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Chemical, Petrographic, and K-Ar Age Data to Accompany Reconnaissance Geologic Strip Map from Kingman to South of Bill Williams Mountain, Arizona

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by

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ABSTRACT

As part of a reconnaissance mapping project, 40 chemical analyses and 13 potassium-argon age dates were obtained for Tertiary volcanic and Precambrian granitic rocks between Kingman and Bill Williams Mountain, Arizona. The dated volcanic rocks range in age from 5.5 ± 0.2 Myr for basalt in the East Juniper Mountains to about 25 Myr for a biotite-pyroxene andesite. The date for Picacho Butte, a rhyodacite in the the Mt. Floyd volcanic field, was 9.8 ± 0.07 Myr, making it the oldest rhyodacite dome in that volcanic field. Dated rocks in the Fort Rock area range from 20.7 to 24.3 Myr. No ages were obtained on the Precambrian rocks. Compositionally, the volcanic rocks analyzed range from alkali basalt to rhyolite, but many rocks on the western side of the map area are unusually potassic. The granites chosen for analysis include syenogranite from the Hualapai Mountains, a muscovite granite from the the Picacho Butte area, and two other granites. The chemical and K-Ar age data and petrographic descriptions included in this report accompany the reconnaissance geologic strip map published as LA-9202-MAP by Goff, Eddy, and Arney.

I. INTRODUCTION

As part of the national Hot Dry Rock evaluation program, we mapped a strip about 10 to 15 km wide and 160 km long from Kingman to just south of Bill Williams Mountain in Arizona (Fig 1.) The purpose was to obtain a reconnaissance map which would follow the trace of a magnetotelluric (MT) survey being done by Los Alamos National Laboratory across the transition zone between the Basin and Range and the Colorado Plateau tectonic provinces (Aiken and Ander 1981; Ander and Furgerson 1982; Ander 1983). The color strip map has been published separately by Los Alamos National Laboratory (Goff et al. 1983).

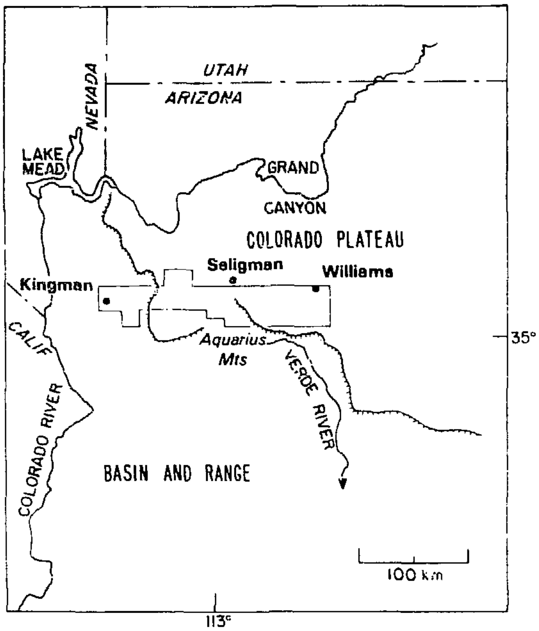


Fig. 1.
Map showing southwest boundary between Basin and Range and Colorado Plateau Provinces and location of area covered by strip map.

Considerable geochemical data on the volcanic rocks and limited data on Precambrian rocks of the area were obtained and are presented in this report. Petrographic descriptions of rocks that were analyzed or dated are given in the Appendix.

The map crosses three geologic zones. The western part of the map crosses the eastern edge of the Basin and Range Province. This zone is characterized by mafic volcanism and block faulting along north-trending faults. The eastern part of the map crosses the Mt. Floyd volcanic area, part of the greater San Francisco Peaks volcanic field. In this zone basalts and basaltic andesite overlie Paleozoic sedimentary rocks of the Colorado Plateau. In between, from Tin Mountain on the west to the Chino Valley on the east, the map crosses a tectonic transition zone between the Basin and Range and the Colorado Plateau. On the west side of this middle zone, Tertiary volcanics of basaltic to rhyolitic composition overlie Precambrian granite and gneiss. The thickness of Paleozoic sedimentary rocks increases to the east across this zone, and the volcanic rocks overlie increasingly younger Paleozoic rocks. The structure is dominated by northwest-trending normal faults, with displacement generally down to the west. Stratigraphic relations and the age dates presented in Table I show that the ages of the volcanic rocks, particularly the basaltic rocks, generally decrease to the east across the transition zone.

II. WESTERN ZONE

Volcanic rocks of the Kingman area include olivine basalt, basaltic andesite and the Peach Springs Tuff, a rhyolite ash-flow tuff that probably originated northwest of Kingman and flowed eastward for more than a hundred kilometers (Young and Brennan 1974). There is uncertainty about the age

TABLE I
POTASSIUM-ARGON DATES[a] OBTAINED FROM VOLCANIC ROCKS MAPPED BETWEEN KINGMAN AND BILL WILLIAMS MOUNTAIN, ARIZONA

Sample	Location	Map Symbol	Rock Type	Material	%K	Moles Radiogenic Argon**	% Radiogenic Argon	Age, Myr	Comments
Volcanic rocks of Black Mesa, Tin Mtn. NW 7 1/2 Quad									
1. F78-59	SE1/4,Sec33,T21N,R13W	Tbpd	Porphyritic Dacite	Bio	6.17	$4.33x10^{-11}$	48.0	20.5 ± 1.0	Unit was mapped as overlying Peach Springs Tuff, but tuff may only fill a swale on NW side of dacite flow.
2. F78-64	SE1/4,Sec17,T21N,R13W	Tba	Andesite	W/R	2.28	$2.83x10^{-11}$	27.9	13.8 ± 0.7	Andesite flow overlies Peach Springs Tuff.
Volcanic rocks of Fort Rock and Slurry Line									
3. F78-72	Tin Mtn. 7 1/2 Quad N1/2, Sec11, T21N, R12W	TrhI	Hbl Latite	Bio	3.57	$3.08x10^{-11}$	38.2	24.3 ± 0.8	Latite dome overlies hornblende-bearing alkali-olivine basalt.
4. F78-85	Bull Springs 7 1/2 Quad Lat.35°12',Long.113°25'	Trbi	Hbl Oliv Basalt	W/R	1.98	$4.43x10^{-11}$	57.8	22.0 ± 0.7	Basalt dike cuts Fort Rock Creek Tuff (of Fuis, 1973).
5. BA78-73	Ft. Rock NE 7 1/2 Quad Lat.35°14', Long.113°20'	Tsba	Basaltic Andesite	W/R	3.16	$5.58x10^{-11}$	66.0	20.7 ± 0.6	Flows were mapped as equivalent to ones that overlie Peach Springs Tuff to north; these flows may interfinger with Peach Springs Tuff.
Volcanic rocks of Squaw Peak									
6. BA78-52A	Cross Mtn. NE 7 1/2 Quad Lat.35°12',Long.113°6'	Tpob	Olivine Basalt	W/R	0.63	$5.19x10^{-12}$	14.2	9.0 ± 1.2	Youngest flow in stack erupted from Squaw Peak; flows generally outcrop to east and are cut by numerous normal faults.
Volcanic rocks of East Juniper Mtns., Turkey Canyon NE 7 1/2 Quad									
7. BA78-82	Center, Sec21,T21N,R5W	Tjpb	Olivine Basalt	W/R	1.50	$7.44x10^{-12}$	77.5	5.5 ± 0.2	Eroded dike and cone complex at mouth of Big Chino Wash as it enters Big Chino Valley; appears older than Mt. Floyd lavas to NE.
8. BA78-90	Center, Sec1,T20N,R6W	Tjob	Olivine Basalt	W/R	1.16	$6.09x10^{-12}$	45.8	6.2 ± 0.3	Basalt flow overlies Redwall Limestone; adjacent to BA78-72 mentioned below.
Mt. Floyd Volcanic Field, Picacho Butte 7 1/2 Quad									
9. F78-113	Crest of Picacho Butte	Tfhd	Hbl Rhyo-dacite	Hbl	0.87	$9.02x10^{-12}$	19.2	9.8 ± 0.7	Eroded rhyodacite dome surrounded by basalt flows of Mt. Floyd volcanic field.
Andesites of Turkey Canyon									
10. F78-88	Ft. Rock NE 7 1/2 Quad Lat.35°11', Long.113°18'	Ttc	Bio-Pyr Andesite	Bio	6.61	$5.26x10^{-11}$	61.0	22.4 ± 0.8	Andesite dome and flow overlain and surrounded by younger basalt flows.
11. BA78-72	Turkey Can. NE 7 1/2 Quad SE1/4,Sec12,T20N,R6W	Ttc	Bio-Pyr Andesite	Bio	7.16	$8.23x10^{-11}$	41.3	36.1 ± 1.2	Andesite flow and cone (Juniper Cone); appears to be relatively uneroded and thought to be somewhat younger than F78-88 above. Estimated age from K/Ar dates is ≤30 Myr.
"	"	"	"	"	7.16	$6.62x10^{-11}$	27.0	32.0 ± 2.0	
"	"	"	"	W/R	4.10	$2.72x10^{-11}$	60.1	24.4 ± 1.2	

[a] K-Ar age dates by Daniel Krummenacher, San Diego State University, San Diego, CA.

of the Peach Springs Tuff. Young and Brennan (1974) report dates of 16.9 and 18.3 Myr, but believe it to be a single cooling unit. Because this unit is the primary stratigraphic marker in Tertiary volcanic rocks of this region, an age of 17.6 Myr is used in this report (Young and Brennan 1974). In the Kingman area, the Peach Springs Tuff overlies basalts and basaltic andesites that Young (1985, oral commun.) believes are not much older than the tuff. Many of the basaltic andesites and andesites (Table II) contain resorbed quartz xenocrysts. The volcanic rocks directly overlie Precambrian granite, schist, and gneiss. Two K-Ar dates (20.5 ± 1.0 and 13.8 ± 0.7 Myr) were obtained on volcanic rocks of Black Mesa (southeast of the Peacock Mountains and west of the Cottonwood Cliffs). These rocks range from dacite to alkali basalt but are chemically unique to Black Mesa and not representative of volcanic rocks in the western zone of the mapped area.

