.83	4.00	0.30	0.17	~~0.09~~	~~0.11~~	~~0.25~~
LF-48-H7	74.64	12.79	0.17	2.46	0.05	0.34	1.99	3.49	(4.53)	0.19	0.05			
DV2-B	78.63	~~12.02~~ 11.99	0.19	0.87	0.01	0.09	0.19	2.32	5.58	0.07	0.03	~~0.09~~	~~0.10~~	~~0.56~~
~~CA~~ CA-958-6A	67.58	15.41	0.70	3.18	0.08	2.02	3.96	3.89	2.59	0.45	0.14	~~0.03~~	~~0.05~~	~~0.20~~ ✓
CA-958-6B	66.43	~~15.14~~ 14.97	0.55	3.20	0.08	1.85	3.73	3.71	2.94	0.43	0.13	~~0.17~~	~~0.03~~	~~0.40~~ ✓
CA-958-6 Pulka	64.88	16.84	4.18 →		0.08	2.02	4.11	~~2.71~~ 4.40	~~4.40~~ 2.71	0.51	0.17			
Rhy. dike Pulka	76.40	12.40	⊢ 0.81 ⊣		0.01	0.46	0.72	3.79	5.19	0.15	0.05			
GDC21-1 5866' (RUTH)	72.87	14.63	(0.29)	(0.85)	0.04	0.65	2.32	3.83	4.08	0.23	0.06			
CA-958-6₁ RUTH	67.44	16.13	0.26	3.14	0.07	1.94	3.82	3.38	2.92	0.46	0.15			
CA-958-6₂ RUTH	68.79	15.28	0.28	2.99	0.07	1.87	3.97	3.10	2.81	0.47	0.14			
DV-2-2 RUTH	80.43	11.23	0.27	0.47	0.01	0.10	0.15	2.00	5.08	0.08	<0.01			
GDC 21-2 RUTH	72.69	13.83	0.37	0.97	0.03	0.74	1.95	3.69	5.01	0.26	0.14			
LF-48-2 RUTH	76.47	12.11	0.39	1.01	0.04	0.30	1.19	3.32	4.69	0.20	0.03			
DV-2 3710.7' RTH	79.95	11.23	0.29	0.55	0.01	0.07	0.14	1.82	5.78	0.08	<0.01			
LF-48 ~~890~~ 809? RTH	76.30	12.07	0.55	1.28	0.05	0.32	1.10	3.16	4.72	0.19	0.03			
C-11 RUTH	77.09	11.77	0.13	0.58	0.03	0.08	0.58	2.91	5.42	0.11	<0.01			

normalized to 100% water-free

Activation Laboratories Ltd. Work Order: 7652 Report: 7571

Sample description	AU PPB	AS PPM	BR PPM	CO PPM	CR PPM	CS PPM	HF PPM	HG PPM	IR PPB	MO PPM	RB PPM	SB PPM	SC PPM	SE PPM	TA PPM	TH PPM	U PPM	W PPM	LA PPM	CE PPM	ND PPM	SM PPM	EU PPM	TB PPM
AI-86-102	<2	<1	<0.5	0.7	<0.5	<0.2	14.4	<1	<1	2	66	0.1	9.5	<0.5	4.4	8.1	2.0	<1	58.8	111	49	9.67	2.31	1.8
AI-86-105	<2	3	4.0	0.8	<0.5	1.0	15.7	<1	<1	5	99	0.3	3.4	<0.5	7.1	11.8	3.3	<1	83.9	149	62	12.0	0.91	2.3
AI-86-107	<2	1	1.8	0.6	1.9	<0.2	13.7	<1	<1	2	62	0.1	5.1	<0.5	6.8	8.4	1.3	<1	61.9	115	49	5.36	1.65	1.5
AS-8	<2	2	1.2	0.7	<0.5	0.5	11.2	<1	<1	3	39	0.2	7.0	<0.5	4.6	6.9	2.1	<1	54.1	101	43	8.66	2.92	1.5
GH-1,353	<2	2	<0.5	0.6	<0.5	<0.2	14.3	<1	<1	<2	86	0.2	3.9	<0.5	5.8	12.0	3.9	<1	83.7	150	67	13.0	1.11	2.2
GE-5,567	<2	<1	<0.5	1.3	6.4	<0.2	7.2	<1	<1	<2	28	0.1	17.4	<0.5	2.6	3.8	1.0	<1	40.0	77	37	7.86	4.59	1.3
GH-6,63	2	<1	<0.5	0.6	<0.5	<0.2	14.7	<1	<1	2	69	<0.1	9.5	<0.5	4.2	8.4	2.0	<1	60.6	115	51	10.2	2.36	1.8
GDC-21-1	5	4	2.2	2.9	42.4	6.0	2.9	<1	<1	12	135	0.8	4.2	<0.5	0.9	17.5	9.0	10	16.8	36	15	2.99	0.33	0.6
GDC-21-3	4	5	2.3	4.8	36.5	9.5	2.8	<1	<1	10	168	0.9	5.8	<0.5	0.9	14.5	7.3	2	17.8	38	16	3.48	0.45	0.8
LP-48-87	4	15	4.6	2.5	31.0	8.7	3.0	<1	<1	9	173	1.8	3.2	<0.5	0.7	18.2	7.2	8	25.4	47	18	3.01	0.39	0.6
DV-2-B	<2	8	1.1	0.8	11.3	6.8	3.1	<1	<1	<2	292	1.4	3.6	<0.5	1.2	22.6	12.9	<1	16.0	36	13	3.18	<0.05	0.8
CA-958-6-A	<2	2	1.4	8.2	26.4	8.9	3.4	<1	<1	2	112	0.4	11.4	<0.5	0.5	12.7	4.0	3	28.5	52	20	3.97	0.87	0.6
CA-958-6-B	<2	3	2.4	8.1	25.4	9.2	3.4	<1	<1	3	137	0.9	10.4	<0.5	0.5	14.9	4.2	<1	31.9	59	24	4.24	0.87	0.6
MRG-1-1803	8	<1	<0.5	88.6	460	<0.2	3.8	<1	<1	<2	25	0.6	53.1	<0.5	0.8	0.9	<0.1	<1	9.8	32	18	4.63	1.50	0.5

Activation Laboratories Ltd. Work Order: 7652 Report: 7571

Sample description	YB PPM	LU PPM	Mass g
AI-86-102	5.82	0.77	1.522
AI-86-105	7.82	1.03	1.747
AI-86-107	4.91	0.70	1.828
AS-8	4.81	0.66	1.767
GE-1,353	7.25	0.98	1.641
GE-5,567	3.52	0.49	1.412
GE-6,69	5.89	0.83	1.547
GDC-21-1	2.20	0.33	1.319
GDC-21-3	2.53	0.37	1.398
LF-48-87	1.98	0.30	1.332
DV-2-B	3.20	0.47	1.446
CA-958-6-A	1.80	0.25	1.769
CA-958-6-B	1.75	0.25	1.748
MHG-1-1803	0.90	0.13	0.6470

Activation Laboratories Ltd. Work Order: 7652 Report: 7571BB

SAMPLE #	Ba PPM	Sr PPM	Y PPM	Sc PPM	Zr PPM
AI-86-102	1194	21	65	12	890
AI-86-105	72	2	90	4	861
AI-86-107	312	25	53	5	787
AS-8	828	163	61	9	708
GH-1,353	196	5	85	4	748
GH-5,567	2162	28	43	20	405
GH-6,69	1217	19	65	12	838
GDC-21-1	325	121	23	5	97
GDC-21-3	431	106	28	7	86
LF-48-H7	684	99	20	4	83
DV-2-B	208	32	33	4	54
CA-958-6-A	1110	352	20	13	147
CA-958-6-B	1123	338	21	12	143

