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November 21, 1988

Dr. Daniel Carrier
Unocal Geothermal Division
Unocal Corporation
3576 Unocal Place
Santa Rosa CA 95406

Dear Dr. Carrier,

Attached are the revised results of XRD analysis and reconnaissance petrographic analysis of cuttings from the "8"-series group. These results, initially mailed to you in mid-October, are further interpreted in the text that follows.

Most of these samples from the "8"-series group (except for 8-10 and 8-18) are dominated by porphyritic to aphyric basalt to basaltic andesite and similar but slightly more coarsely-crystalline microdiabase. All or most appear to have contained primary pyroxene and are altered to a variety of secondary phases. Actinolite has replaced some of the pyroxene and all the primary hornblende, although traces of the latter may still be present in a few chips.

Sample 8-10 is quartz latite to quartz monzonite, essentially identical to that documented for previously analyzed samples 6-2 and 6-3. Well-developed spherulitic, granophyric and micropegmatitic textures are locally present. The lithology and devitrification textures of sample 8-10 may represent either a thick flow, or an extrusive dome, or possibly a shallow (hypabyssal or subvolcanic) intrusive.

Sample 8-18 is a rhyodacite to microgranodiorite with a sub-trachytic texture. It exhibits more flow texture than 8-10 but could also represent a dome or shallow intrusive.

Sample 8-17A may be a hydrothermal breccia; subrounded and altered clasts are present within a fine-grained matrix. The clasts are composed of fragments of porphyritic to aphyric basaltic andesite. Quartz-filled fractures crosscut the clasts within the breccia. Fragments of lineated rock lacking phenocrysts may represent minor amounts of gouge or microbreccia material in samples 8-9 to 8-15.

Like the 6-series rocks, samples 8-9 to 8-17 host a variety of secondary minerals indicative of formation at relatively high temperatures. For example, actinolite generally forms at temperatures above 280°C; biotite forms above 220 °C (more commonly above 300°C); and epidote forms above 240° C (e.g. Browne, 1978, 1984; Hulen and Nielson, 1986). Other secondary alteration phases in these samples (such as chlorite) are ambiguous as geothermometers. Some of the actinolite could be deuteric in origin, as could the chlorite and epidote, but the common occurrence of these minerals as well-developed veinlets strongly argues in favor of a fairly high-temperature hydrothermal origin. Minor amounts of discrete smectite in these samples are probably saponite; trioctahedral smectites that are more stable at higher temperatures than their dioctahedral counterparts (Eberl, Whitney and Khoury, 1978).

Traces of subordinate phases such as prehnite and serpentine identified petrographically in samples 8-11 and 8-12 also suggest a fairly high-temperature alteration of these rocks. Prehnite is believed to form between 250°C to 350° C (e.g. Bird et al., 1984).

Thank you for the opportunity to work with these interesting cuttings and for sending another core chip of sample 8-17. Diffraction of the "17"-series group is nearly completed, so those results should be forthcoming in the next few weeks. Please call me at (801) 524-3425 if you have any further questions concerning the x-ray or petrographic signatures of these rocks.

Sincerely,

Susan Lutz

Susan Lutz
Manager,
X-ray Diffraction Laboratory

References:

Browne, P.R.L., 1978, Hydrothermal alteration in active geothermal fields: Ann. Rev. Earth Planet. Sci., v. 6, p. 229-250.

Browne, P.R.L., 1984, Lectures on geothermal geology and petrology: United Nations Univ., Geoth. Training Prog., Rept. 1984-2, 92 p.

Eberl, D., Whitney, G. and Khoury, H., 1978, Hydrothermal reactivity of smectite: American Mineralogist, v. 63, p. 401-409.

Hulen, J.B., and Nielson, D.L., 1986, Hydrothermal alteration in the Baca geothermal system, Redondo dome, Valles caldera, New Mexico: J. Geophs. Res., v. 91, p. 1867-1886.

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10 CUTTINGS SAMPLES
8-9 TO 8-18