III. TRANSITION ZONE

Based on potassium content and age dates, the volcanic rocks of the transition zone form three groups (Figs. 2 and 3): a high-potasium group on the west side (Tin Mountain-Cross Mountain), a younger low-potassium group toward the east (Juniper Mountains-Mt. Floyd volcanics), and biotite-pyroxene andesites (Turkey Canyon Andesite). This last group predates Basin and Range faulting and most transition zone volcanism and forms a chain of plugs, domes, and flows that crosses the present N-NW structural trends (Fig. 2). The groups are not very distinct in their major element concentrations aside from potassium (Fig. 4). The biotite-pyroxene andesites do not appear to be related to the younger volcanics in chemistry or in time. The K-Ar dates determined on biotite separates from two of the andesites are 22.4 Myr and 32-36 Myr (two dates). A whole-rock date on the last sample was <4.4 Myr, considerably younger than the dates from biotite separates of that rock but a more reasonable age in light of the chemical similarities of this group of lavas.

The only major occurrence of silicic rocks in the entire mapped area is in the Fort Rock area, just east of Tin Mountain. Volcanic rock types in the Fort Rock area include pyroxene andesites, hornblende andesites, dacites and latites as well as basalt, basaltic andesite, and two rhyolitic tuff units. One latite dome on the west edge of the area contains a rare occurrence of scapolite phenocrysts (Goff et al. 1982). The most easterly known outcrop of

TABLE II
CHEMICAL ANALYSES IN WEIGHT-PERCENT OF 45 VOLCANIC AND GRANITIC ROCKS BETWEEN KINGMAN AND BILL WILLIAMS MOUNTAIN, ARIZONA[a]

	Kingman Area			Hualapai Mtns.	Peacock Mtns.	Black Mesa Area				Peach Springs Tuff	
Rock Type	Olivine Basalt	Basaltic Andesite	Basaltic Andesite	Syenogranite	Olivine Andesite	Andesite	Biotite-Olivine Andesite	Porphyritic Dacite	Granite	Black Mesa	Aquarius Mtns.
Sample No.	F78-50	F78-45	F78-49	F78-54	6-78-ACE-16	F78-64	F78-61	F78-59	F78-60	F78-63	Fuis, 1973
SiO_2	44.33	56.26	59.72	71.02	54.91	55.17	57.96	65.61	77.25	74.55	67.0
TiO_2	2.75	0.96	1.18	0.19	1.33	0.98	0.94	0.56	0.12	0.25	0.21
Al_2O_3	9.97	14.92	15.25	14.99	11.76	18.94	13.39	15.94	12.22	13.48	13.8
Fe_2O_3	2.46	2.76	3.05	0.83	3.18	3.30	2.89	1.68	0.37	0.59	1.0
FeO[b]	8.85	3.16	3.48	0.95	3.64	3.78	3.30	1.92	0.43	0.68	0.22
MgO	13.76	4.78	4.31	0.35	6.66	[illegible].39	5.76	2.42	0.23	0.42	1.3
CaO	10.13	7.16	5.82	0.85	7.60	5.92	5.98	3.90	0.31	0.96	1.4
MnO	0.17	0.09	0.09	0.02	0.10	0.10	0.09	0.06	0.03	0.07	0.08
Na_2O	3.31	3.42	4.03	3.38	2.74	4.61	2.63	4.05	2.82	3.54	3.6
K_2O	1.30	3.10	3.06	6.80	5.96	2.37	5.80	3.56	5.11	5.37	4.4
P_2O_5	0.78	0.53	0.35	0.05	0.90	0.42	0.70	0.22	0.03	0.04	0.04
$H_2O(+)$		1.05				0.17					3.53
$H_2O(-)$		0.33				0.18					3.15
CO_2		0.61				0.27					0.44
BaO		0.17				0.13					
SrO		0.13				0.10					
Total	97.81	99.43	100.34	99.43	98.78	99.33	99.44	99.92	98.92	99.95	100.17
CIPW Norms (wt %)											
Q		6.69	8.32	22.78		3.04	3.78	17.15	40.21	30.62	25.60
Co				.64					1.56	.19	1.69
Or	7.68	18.32	18.08	40.18	35.22	14.00	34.27	21.04	30.20	31.73	26.00
Ab	10.60	28.94	34.10	28.60	23.19	39.01	22.25	34.27	23.86	29.95	30.46
An	8.51	16.20	14.48	3.89	2.19	23.99	7.60	14.80	1.34	4.50	3.90
Ne	9.43										
Di	29.28	10.02	9.60		23.36	1.15	13.83	2.47			
Hy		9.28	8.28	1.65	.64	9.43	10.11	6.18	.91	1.52	3.24
Ol	21.72				4.97						
Mt	3.57	4.00	4.42	1.20	4.61	4.78	4.19	2.44	.54	.86	.36
Ilm	5.22	1.82	2.24	.36	2.53	1.86	1.79	1.06	.23	.47	.40
Hm											.75
Ap	1.85	1.26	.83	.12	2.13	.99	1.66	.52	.07	.09	.09
Cc		1.39				.61					1.00

TABLE II (cont)

Rock Type	Fort Rock Creek Tuff[c]			Fort Rock Area				
	Lithic Tuff	Massive Tuff	Bedded Tuff	Olivine Basalt	Olivine Basalt	Olivine Basalt	Pyroxene Andesite	Hornblende Andesite
Sample No.	6-78-ACE-22	Fuis, 1973	Fuis, 1973	6-78-ACE-30C	Fuis, 1973	6-78-ACE-35	Fuis, 1973	F78-85
SiO_2	69.38	76.92	70.94	48.71	50.0	52.14	54.9	57.81
TiO_2	0.36	0.28	0.26	1.69	1.2	1.62	1.25	1.13
Al_2O_3	13.68	11.82	15.04	15.98	14.7	17.46	15.3	17.28
Fe_2O_3	1.05	1.53	1.69	2.17	6.9	2.17	5.1	3.62
FeO^b	1.20	0.39	0.55	7.83	1.2	7.83	2.16	4.15
MgO	3.71	1.31	1.27	5.51	4.6	4.96	5.8	3.19
CaO	3.97	2.74	2.33	9.64	8.7	9.54	6.7	6.41
MnO	0.08	0.08	0.11	0.16	0.13	0.16	0.10	0.09
Na_2O	2.62	1.86	3.60	3.70	2.9	4.25	3.8	4.01
K_2O	3.83	2.95	4.13	1.64	3.1	0.77	2.4	2.84
P_2O_5	0.12	0.12	0.08	1.41	0.99	0.38	0.44	0.34
$H_2O(+)$					1.6		1.05	
$H_2O(-)$					1.8		0.96	
CO_2					1.6		<0.05	
BaO								
SrO								
Total	100.00	100.00	100.00	98.44	99.42	101.28	100.0	100.87
CIPW Norms (wt %)								
Q	26.38	47.33	27.53	4.80		4.61	6.65	
Co		.87	.60					
Or	22.63	17.43	24.41	9.69	18.32	4.55	14.18	16.78
Ab	22.17	15.74	30.46	30.45	24.54	35.96	32.15	33.93
An	14.26	12.81	11.04	22.15	17.94	26.29	17.60	20.76
Ne				.47				
Di	3.66			13.48	6.73	15.26	9.93	7.08
Hy	8.42	3.26	3.16		8.34	4.06	9.84	7.48
Ol				12.58		8.06		
Mt	1.52	.71	1.38	3.15	.81	3.15	3.67	5.25
Ilm	.68	.53	.49	3.21	2.28	3.08	2.37	2.15
Hm		1.04	.74		6.34		2.57	
Ap	.28	.28	.19	3.34	2.34	.90	1.04	.81
Cc					3.64			

TABLE II (cont)

