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Petrography of Some Rock Types of the
Precambrian Basement Near the Los Alamos
Scientific Laboratory Geothermal Test Site,
Jemez Mountains, New Mexico

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

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Petrography of Some Rock Types of the Precambrian Basement Near the Los Alamos Scientific Laboratory Geothermal Test Site, Jemez Mountains, New Mexico

by

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**PETROGRAPHY OF SOME ROCK TYPES OF THE PRECAMBRIAN BASEMENT
NEAR THE LOS ALAMOS SCIENTIFIC LABORATORY GEOTHERMAL TEST SITE,
JEMEZ MOUNTAINS, NEW MEXICO**

by

Priscilla C. Perkins

ABSTRACT

The proposed geothermal energy experiment by the Los Alamos Scientific Laboratory is to be conducted in Precambrian rocks underlying the Jemez Plateau, New Mexico. This study describes 25 samples from 152 ft of drill core taken from Granite Test Hole One, and 12 examples of Precambrian rocks of the region not far distant from the proposed geothermal test site.

The upper 94 ft of Precambrian rock in the test hole is granite and granodiorite, partly gneissic in texture. The lower 61 ft is biotite-amphibolite veined by tonalite-aplite.

All cracks observed in thin section follow thin calcite veins. In hand specimen, chlorite-lined fracture surfaces are also present.

Rocks of the drill core provide a good variety of compositions representative of many of the rock types collected for this study from regional localities (Sandia Mountains, San Pedro Mountain, Soda Dam, Guadalupe Box, and the Nacimiento Mountains). As fresh samples, they will provide suitable material for hydrothermal experiments.

The presence of "red granite" xenoliths in pyroclastic rocks of the Jemez Plateau, and the predominance of granitoid rocks over amphibolite in regional outcrops suggest that granitic rocks are the predominant rock type below the test site.

1. INTRODUCTION

The proposed geothermal energy experiment by the Los Alamos Scientific Laboratory is to be conducted in Precambrian rocks underlying Paleozoic and Mesozoic sediments and Cenozoic volcanics of the Jemez Plateau, New Mexico. In the experiment, water will be circulated at depth in the Precambrian basement.

The purpose of this petrographic study is to provide information pertinent to the following questions:

1. What are the likely host rocks for the experiment, which is to be carried out at depth below the level of present drill holes?

2. What will be the chemical effects of circulating hot fluids in fractured basement rocks?

Until further test holes are drilled, the first question can be addressed only indirectly. The petrographic study seeks to establish the range of typical rock types present in recovered drill core and in available regional Precambrian exposures in the general area. If areal variation in the Precambrian terrain exposed at the surface is similar to variability with depth in the basement, a general range of likely host rock types can be established. Toward this end, this report characterizes samples from two sources: 1) drill core from Granite Test Hole One, Barley

Canyon, Jemez Plateau; and 2) outcrops of Precambrian rocks selected because of their proximity to the proposed geothermal test site.

After anticipated host rock types have been identified, laboratory experiments can be begun to establish the nature of chemical reactions between hot fluids and the rocks at the temperatures expected in the geothermal experiment. The petrographic study provides baseline information on the samples for experimental study by tabulating identity and abundance of mineral constituents, mineralogy of vein and fracture fillings, and frequency and identity of crystal-crystal contacts in the rock matrix along which fluids may be expected to pass.

II. LOCATION OF SAMPLES

Granite Test Hole One, near the proposed test site, was drilled during May 1972 in Barley Canyon, Jemez Mountains. An interval of 155 ft in Precambrian granite and amphibolite was penetrated. Table I lists the locations of samples from the recovered drill core sectioned for petrographic examination.

Precambrian outcrops near the drill site were sought, but unfortunately the closest exposures available were 13 to 16 miles distant.¹ Figure 1 shows the locations sampled. Localities are described in Table II.