Activation Laboratories Ltd. Work Order: 7652 Report: 7571C

Sample description	CU PPM	PB PPM	ZN PPM	AG PPM	NI PPM	CD PPM	BI PPM	V PPM	BE PPM
AI-86-102	3.	5.	142.	0.5	3.	<0.5	6.	2.	4.
AI-86-105	4.	8.	139.	0.5	6.	0.5	6.	2.	6.
AI-86-107	3.	6.	95.	0.5	3.	<0.5	8.	3.	3.
AS-8	3.	5.	116.	0.5	3.	<0.5	10.	2.	3.
GE-1,353	5.	11.	135.	0.5	5.	<0.5	<5.	3.	5.
GE-5,567	2.	10.	117.	0.8	5.	<0.5	<5.	3.	2.
GE-6,69	2.	10.	128.	0.5	3.	<0.5	<5.	2.	3.
GDC-21-1	17.	16.	17.	0.5	37.	<0.5	6.	12.	2.
GDC-21-3	18.	12.	25.	0.5	31.	<0.5	<5.	18.	2.
LP-48-87	52.	38.	45.	0.5	31.	<0.5	7.	10.	2.
DV-2-B	7.	16.	10.	0.5	10.	<0.5	10.	2.	3.
CA-958-6-A	43.	13.	62.	0.5	14.	<0.5	<5.	60.	<2.
CA-958-6-B	37.	17.	75.	0.5	16.	<0.5	<5.	57.	<2.

Activation Laboratories Ltd. Work Order: 7652 Report: 7571D

SAMPLE DESCRIPTION	S	CO2	CL
	%	%	%
GDC-21-1	0.006	0.221	0.10
GDC-21-3	0.020	0.221	0.13
LF-48-B7	0.007	0.240	0.12
DV-2-B	0.005	0.259	0.03
CA-958-6-A	0.010	0.112	0.04
CA-958-6-B	0.008	0.095	0.06

JEFF HULEN

GEYSERS GDC-21 ~5866'
50

ELEMENT			CONCENTRATION	
NA	% OX.		3.771	
K	% OX.		4.021	
CA	% OX.		2.281	
MG	% OX.		0.634	
FE1	% OX.		~~1.218~~	.285
AL	% OX.		14.415	
SI	% OX.		71.800	
TI	% OX.		0.229	
P	% OX.		0.061	
SR	PPM		120.050	
BA	% OX.		0.030	
V	PPM	<	250.000	
CR	PPM		2.400	
MN	% OX.		0.043	
CO	PPM		43.550	
NI	PPM	<	5.000	
CU	PPM	<	5.000	
MO	PPM	<	50.000	
PB	PPM	<	10.000	
ZN	PPM		28.250	
CD	PPM	<	5.000	
AG	PPM	<	2.000	
AU	PPM	<	4.000	
AS	PPM		41.050	
SB	PPM	<	30.000	
BI	PPM	<	100.000	
U	PPM	<	2500.000	
TE	PPM	<	50.000	
SN	PPM		6.600	
W	PPM	<	1200.000	
LI	PPM		17.250	
BE	PPM		2.000	
B	PPM		236.000	
ZR	PPM	<	5.000	
LA	PPM	<	5.000	
CE	PPM	<	10.000	
TH	PPM	<	150.000	
LOI	%		0.22	
CL	%		0.100	
FeO	%		0.84	
		TOTAL	98.829	98,757
F	%		0.021	

JEFF HULEN

CA-958-6 GGC FELSITE CORE
50

ELEMENT			CONCENTRATION
NA	% OX.		3.351
K	% OX.		2.895
CA	% OX.		3.794
MG	% OX.		1.914
FE1	% OX.		0.253
AL	% OX.		16.005
SI	% OX.		66.897
TI	% OX.		0.457
P	% OX.		0.147
SR	PPM		321.450
BA	% OX.		0.113
V	PPM	<	250.000
CR	PPM		23.050
MN	% OX.		0.072
CO	PPM		96.150
NI	PPM		14.200
CU	PPM		48.800
MO	PPM	<	50.000
PB	PPM	<	10.000
ZN	PPM		97.300
CD	PPM		17.450
AG	PPM		2.750
AU	PPM	<	4.000
AS	PPM		100.000
SB	PPM		95.300
BI	PPM	<	100.000
U	PPM	<	2500.000
TE	PPM	<	50.000
SN	PPM		75.000
W	PPM	<	1200.000
LI	PPM		34.300
BE	PPM		2.200
B	PPM	<	20.000
ZR	PPM		34.450
LA	PPM		60.700
CE	PPM		30.000
TH	PPM	<	150.000
FEO	%		3.11
LOI	%		0.40
F	%		0.075
CL	%		0.112
		TOTAL	99.595

JEFF HULEN

CA-958-6 (2)
50

ELEMENT			CONCENTRATION
NA	% OX.		3.073
K	% OX.		2.719
CA	% OX.		3.936
MG	% OX.		1.852
FE1	% OX.		0.275
AL	% OX.		15.153
SI	% OX.		68.240
TI	% OX.		0.464
P	% OX.		0.140
SR	PPM		296.550
BA	% OX.		0.119
V	PPM	<	250.000
CR	PPM		33.400
MN	% OX.		0.066
CO	PPM		68.450
NI	PPM		16.200
CU	PPM		42.400
MO	PPM	<	50.000
PB	PPM		15.150
ZN	PPM		88.300
CD	PPM		15.150
AG	PPM		2.350
AU	PPM	<	4.000
AS	PPM		100.000
SB	PPM		92.100
BI	PPM	<	100.000
U	PPM	<	2500.000
TE	PPM	<	50.000
SN	PPM		72.500
W	PPM	<	1200.000
LI	PPM		35.900
BE	PPM		2.150
B	PPM		31.000
ZR	PPM		46.350
LA	PPM		87.000
CE	PPM		86.150
TH	PPM	<	150.000
FEO	%		2.97
LOI	%		0.32
F	%		0.061
CL	%		0.112
		TOTAL	99.500

JEFF HULEN

DV-2 (2)
50

ELEMENT			CONCENTRATION
NA	% OX.		1.933
K	% OX.		4.912
CA	% OX.		0.148
MG	% OX.		0.097
FE1	% OX.		0.259
AL	% OX.		10.866
SI	% OX.		77.800
TI	% OX.		0.076
P	% OX.	<	0.002
SR	PPM		27.800
BA	% OX.		0.023
V	PPM	<	250.000
CR	PPM		19.950
MN	% OX.		0.008
CO	PPM		139.850
NI	PPM	<	5.000
CU	PPM	<	5.000
MO	PPM	<	50.000
PB	PPM	<	10.000
ZN	PPM		27.250
CD	PPM		6.200
AG	PPM	<	2.000
AU	PPM	<	4.000
AS	PPM		99.000
SB	PPM		92.750
BI	PPM	<	100.000
U	PPM	<	2500.000
TE	PPM	<	50.000
SN	PPM		109.000
W	PPM	<	1200.000
LI	PPM		35.150
BE	PPM		3.750
B	PPM		766.000
ZR	PPM		26.550
LA	PPM		48.500
CE	PPM	<	10.000
TH	PPM	<	150.000
FEO	%		0.45
LOI	%		0.79
F	%		0.006
CL	%		0.149
		TOTAL	97.520