	Fort Rock Area					North Fort Rock Area			
Rock Type	Basaltic Andesite	Hornblende Andesite	Hornblende Latite	Porphyritic Rhyodacite	Granite	Olivine Basalt	Basaltic Andesite	Basaltic Andesite	Hypersthene Andesite
Sample No.	6-78-ACE-37	BA78-14	F78-74	BA78-30	F78-87	F78-83	BA78-37	F78-79	BA78-89
SiO_2	58.26	62.62	68.48	71.14	74.46	53.00	52.85	56.44	60.54
TiO_2	1.33	0.65	0.33	0.36	0.24	1.00	1.48	1.05	0.90
Al_2O_3	17.27	17.88	17.71	14.48	14.67	13.34	18.26	14.63	14.42
Fe_2O_3	3.16	2.29	1.29	1.16	0.69	1.60	1.80	3.21	2.78
FeO^b	4.28	2.62	1.47	1.33	0.79	5.75	6.48	3.68	3.19
MgO	2.22	1.15	0.93	1.18	0.65	10.33	4.48	6.69	5.06
CaO	5.91	4.05	2.48	2.61	2.53	7.16	9.22	7.49	5.51
MnO	0.12	0.08	0.06	0.04	0.04	0.12	0.13	0.11	0.08
Na_2O	4.29	4.39	4.36	3.98	3.82	2.72	3.83	3.47	3.48
K_2O	2.96	4.14	4.14	3.38	3.35	2.37	1.28	3.09	3.81
P_2O_5	0.47	0.44	0.21	0.13	0.07	0.40	0.41	0.40	0.31
$H_2O(+)$						0.01			
$H_2O(-)$						0.21			
CO_2						1.28			
BaO						0.12			
SrO						0.12			
Total	100.27	100.31	101.46	99.79	101.31	99.53	100.22	100.26	100.08
CIPW Norms (wt %)									
Q	7.38	11.26	20.62	27.72	32.97			2.54	9.00
Co			2.05		.33				
Or	17.49	24.46	24.46	19.97	19.80	14.00	7.56	18.26	22.51
Ab	36.30	37.15	36.89	33.68	32.32	23.02	32.41	29.36	29.45
An	19.12	16.85	10.93	11.66	12.09	17.19	28.85	15.22	12.47
Ne									
Di	5.80	.30		.35		6.53	11.64	15.27	10.16
Hy	5.98	4.71	3.52	3.74	2.18	30.29	12.64	12.04	10.02
Ol						.09	.75		
Mt	4.58	3.32	1.87	1.68	1.00	2.32	2.61	4.65	4.03
Ilm	2.53	1.23	.63	.68	.46	1.90	2.81	1.99	1.71
Hm									
Ap	1.11	1.04	.50	.31	.17	.95	.97	.95	.73
Cc						2.91			

TABLE II (cont)

	Cross Mtn. Area			Squaw Peak Area			Henry Brown Mtn.	Turkey Canyon Andesite			East Juniper Mts. Area	
Rock Type	Basaltic Andesite	Olivine Andesite	Biotite Andesite	Olivine Basalt	Basaltic Andesite	Hornblende Andesite	High-Alumina Basalt	Biotite-Pyroxene Andesite	Biotite-Pyroxene Andesite	Biotite-Pyroxene Andesite	Pyroxene Basalt	Basaltic Andesite
Sample No.	F78-89	8-78-ACE-21	F78-102	BA78-52	BA78-59	BA78-63	8-78-ACE-14	F78-88	F78-98	BA78-71	BA78-82	BA78-76
SiO_2	54.92	56.03	59.73	50.70	58.10	59.85	48.29	60.33	56.39	63.42	54.94	59.22
TiO_2	1.08	0.87	1.07	1.32	0.92	0.89	2.10	1.07	1.10	0.72	1.46	.96
Al_2O_3	13.31	13.00	13.84	15.61	15.02	16.06	17.75	14.90	14.91	14.53	16.71	16.00
Fe_2O_3	3.88	3.60	2.90	2.20	3.65	2.94	2.46	2.86	3.12	2.22	3.67	2.91
FeO	4.45	4.13	3.33	7.92	4.15	3.37	8.84	3.28	3.57	2.55	4.20	3.34
MgO	8.93	9.10	5.55	8.69	6.58	4.18	5.56	3.22	4.05	3.32	5.61	3.83
CaO	6.45	6.60	6.13	9.33	6.84	5.87	9.53	5.69	6.30	4.85	6.21	6.35
MnO	0.12	0.11	0.09	0.17	0.13	0.10	0.17	0.10	0.10	0.06	0.14	0.10
Na_2O	2.94	2.90	3.64	3.45	3.34	3.92	3.91	3.51	3.12	3.40	3.82	4.06
K_2O	3.38	3.09	3.77	0.71	1.68	2.81	0.83	5.35	4.80	4.55	1.92	1.76
P_2O_5	0.32	0.28	0.41	0.29	0.23	0.33	0.33	0.71	0.73	0.32	0.35	0.28
$H_2O(+)$									0.44			0.40
$H_2O(-)$									0.10			0.18
CO_2									0.47			0.07
BaO									0.17			0.11
SrO									0.12			0.07
Total	99.78	99.71	100.46	100.39	100.62	100.32	99.77	101.02	99.49	99.94	101.02	99.64
CIPW Norms (wt %)												
Q	.72	2.68	6.68		9.36	9.24	6.63	4.85	13.37	2.67	11.33	
Co												
Or	19.97	18.26	22.22	4.20	9.93	16.61	4.90	31.61	28.36	26.89	11.29	10.40
Ab	24.88	24.54	30.80	29.19	28.26	33.17	28.77	29.70	26.40	28.77	32.32	34.35
An	13.14	13.23	10.29	25.01	21.03	17.93	28.43	9.10	12.50	10.95	22.81	20.24
Ne							2.34					
Di	13.25	13.89	13.78	15.69	9.05	7.19	13.71	11.55	9.26	8.76	12.39	7.47
Hy	19.40	19.50	9.44	6.84	15.45	9.47		4.60	8.04	5.89	10.65	8.32
Ol				13.10			13.30					
Mt	5.63	5.22	4.20	3.19	5.26	4.26	3.57	4.15	4.52	3.22	5.32	4.22
Ilm	2.05	1.65	2.03	2.51	1.75	1.69	3.99	2.03	2.09	1.37	2.77	1.82
Hm												
Ap	.76	.66	.97	.69	.54	.78	.78	1.68	1.73	.76	.83	.66
Cc									1.07			.16

TABLE II (cont)

Rock Type	Picacho Butte Area High-Alumina Basalt	Olivine Basalt	Olivine Basalt	Hornblende Rhyodacite	Muscovite Granite
Sample No.	F78-115	8-78-ACE-125	8-78-ACE-123	F78-113	F78-110
SiO_2	49.83	50.70	51.10	70.30	73.68
TiO_2	1.37	1.96	1.95	0.30	0.15
Al_2O_3	17.44	17.58	17.33	14.85	14.23
Fe_2O_3	2.23	2.36	2.34	1.21	0.48
FeO^b	8.01	8.48	8.42	1.39	0.54
MgO	5.93	4.33	5.24	0.94	0.38
CaO	10.40	7.64	8.62	2.47	0.36
MnO	0.17	0.17	0.16	0.06	0.03
Na_2O	3.52	4.39	4.15	3.68	2.51
K_2O	0.62	1.55	1.33	3.18	5.62
P_2O_5	0.26	0.79	0.67	0.13	0.21
$H_2O(+)$					
$H_2O(-)$					
CO_2					
BaO					
SrO					
Total	99.78	100.15	101.31	98.51	98.19
CIPW Norms (wt %)					
Q				29.87	36.64
Co				1.17	3.87
Or	3.66	9.16	7.86	18.79	33.21
Ab	29.79	37.15	35.12	31.14	21.24
An	29.96	23.69	24.73	11.40	.41
Ne					
Di	16.34	7.49	11.22		
Hy	2.52	2.29	1.66	3.51	1.35
Ol	11.09	11.40	12.08		
Mt	3.23	3.42	3.39	1.75	.70
Ilm	2.60	3.72	3.70	.57	.28
Hm					
Ap	.62	1.87	1.59	.31	.50
Cc					

[a] Samples F78-45, F78-64, F78-83, F78-98, and 8A78-76 were wet chemically analyzed by J. Husler, Univ. of New Mexico; all other analyses (except those published by Fuis) are by P. Hooper, Washington State University, using XRF techniques.

[b] Fe_2O_3 set at 0.20 total Fe (as Fe_2O_3) for ≤53% SiO_2 and at 0.44 total Fe for >53% SiO_2 except for Fuis' published data.

[c] All normalized to 100% water free.