TABLE I
LOCATION OF SAMPLES FROM GRANITE TEST HOLE ONE

(Samples numbered and located by R. Potter)

Thin Section Sample Number	"True Depth" Core Interval (depth below surface)	Cumulative Depth below 2422-ft Level (nearest foot)
PD-2-a,b,c	2422 ft (approximate)	0
PD-2-1	2329 ft, 5 in. to 2329 ft, 8-1/2 in.	8
PD-3-5	2437 ft, 11 in. to 2438 ft, 1-1/2 in.	16
PD-2-2	2444 ft to 2444 ft, 4 in.	22
PD-2-3	2466 ft, 4 in. to 2467 ft	45
PD-2-4	2481 ft to 2481 ft, 3 in.	59
PD-2-5	2484 ft, 2 in. to 2484 ft, 4 in.	62
PD-3-7	2497 ft (approximate)	75
PD-2-6	2500 ft, 7 in. to 2500 ft, 9-1/2 in.	79
PD-2-7	2501 ft, 8 in. to 2502 ft	80
PD-2-8	2510 ft, 3 in. to 2510 ft, 6 in.	88
PD-2-12	2515 ft, 6 in. (approximate)	93
PD-3-6	2516 ft, 3-1/2 in. to 2516 ft, 5-1/2 in.	94
PD-2-13	2517 ft, 9 in. to 2518 ft	96
PD-2-14	2519 ft, 3 in. to 2519 ft, 8 in.	98
PD-3-8	2520 ft (approximate)	98
PD-2-15	2520 ft, 10-1/2 in. to 2521 ft, 8 in.	100
PD-2-9	2527 ft, 1 in. to 2527 ft, 3-1/2 in.	105
PD-2-11	2529 ft, 6 in. to 2529 ft, 10 in.	108
PD-2-10	2530 ft, 2-1/2 in. to 2530 ft, 5-1/2 in.	108
PD-2-16	2541 ft, 9 in. to 2542 ft	120
PD-3-1	2548 ft, 10-1/2 in. to 2549 ft, 1 in.	127
PD-3-3	2556 ft, 11 in. to 2557 ft, 2-1/2 in.	135
PD-3-2	2559 ft, 3-1/2 in. to 2559 ft, 5 in.	137
PD-3-4	2573 ft, 11-1/2 in. to 2574 ft, 3 in.	152
End of core	2575 ft	155

Fig. 1.

Index map of sample locations and Precambrian outcrops in the vicinity of the proposed geothermal test site. Precambrian outcrops after Dane and Backman.¹

III. PETROGRAPHIC CONVENTIONS AND TECHNIQUES

A. Rock Names

The names of granitoid rocks are assigned on the basis of the triangular diagram, Fig. 2. The percentages of quartz (Q), alkali feldspar (A), and plagioclase (P) are recalculated to 100 from the modal analysis.

Mineral modifiers preceding rock names are written in order of increasing abundance. Thus a "quartz-biotite amphibolite" has more biotite than quartz.

In this report, the terms amphibolite, aplite, and gneiss are used as follows:

- Amphibolite. Metamorphic rock composed mainly of plagioclase and hornblende; compositional term.

- Aplite. Fine- to medium-grained sugary veins of quartz and feldspar lacking dark minerals; textural term.

- Gneiss. Irregularly banded or foliated rock with alternating layers of light and dark, granular and micaceous minerals; textural term; adjective "gneissic."

TABLE II

LOCATIONS OF SAMPLES FROM PRECAMBRIAN OUTCROPS

Sandia Mountains

Samples transmitted to D. B. Slemmons by J. Rowley, letter of 10 May 1972.

- 1 "From the granite 'shield' of the north end of the Sandias; described by Orson [Anderson] as being 'essentially a 500 foot thick mass of almost unjointed granite'"
- 2 "Obtained about 100 feet away from sample #1"
- 3 "Obtained from a road cut in Tijeras Canyon at the extreme southern end of the Sandia Mountains; described by Orson and observed by me to be highly jointed, both vertically and horizontally"

San Pedro and Nacimiento Mountains

Collected by P. Perkins, with assistance of O. Anderson, F. West, and J. Balagna.

