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EARTH SCIENCE LABORATORY
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October 18, 1988

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

Dear Dr. Carrier:

Attached are the preliminary results of x-ray diffraction and petrographic analyses for 10 drill cutting samples which you submitted in early August.

These samples of the "8"-series group are predominately andesites or porphyritic andesites with the exception of samples 8-10 and 8-18 which contain principally quartz latite or rhyodacite.

Sample 8-18 consists almost entirely of quartz, plagioclase and potassium feldspar. Sample 8-10 contains more primary quartz with some phenocrysts exhibiting dissolution phenomena. Granophyric, axiolitic and spherulitic textures are well developed in sample 8-10 and in some chips of quartz latite in sample 8-12.

Principal hydrothermal alteration products in these rocks are potassium feldspar, quartz, actinolite, chlorite (and mixed-layer chlorite-smectite), epidote, and leucoxene. Calcite, prehnite, wairakite and phengite are important subordinate vein-forming minerals. In the more porphyritic andesites, actinolite appears to replace primary clinopyroxene phenocrysts, especially in samples 8-13 and 8-16. (However, clinopyroxene in sample 8-11 appears relatively unaltered.) Actinolite also occurs as long prisms within quartz veins in sample 8-13. In sample 8-16, actinolite occurs in a large vein with epidote and chlorite and as a replacement of clinopyroxene phenocrysts.

Potassium feldspar veining and flooding is common in sample 8-13. In samples 8-9 and 8-11, some of the primary plagioclase is

replaced by carbonate and some by sericite. Epidote (with or without leucoxene) also commonly replaces plagioclase phenocrysts.

The quartz latite samples (8-10 and 8-18) contain mostly primary potassium feldspar and quartz as devitrification aggregates. Epidote and chlorite appear as the principal alteration products in these quartz latites or rhyodacittes.

Unfortunately, a thin section of sample 8-17 was not made so it is not possible to determine from the diffraction patterns alone whether the amphibole is primary hornblende or secondary actinolite, and whether the 10 angstrom mica is primary biotite or secondary illite and/or phengite. Another problem is the presence of an unidentified 9.40 angstrom peak in diffractograms of samples 8-11, 8-12 and 8-13 which may represent a talc-group mineral not recognized petrographically (although traces of serpentinite are evident).

As I mentioned in our phone conversation, a more detailed geologic and mineralogic report will be prepared after Jeff returns in a few weeks time. I've sent the "17"-series group out to be made into thin sections and hope to look at them fairly soon.

Thank you for this great introduction to hydrothermal alteration mineralogy. Please call me if you have any questions or if you would prefer only XRD data sent initially.

Sincerely,

Susan Lutz

Susan Lutz
Manager,
X-ray Diffraction Laboratory

SJL:kr

UNOCAL GEOTHERMAL - DANIEL CARRIER

10 CUTTINGS SAMPLES

8-9 TO 8-18

PRELIM. BULK XRD

MINERALOGY, APPROX. WT.% [X] (or) RELATIVE ABUNDANCE [ ]

SAMPLE NO.	QUARTZ	PLAGIOCLASE	K-FELDSPAR	CALCITE	CLINOPYROX.	ACTINOLITE	HORNBLENDE	EPIDOTE	PREHNITE	ANHYDRITE	TOTAL OPAQUES	ILMENITE & /OR LEUCOXENE	HEMATITE	PYRITE	SPHENE/ LEUCOXENE	WAIRAKITE	SMECTITE	MIXED-LAYER CHLOR.-SMECT. ILLITE AND/ OR HEULANDITE	BIOTITE	CHLORITE	TALC	
8-9	7	45	5	TR	3	7	3	4			20	13	2	5			1				5	TRACE - SERPENTINITE
8-10	43	34	17					1			1						1		2		1	
8-11	9	36	3	1	15	5		5	TR		17						1		1		7	TRACE - SERPENTINITE
8-12	6	40	8	1	6	5	3	6	TR		16	6			10		1				8	
8-13	2	39	7		3	12		7			21	8			13		1				8	
8-14	2	43	3		2	9	1	2			27	14		5	7	?	1				10	
8-15	1	47	6	1	3	10	2	3			20	10		4	6		1				6	
8-16	7?	37?	12°		3	14		11			14						1				11	
8-17	2	35		2	10		13	9				5		2	5				*11		4	(NO THIN SECTION)
8-18	18	56	14					8			1										3	