REVISED BULK XRD

MINERALOGY, APPROX. WT.% ☑ (or) RELATIVE ABUNDANCE ☐

SAMPLE NO.	QUARTZ	PLAGIOCLASE	K-FELDSPAR	CALCITE	CLINOPYROXENE	ACTINOLITE	EPIDOTE	PRENHNITE	ANHYDRITE	ILMENITE AND/OR MAGNETITE	HEMATITE	PYRITE	SPHENE/LEUCOXENE	SMECTITE	MIXED-LAYER CHLOR-SMECT. ILLITE AND/OR VERMICULITE	BIOTITE	CHLORITE	TALC	OTHER	
8-9	7	45	5	TR	3	9≠	4			9	2		9	1	TR			5		TR. SERPENTINE
8-10	41	34	17		TR	TR	2			1	TR		3	1				1		
8-11	8	38	5	1	15	5	5			7	2		6	1	1	TR		5	1	TR. SERPENTINE
8-12	4	46	7	TR	3	8≠	6	TR		9	TR	TR	7	1		TR		8	1	
8-13	1	49	6		2	10	5		TR	10		TR	7	1		1		7		
8-14	3	51	3		2	9≠	3			13		TR	7	1		TR		8		
8-15	2	54	3	TR	2	10≠	3			10		TR	6	1		TR		9		
8-16	11	46				7	9			7	TR		11					9		
8-17B	1	41	3	TR		19	5			10		1	7	TR			11	6		
8-18	18	45	18				7					TR	5					7		

≠ POSSIBLY INCLUDING VERY MINOR PRIMARY HORNBLENDE

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

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8-9 TO 8-18

REVISED CLAY XRD

MINERALOGY, APPROX. WT.% ☑ (or) RELATIVE ABUNDANCE ☐

SAMPLE NO.	SMECTITE	ILLITE AND/OR HEMATITE (UNDIV.)	CHLORITE	MIXED LAYER CHLORITE/MICA	BIOTITE	TALC
8-9	16		79	5		
8-10	10	76	14			
8-11	7	15	56	14		8
8-12	4		86			10
8-13	8		92			
8-14	15		85			
8-15	18		82			
8-16			100			
8-17B	3		63		34	
8-18			100			

MM = PREDOMINANT M = MAJOR m = MINOR Tr = TRACE ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

S. Lutz
11-21-88

ROCK TYPES - REVISED

SAMPLE No.	SUBACT OR BASALTIC ANDESITE	DIABASE Ⓐ	MICROGABBRO Ⓑ	QTZ. LATITE OR RHYODACITE TO MICROGRANODIORITE Ⓒ	HYDROTHERMAL BRECCIA	GOUGE, MICROBRECCIA	VEIN FRAGMENTS							
8-9	MM	m						m	m					
8-10	TR		MM					TR	m					
8-11	MM	m						m	TR					
8-12	MM	m	TR					m	m					
8-13	MM	m	m					m	m					
8-14		m	MM	M				m	m					
8-15			MM	M				TR	TR					
8-16			MM											
8-17A							MM							
8-17B			MM											
8-18					MM									

Ⓐ, Ⓑ, & Ⓒ PROBABLY INTRUSIVE WITH Ⓐ, Ⓑ & Ⓒ PROBABLY JUST DIFFERENT TEXTURAL VARIETIES OF SAME ROCK TYPE.

QTZ LATITE - INITIALLY GLASSY: WELL-DEVELOPED SPHERULITIC, GRANOPHYRIC & MICROPEGMATITIC TEXTURES.

10 CUTTINGS SAMPLES: ROCK TYPES OBSERVED DURING RECONNAISSANCE PETROGRAPHY

SAMPLE NO.	QUARTZ	CALCITE	KF ± QTZ	EP ± Q, KF	ACT ± Q, KF, EP	CHL ± QTZ	ILLITE ± PHENGITE - QTZ	PREHNITE ± EP, QTZ, KF	WAIRAKITE ± EP, QTZ, KF	LEUCOXENE	BIOTITE ± QTZ	TALC - ACT.			
8-9	°TR	TR	✓	✓	✓	✓	TR								KF, EP-PHENGITE CAL-HEM
8-10	✓		*✓	✓		✓									
8-11	✓	✓		✓	✓	✓		TR							PHENGITE - EP - HEM EP - PREHNITE
8-12	✓	TR	✓	✓	✓	✓	TR	TR		TR		✓			QTZ - ACT EP - LEUCOXENE
8-13	✓	TR	✓	•✓	✓	✓	TR		?TR	✓					KF, EP-LEUCOXENE QTZ - ANH - EP
8-14	✓			✓	✓	✓	TR			TR					QTZ - ACT, PHENGITE - CHALCEDONY
8-15	✓	TR		✓	✓	✓				TR					EP - KF - ACT
8-16				✓	✓	✓									CHL - QTZ NODULES
8-17A	✓										✓				
8-17B	✓			✓	✓★	✓									ACT - Q - KF - MAG - SPH. ± EP
8-18			*✓	✓											EP - QTZ NODULE + VEIN

* MICROPEGMATITIC Q-KF INTERGROWTH

° CHALCEDONY

★ WITH SPHENE

TR - SCATTERED TRACES

• WITH ANHYDRITE

10 CUTTINGS SAMPLES : VEINLETS OBSERVED DURING RECONNAISSANCE PETROGRAPHY