OA-1-4,5	Boulders in creek, Clear Creek Forest Camp, 2 miles west of Rio de Las Vacas on Highway 126. Same source as granite sent to the Haliburton Co. for hydrofracture experiment (D. Brown, personal communication, 1972)
OA-2-1	Roadcut on west side of Highway 4 at Soda Dam, north of Jemez Springs
OA-2-2	South side of southernmost tunnel in Guadalupe Box, canyon of Rio de Las Vacas
OA-2-4	North side of northernmost tunnel in Guadalupe Box, canyon of Rio de Las Vacas
OA-2-5,7	Bales Canyon, Forest Road 534, about 1 mile northwest of Rito la Cueva spring
OA-2-9,10	Nacimiento Mountains, Forest Road 534, 5.5 road miles west of Porter Landing junction

Thus, a "tonalite-aplite" has the mineralogy of a tonalite and the texture of an aplite. A "gneissic granite" has the texture of a gneiss and the mineralogy of a granite, and is of presumed igneous origin. A "granite gneiss" would have the mineralogy of a granite and the texture of a gneiss, with no presumed igneous origin.

Fig. 2.
Classification scheme for granitoid rocks (modified from Hyndman²).

B. Color

Colors are described in accordance with the Rock-Color Chart of the Geological Society of America.³ Rock colors for hand specimens refer to wet sawed surfaces in the interior of core fragments.

C. Grain Size

Grain sizes refer to the following dimensions: fine-grained, less than 1 mm; medium-grained, 1 to 5 mm; coarse-grained, 5 mm to 3 cm.

D. Texture

Foliation refers to any planar or subplanar structure observable in hand specimen or thin section. The orientation of the foliation in the core fragments is referred to the axis of the core and the "up" (toward the surface) arrow marked on all specimens. The following diagram illustrates a foliation dip of 35°.

E. Plagioclase Composition

The composition of plagioclase was determined by universal stage measurements of twinned grains using the methods of Slemmons.⁴ Ambiguous cases were resolved by refractive index comparisons with Canada balsam and, where possible, measurements of Carlsbad or Carlsbad-albite twins and twins with a second set of cleavages.

IV. MODAL ANALYSES

Modal analyses were made with a Swift automatic point counter. One analysis was made of each homogeneous thin section and of each distinctive layer in banded sections. Counting intervals were 1/3 mm horizontally and 2/3 mm vertically for the PD-2 series, and 1/3 mm horizontally and vertically for the other slides. The number of counts per slide is indicated later in the summary tables. To test reproducibility, modal analyses of slides PD-2-b and PD-2-5 were performed twice (Table III). An average of the two analyses is recorded in the summary table.

A chart for evaluating point counting results has been presented by Van Der Plas and Tobi (Ref. 5, Fig. 1, p. 88). This chart is applicable to cases where the counting interval is larger than the largest grains included in the analysis. This is not the case for the medium-grained rocks discussed here. However, the chart may be consulted as an approximate indication of reliability. Results in the summary tables (Tables IV, V, and VI) represent values to the nearest percent. For trace minerals with abundance of less than 1%, the actual number of counts is recorded in the tables.

TABLE III

REPRODUCIBILITY OF MODAL ANALYSES (Values to the nearest percent)

	PD-2-b First Trial	PD-2-b Second Trial	PD-2-5 First Trial	PD-2-5 Second Trial
Quartz	38	35	33	31
Microcline	18	19	27	31
Plagioclase (Total)	36	39	33	31
Biotite	6	6	5	5
Accessories	2	1	2	2

KEY TO TABLES IV AND V

Counts: Points counted; in cases where slides were analyzed twice, counts from both traverses were added together.

