

# UURI

EARTH SCIENCE LABORATORY  
391 CHIPETA WAY, SUITE C  
SALT LAKE CITY, UTAH 84108-1295  
TELEPHONE 801-524-3422

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. Geophys. Res., v. 91, p. 1867-1886.

UNOCAL GEOTHERMAL - DANIEL CARRIER

10 CUTTINGS SAMPLES

8-9 TO 8-18

REVISED BULK YRD  
SAMPLE NO.

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

QUARTZ  
PLAGIOCLASE  
K-FELDSPAR  
CALCITE  
CLINOPIROXENE  
ACTINOLITE  
EPIDOTE  
PREHNITE  
ANHYDRITE  
TALC  
OR  
MICA  
HEMATITE  
PYRITE  
SPHENE  
KENCORONE  
SMECTITE  
MIXED-LAYER  
CHLOR-SMECT.  
ILLITE AND  
MONTMORILLONITE  
BIOTITE  
CHLORITE  
TALC  
OTHER

Latite  
Flow

SAMPLE NO.	QUARTZ	PLAGIOCLASE	K-FELDSPAR	CALCITE	CLINOPIROXENE	ACTINOLITE	EPIDOTE	PREHNITE	ANHYDRITE	TALC	OR	MICA	HEMATITE	PYRITE	SPHENE	KENCORONE	SMECTITE	MIXED-LAYER	CHLOR-SMECT.	ILLITE AND	MONTMORILLONITE	BIOTITE	CHLORITE	TALC	OTHER	
8-9 6940	7	45	5	TR	3	9	4		9	2				9	1	TR							5			TR. SERPENTINE
8-10 7070	41	34	17		TR	TR	2		1	TR				3	1								1			
8-11 7300	8	38	5	1	15	5	5		7	2				6	1	1	TR					5	1			TR. SERPENTINE
8-12 7700	4	46	7	TR	3	8	6	TR	9	TR		TR		7	1		TR					8	1			
8-13 7890	1	49	6		2	10	5	TR	10			TR		7	1		1					7				
8-14 8060	3	51	3		2	9	3		13			TR		7	1		TR					8				
8-15 8160	2	54	3	TR	2	10	3		10			TR		6	1		TR					9				
8-16 6593	11	46				7	9		7	TR				11								9				
8-17 B 8409/17	1	41	3	TR		19	5		10				1	7	TR					11		6				
8-18 F.L.	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**  
UNIVERSITY OF UTAH RESEARCH INSTITUTE, EARTH SCIENCE LABORATORY

S. Lutz  
11-21-88

ROCK TYPES - REVISED

SAMPLE No.	DIABASE	MICRODIABASE	QZ-LATITE OR QZ-LATITE MICRODIABASE	HYDROTHERMAL BSECCIA	QZ-LATITE	VEIN FRAGMENTS														
8-9 6940	MM	m					m	m												
8-10 7070	TR		MM				TR	m												
8-11 7300	MM	m					m	TR												
8-12 7700	MM	m	TR				m	m												
8-13 7890	MM	m	m				m	m												
8-14 8060		m	MM	M			m	m												
8-15 8160			MM	M			TR	TR												
8-16 8592			MM																	
8-17A 8409							MM													
8-17B 8415			MM																	
8-18 82					MM															

(A), (B), & (C) PROBABLY  
INTRUSIVE WITH  
(A), (B) & (C) PROBABLY  
JUST DIFFERENT  
TEXTURAL VARIETIES  
OF SAME ROCK TYPE.  
QZ-LATITE -  
INITIALLY GLASSY;  
WELL-DEVELOPED  
SPHERULITIC,  
GRANOPHYRIC &  
MICROFELDMATIC  
TEXTURES.