LOI	%	0.48
F	%	0.012
CL	%	0.173

JEFF HULEN

GDC-21 (2)
50

ELEMENT			CONCENTRATION
NA	% OX.		3.637
K	% OX.		4.934
CA	% OX.		1.924
MG	% OX.		0.730
FE1	% OX.		0.365
AL	% OX.		13.627
SI	% OX.		71.603
TI	% OX.		0.257
P	% OX.		0.138
SR	PPM		111.650
BA	% OX.		0.057
V	PPM	<	250.000
CR	PPM		16.000
MN	% OX.		0.025
CO	PPM		125.050
NI	PPM	<	5.000
CU	PPM		11.600
MO	PPM	<	50.000
PB	PPM		42.550
ZN	PPM		52.850
CD	PPM		8.000
AG	PPM	<	2.000
AU	PPM	<	4.000
AS	PPM		99.000
SB	PPM		92.500
BI	PPM	<	100.000
U	PPM	<	2500.000
TE	PPM	<	50.000
SN	PPM		66.000
W	PPM	<	1200.000
LI	PPM		20.950
BE	PPM		1.850
B	PPM		824.000
ZR	PPM		27.450
LA	PPM		57.700
CE	PPM		63.500
TH	PPM	<	150.000
FEO	%		0.96
LOI	%		0.485
F	%		0.034
CL	%		0.204
		TOTAL	98.981

JEFF HULEN

LF48 (2)
50

ELEMENT			CONCENTRATION
NA	% OX.		3.246
K	% OX.		4.590
CA	% OX.		1.167
MG	% OX.		0.290
FE1	% OX.		0.384
AL	% OX.		11.848
SI	% OX.		74.801
TI	% OX.		0.195
P	% OX.		0.034
SR	PPM		82.350
BA	% OX.		0.055
V	PPM	<	250.000
CR	PPM	<	2.000
MN	% OX.		0.042
CO	PPM		190.400
NI	PPM		6.050
CU	PPM		38.100
MO	PPM	<	50.000
PB	PPM		42.900
ZN	PPM		71.150
CD	PPM		8.450
AG	PPM		5.450
AU	PPM	<	4.000
AS	PPM		94.000
SB	PPM		92.600
BI	PPM	<	100.000
U	PPM	<	2500.000
TE	PPM	<	50.000
SN	PPM		59.000
W	PPM	<	1200.000
LI	PPM		22.100
BE	PPM		2.300
B	PPM		92.000
ZR	PPM		17.550
LA	PPM		54.100
CE	PPM		10.650
TH	PPM	<	150.000
FEO	%		0.99
LOI	%		0.48
F	%		0.012
CL	%		0.173
		TOTAL	98.308

JEFF HULEN

GEYSERS DV-2 3710.7'
50

ELEMENT			CONCENTRATION
NA	% OX.		1.767
K	% OX.		5.606
CA	% OX.		0.135
MG	% OX.		0.072
FE1	% OX.		~~0.074~~ .285
AL	% OX.		10.895
SI	% OX.		77.600
TI	% OX.		0.075
P	% OX.	<	0.002
SR	PPM		31.550
BA	% OX.		0.020
V	PPM	<	250.000
CR	PPM	<	2.000
MN	% OX.		0.013
CO	PPM		67.900
NI	PPM	<	5.000
CU	PPM	<	5.000
MO	PPM	<	50.000
PB	PPM	<	10.000
ZN	PPM		15.700
CD	PPM	<	5.000
AG	PPM	<	2.000
AU	PPM	<	4.000
AS	PPM		43.050
SB	PPM	<	30.000
BI	PPM	<	100.000
U	PPM	<	2500.000
TE	PPM	<	50.000
SN	PPM		22.350
W	PPM	<	1200.000
LI	PPM		33.050
BE	PPM		2.450
B	PPM		200.000
ZR	PPM	<	5.000
LA	PPM	<	5.000
CE	PPM	<	10.000
TH	PPM	<	150.000
LOI	%		0.59
CL	%		0.048
FeO	%		0.53
F	%		0.009

TOTAL ~~97.700~~ 97.650

1% = 10,000 ppm
0.1% = 1,000 ppm
0.01% = 100 ppm
0.001% = 10 ppm

$\frac{1}{100} = \frac{x}{10^6}$
10^2

B) CHEMICAL GROUPINGS

Four major varieties of intrusive rocks exist in the subsurface at Ford Flat (Table 4). A generalized rock classification for the Clear Lake Volcanics is based on percent silica and measured on a water-free basis (Hearn 1981) where basalt contains less than 54%, basaltic andesite 54-58%, andesite 58-62%, dacite 62-71% and rhyolite greater than 71%. Two types of mafic intrusive rocks are found which occur at different levels in boreholes. The upper mafic intrusive (#1) is associated with serpentine and blueschist at shallow levels in the PDC wells and averages 52% SiO_2. The second type of mafic intrusives (#2), averaging 46.5% SiO_2, are situated deeper in the PDC/Moody wells

	MAFIC #1	MAFIC #2	INTER. INTR.	ANDES. of FF	FELSIC INTR.	MOODY OBSID.	FELSITE CORE
SiO_2	52.09	46.54	56.25	56.69	74.00	74.03	63.49
TiO_2	.97	2.32	.73	.83	.15	.14	.50
Al_2O_3	12.92	13.20	15.20	16.96	12.01	12.00	16.48
Fe_2O_3	12.05	13.76	5.49	6.07	.78	1.19	4.18
MnO	.16	.23	.09	.10	.01	.02	.08
MgO	7.87	8.89	6.00	5.56	.45	.40	1.98
CaO	6.77	5.73	6.82	8.11	.70	.59	4.02
K_2O	.16	2.52	1.51	1.19	5.03	5.23	2.65
Na_2O	4.57	2.03	2.78	2.80	3.67	2.99	4.30
P_2O_5	.14	.76	.18	.18	.05	.03	.17
LOI	3.36	5.63	4.11	3.45	2.35	2.76	2.45
SUM	101.05	101.67	99.16	101.94	99.21	99.40	100.31
N	5	25	28	2	11	3	1

TABLE 4. Average whole rock XRF analysis for groups of intrusive and extrusive rocks at Ford Flat. Mafic #1 is associated with blueschist in the PDC wells. Mafic #2 are mafic intrusives that correlate between the PDC/Moody wells. An average of 28 analysis are shown for intermediate intrusives (Inter. Intr.) that are similar in composition to the Andesite of Ford Flat (Andes. of FF). Felsic intrusives (Felsic Intr.) in the PDC wells appear to be similar to obsidian lapilli (Moody Obsid.) in an ash flow near the surface in the Moody wells. The felsite core from the main batholith is dacitic in composition.

JEFF HULEN

GEYSERS LF-48 ~8092.3'
50

ELEMENT			CONCENTRATION
NA	% OX.		3.171
K	% OX.		4.737
CA	% OX.		1.102
MG	% OX.		0.322
FE1	% OX.		0.549
AL	% OX.		12.104
SI	% OX.		76.500
TI	% OX.		0.193
P	% OX.		0.026
SR	PPM		82.200
BA	% OX.		0.059
V	PPM	<	250.000
CR	PPM		5.750
MN	% OX.		0.046
CO	PPM		53.550
NI	PPM		7.900
CU	PPM		148.100
MO	PPM	<	50.000
PB	PPM		60.350
ZN	PPM		80.200
CD	PPM		9.800
AG	PPM		7.200
AU	PPM	<	4.000
AS	PPM		100.000
SB	PPM		108.250
BI	PPM	<	100.000
U	PPM	<	2500.000
TE	PPM	<	50.000
SN	PPM		38.300
W	PPM	<	1200.000
LI	PPM		25.150
BE	PPM		2.200
B	PPM	<	400.000
ZR	PPM		7.150
LA	PPM	<	5.000
CE	PPM		59.550
TH	PPM	<	150.000
LOI	%		0.40
CL	%		0.162
FEO	%		1.28
F			0.014