Act: actinolite	My: myrmekite (probably intergrowth of quartz and oligoclase)
Al: allanite	Op: opaque minerals: see also Table IX
Ap: apatite	Pl: plagioclase (includes antiperthite blebs of microcline and rims of albite): see also Table VII
Bi: biotite	Ps: altered plagioclase, generally sericitized: see Table VIII
Cc: calcite	Q: quartz
Ch: chlorite	Sp: sphene
Cm: cummingtonite	Zi: zircon
Ep: epidote	
Hb: hornblende	
Mi: microcline (includes perthite films of plagioclase)	
Mu: muscovite (discrete flakes larger than sericite in altered plagioclase)	

TABLE IVa
MODAL ANALYSES OF GRANITOID ROCKS^a

Granite Test Hole One

Thin Section	Depth below 2422 ft (ft)	Counts	Bi	Mi	Pl	Ps	Q	Al	Ap	Cc	Ch	Ep	Hb	Mu	My	Op	Sp	Zi
PD-2-a	0	2274	4	32	20	3	39		5c	2c	4c			1c	1	12c		
PD-2-b	0	4631	6	18	37	1	37		4c	1c	4c			1c	12c	1		
PD-2-c	0	2040	8	21	29	1	39		6c	1c	5c				1	1	1c	1c
PD-2-1	8	2548	2	28	18	8	40		2c		1	7c		8c	2c	1	3c	
PD-3-5	16	2616	6	40	19	6	27		4c	2c	1			6c	12c	1	16c	
PD-2-2	22	2296	6	35	21	13	20		8c	13c	11c	5c		16c	6c	1	17c	1c
matrix	22	1016	10	21	32	18	13		4c	8c	3c	2c		5c	9c	9c	2	1c
aplite	22	565		52	6	3	39											
PD-2-3	45	2268	4	37	20	8	28	2c	3c	3c	6c	5c		6c	9c	1	6c	
PD-2-4	59	2583	6	30	27	3	31		8c	4c	11c	1c		9c	10c	1	1	
PD-2-5	62	5445	5	29	29	3	32		3c	8c	12c			14c	16c	8c		1c
matrix	62	986	8	22	39	1	29		2c				1c	2c	4c	2c		
PD-3-7	75	1688	13	15	27	10	32		2c		8c	2c		2c	1	1		
PD-2-6	79	2197	8	24	32	11	22			8c	5c	2c		1	10c	1	7c	
matrix	79	1021	15	2	51	4	26		2c	3c	3c			2c	2c	8c	1c	
PD-2-7	80	2185	21	10	38	1	27		7c		1c	1c		1c	1	1	6c	
PD-2-8	88	2256	14	13	43	4	23		3c		3c	1c		1c	1	1	4c	1c
PD-2-12	93	2028	13	10	32	14	26		4c	4c	1	1		3c	9c	6c	5c	1c
PD-3-6	94	2432	11	7	12	35	30		12c	1c	5c	15c		1	2	7c	1	1c

^aIn last 16 columns: c = actual counts; other numbers are percentages

TABLE IVb
MODAL ANALYSES OF GRANITOID ROCKS^a

Thin Section	Counts	Bi	Mi	Pl	Ps	Q	Ap	Cc	Ch	Ep	Hb	Mu	My	Op	Sp	Zi
1 ^b	2258		44	1	33	16										
2 ^b	2306		18	1	38	34	5c									
3 ^b	2943	15	16	7	12	39	6c	2c	4	1c	9c			1		
OA-1-4 ^c	1557	5	19	3	29	42	1		8c	1	3c		1	2	6	1c
OA-1-5 ^c	2694	4	25	4	44	19	2c		2c	3	2c			2c		
OA-2-1 ^d	1849		11	4c	57	29	2c		14c	4		4c			7c	
OA-2-2 ^c	2741	8	18	23	25	18	1c		4c			2		1c	1c	
OA-2-4 ^c	2434	1	49	1	25	15	11	7c	12c	1	3		1c	1	1	
OA-2-5 ^f	2832	4	44	8	17	27	5c		5	12c	5c		3c	1	2	
OA-2-7 ^f	2039	3	39	7	24	27			4c	2c		1	3c	1c		

^aIn last 15 columns: c = actual count; other numbers are percentages ^dSoda Dam
^bSandia Mountains ^eGuadalupe Box
^cSan Pedro Mountain ^fNacimiento Mountains