10 CUTTINGS SAMPLES: ROCK TYPES OBSERVED DURING RECONNAISSANCE PETROGRAPHY

UNOCAL GEOTHERMAL - DANIEL CARRIER

REVISED CLAY XRD SAMPLE NO.	MINERALOGY, APPROX. WT.% <input checked="" type="checkbox"/> (or) RELATIVE ABUNDANCE <input type="checkbox"/>													
	SMECTITE	ILLITE AND PHENOCRYSTALLIN.	CHLORITE	MIXED LAYER CHLOR./SMECT.	BIOTITE	TALC								
8-9 6490	16		79	5										
8-10 770	10	76	14											
8-11 7300	7	15	56	14		8								
8-12 7700	4		86			10								
8-13 7890	8		92											
8-14 8060	15		85											
8-15 8160	18		82											
8-16 6593			100											
8-17 B 8417	3		63		34									
8-18 F.L.			100											

NO OTHERS GRABED  
EXCEPT BUT NOT  
ALL HANDLES HAS  
GENERIC REFERENCE  
/m  
Determined by XRD and

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

SAMPLE NO.	VEINLETS														
	QUARTZ	CALCITE	KF ± QTZ	EP ± Q, KF	ACT ± Q, KF, EP	CHL ± QTZ	ILLITE ± PHENITE	PREHNITE ± QTZ	EP, Q, KF ± WHITKHITE ± EP ± Q, KF	LEUCOXENE	BIOTITE ± QTZ	TALC - ACT.			
8-9	TR	TR	✓	✓	✓	TR									KF, EP-PHENITE CAL-HEM
8-10	✓	*✓	✓	✓	✓										
8-11	✓	✓	✓	✓	✓	TR									PHENITE-EP-HEM EP-PREHNITE
8-12	✓	TR	✓	✓	✓	TR	TR		TR	✓					QTZ-ACT EP-LEUCOXENE
8-13	✓	TR	✓	*✓	✓	TR		?TR	✓						KF, EP-LEUCOXENE QTZ-ANM-EP
8-14	✓		✓	✓	✓	TR			TR						QTZ-ACT, PHENITE-CHALCEDONY
8-15	✓	TR	✓	✓	✓				TR						EP-KF-ACT
8-16			✓	✓	✓										CHL-RTZ NODULES
8-17A	✓									✓					
8-17B	✓		✓	*✓	✓										ACT-Q-KF-MAG-SPH. ± EP
8-18		*✓	✓												EP-RTZ NODULES + VEIN
* MICROPEGMATITIC															
Q-KF INTERGROWTH															
° CHALCEDONY															
★ WITH SPHENE															
TR- SCATTERED TRACES															
• WITH ANHYDRITE															

10 CUTTINGS SAMPLES : VEINLETS OBSERVED DURING RECONNAISSANCE PETROGRAPHY

# UURI

Invoice

Payor's Name and Address  Unocal Geothermal Division Unocal Corporation P.O. Box 6854 Santa Rosa, CA 95406	Payor's Reference AFE #470944-Daniel Carrier Samples 8-9 to 8-18	
	Total Amount \$1,800.00	
Payee's Name and Address  UNIVERSITY OF UTAH RESEARCH INSTITUTE Research Park 391 Chipeta Way, Suite C Salt Lake City, Utah 84108-1295 801-524-3422	Payee's Reference * 5-84701-442	
	Invoice # 26	Invoice Date 11-17-88
	Billing Period November 1988	

\* Please include Payee's reference number with payment

<u>Description</u>		<u>Amount</u>
Semi-quantitative XRD; Bulk Samples	10	\$600.00
Qualitative XRD; Bulk Samples	0	\$0.00
Semi-quantitative XRD; Clay Mineralogy	10	\$1,050.00
Qualitative XRD; Clay Mineralogy	0	\$0.00
SUBTOTAL		\$1,650.00
SPECIAL CHARGES		
Reconnaissance petrography, 3 hrs @ \$50/hr "8" - series		\$150.00
RUSH CHARGE 50%		\$0.00
TOTAL		\$1,800.00

Total amount due and payable within 30 days of invoice date