TOTAL ~~100.651~~ 100.665

JEFF HULEN

GEYSERS C-11 ~8479'
50

ELEMENT			CONCENTRATION
NA	% OX.		2.858
K	% OX.		5.318
CA	% OX.		0.570
MG	% OX.		0.075
FE1	% OX.		~~0.765~~ .131
AL	% OX.		11.558
SI	% OX.		75.700
TI	% OX.		0.113
P	% OX.	<	0.003
SR	PPM		52.500
BA	% OX.		0.030
V	PPM	<	250.000
CR	PPM	<	2.000
MN	% OX.		0.030
CO	PPM		205.750
NI	PPM	<	5.000
CU	PPM		38.000
MO	PPM	<	50.000
PB	PPM	<	10.000
ZN	PPM		39.500
CD	PPM	<	5.000
AG	PPM	<	2.000
AU	PPM	<	4.000
AS	PPM		78.500
SB	PPM	<	30.000
BI	PPM	<	100.000
U	PPM	<	2500.000
TE	PPM	<	50.000
SN	PPM	<	5.000
W	PPM		692.000
LI	PPM		26.600
BE	PPM		2.350
B	PPM		33.400
ZR	PPM	<	5.000
LA	PPM	<	5.000
CE	PPM	<	10.000
TH	PPM	<	150.000
LOI	%		0.29
CL	%		0.252
FeO	%		0.57
		TOTAL	~~98.559~~ 98.528
F	%		0.013

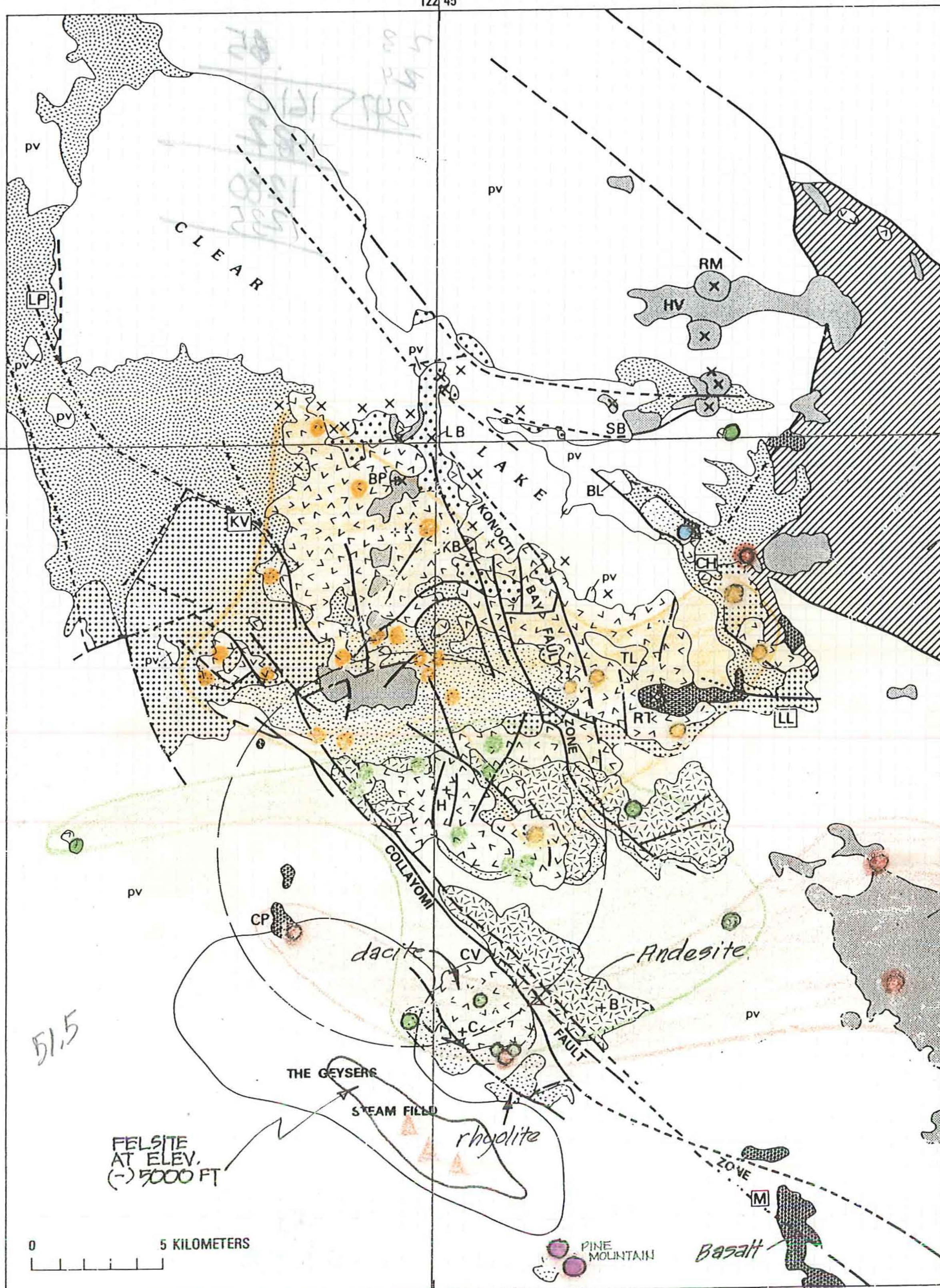
F. Goff

ANALYSES OF COBB MTN LAVAS
(E. Kluk, EES-1)

Name	Cobb Valley Da	Alder Crk Ro	Cobb Mtn Da	Geysers Felsite
Sample No	F91-17	F92-33	F92-34	CA-9586
Major elements (wt-%)				
SiO2	64.86	69.97	66.84	
TiO2	0.589	0.355	0.716	
Al2O3	17.14	14.35	15.89	
Fe2O2 (Tot)	4.11	2.72	3.88	
MnO	0.055	0.046	0.060	
MgO	2.50	1.27	1.14	
CaO	1.69	2.52	3.69	
Na2O	3.01	3.24	3.71	
K2O	2.79	3.91	2.97	
P2O5	0.122	0.094	0.161	
LOI	2.90	1.75	0.47	0.20
Total	99.77	100.23	99.53	
Trace elements (ppm)				
V	61.8	50.1	45.9	
Cr	114.2	15.6	<10	
Ni	52.8	7.4	4.6	
Zn	66.5	39.2	54.6	
Rb	102.1	170.4	119.0	
Sr	326.8	302.3	342.9	
Y	15.4	21.1	26.2	
Zr	158.1	121.7	149.8	
Nb	7.6	9.2	9.8	
Ba	866.3	648.6	625.4	

1.7 – 2.1 Ma
1.3 – 1.7 Ma
0.8 – 1.2 Ma
0.3 - 0.6 Ma
0 – 0.2 Ma

247
161



5=51.5 10=103
51.2 102.4 66

MAP SCALES DON'T JIBE (✓)
O = K-Ar DATES FROM DONNELY-NOLAN, et al. 1981
GEOLOGIC MAP FROM HEARN ET AL, 1981

▲ $^{40}Ar/^{39}Ar$ MINIMUM AGES ON FELSITE fr DALRYMPLE, 1992

$\frac{51.2}{5} = \frac{x}{1.8}$
18.4
12=1.8
$\frac{12}{1.8} = \frac{x}{1}$
6.66=

IGNEOUS ROCK DATES

Return to M. Walters

(get bkgr. info.)