TABLE V
MODAL ANALYSES OF AMPHIBOLITES AND APLITES^a

Granite Test Hole One

Thin Section	Depth below 2422 ft (ft)	Counts	Act	Bi	Cm	Hb	Pl	Ps	Q	Ap	Cc	Ch	Ep	Mi	Mu	Op	Sp	Zi
PD-2-13																		
light band	96	950		15		8	36	2	36				6c	2		3c	1c	1c
dark band	96	345		16		42	26	3	12				2c	1c			1c	
aplite	96	527		5		1	42	6	41			1c	3c	4		3c		
PD-2-14	98	2303		9		61	21	6		1c	2	4c	15c			4c	1	
PD-3-8	98	1952		17		44	20	16	1	2c	3c	7c	7c			3c		
PD-2-15	100	2205		14		18	15	26	24	5c	3c	1	16c		1c	1c	1	
matrix	100	381		22		42	13	13	5	2c		2	2c			1c	2	
aplite	100	727		3		3	19	38	36			2c						
PD-2-9	105	2276		15		46	19	11	8	1c		6c				9c	12c	
PD-2-11																		
matrix	108	1192		22		44	20	11	1	3c	1	3c	1c		1c		1	
aplite	108	676		7		1	18	35	39									
PD-2-10																		
matrix	108	1033		56		5	35		2		3c					1c	5c	
aplite	108	593		7		38	11		40									
PD-2-16	120	2495		11		55	20	13		2c	1c	15c	5c			1c	11c	
PD-3-1 ^b	127	2192	26				12	35	8c		7	18	12c				1	
PD-3-3	135	3003		20		12	23	11	34	2c	8c	8c	1c			6c	7c	2c
matrix	127	889		10		39	21	22	6	2c	4c	4c	1c			1c	3c	
aplite	127	1167		5		16	8	70			1c	3c					1c	2c
biotite band	127	947		47			34	3	15			1c				5c	3c	
PD-3-2	137	1084		29		28	19	12	10	2c	4c	1c	2c				1	
PD-3-4	152	1375		15		29	24	14	14	3c	1c	1	4c			1c	1	1c
OA-2-9	---	2685				54	29	14	2	1c						1		
OA-2-10	---	2326		1	18	73	7	1			1c					3c	9c	

^aIn last 9 columns: c = actual counts; other numbers are percentages
^bNot amphibolite, but chlorite-actinolite-plagioclase rock

TABLE VIa
CRYSTAL CONTACTS^a

Granites

Sample Crystals	PD-2-c	PD-3-5	PD-3-7	PD-3-6	1	2	3	OA-1-4	OA-1-5	OA-2-1	OA-2-2	OA-2-4	OA-2-5 ^b	OA-2-7 ^b
Bi-Bi	3c	5c	4c	5c			5c	4c	7c		6c			
Bi-Mi	4c	2c	1c	1c			2c	1c						
Bi-Pl/Ps	8	9	13	7			1c				6			1c
Bi-Q	5	7	7	5			9	4c	4c		8		6c	1c
Mi-Mi	4	1c	4	1c	4	1c	1c				1c	1c	1c	1c
Mi-Pl/Ps					9	8			1c			20	8	3c
Mi-Q	7	14	9	2c	14	14	8	4	9	1c		2c	5	7c
Pl/Ps-Pl/Ps	20		2c	32	7		2c			73		13	7	1c
Pl/Ps-Q	18	13	20	7	1c	5			11	10	14	5	9c	6c
Q-Q	16	14	13	40	51	52	30	70	54	12	27		14	11c
Cracks ^b													58	92
[Footnote c]	9	3	5	13	3	3	4	9	5	19	4	3	10	35

^ac = number of counts for uncommon pairs; other numbers are percentages of contacts

^bSamples OA-2-5 and OA-2-7 are weathered and have begun to disintegrate along grain boundaries, leaving open cracks in thin section

^cPercentage of total modal counts represented by crystal contacts or open cracks encountered in analysis