• NO T.S. - COULD BE ACTINOLITE

* NO T.S. - COULD INCLUDE BIOTITE

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

PRELIM. CLAY XRD

MINERALOGY, APPROX. WT.% [X] (or) RELATIVE ABUNDANCE [ ]

SAMPLE NO.	SMECTITE	ILLITE & PHENG. UNDIVIDED	CHLORITE	MIXED LAYER CHLORITE/MICA?	BIOTITE	TALC
8-9	16		79	5		
8-10	6	89	5			
8-11	7	15	72	6	?	
8-12	~~4~~		~~86~~	~~6~~	(10?)	
8-13	8		92	~~2~~	Tr ~~?~~	
8-14	15		85			
8-15	18	3	79			
8-16			100			
8-17	3	*34	63			
8-18			100			

+ MAY INCLUDE OTHER 10Å MICA - BIOTITE (NO THIN-SECTION)

? UNIDENTIFIED 9.4Å PEAK

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VEINLETS & VEINLET FRAGMENTS

10 CUTTINGS SAMPLES
8-9 TO 8-18

PRELIM. VEINLETS

SAMPLE NO.

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

SAMPLE NO.	QTZ	CHL	KF ± QTZ	EP ± Q, KF	ACT ± Q, KF, EP	CHL ± QTZ	PHENGITE ± IL, CHL, QTZ	PREHNITE ± EP, QTZ, KF	WAIRAKITE ± EP, QTZ, KF	LEUCOXENE	BIOTITE	SERICITE ± QTZ	
8-9	°TR	TR	✓	✓	✓	✓	TR		✓		✓		KF, EP-PHENG, EP-WAIRAKITE
8-10	✓		*✓	✓		✓							EP-CHL
8-11	✓	✓		✓	✓	✓		TR			✓		EP-PREHNITE
8-12	✓	TR	✓	✓	✓	✓	TR	TR		TR			QTZ-ACT, EP-LEUCOXENE
8-13	✓	TR	✓	✓	✓	✓	TR		✓	✓			KF EP-LEUCOXENE, WAIR-CHL
8-14	✓			✓	✓	✓	TR			TR			QTZ-ACT, KF-CHL, PHENGITE-CHALCEDONY
8-15	✓	TR		✓	✓	✓							EP-KF-ACT
8-16				✓	✓	✓							CHL-QTZ (NODULES), EP-CHL-ACT
8-17													NO THIN-SECTION
8-18			*✓	✓									EP-QTZ (NODULE), EP-QTZ (VEIN)

* MICROPEGMATITIC Q-KFSP INTERGROWTH

° CHALCEDONY

TR = SCATTERED TRACES

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SUMMARY OF X-RAY DIFFRACTION ANALYSIS

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ROCK TYPES

10 CUTTINGS SAMPLES
8-9 TO 8-18

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

PRELIM. ROCK TYPE / SAMPLE NO.	BASALT OR ANDESITE	PALAGONITIC BASALT-ANDESITE	MICRODIABASE & MICRODIORITE	QTZ LATITE OR RHYODACITE	QTZ MICRODIORITE/ MICROGRANODIORITE	QTZ MICRO-MONZONITE																					NOTES
8-9	M	M	m	m		TR																					
8-10	m			MM	TR																						
8-11	MM	m	m																								
8-12	M			M																							
8-13	MM	m	m	TR?																							
8-14	M	M	m																								
8-15	M	M	m																								
8-16		MM																									
8-17																											no thin-section
8-18				MM																							

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

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

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