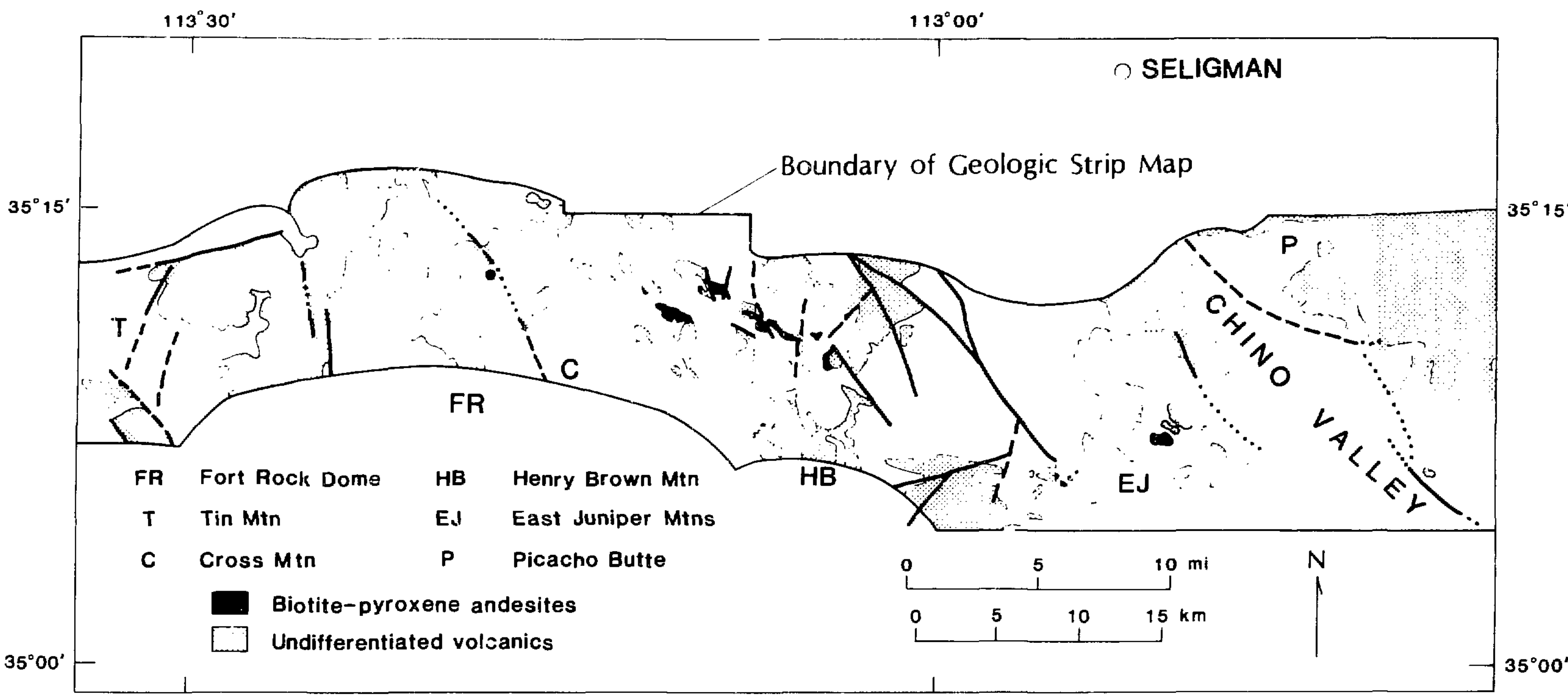


Fig. 2.
Sketch of portion of strip map crossing transition zone. Volcanic units and locations mentioned in text are indicated.

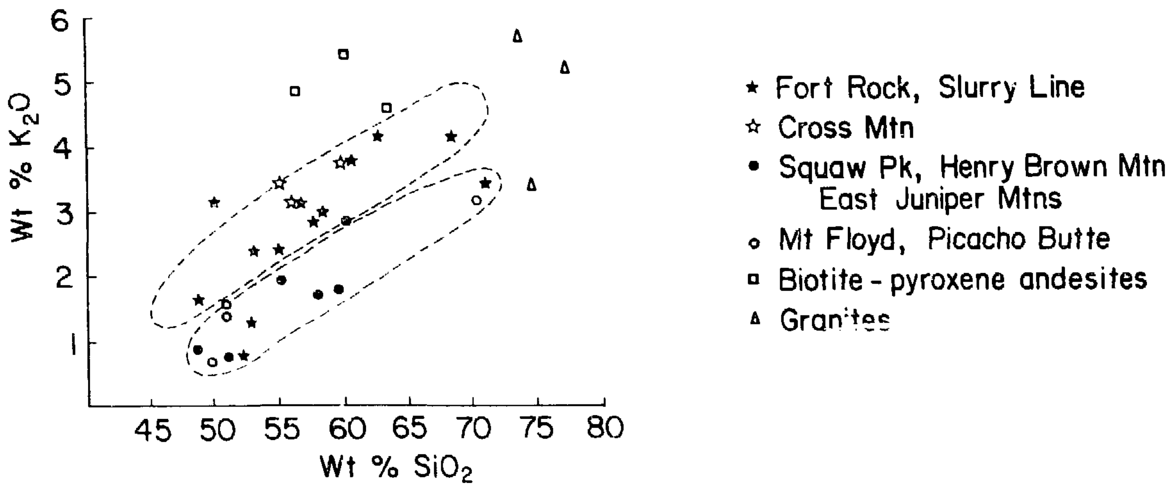


Fig. 3.
K_2O vs SiO_2 diagram showing eastern (low-potassium) and western (high-potassium) groups.

Peach Springs Tuff occurs north of Cross Mountain. The other tuff in this area is the Fort Rock Creek Tuff, equivalent to the Fort Rock Creek Rhyodacite of Fuis (1973), which underlies the Peach Springs Tuff. Peach Springs Tuff overlies most of the volcanics, but basalts and basaltic andesites in the North Fort Rock-Slurry Line area are younger than Peach Springs Tuff. Most of the Fort Rock volcanics are in the high-potassium group (Table II).

The Cross Mountain basalts fall into the high-potassium group, but our one attempt to date this group was unsuccessful because the argon was 100% atmospheric. The age dates we obtained from Fort Rock volcanic rocks range in age from 24.3 to 20.7 Myr (Table I). Although Young and McKee (1978) obtained a date of 18.2 Myr on a basalt which underlies Fort Rock Creek Tuff, a basalt dike in the center of the Fort Rock area, which has cut and locally metamorphosed the Fort Rock Creek Tuff, was dated at 22.0 Myr. More dates are needed to resolve age-dating discrepancies and to better understand this complex volcanic area.

Precambrian rocks, mostly granite and granite gneiss, underlie the basalts in the Ft. Rock area. West of Cross Mountain, Cambrian sedimentary rocks overlie the Precambrian granite. Cross Mountain itself is composed of limestone. Basalts overlie the limestone at lower elevations.

The eastern part of the transition zone contains volcanic rocks from the Squaw Peak, Henry Brown Mountain, and East Juniper Mountain areas. Each area

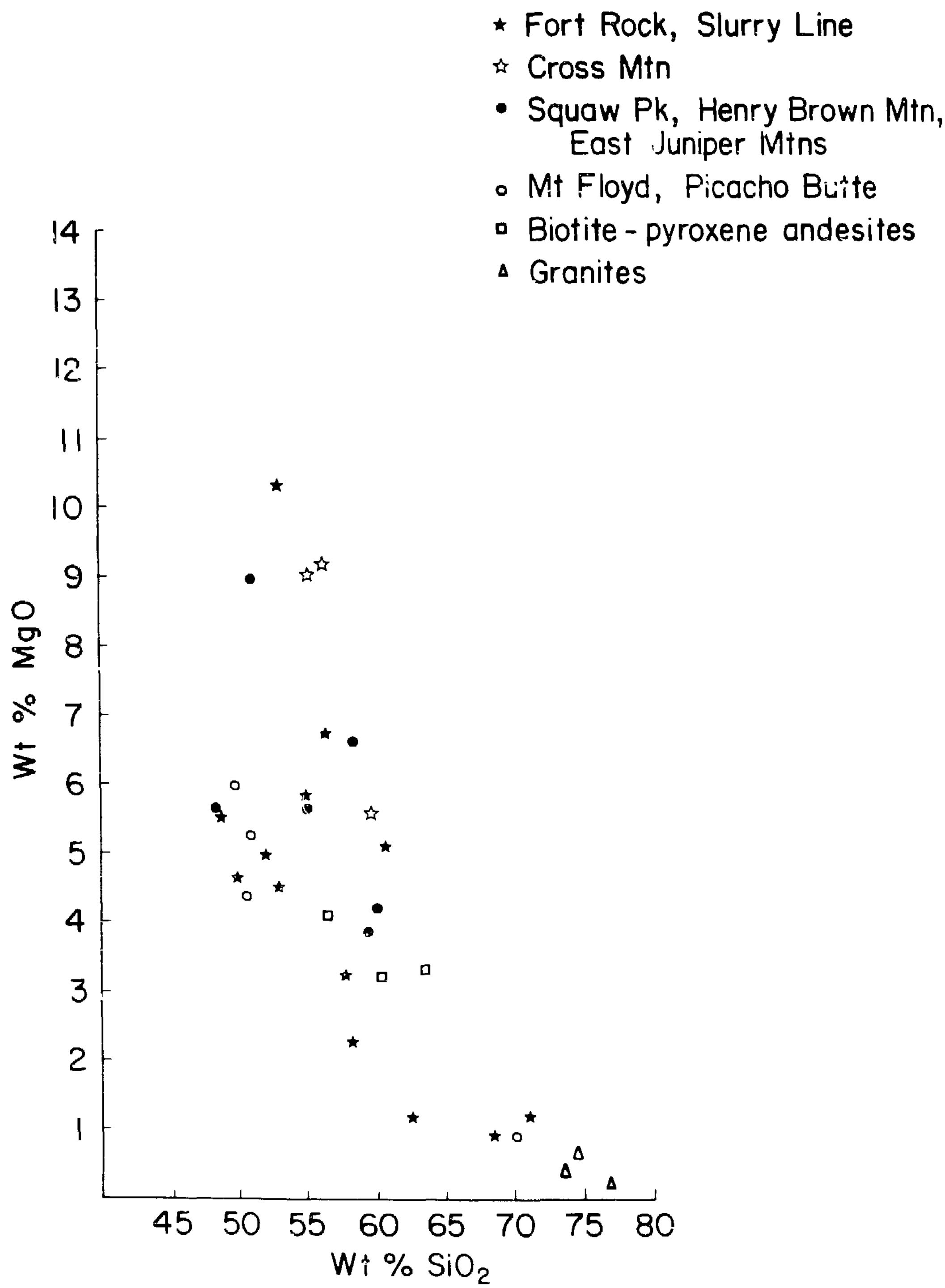


Fig. 4.
Harker variation diagrams for selected elements other than K_2O.