TABLE VIb
CRYSTAL CONTACTS^a

Amphibolites

Sample Crystals	PD-3-8	PD-3-3	PD-3-2	PD-3-4	OA-2-9	OA-2-10
Bi-Bi	5	1c	2c	15		
Bi-Cm						2c
Bi-Hb	22	5c	7			3c
Bi-Pl/Ps	13	11	15	43		2c
Bi-Q	2c	5	19	26		
Cm-Cm			-			8
Cm-Hb						22
Cm-Pl/Ps						8
Hb-Hb	17	22	10		40	50
Hb-Pl/Ps	36	33	27		50	11
Hb-Q		3c	8		6c	
Pl/Ps-Pl/Ps	5c	4c	4c	5c	8	1c
Pl/Ps-Q		12	2c	8	2c	
Q-Q		3c	1c			
[Footnote b]	15	13	10	15	15	19

^ac = number of counts for uncommon pairs; other numbers are percentages of contacts

^bPercentage of total modal counts represented by crystal contacts or open cracks encountered in analysis

V. CRYSTAL CONTACTS

During the proposed geothermal experiment, hot water will be circulated in Precambrian rocks at depth. Because circulating fluids are likely to pass along grain boundaries, a study of the frequency of contacts between crystals was made in the course of modal analysis.

During the analysis, as the slide is automatically advanced, the intersection of the cross-hairs usually falls within a single grain. In this case, the identity of the grain is noted and added to the modal count. When the cross-hairs fall on the contact between two grains, the following convention is observed. A note is made of the identity of the two touching crystals, and the crystal being approached as the slide is advanced is counted toward the mode. In this manner, simultaneous records are kept of grains in the modal count and frequency and identity of crystal-crystal contacts.

TABLE VII
PLAGIOCLASE COMPOSITION

Sample	Rock	Anorthite Content (%)
PD-2-a	gneissic adamellite	23
PD-2-b	gneissic adamellite	24-26
PD-2-c	gneissic adamellite	24
PD-2-1	gneissic adamellite	24
PD-2-2	adamellite veined by syeno- granite-aplite/pegmatite	24-26
PD-2-4	adamellite	24-26
	albite rims on oligoclase	3-5
PD-2-5	gneissic granodiorite matrix	30
	adamellite-aplite	28-30
PD-2-7	gneissic granodiorite	25-28
PD-2-8	gneissic granodiorite	29
PD-2-12	gneissic granodiorite	25-29
PD-2-13	quartz-biotite amphibolite	
	biotite-quartz-oligoclase	
	gneiss	26
	tonalite-aplite	27-30
PD-2-15	biotite-amphibolite	
	tonalite-aplite	27-31
PD-2-11	biotite-amphibolite	30
	tonalite-aplite	30
PD-2-16	biotite-amphibolite	34-38

TABLE VIII

ALTERATION OF PLAGIOCLASE [Ps/(Pl+Ps)] AND
Q-A-P VALUES (Q, Mi, Pl+Ps = 100) CALCULATED
FROM MODAL ANALYSES BEFORE ROUNDING

Thin Section	Alteration of Plagioclase (%)	Q (%)	A (%)	P (%)	$\frac{A}{A+P}$ (%)
PD-2-a	13	41	34	25	0.58
PD-2-b	3	40	20	40	0.33
PD-2-c	5	43	23	34	0.41
PD-2-1	31	44	27	29	0.49
PD-3-5	23	29	43	28	0.61
PD-2-2					
matrix	35	15	26	59	0.30
aplite	33	39	53	8	0.87
PD-2-3	28	31	40	29	0.58
PD-2-4	10	35	33	32	0.51
PD-2-5	10	34	31	35	0.48
matrix	2	32	24	44	0.35
PD-3-7	27	39	18	43	0.29
PD-2-6	3	28	31	41	0.43
matrix	8	31	2	67	0.03
PD-2-7	4	35	13	52	0.21
PD-2-8	8	27	15	58	0.20
PD-2-12	45	32	12	56	0.18
PD-3-6	75	36	8	56	0.15
PD-2-13					
light band	5				
dark band	11				
aplite	13	44	4	52	0.07

VI. OPAQUE MINERALS

Polished sections were prepared from approximately one half of the samples from Granite Test Hole One. The results of preliminary examination in reflected light are shown in Table IX.