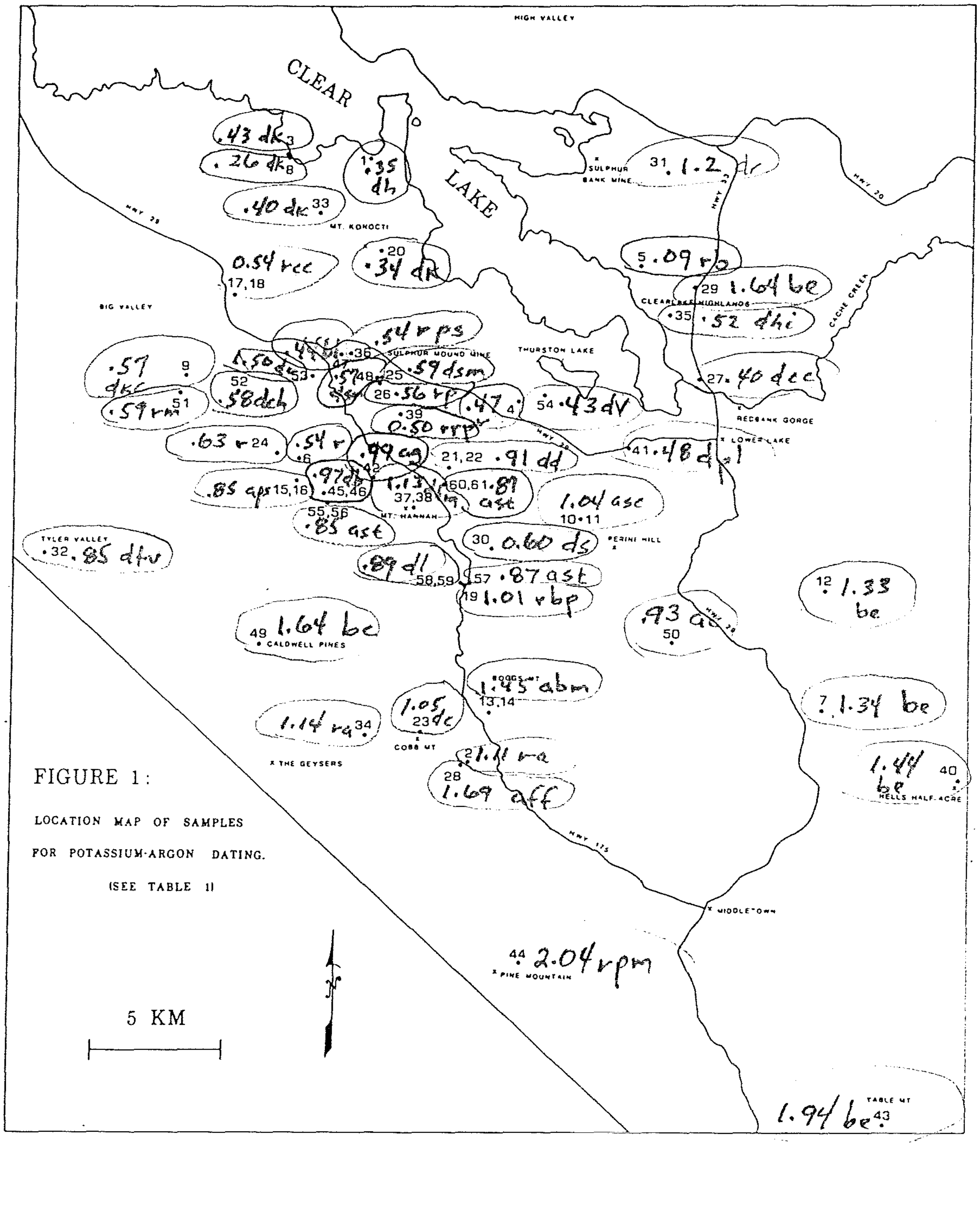


FIGURE 1:

LOCATION MAP OF SAMPLES FOR POTASSIUM-ARGON DATING.

(SEE TABLE 1)

Sonoma Volcanics (youngest published age, 2.9 ± 0.2 m.y., Mankinen, 1972).

m.y. ago. A gap may exist at 1.9–1.7 m.y., although it

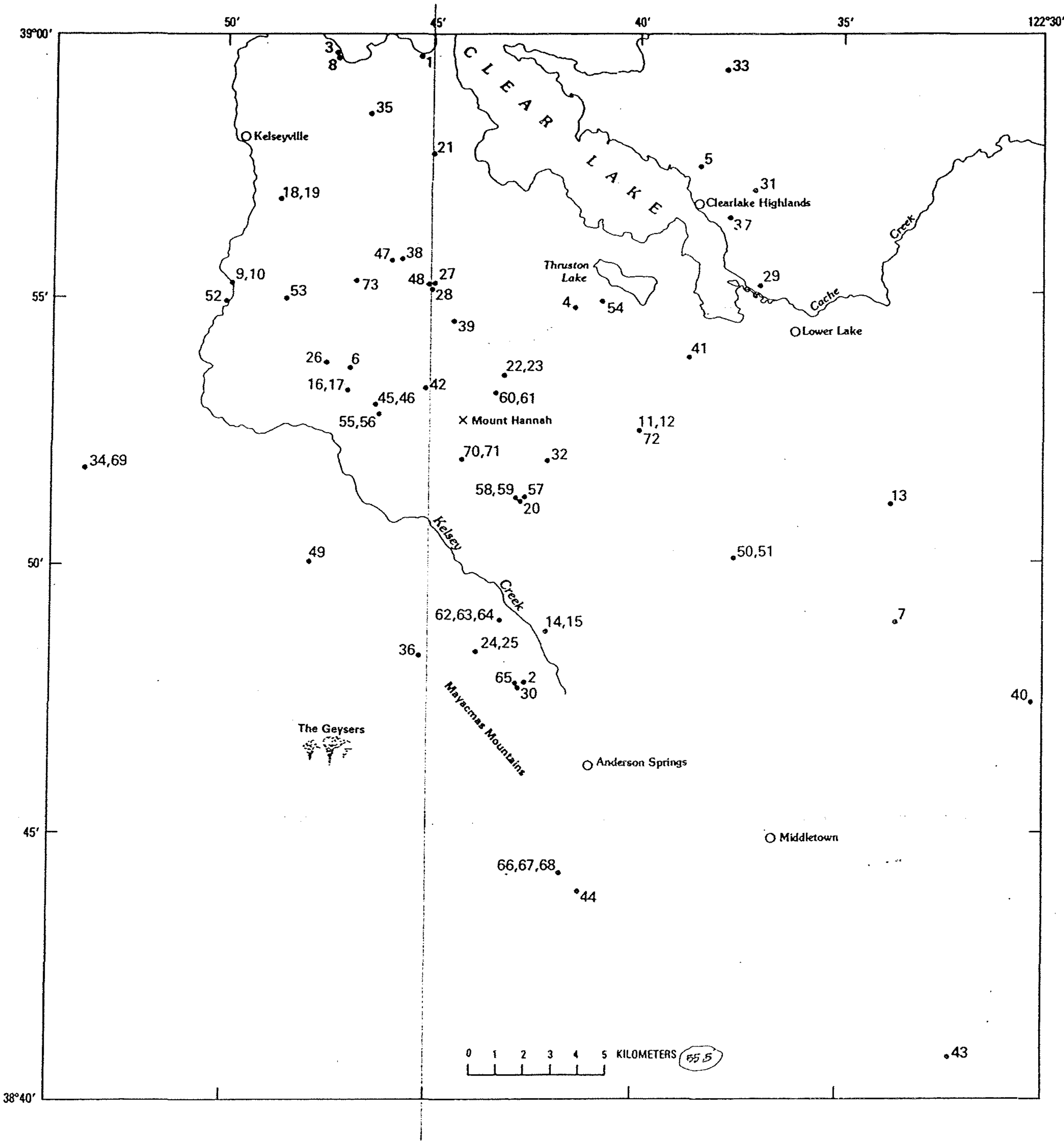


FIGURE 20.—Locations of samples for potassium-argon dating (see table 1).

argillite" is observed elsewhere in the Geysers (Crecraft, 1983, Gallinatti, 1984a, Sternfeld, 1981).