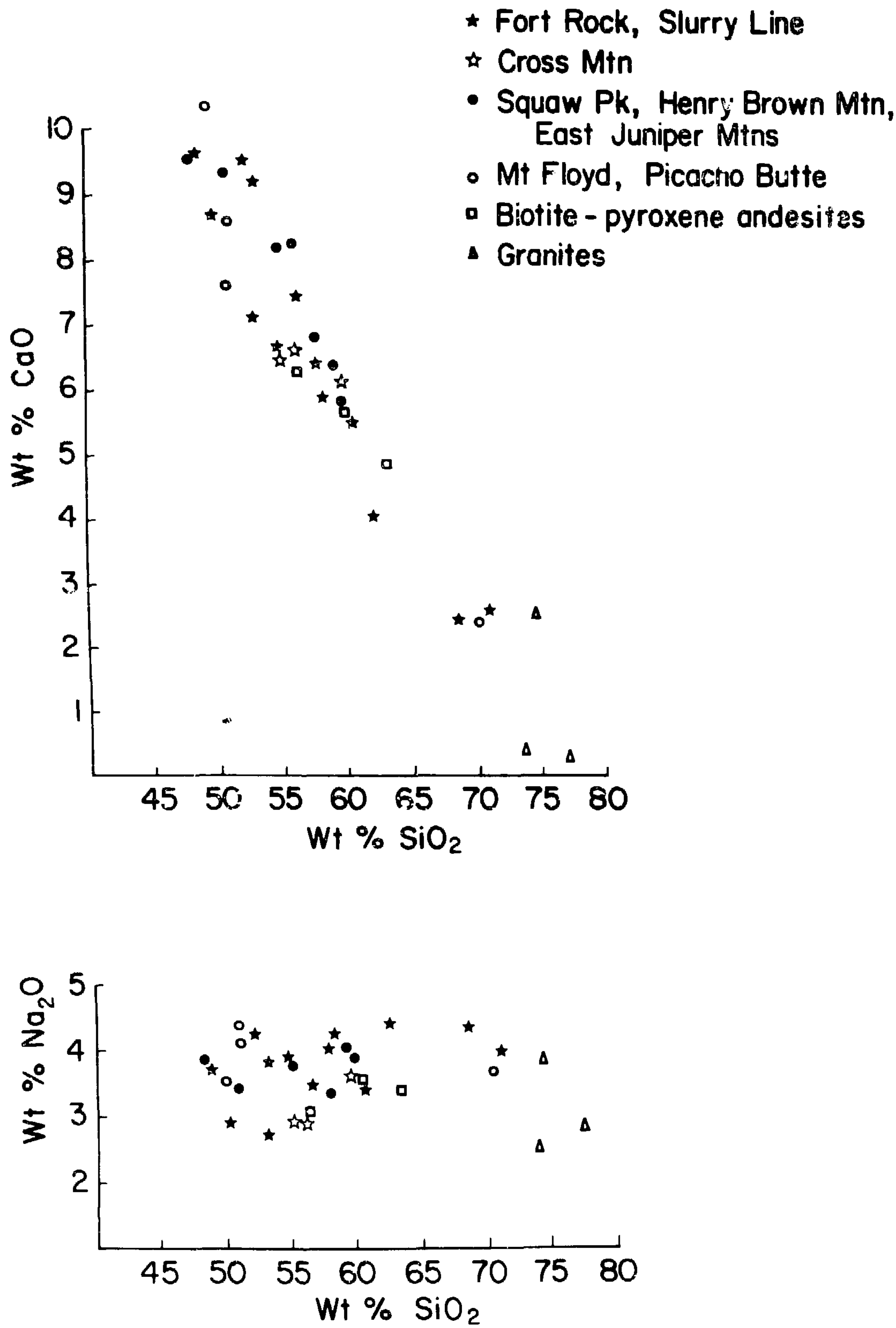
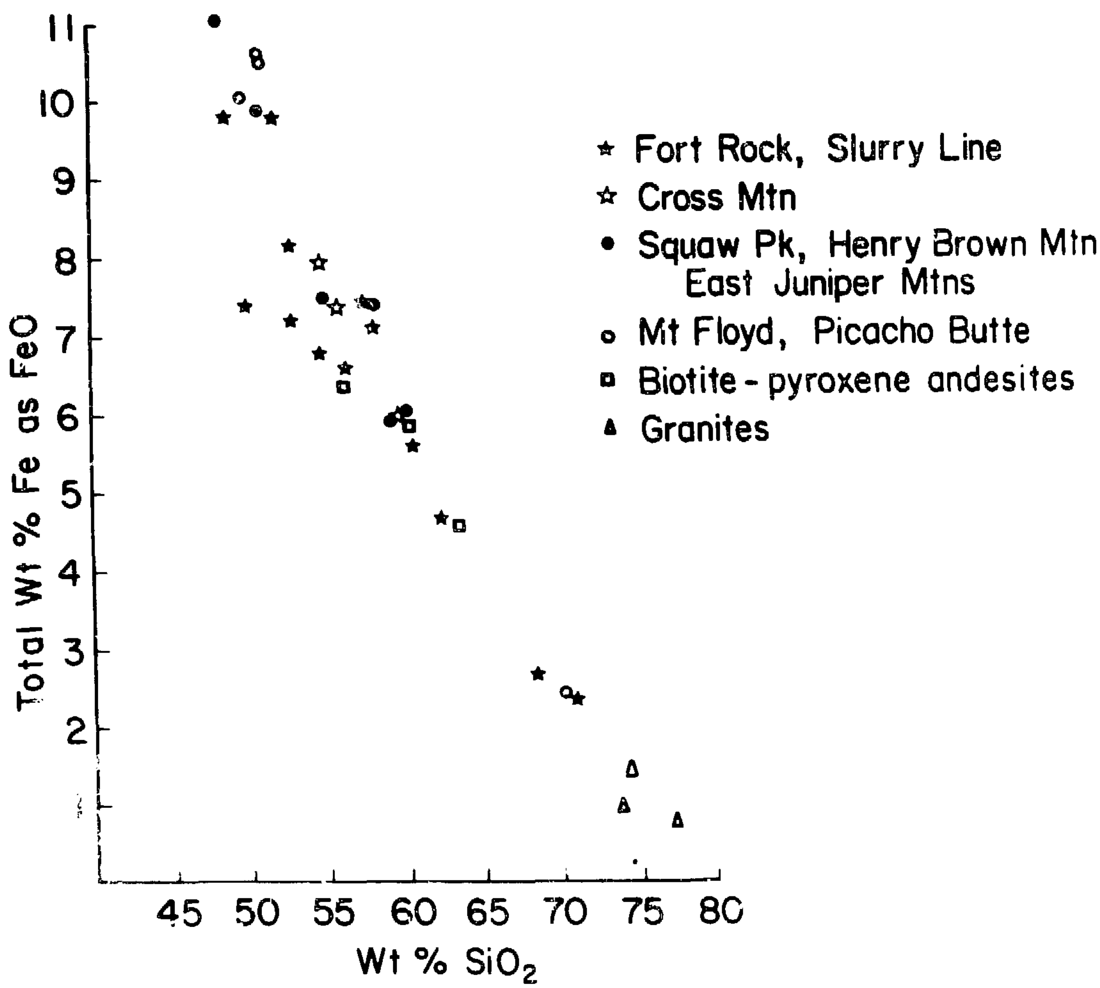

Fort Rock, Slurry Line
Cross Mtn
Squaw Pk, Henry Brown Mtn, East Juniper Mtns
Mt Floyd, Picacho Butte
Biotite - pyroxene andesites
Granites
Wt % CaO
Wt % SiO2
Wt % Na2O
Wt % SiO2

Fig. 4. (cont)


Fort Rock, Slurry Line
Cross Mtn
Squaw Pk, Henry Brown Mtn, East Juniper Mtns
Mt Floyd, Picacho Butte
Biotite - pyroxene andesites
Granites
Total Wt % Fe as FeO
Wt % SiO2
45 50 55 60 65 70 75 80
2 3 4 5 6 7 8 9 10 11

