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CONFIDENTIAL

Analysis of 70 Felsic- to Mafic-Composition Volcanic Rock Cuttings Samples by X-ray Diffraction

by

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Introduction

This report documents the results of qualitative X-ray diffraction (XRD) analysis of 70 cuttings samples submitted by Richard Gunderson of Union Oil Company's Union Geothermal Division late in July. Results of the analyses, completed in mid-August, were mailed in preliminary form to Union's Santa Rosa office August 20; they are also appended to this report and briefly discussed in the text which follows. Corresponding X-ray diffractograms have been shipped under separate cover.

Methods and Procedures

Each cuttings sample, in preparation for bulk XRD analysis, was lightly crushed to < 18 mesh (< 1 mm) and thoroughly mixed to ensure homogenization. A representative one-gram split of each then was ground in acetone in an agate mortar to < 325 mesh (< 42 microns). These powders were irradiated at 2°2θ per minute from 2-65°2θ using CuKα radiation at the following instrument settings: accelerating voltage - 40 kv; tube current - 40 ma; full-scale deflection - 2500 counts per second; time constant - 1/2 second. All samples were vapor glycolated at 60°C for 24 hours and re-scanned (at the same instrument settings) from 2-10°2θ to check for expandable clays. The relative abundances of the phases identified on the resulting diffractograms were determined by comparing diagnostic peak intensities with those generated by pure reference standards.

Results and Discussion

The X-ray signatures of these 70 samples indicate that the boreholes from which they were collected penetrated principally felsic and intermediate- to mafic-composition volcanic rocks. The dominant minerals in the felsic rocks are sanidine and cristobalite with variable amounts of tridymite and quartz;

plagioclase and hematite are locally present. Calcic (?) plagioclase and glass (± other, less likely amorphous phases) are the principal constituents of the intermediate- to mafic-composition samples, many of which also contain ilmenite, magnetite and hematite in various combinations. The plagioclase may be compositionally zoned. Its many strong peaks mask most of the feeble reflections possibly generated by other minerals suspected to be present in trace to minor amounts -- clinopyroxene, orthopyroxene, olivine and apatite. Confident identification of these minerals must await petrographic confirmation.

Smectite is the most common and abundant layer silicate in these samples, occurring in all wells, but concentrated in 45-36 and 86-23 (from which no felsic rocks were identified). Chlorite is uncommon, occurring only in the deeper portions of 45-36 and 28-32 (in this well, its distribution is antithetic to that of smectite). Abundant chlorite in the sample from 4500' in 28-32 is accompanied by illite (and/or mica), calcite, analcime or wairakite, and pyrite.

Based on XRD alone, most of these samples appear to be only weakly altered, and much of that alteration could be deuteric. The association of quartz, illite, abundant chlorite, calcite, analcime or wairakite and pyrite in cuttings from the deeper portions of well 28-32, however, suggests that these rocks have probably interacted with circulating hydrothermal fluids.

27-27, 3000': → ‡ 2.71 Å PEAK (NOT PY. OR MARC.) MAY BE IMPURE HEMATITE
* MAY INCLUDE OTHER AMORPHOUS PHASES SUCH AS OPAL

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

SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNET.	SMECTITE	ILLITE &/OR MICA	CHLORITE	KAOLIN OR SERPENTINE	CALCITE	GLASS *									OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AM'TS.
WELL 14-23																							
444'	<m				MM	<m		<m?						m?									CPX, OPX, AP
816'					M	<m								M									AP, GOE
1462'					MM			<m?	m					m?									AP
1903'		m			m									MM									
2325'	<m	m?	m	M	m				<m														
2599'					MM		<m?	<m?	M														AP
2998'					MM			<m?	<m					m?									AP
WELL 18-34																							
583'					MM	<m								m?									AP, OLV
1289'														MM									
1983'	m	M	m	M			<m		<m	<m?													
2507'		M		M	m									m?									
2932'					MM	<m	<m		m					m?									AP
3498'					MM	<m	<m?		m					m?									OPX, AP
WELL 27-27																							
619'					MM									m?									CPX, AP
1266'					MM		<m?							m?									AP, OLV
1635'					M									M									OLV
2145'					MM	<m	<m?							m?									CPX, AP, OLV
2543'					MM	<m	<m?	<m?						m?									CPX, AP, OLV
3000'					MM		m?‡		<m					m?									AP, OLV