2) Argillite which is higher in chlorite and mixed layer clays than the surrounding graywacke, with local serpentine, occurs within the Little Geysers Basin unit. This is similar to "argillite" which occurs along fault zones in the North Geysers area (Gallinatti, 1984a) and may represent local shear zones within the Little Geysers Basin unit.

3) Hornfels which occurs as a product of thermal metamorphism due to felsite intrusion (discussed below) is commonly logged as argillite. The initial stages of recrystallization during thermal metamorphism results in grain size reduction. Dark coloring in these rocks is due to biotite formation. Thus, megascopically the sample appears similar to argillite.

Intrusive History

Felsite in Geysers wells has previously been described by Schriener and Suemnicht (1980) and Hetherington (1984). Compositionally and/or texturally felsite intrusions encountered in the Unit 20-18 wells can be divided into at least 4 intrusive units (Figures 3 and 4): 1) biotite granite prophyry (DV 2), 2) biotite granite (DV2, FF 52-32), 3) biotite + clinopyroxene microgranite and 4) biotite ± clinopyroxene granodiorite. Classification as granite or granodiorite is based on quartz/K-feldspar/plagioclase ratios (figure 7), and may be misleading if secondary silica and K-feldspar are extensive.

It is not possible to conclude whether the four intrusive units represent variations of the same intrusion, separate phases of a single intrusive event or separate intrusive events. However, by using limited age dates, spatial relations, and alteration zoning, a tentative sequence of events can be proposed. This interpretation must be viewed with caution for the following reasons: 1) age dates are limited with not all units have been dated, 2) felsite is slightly to extremely altered thus age dates may be erroneous, 3) cross cutting features cannot be observed in cuttings, and 4) the degree of fracturing and, therefore, alteration may be a function of volatile content and depth of intrusion rather than age. Similar alteration may have formed during more than one episode.

Keeping in mind the above limitations, a tentative sequence of oldest to youngest felsite is: 1) biotite granite porphyry, 2) biotite granite, 3) biotite ± clinopyroxene microgranite, and 4) biotite ± clinopyroxene granodiorite. Evidence for this sequence and features of each unit are as follows:

Biotite granite porphyry: Core from this unit was dated at 2.4 ± 0.2 m.y. (K/Ar). This should be viewed with caution due to the highly altered nature of the sample. The date is slightly older than that obtained on the Pine Mountain dacite to the SW (2.06 ± .02 my) (Donnelly-Nolan et al, 1981). This is the oldest Clear Lake volcanic member identified. The porphyry is the most highly altered and fractured of the 4 "intrusions", with extensive tourmaline veining.

Biotite granite porphyry is identified in DV 2 only (figure 4), and is the shallowest felsite drilled to date in the Geysers (-377 vertical subsea depth)(Schriener, 1983, Hetherington, 1984, and Gambill, 1984). It defines the upper limit of the Unit 18 dome (Sussman and Thompson, 1984). In the wells studied, this is the only felsite to intrude the shallow Little Geysers Basin unit (figure 4).

Biotite granite: Identified at depth in DV 2 (figure 4) and FF 52-32 Unit of the Clear Lake Volcanics (figure 3), cuttings from this unit have been dated (sample from FF) at 1.7 ± 0.2 m.y. Biotite granite is only slightly altered, with minor tourmaline veining.

Biotite ± clinopyroxene microgranite: This unit has been dated at ∿.9 M.Y. from a core obtained on GDC 21. Alteration is slight with rare tourmaline veining. Although not as shallow as the porphyry, this unit forms the intermediate level of the Unit 20 dome (Sussman and Thompson, 1984).

Biotite ± clinopyroxene granodiorite: This unit has not been dated in the study area. Alteration is slight with rare tourmaline veining. The tourmaline veining appears zoned about the granodiorite (see "Alteration") in all other felsite and Franciscan units and may, therefore, have resulted from intrusion of the granodiorite. Granodiorite is interpreted to be the youngest intrusion in the wells studied.

Granodiorite forms the deeper part of the intrusive complex in Unit 20 but shallows toward Unit 14 (figure 4) and may form the felsite dome in that area.

Recent Structure

Tepper (1984) and Tepper et al. (1984) mapped a NW trending near vertical structure parallel to the Big Sulphur Creek I fault zone (figure 2). The structure (here referred to as Big Sulphur Creek II fracture zone) is defined by alteration and hot springs and is thought to be much younger than the

THOMPSON
1989
GRC Trans.

only re the FELSITE

* he says ~~a~~ K-Ar ages from 0.9 – 2.4 Ma
(some unpublished dates)

* granite to granodiorite

* axis of felsite trends NW-SE clearly controls field

THOMPSON & GUNDERSON,
1989

* axis of reservoir coincides w/ axis of ~~st~~ felsite
* top of reservoir mimics shape of top of felsite
* different major fracture patterns in felsite vs graywacke steam reservoir.

Ⓐ within given horizontal slice through reservoir:

(1) FELSITES HAVE spotty steam entry distribution

(2) GRW's at same elev. have steam entries occurring in laterally extensive areas

(3) FELSITE STEAM ENTRIES: ~~at~~ in areas where they do occur few in no., but ~~occur~~ distributed fairly uniformly with depth.

BEST FELSITE PRODUCTION FROM NW-TRENDING FRACTURE ZONES

(4) GRW STEAM ENTRIES: — steam entries concentrated preferentially at certain elevation intervals — highly variable steam-entry frequency vs. depth.

Ⓑ ~~fracture~~ Major steam-bearing fractures in felsite tend to be high-angle — near vertical

Ⓒ Major steam-bearing frx in MEW much more likely to be low-angle

NW Geysers

STERNFELD, 1989

GRC Trans.

only re the FELSITE

(I) there is an "...intrinsic relationship between distribution of steam (The Geysers reservoir) & distribution of felsic intrusives"

(A) strong correlation between configuration/orientation of top of reservoir & top of felsite body.

(1) shallowest steam — shallowest felsite (Hebein, 1986)

(II) Reasons for the felsite/steam-reservoir correlation

(1) Porosity creation or enhancement by pluton-related processes → within what's now the steam-reservoir

(A) Magmatic- and meteoric-hydrothermal fracturing & brecciation

(B) Mineral Dissolution and replacement processes in an earlier, magmatically-heated, high-temperature liquid-dominated hydrothermal system.

(me) (2) Heat supplied to the steam-reservoir by cooling plutons

(A) remember Schriener & Suemnicht say dated plutons too old to be heat sources. (but younger ones would not be)

(III) His Reasons for paucity of steam entries in hornfels

(1) brittle fractures induced by the pluton did not form because of plastic flow in partially melted hornfels

(me) → other reasons, more likely

(1) No dissolution of Franciscan calcite to form vugs massive rexlzn to oligoclase, calc-silicates (in preference of qtz.)

(2) solid-state granoblastic rexln. of vein material, mostly qtz.

(3) deposition of qtz. at high-T due to retrograde solubility.

WALTERS ET AL., 1988

~~SPE~~ Stanford Reserv. Eng. conf paper

only re the felsite

① "dominant 2nd minrlzn. (in Geysers reservoir) is strongly zoned succession of Quaternary mineral assemblages deposited by liquid-dom. hydrothermal system induced by felsite intrusion."

② Intrusions caused heating, uplift, and (likely) induced fracturing in overlying [Franciscan] rx.