VII. DISCUSSION

This study describes 25 samples (27 thin sections) from 152 ft of drill core taken from Granite Test Hole One, and 12 examples of Precambrian rocks from the region of the proposed geothermal test site.

The specimens fall into two groups: granitoid rocks and amphibolites. Such rocks are typical constituents of

TABLE IX

OPAQUE MINERALS
(Listed in order of decreasing abundance)

Sample Number	Depth below 2422 ft (ft)	Mineralogy
PD-2-abc	0	magnetite, ilmenite with minute exsolution lamellae of hematite
PD-3-5	16	magnetite, pyrite, chalcopyrite
PD-2-2	22	magnetite, pyrite, chalcopyrite
PD-2-3	45	magnetite, pyrite
PD-2-4	59	magnetite, pyrite
PD-3-7	75	magnetite
PD-2-8	88	magnetite
PD-3-6	94	pyrite
PD-3-1	127	magnetite, pyrite, chalcopyrite
PD-3-3	135	magnetite, pyrite
PD-3-4	152	pyrite, chalcopyrite

the Precambrian terrains of many areas of the world. The compositions of granitoid rocks are shown in Figs. 3 and 4. Compositions are plotted in terms of the Q-A-P classification. The sequence of rock types in Granite Test Hole One is shown in Table X.

The core in Precambrian crystalline rocks consists of two major units. The upper unit (about 94 ft) consists of medium- to coarse-grained, brownish-gray granitoid rocks with variable amounts of pale red microcline and texture varying from typical granitic (massive, hypidiomorphic granular) to gneissic (alternating bands of quartz-feldspar and biotite) with megacrysts of microcline. The lower unit (about 61 ft in the interval sampled) consists of fine-grained, dark-gray biotite-amphibolite veined by medium-grained, light-gray aplite. The upper 3 ft of the amphibolite is foliated, probably parallel to the foliation of the overlying granodiorite gneiss. Near the contact with the granodiorite, the amphibolite contains accessory microcline.

a:PD-2-a
b:PD-2-b
c:PD-2-c
d:PD-2-1
e:PD-3-5
f:PD-2-2 f_1 aplite; f_2 matrix
g:PD-2-3
h:PD-2-4
i:PD-2-5 i_1 whole rock; i_2 matrix
j:PD-3-7
k:PD-2-6 k_1 whole rock; k_2 matrix
l:PD-2-7
m:PD-2-8
n:PD-2-12
o:PD-3-6
p:PD-2-13

Fig. 3.

Compositions of granitoid rocks, Granite Test Hole One and regional outcrops.

In granitoid rocks the variability of the core is due largely to variable microcline content. Microcline is ubiquitous (30-40%) in the upper 60 ft, but is spotty in the 2484- to 2501-ft interval (in clusters of megacrysts and in adamellite-aplite) and constitutes 10% of the rock in the lower 13 ft of the granitoid mass. The texture of the granitoid unit is gneissic at the top (with augen of microcline) and at the bottom (defined by abundant biotite), and massive in the middle 40 ft. As microcline content decreases, biotite content increases with depth from 5% in the upper augengneissic granite to 20% in the lower gneissic granodiorite, as the amphibolite is approached.

Because a hydrofracturing experiment is to be conducted in these rocks, special attention was paid to cracks which occurred before or during the process of thin-sectioning. All cracks observed in thin section are along thin calcite veins. These veins are both parallel to and transverse to the foliation of the rocks. No cracks were found in thin section independent of calcite, but not all calcite veins are associated with cracks. In hand specimen, cracks parallel to calcite veins and parallel to chlorite-coated surfaces are present.

Fig. 4.