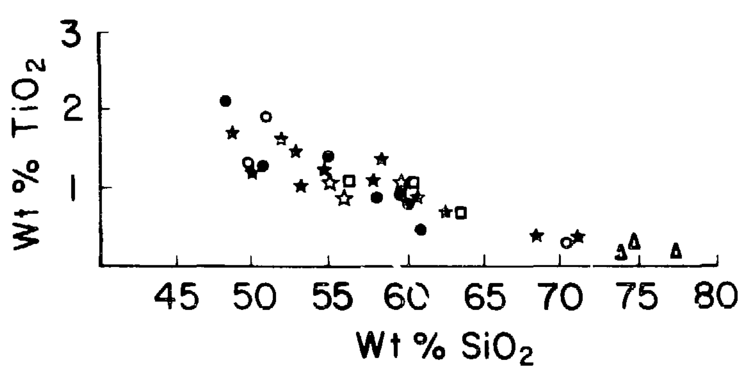
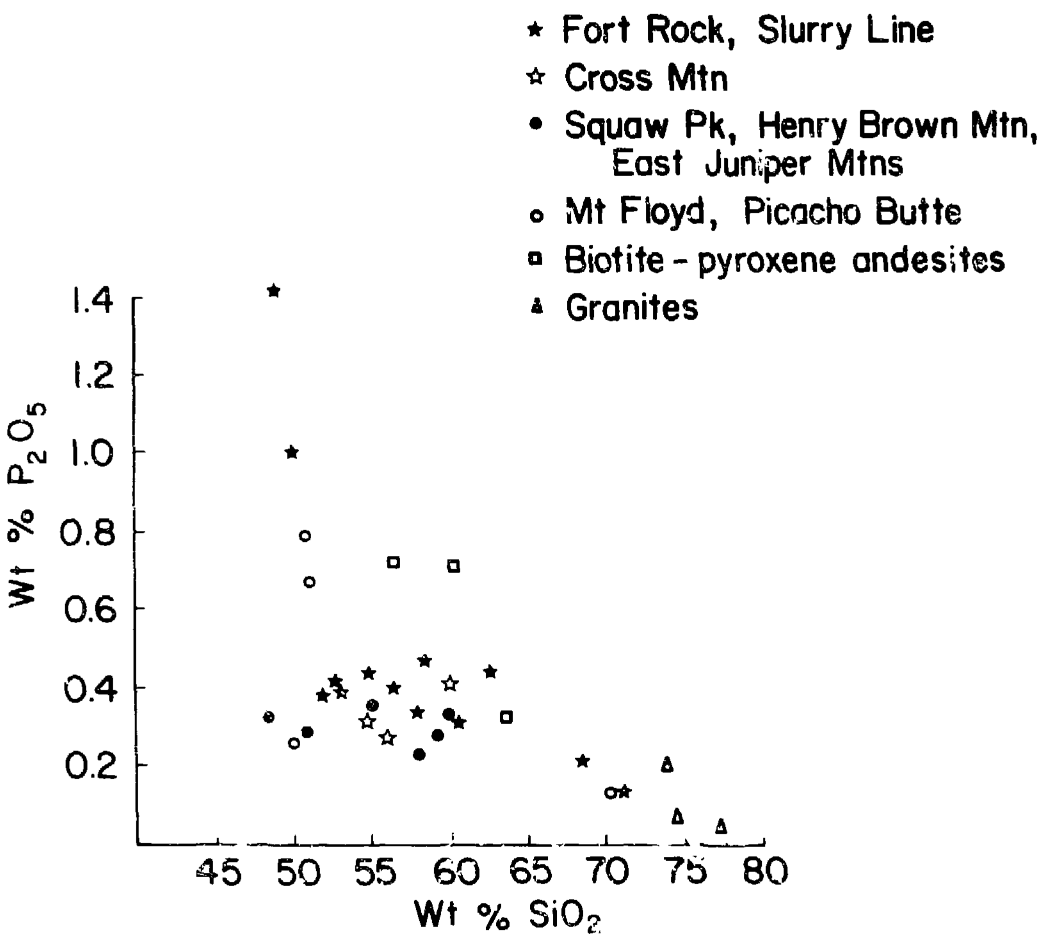

Wt % TiO2
Wt % SiO2
45 50 55 60 65 70 75 80
1 2 3

Fig. 4. (cont)


Fort Rock, Slurry Line
Cross Mtn
Squaw Pk, Henry Brown Mtn, East Juniper Mtns
Mt Floyd, Picacho Butte
Biotite - pyroxene andesites
Granites
Wt % P2O5
1.4
1.2
1.0
0.8
0.6
0.4
0.2
45
50
55
60
65
70
75
80
Wt % SiO2

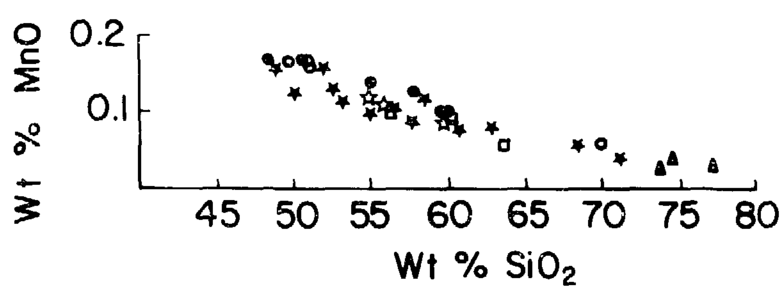

Wt % MnO
0.2
0.1
45
50
55
60
65
70
75
80
Wt % SiO2

Fig. 4. (cont)

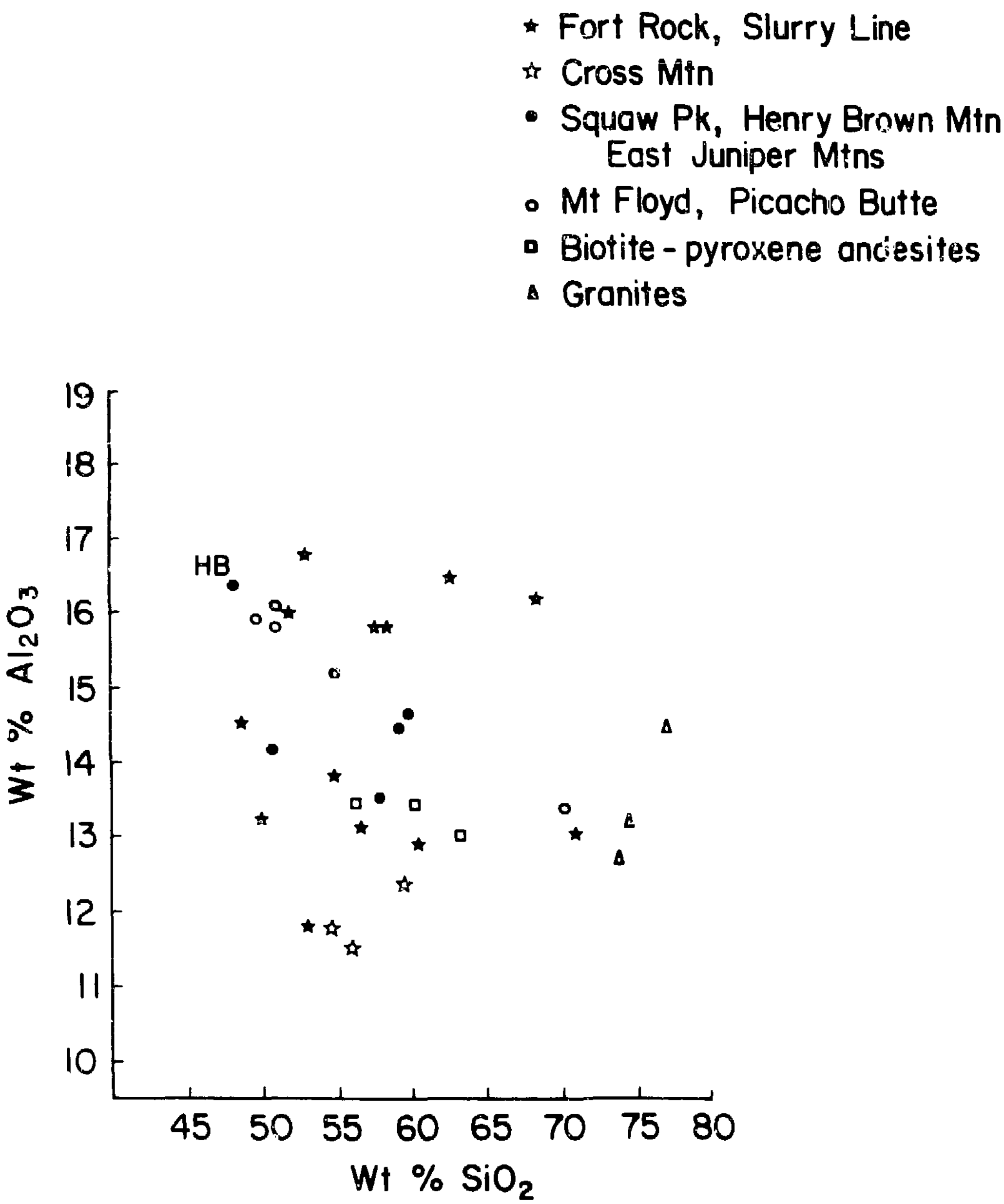

Fort Rock, Slurry Line
Cross Mtn
Squaw Pk, Henry Brown Mtn, East Juniper Mtns
Mt Floyd, Picacho Butte
Biotite - pyroxene andesites
Granites
HB
19
18
17
16
15
14
13
12
11
10
45 50 55 60 65 70 75 80
Wt % SiO2
Wt % Al2O3

Fig. 4. (cont)

within the group has its own sequences of basalt that are distinct petrographically and chemically. Squaw Peak basalts are tholeiitic and contain clusters of olivine phenocrysts. Henry Brown Mountain basalts are coarse-grained high-alumina basalts with diktytaxitic texture. The East Juniper Mountain area has three types of basalt: olivine basalt, alkali basalt with abundant large phenocrysts of olivine, pyroxene, plagioclase, and a basaltic andesite with felted feldspar. The rocks from all these areas are grouped together by their lower potassium contents and younger ages than the Fort Rock-Cross Mountain volcanic rocks (Fig. 3 and Table I). There appears to be a gap between the ages of the youngest rocks in the Fort Rock area and the basalts of the eastern transition zone, but the oldest basalt in the eastern zone for which we obtained a date (9.0 Myr + 1.2 Myr) is the youngest of the Squaw Peak eruptive series and the ages of the older units in the area are unknown. At present, there are too few dates to determine if the age gap is apparent or real.