③ Intrusions caused thermal metamorphism close to themselves (made hornfels)

④ Intrusions initiated hydrothermal systems, liquid-dominated, antedating the modern steamfield.

⑤ Intrusion much deeper in NW Geysers, so evolution perhaps different than in GW-hosted reservoir above shallow felsite in the south

⑥ ——

HEBEIN, 1985
GRC Bulletin

① Multiple liquid-dom. hydroth. systems driven by successive igneous intrusive heat fluxes. antedated current steam field.

② More [even younger] recent intrusions [beneath older "felsite" plutons] may supply the heat which ~~drives~~ supports the present vapor-static system. (FIRST TO SAY THIS IN PRINT)

③ several stages postulated for The Geysers steam-field development, but NO SUPPORTING DATA.

Ⓐ Franciscan metamorphism, shearing

Ⓑ Extensional tectonic regime begins
deep plutons (felsite) emplaced

Ⓒ multiple, more intrusions w/ accompanying boron metasomatism

Ⓓ ~~m~~ continued intrusive emplacement — development of major ~~T.~~ hot water systems
high-level hydrothermal brecciation, hot springs, etc.

Ⓔ Boil-down, shallow condensate

Ⓕ sericitic sealing &
ADSORPTION OF WATER IN MICROPORES

further comparison of local age dates for volcanics (from Donnely ?)

1.04 – 1.69 Ma in immediate vicinity of Geysers field (incl. Cobb etc.)

0.85 in Tyler Valley to North

2.04 Ma @ Pine Mtn. ~ 7 km. S. of field.

0.09 – 1.64 Clear Lake volcanic field. (maybe younger)

- Gravity low centered on Mt. Hannah (Isherwood, 1976)
- Teleseismic P-wave delays – anomaly including The Geysers may indicate a deep magma chamber.

CONCLUSIONS: FELSITES Temporally & chemically related to the Cobb Mtn. / Clear Lake volcanics

Too old to be the heat source for The Geysers field.

(but (me) → genetically related but younger plutons beneath those penetrated could be the heat sources.

THOMPSON & GUNDERSON
1989

(GRC Trans.) (2)

★ Felsite cores — nearly all fractures are high-angle and mineralized
qtz, tourmaline, epidote
(me: also chlorite & KFSP)

★ GRW cores — veins occur at all angles
→ "mineralogy similar to felsite" ???
except grw-hosted veins outside reservoir, which have calcite

★ GRW - reservoir
① "large areas of consistent production & [generally] uniform steam-entry frequency" at a given well inclination.
implies → gen. random orientation of steam-producing fractures

but: steam-entry frequency decreases in GW w/ increasing inclination.
→ so many of the major GW frx may be low-angle structures.

★ NO CONSISTENT CORRELATION BETWEEN STEAM ENTRIES & HIGH-ANGLE STRUCTURES RELATED TO CURRENT STRIKE-SLIP TECTONICS

∴ the steam-entry vs. fracture inclination pattern for GW-hosted reservoir suggests that these frx are re-opened Franciscan structures

(since calcite is missing from the reservoir) DISSOLUTION OF FRANCISCAN CALCITE IS THE LIKELY PROCESS BY WHICH THESE OLDER, INITIALLY TIGHT STRUCTURES HAVE BECOME PERMEABLE THERMAL-FLUID CHANNELS.

(calcite dissolution is also the mechanism by which porosity for water storage is created or enhanced)

THEY SAID IT IN 1989

Predominance of vertical frx in felsite (formed since 2.5 Ma) may be related to more recent strike-slip tectonics).

McLaughlin et al., 1983 (abs)
GSA

(GSA abs)

- studied cuttings & cores both
- reiterate documentation & dating of felsites by Unocal (cf Schriener & Suemnicht, 1981)

★★ → first mention of felsite intrusions generating high-temperature, liquid-dominated hydrothermal systems antedating the modern steam field.

① fracturing and tourmalinization in contact zones around the plutons.
   Ⓐ > 350°C

② within what is now the steam reservoir
   EPIDOTE–ACTINOLITE–PREHNITE–CHLORITE–KFSP–QTZ–PY–PO
   Ⓐ > 290°C

③ At higher levels:
   Ⓐ QTZ–ADUL–CHL–MICA–PY   > 210°C

LATE
ADULARIA DATE 0.69 Ma

④ very latest stage:
   CALCITE–DATOLITE–SULFIDES.   T = ?

Our work has different paragenesis, but its OK. ↑

THEY CLEARLY STATE THAT MODERN STEAM RESERVOIR EVOLVED FROM LIQUID-DOMINATED PRECURSOR

Sternfeld even earlier

SCHRIENER & SUEMNICHT, 1981

(USGS OF-Rept)

Felsite in Burned Mtn. well is quartz normative biotite-bearing felsite

a. porphyritic to equigranular

b. ① porphyritic

phenocrysts

* subhedral qtz. up to 2 mm dia
* albitic plag. up to at least 2mm L
  → twinned, zoned
* biotite < 1 mm L, anhedral

groundmass

* qtz. & orthoclase, mosaic 0.25 mm dia xls.

minor minerals

* OPXN, CPXN, AP, ZIRC, OXIDES, SULFIDES

b. distinctly calc-alkaline in nature when $CaO \cong Na_2O + K_2O$, SiO_2 = 56-61 wt.%

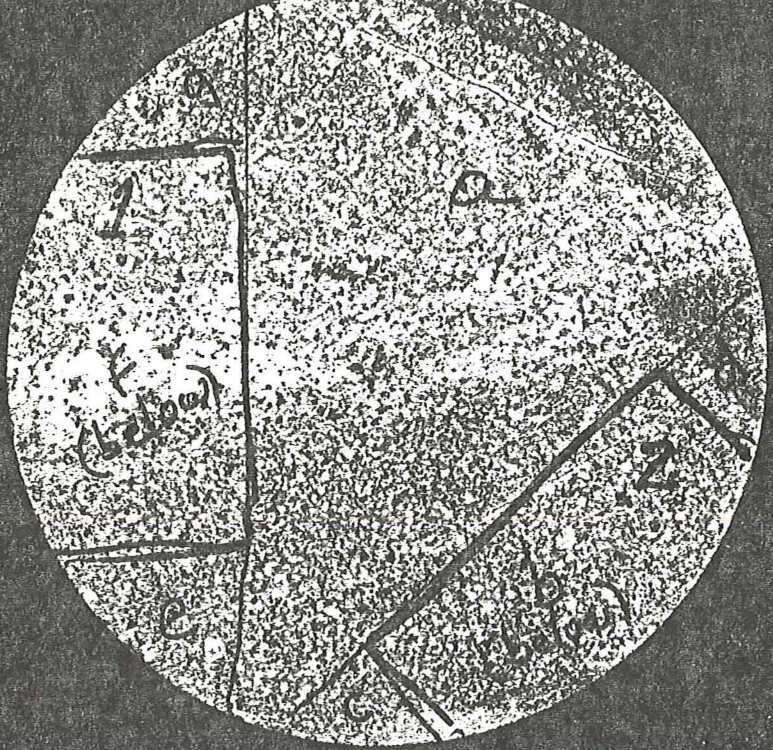
B. They say SiO_2 and K_2O increase w/depth in the felsites (w/ corr. decrease in Al_2O_3, CaO, Fe_2O_3, MgO, Na_2O, & P_2O_5)

a. our mineral %'s show qtz. decreases w/depth, and that CaO should increase at expense of Na_2O as plag. becomes more oligoclase than albite