Compositions of granitoid rocks: Sandia Mountains (1, 2, 3), San Pedro Mountain (OA-1-4, 5), Soda Dam (OA-2-1), Guadalupe Box (OA-2-2, 4), Nacimiento Mountains (OA-2-5, 7).

Boehm lamellae (planes of tiny fluid inclusions, some with moveable bubbles) are present in much of the quartz of the granitoid rocks. The lamellae are continuous across grain boundaries. One set of lamellae is approximately parallel to the foliation; in some sections a second set appears in thin section at approximately right angles to the first. Quartz in the core almost always shows undulatory extinction.

Preliminary observations of the structure of the core rocks suggest that the foliation, where present, dips, on the average, 45° relative to the core axis. The direction of strike of the foliation is not known. However, the dip of the foliation of the granodiorite gneiss and the foliation of the underlying biotite-amphibolite (and the dip of aplite veins in the amphibolite) are similar. If the foliations of these two rock types have the same strike, the structures in both rock types have a similar attitude. Calcite veins in hand specimen have two dominant orientations: parallel to the foliation and parallel to the axis of the core.

It is impossible to predict with certainty what sequence of rocks underlies the cored interval. However, preliminary field reconnaissance of surface Precambrian exposures suggests that granitic rock types are most abundant and amphibolite is of local extent. Although a large portion of Granite Test Hole One is in amphibolite (64 ft out of 155 ft total), it is likely that granitic rocks are dominant at depth.

Robert L. Smith (personal communication, August 22, 1972) has observed in his studies of the Tertiary volcanics of the Jemez Mountains region that "red granite" is the

TABLE X

SEQUENCE OF ROCK TYPES IN GRANITE TEST HOLE ONE

Depth (ft)	Interval Between Samples (ft)	Thin Section	Rock Type
2422	(8)	PD-2-a	Augengneissic granite, variety adamellite
2430		PD-2-1	
2438	(43)	PD-3-5	Granite, variety adamellite
2481		PD-2-4	
2484	(17)	PD-2-5	Gneissic granite, variety adamellite; average composition resulting from isolated clots of microcline megacrysts in matrix ranging from gneissic granodiorite to gneissic tonalite
2501		PD-2-6	
2502	(14)	PD-2-7	Gneissic biotite-granodiorite
2516		PD-3-6	
2518	(2)	PD-2-13	Biotite-amphibolite with minor microcline; tonalite-aplite veins
2520		PD-2-14	
2549	(25)	PD-3-1	Chlorite-actinolite-plagioclase rock
2574		PD-3-3	
(3)			
Bottom of hole			

dominant type of basement xenolith included in the pyroclastic rocks. Samples PD-2-2, 3, and 4 of this study (in the middle massive granite unit) are similar to the inclusions in the volcanics, according to Smith. He estimates that perhaps 95% of the xenoliths are "red granite," and he does not recall seeing amphibolite xenoliths. If amphibolites and metasedimentary rocks are a significant proportion of the basement, they should be more abundantly represented in the inclusion suite. On this basis, it is suggested that the amphibolite, which represents a considerable portion of the core, is a local septum in a dominantly granitoid basement.

A comparison of Figs. 3 and 4 shows that samples of regional Precambrian rocks resemble some of the rocks of the core in terms of quartz and feldspar ratios. The suite of rock types from Granite Test Hole One provides a good

representation by fresh samples of regional rocks, with the exception of varieties unusually high in quartz or microcline content.

Hornblende-bearing granitoid rocks are represented in the regional samples (Table IVb) but are not present in the core. Also, an amphibolite with coexisting hornblende and cummingtonite (each with exsolution lamellae of the other, sample OA-3-10) was collected in the Nacimiento Mountains. This rock type is not present in the core.

The study of frequency of crystal-crystal contacts shows that, in granitoid rocks, the most common pairs, in decreasing order of abundance, are quartz-quartz, quartz-plagioclase, microcline-quartz, and biotite-quartz. In amphibolites, the most common pairs are, in decreasing order, hornblende-plagioclase, hornblende-hornblende, biotite-plagioclase, and biotite-hornblende.

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