ESL-85025R-TR
(Proprietary)

Bulk and Layer Silicate Mineral Zoning in Well 68, as Determined by X-ray Diffraction

by

Jeffrey B. Hulen
University of Utah Research Institute
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108

for

Union Geothermal Division
Union Oil Company of California
2099 Range Avenue
Santa Rosa, California 95406

October 29, 1985

Introduction

This report documents the results of semi-quantitative X-ray diffraction (XRD) analysis of 16 cuttings samples submitted by Union Oil Company of California's Union Geothermal Division early in September. Results of the analyses were mailed in preliminary form to Union's Santa Rosa office October 2; 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 CuK_α 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 approximate abundances of the phases identified on the resulting diffractograms were determined by comparing diagnostic peak intensities with those generated by pure reference standards (with appropriate corrections for estimated matrix absorption).

For clay analysis, the samples were first gently crushed to expose fresh surfaces from which layer silicates could be liberated. The crushed samples then were sonically disaggregated in deionized water, allowed to settle for 37 minutes 30 seconds, decanted (the upper 5 cm) and centrifuged. The resulting < 5 micron slurries were smeared on glass slides and scanned with a Phillips

diffractometer 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-one second. All samples were irradiated at 1°2θ per minute after the following treatments: air-drying (2-37°2θ), vapor glycolation at 60°C for 24 hours (2-22°2θ), heating to 250°C for one hour (2-15°2θ) and heating to 550°C for one hour (2-15°2θ). Approximate amounts of layer silicates identified on corresponding diffractograms were determined by comparing diagnostic peak intensities with those generated by reference standards.

Results and Discussion

The 16 samples analyzed comprise principally basalt and andesite, with two samples listed as "tuff or volcaniclastic", one dacite, and one altered silicic flow rock. As expected, plagioclase is the main component of the intermediate- to basic-composition rocks. The plagioclase is accompanied by minor magnetite, ilmenite and hematite, and probably pyroxene. The few and poorly-developed peaks of both clino- and orthopyroxene are masked by the strong and numerous reflections of the abundant plagioclase, and so are difficult to identify reliably; petrographic confirmation is necessary. Above 5000', the intermediate-composition rocks contain minor smectite; below 1200', minor quartz and chlorite and sporadic K-feldspar and calcite are present. Possible traces of analcime or wairakite occur below 4400', and 3% epidote is present in all samples below 4800'.

The rock field-named dacite at 1600' contains appreciable alkali feldspar and may actually be quartz latite or rhyolite. This sample also contains 2% mordenite and 10% smectite, and is probably hydrothermally altered. The altered silicic flow rock at 2200' is very rich in quartz and contains, in addition to minor smectite, 5% illite and 2% chlorite. The "tuff or

volcaniclastic" at 5000' is shown by XRD to be an intermediate-composition rock which has been moderately propylitized.

The clay fractions extracted from the bulk cuttings samples show well-defined layer silicate zoning, probably in response to increasing temperature with depth, either presently or at some time in the past. Smectite and kaolin are strongly concentrated above 1900', below which depth chlorite and minor illite predominate. The rock at 1900' contains smectite-rich interstratified smectite-chlorite; three samples below 1900' contain mixed-layer chlorite-smectite which is much richer in chlorite. If the clay mineral zoning revealed in well 68 reflects the present thermal regime, it may be possible to establish vectors toward heat centers using layer silicate assemblages in combination with other available surface and downhole data.

BULK

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

SAMPLE NO.	QUARTZ	CRISTOBALITE	K-FELDSP.	PLAGIOCLASE	CALCITE	MORDENITE	MAGNETITE	ILMENITE	HEMATITE	PYRITE	CLINOPYROXENE (*) ORTHOPYROX.	AMPHIBOLE	EPIDOTE	APATITE	SMECTITE	ILLITE ± MICA	CHLORITE	KAOLIN	ANALCIME OR WAIRAKITE	OTHER *
68-400				62			2?	1	1					1						33
68-800				55				1	2		>10?			1?	6					<25
68-1200				58				1	1		>10?			1?	9					<20
68-1600	8	15	40	12		2			1						10		TR?	TR?		12
68-1900	17		5	48	1			2	3		>5?				5		2			<12
68-2200	40		32	17					1						3	5	2			
68-3000	14		2	45	7				4		>10?				2	2	6			<8
68-3400	10		1?	46	3				4		>10?				5		3			<18
68-3800	8			48				2	2		>10?			1?	14		7			<8
68-4400	8			48	8			1	4		>10?				3		8			<10
68-4800	14		2	53				2	2		?	2			TR		5		TR?	20
68-5000	13		2	48	1				2				3				11			20
68-5200	9			53	1				2				3				9			23
68-5600	11		2	47	3				3				3				4		1?	26
68-6000	11		1	52	3				3				3				5		1?	21
68-6400	12		2	55	4				3			2	3				5		TR?	14

* INCLUDES AMORPHOUS PHASES, THOSE BELOW DETECTION LIMIT, AND THOSE WHOSE REFLECTIONS ARE MASKED BY PLAGIOCLASE PEAKS. MAY INCLUDE SOME LOST CIRCULATION MATERIAL.

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

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY

CLAY FRACTION

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

SAMPLE NO.	SMECTITE	MIXED-LAYER SMECT.-CHLOR. (A)	MIXED-LAYER CHLOR.-SMEC.	CHLORITE	ILLITE	MIXED-LAYER ILLITE-SMEC. (C)	KAOLIN
68-400	100						
68-800	100						
68-1200	97						3
68-1600	95						5
68-1900		40		50	5	5	
68-2200	55			10	35		
68-3000				90	10		
68-3400	37			60	3		
68-3800	65		15 (E)	20			
68-4400	5			95			
68-4800	3			93	4		
68-5000	Tr			98	2		
68-5200				98	2		
68-5600		5		80	15		
68-6000			10 (B)	75	15		
68-6400			5 (E)	80	15		

(A) >75% SMECTITE
(B) 90% CHLORITE
(C) >80% ILLITE
(D) MAY INCLUDE PRIMARY MICA
(E) ≈50% CHLORITE

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

SUMMARY OF X-RAY DIFFRACTION ANALYSIS

UNIVERSITY OF UTAH RESEARCH INSTITUTE , EARTH SCIENCE LABORATORY