MM = PREDOMINANT M = MAJOR m = MINOR <m = <5WT% ? = TENTATIVE IDENTIFICATION

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

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SAMPLE NO.	QUARTZ	CRISTOBAL.	TRIDYMITE	K-FELDSP.	PLAGIOCL.	ILMENITE	HEMATITE	MAGNETITE	SMECTITE	ILLITE &/OR MICA	CHLORITE	KAOLIN &/OR SERPENTINE	CALCITE	GLASS *	ANALCIME OR WAIRAKITE	PYRITE	OTHER PHASES POSSIBLY PRESENT IN TRACE TO MINOR AMOUNTS
WELL 28-32																	
440'		M	m	MM	<m?		<m										
860'	m	M	m	MM					<m								
1280'		M		M	m				<m								
1500'	m	M		M	m				<m?	<m							
1950'	<m?			<m?	MM		M		<m					m?			CPX, AP
2480'		M		M			<m?		m								
2950'	M			MM			<m										
3532'	m			<m?	MM	<m	<m	<m?	M			<m?		m?			CPX, AP
3968'	M			m?	M		m				m		<m				
4500'	m			m?	M					<m	M		<m		<m	m	
WELL 29-1																	
467'					MM									M			AP
1297'		M	m	MM					<m								
1951'		m	M	MM					<m								
2375'								<m						MM			AP
2803'	<m?			<m?	MM	<m?		<m?	M					m?			AP
3088'					MM			<m?	m					m?			CPX, AP

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WELL 45-36																
100'					MM	<m	<m							m?		CPX, OPX, AP
480'	m	M	m	MM					<m							
1000'					MM		<m		m					m?		CPX, OPX, AP
1470'					MM	<m	<m		m					m?		CPX, OPX, AP
1860'					MM	<m	m		M					m?		AP
2390'					MM	<m	<m		M			<m		m?		AP
2780'	M			M	m		<m?				<m				<m	
3100'	M			M	M		<m?				<m					
3600'	m				MM	<m?			M					m?		CPX, AP
4000'	m			m	MM			<m			m			m?		AMPH
WELL 57-13																
781'					<m									MM		CPX
1423'					m									MM		
1637'					<m									MM		
2079'	m	<m	M	MM			<m		<m	<m						
2426'									<m					MM		
2929'					MM				M					m?		CPX

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WELL 62-21																		
530'					MM	<m	<m		<m					m?				CPX, OPX, AP
1035'					MM		<m		M					m?		<m	<m?	
1700'					MM				M				<m	m?				CPX, AP
1973'					MM		<m	<m?	M				<m?	m?		<m		CPX, AP
2132'					MM	<m?	<m		M					m?				CPX, AP
WELL 68-16																		
508'		M		MM	m		<m											
1039'		M		MM	m		<m		<m?									
1338'					m									MM				
1740'					M				<m					M				CPX,
1857'					m				<m	<m?				MM				
2227'					MM		<m?		m					m?				CPX, AP
2599'		MM	m	M			<m											
2936'		MM		M			<m		<m									
WELL 86-23																		
694'					MM		<m		<m					m?				CPX, AP
1085'					MM		<m		<m					m?				CPX, OPX, AP
1554'					MM		m		m					m?				CPX, AP
2258'					MM		<m		<m					m?				CPX, AP
3157'					MM		<m		M					m?				CPX, OPX, AP
3497'					M				M					m?	<m			CPX, AP

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