Many basalts in all areas of the transition zone contain resorbed quartz xenocrysts suggesting that crustal contamination may have played a part in the generation of these magmas. The scapolite phenocrysts in a latite from the Fort Rock area and the similarity in the K_2O/Na_2O ratio of many volcanics and underlying granites also indicate a crustal component during generation of many intermediate to silicic melts. Unfortunately there are no isotopic or trace element data to better define petrogenetic relationships between the different rock types.

IV. MT. FLOYD VOLCANIC FIELD (EASTERN ZONE)

The Mt. Floyd-Picacho Butte area lies east of the Chino Valley and includes some flows just north of East Juniper Mountains. The Mt. Floyd-Picacho Butte volcanics fit the Eastern Transition Zone group chemically, but structurally the area is part of Colorado Plateau. The basalts are alkali olivine and alkali-rich high-alumina basalts. Just east of Chino Valley they have flowed around the rhyodacite dome of Picacho Butte. A date of 9.8 Myr was obtained for this dome (Table I). Chemically and mineralogically it is similar to other silicic domes in the Mt. Floyd field (Nealey 1980) and may be the oldest and southernmost silicic dome of that group. The Mt. Floyd field is adjacent to and continuous with the San Francisco volcanic field.

V. SUMMARY

A 10- to 15-km-wide strip was mapped crossing the transition zone between the Basin and Range on the west and the Colorado Plateau on the east. Chemical analyses and age dates were obtained for the volcanic rocks to aid in the mapping and to discern general trends in chemistry, time, and space. Volcanic rocks of the Basin and Range are basalt, basaltic andesite, andesite, dacite, and Peach Springs Tuff, a rhyolitic ash-flow tuff. Volcanic rocks overlie Precambrian granite, gneiss and schist. A silicic volcanic field of small volume occurs in the Fort Rock area on the western part of the transition zone. Volcanic rocks include basalt, basaltic andesite, andesite, latite, dacite, a rhyodacite tuff, and Peach Springs Tuff. Ages on rocks underlying Peach Springs Tuff range from 20.7 ± 0.6 to 24.3 ± 0.8 Myr. Volcanic rocks in the eastern part of the transition zone are mostly basalt, and our dates range in age from 5.5 ± 0.2 to 9.0 ± 1.2 Myr. An older (~22 to 25 Myr) group of biotite-pyroxene andesites occurs along an E-W band of unknown tectonic significance crossing the central transition zone. The volcanic rocks overlie Precambrian granite and granite gneiss in the west and Paleozoic sediments of increasing thickness in the eastern part of the transition zone.

The volcanic rocks in the Colorado Plateau Province are mostly basalts and basaltic andesites of the Mt. Floyd and San Francisco volcanic fields. A date of 9.8 ± 0.7 Myr obtained on a rhyodacite from Picacho Butte makes it the oldest rhyodacite complex in the Mt. Floyd-San Francisco Peak volcanic fields.

ACKNOWLEDGMENTS

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APPENDIX

PETROGRAPHIC DESCRIPTIONS OF SAMPLES IN TABLES I AND II

Kingman Area

F78-50 Olivine Basalt (Tkob):* Abundant olivine phenocrysts, slightly resorbed and iddingsitized along fractures and edges; phenocrysts of zoned clinopyroxene; fine-grained intersertal groundmass containing microlites of plagioclase, clinopyroxene and magnetite; vesicles filled with radiating, low birefringent minerals, probably silica and zeolites(?).

F78-45 Quartz-Bearing Basaltic Andesite (Tkqb): Euhedral phenocrysts of clinopyroxene and olivine altered to mixture of Fe-oxides, clays, and silica; euhedral phenocrysts and microphenocrysts of hornblende oxidized to opaque minerals; resorbed and complexly zoned plagioclase phenocrysts; sparse resorbed quartz xenocrysts; trachytic groundmass consists of microcrystalline feldspar, clinopyroxene, hornblende, and glass; fractures and vesicles filled with carbonate.

F78-49 Quartz-Bearing Andesite (Tkqb): Resorbed phenocrysts and clots of hypersthene; small clots of hypersthene and plagioclase; contains resorbed quartz xenocrysts with fine-grained clinopyroxene reaction rims surrounded by haloes of plagioclase-hypersthene-glass; fine-grained intersertal groundmass of plagioclase, clinopyroxene and granular opaques; very little alteration.

Hualapai Mountains

F78-54 Syenogranite (p€g): Very coarse-grained hypidiomorphic-granular texture; contains roughly 56% microcline, 32% quartz, 7% plagioclase, 3% opaques, and 1% biotite; biotite partly altered to chlorite; microcline partly altered to sericite; trace epidote along grain boundaries.

*Letters in parentheses refer to map symbols on LA-9202-MAP.

Peacock Mountains

6-78ACE-16 Olivine Andesite (Tkai): Euhedral pseudomorphs of olivine phenocrysts altered to Fe-oxides, clays, and sericite(?); abundant phenocrysts of clinopyroxene and altered phlogopite in unusual groundmass of poikilitic-like feldspar; additional microlites of magnetite, ilmenite, and fresh phlogopite.

Black Mesa

F78-64 Andesite (Tba): Phenocrysts and glomerophenocrysts of plagioclase in trachytic matrix of felted plagioclase, opaques, and very small clinopyroxene microphenocrysts.

F78-61 Biotite-Olivine Andesite (Tboa): Abundant phenocrysts of biotite, clinopyroxene, iddingsitized olivine, and rare phenocrysts of plagioclase; contains biotite-clinopyroxene clots. Glassy groundmass consists of microlites of clinopyroxene, biotite, and apatite.

F78-59 Hornblende-Biotite Dacite (Tbpd): Large phenocrysts of complexly zoned, resorbed plagioclase and resorbed quartz; some plagioclase shows sieve texture; smaller phenocrysts of resorbed hornblende and biotite in glassy groundmass containing hornblende, biotite and plagioclase microphenocrysts.

F78-60 Granite (p€g): Medium-grained hypidiomorphic-granular texture; contains 40% quartz, 30% microcline and perthitic microcline, 23% plagioclase, 3% myrmekite, 3% opaques, and 1% muscovite + biotite; plagioclase altered partly to sericite; mica altered to chlorite.

Peach Springs Tuff

F78-63 Welded Rhyolitic Tuff (Tps): Phenocrysts of resorbed quartz, euhedral sanidine, and rare phenocrysts of euhedral plagioclase; contains sparse microphenocrysts of oxidized biotite, hornblende, clinopyroxene, sphene, and opaques; partially devitrified eutaxitic groundmass.

Fort Rock Area

6-78ACE-22 Fort Rock Creek Tuff (Tfc): Reworked rhyolitic tuff containing ragged crystal fragments of quartz, K-feldspar, plagioclase, hornblende and biotite and rounded fragments of pumice and other volcanics; crystals make up nearly 50% of rock and are slightly layered; devitrified groundmass consists of glass shards and shard fragments; minor clay alteration.

6-78ACE-30C Olivine Basalt (Trob): Vesicular basalt containing severely iddingsitized olivine, minor clinopyroxene and opaque microphenocrysts; contains about 1% of biotite that may be dueteric or vapor-phase alteration; intersertal groundmass is extremely fine grained and composed of plagioclase, opaques, clinopyroxene and olivine; some vesicles filled with analcime.

6-78ACE-35 Olivine Basalt (Trob): Vesicular basalt having resorbed to euhedral phenocrysts of iddingsitized olivine, clinopyroxene, and plagioclase, and clots of these three phases in intersertal groundmass of plagioclase, clinopyroxene, olivine, opaques, and minor glass.

F78-80 Hornblende Andesite (Trha): Phenocrysts of resorbed oxidized hornblende and microphenocrysts of oxidized hornblende, minor plagioclase, and rare clinopyroxene; larger hornblende phenocrysts contain inclusions of clinopyroxene; groundmass is fine grained, devitrified, slightly vesicular, almost trachytic and contains microlites of plagioclase and opaques.

6-78ACE-37 Basaltic Andesite (Trba): Sparse phenocrysts of resorbed plagioclase and resorbed xenocrysts of quartz with clinopyroxene reaction rims in fine-grained pilotaxitic groundmass having microlites of plagioclase, clinopyroxene, and opaques and minor glass.

BA78-14 Hornblende Andesite (Trha): Phenocrysts of golden-yellow hornblende (0.25 to 1 mm) (4.5%) with oxidized black rims, some are totally opaque; biotite (0.5%), mostly oxidized opaque; sparse quartz and microcline fragments; very fine-grained pilotaxitic groundmass contains plagioclase laths ~0.05 m (25%) and magnetite (6%) in devitrified glass (64%).