C. K-Ar ages:

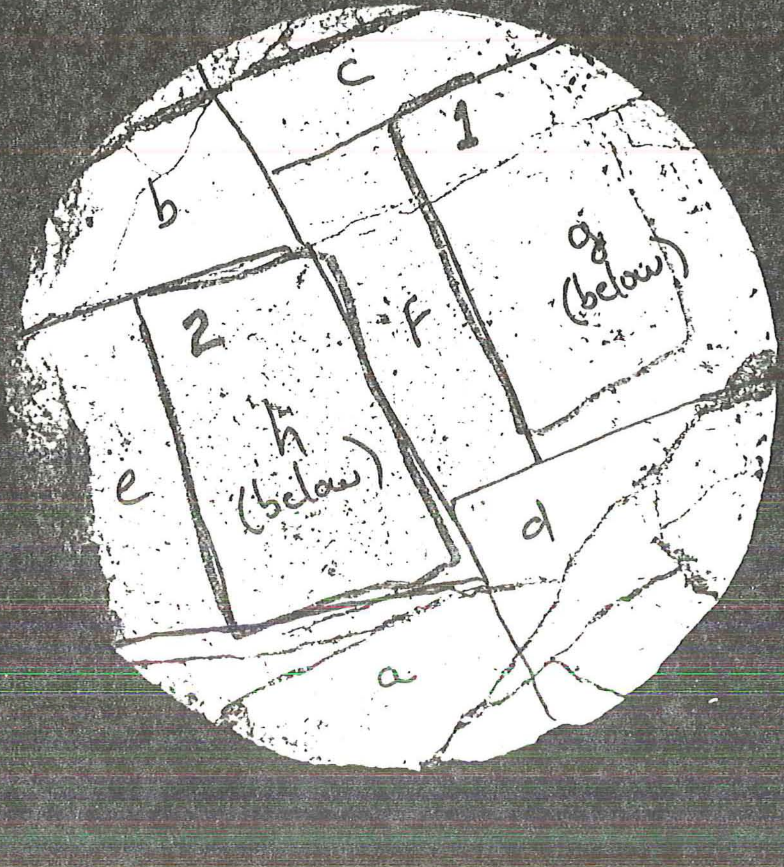
1.6 ± 0.4 Ma (sanidine ??)
2.7 ± 0.3 Ma (biotite)
2.5 ± 0.4 Ma (whole rock)

a. compare with Cobb Mtn. rhyolite to dacite 1.06-1.12 Ma
& basalt of Caldwell Pines: 1.64 Ma.



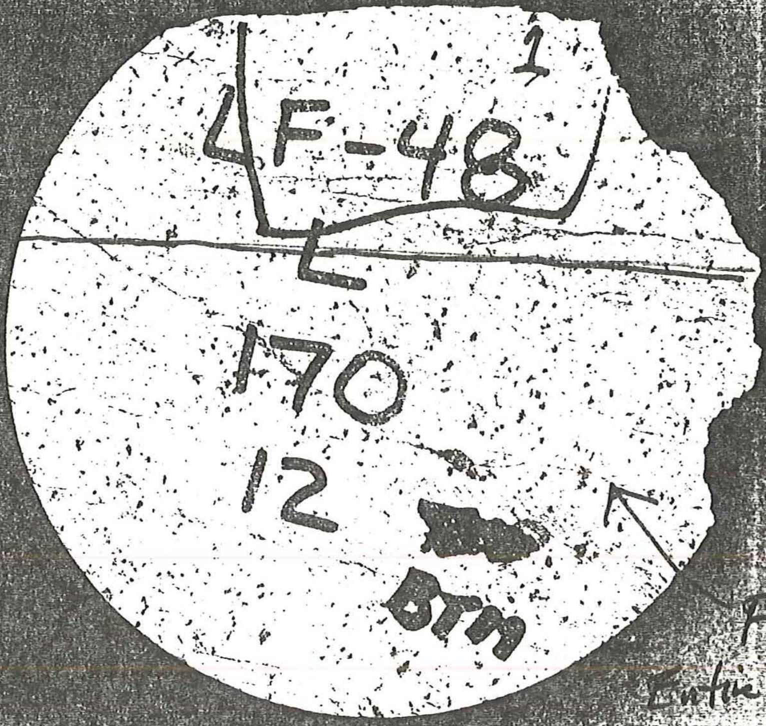
GDC-21
1 & 2 = thin sections

Used b, c, e, & g
for 40/39



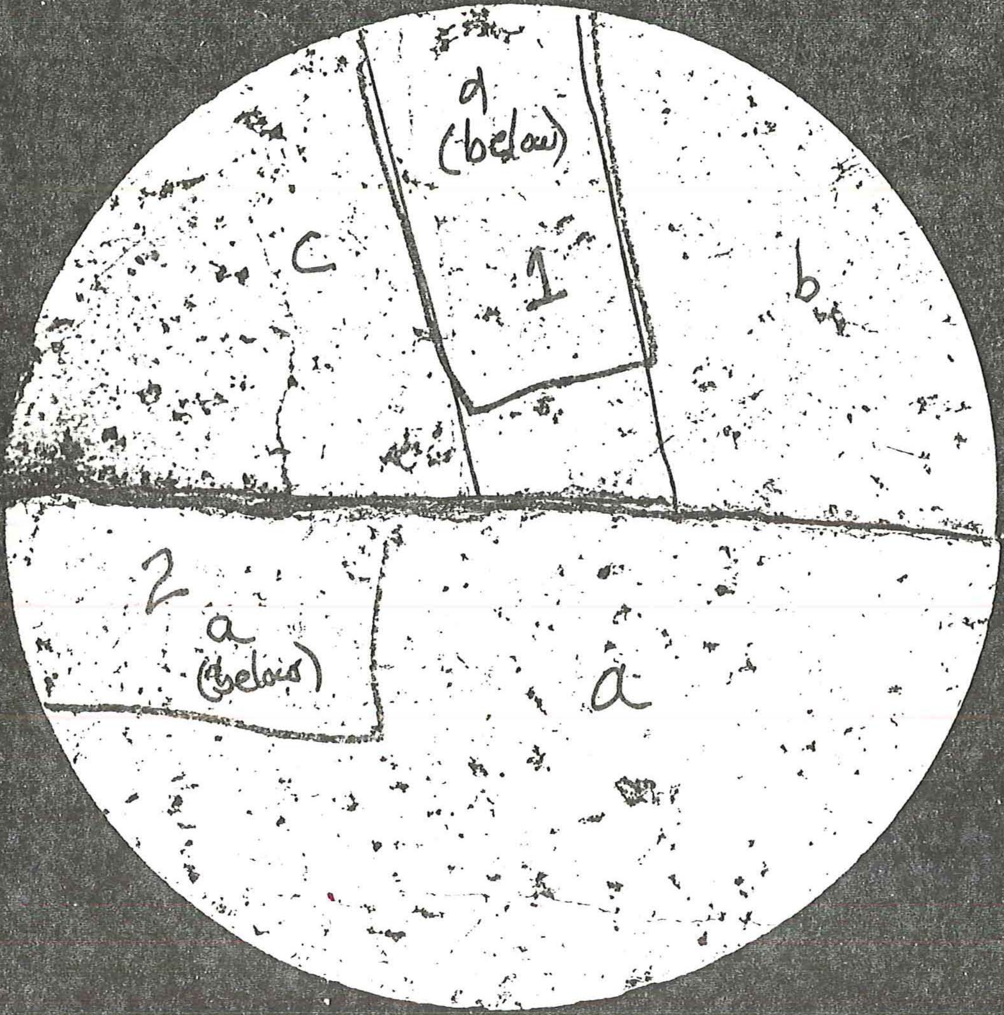
Used f & h for
40/39

DV-2E
1 & 2 = thin sections



FOR 40/39
Entire piece
below red line

#1 = thin section



Used b for 40/39

DV -2B
1 & 2 = thin section