F78-74 Scapolite-Bearing Hornblende Latite (Trhl): Phenocrysts of resorbed to euhedral, complexly zoned plagioclase, hornblende, biotite, and scapolite; contains plagioclase clots and microphenocrysts of allenite and opaques; pilotaxitic groundmass contains microlites of plagioclase, hornblende, biotite, and devitrified glass.

BA78-30 Hornblende Rhyodacite (Trpd): Phenocrysts of euhedral hornblende (5.5%), some zoned, and sparse biotite (0.5%), both up to 1 mm long. Slightly to strongly resorbed, zoned plagioclase phenocrysts (10%), mostly ~1 mm, but some to 2 mm; granular groundmass contains stubby plagioclase (14%), opaques, some of which may be biotite (0.5%) and biotite and amphibole (0.8%) in devitrified glass.

F78-72 Hornblende Latite (Trhl): Phenocrysts of complexly zoned hornblende and minor biotite; contains rare granitic xenoliths; pilotaxitic groundmass contains plagioclase, hornblende, opaques and glass.

F78-85 Olivine Basalt (Trbi): Phenocrysts of iddingsitized olivine and clinopyroxene in glassy, vesicular, groundmass containing microlites of plagioclase, olivine, clinopyroxene, and opaques; contains small plagioclase-clinopyroxene clots.

F78-87 Biotite Granite (p€g): Medium-grained hypidiomorphic - granular texture, locally sheared; contains roughly 40% quartz, 25% microcline, 25% plagioclase, 8% biotite, and 2% opaques, sphene, and others; sericite, epidote, and chlorite alteration particularly along crushed areas between biotite and plagioclase.

North Fort Rock Area (Slurry Line)

F78-83 Olivine Basalt (Tsb): Very porphyritic, roughly 20% phenocrysts of olivine and clinopyroxene in glassy, vesicular, intersertal groundmass containing microlites of plagioclase, clinopyroxene and opaques; contains rare xenocrysts of resorbed quartz; vesicles partly filled with carbonate.

BA78-37 Olivine Basalt (Tsb): Slightly vesicular. Glomerocrysts of plagioclase to 3 mm, and more rarely of plagioclase and clinopyroxene ± olivine, phenocrysts of plagioclase, and of olivine with narrow iddingsitized rims. Intergranular groundmass with interstitial clinopyroxene, orange pseudomorphs after olivine(?) and skeletal opaques. Minor brownish alteration of plagioclase in glomerocrysts.

F78-79 Quartz-Bearing Basaltic Andesite (Tsba): Phenocrysts of iddingsitized olivine and clinopyroxene and xenocrysts of quartz with clinopyroxene reaction rims; contains clots of fine-grained clinopyroxene; glassy intersertal groundmass contains microlites of plagioclase, clinopyroxene and opaques; some vesicles partly filled with carbonate.

BA78-89 Olivine-Hypersthene Andesite (Tsa): Large resorbed phenocrysts of hypersthene occasionally rimmed with olivine or clinopyroxene and small phenocrysts and clots of clinopyroxene, iddingsitized olivine and rare plagioclase; contains resorbed xenocrysts of quartz and rare xenoliths of metamorphosed shale in vesicular hyalopilitic groundmass containing microlites of plagioclase, clinopyroxene and opaques.

BA78-73 Basalt (Tsb): Abundant phenocrysts, glomerocrysts and resorbed fragments of olivine (to 1.25 mm) and clinopyroxene (to 2 mm); rare multigranular fragments of quartz with narrow kelphytic rims (of clinopyroxene); hyalopilitic groundmass of clinopyroxene, plagioclase, and opaques in brown glass.

Cross Mountain Area

F78-89 Basaltic Andesite (Tcob): Abundant small phenocrysts of iddingsitized olivine and clinopyroxene; contains rare resorbed plagioclase phenocrysts and resorbed xenocrysts of quartz; glassy intersertal groundmass contains microlites of plagioclase, clinopyroxene and opaques.

8-78ACE-21 Olivine Andesite (Tcoa): Abundant phenocrysts of iddingsitized olivine and clinopyroxene; contains rare sieve-textured plagioclase and clinopyroxene; contains very rare quartz with clinopyroxene reaction rims; intersertal to almost ophitic groundmass of clinopyroxene, plagioclase, and opaques; minor carbonate filling of vesicles.

F78-102 Biotite Andesite (Tcba): Phenocrysts of clinopyroxene and oxidized biotite; contains sieve-textured clinopyroxene and clinopyroxene clots; contains quartz xenocrysts with clinopyroxene reaction rims and very rare xenocrysts of granular quartz; intersertal to pilotaxitic groundmass of plagioclase, biotite, clinopyroxene and opaques.

Squaw Peak Area

BA78-52 Olivine Basalt (Tpob): Abundant large (0.6 to 3 mm) phenocrysts and glomerocrysts of olivine rimmed with iddingsite; smaller (0.4 to 0.6 mm) olivine phenocrysts are totally iddingsitized; trachytic groundmass with interstitial clinopyroxene and magnetite.

BA78-59 Quartz-Bearing Basaltic Andesite (Tpob): Phenocrysts of resorbed iddingsitized olivine and smaller phenocrysts and clots of hypersthene; abundant xenocrysts of quartz with some reaction rims of fine-grained clinopyroxene; microphenocrysts of iddingsitized olivine and hypersthene; glassy pilotaxitic groundmass containing microlites of plagioclase, clinopyroxene, hypersthene and opaques.

BA78-63 Hornblende Andesite (Tpha): Abundant small (0.3 to 0.4 mm) phenocrysts of hornblende rimmed with opaque, biotite (~0.8 mm) now almost totally opaque, larger very altered (granular) clinopyroxene, sparse plagioclase, sparse quartz xenocrysts with kelphytic rims; groundmass of devitrified glass with plagioclase and rare incipient spherulites.

Henry Brown Mountain

8-78ACE-14 High-Alumina Basalt (Thb): Large phenocrysts of resorbed complexly zoned or sieve-textured plagioclase and resorbed iddingsitized olivine in coarse-grained diktytaxitic groundmass of plagioclase, olivine, clinopyroxene, opaques, and minor glass; vesicles contain minor carbonate.

Turkey Canyon Andesite (Ttc)

F78-88 Biotite-Pyroxene Andesite: Phenocrysts of resorbed clinopyroxene, oxidized biotite, rare resorbed plagioclase, and prismatic apatite; contains biotite, apatite, clinopyroxene clots; contains rare xenocrysts of quartz; fine-grained pilotaxitic groundmass contains plagioclase, clinopyroxene, oxidized biotite, and opaques.

F78-98 Biotite-Pyroxene Andesite: Phenocrysts and clots of clinopyroxene, severely oxidized biotites, and rare phenocrysts of plagioclase; contains large granular clinopyroxene-plagioclase clots; pilotaxitic to almost trachytic groundmass of plagioclase, clinopyroxene, oxidized biotite, and opaques.

BA78-71 Biotite-Pyroxene Andesite: Abundant phenocrysts and glomerocrysts of clinopyroxene and severely oxidized biotite; pilotaxitic groundmass of plagioclase, clinopyroxene, biotite, and opaques, and devitrified glass.

BA78-72 Biotite-Pyroxene Andesite: Abundant phenocrysts of biotite (up to 4 mm, but commonly 1 mm) and less abundant phenocrysts of clinopyroxene (to 1 mm), some glomerocrysts of both; phenocrysts of pyroxene often have inclusions of biotite; larger biotites contain inclusions of clinopyroxene; biotite is oxidized orange but retains original birefringence; contains sparse hornblende; pilotaxitic groundmass contains interstitial hornblende(?) microlites and microphenocrysts of magnetite in devitrified glass.

East Juniper Mountains Area

BA78-82 Pyroxene Basalt (Tjpb): Large (to 3 mm) phenocrysts of corroded plagioclase, slightly resorbed olivine with thin rims of iddingsite, and clinopyroxene; intersertal groundmass of plagioclase, clinopyroxene, opaques, and olivine.

BA78-76 Basaltic Andesite (Tjba): Small phenocrysts (to 1 mm) of plagioclase and microphenocrysts of hypersthene and olivine; pilotaxitic groundmass contains plagioclase, clinopyroxene, and opaques.

BA78-90 Olivine Basalt (Tjob): Large (to 3 mm) phenocrysts of corroded plagioclase, some with sieve texture, and resorbed and embayed olivine with narrow rims of iddingsite. Intersertal groundmass with microphenocrysts of plagioclase and olivine in devitrified glass containing anhedral clinopyroxene and abundant microgranular opaques.

Picacho Butte Area

F78-115 High-Alumina Basalt (Tfob): Small phenocrysts of iddingsitized olivine and plagioclase in medium-grained diktytaxitic groundmass of plagioclase, clinopyroxene, olivine, opaques, and glass.

8-78ACE-125 Olivine Basalt (Tfob): Phenocrysts of complexly zoned to sieve-textured plagioclase, iddingsitized olivine, and ophitic clinopyroxene in trachytic groundmass of plagioclase, clinopyroxene, olivine, and opaques; contains small clinopyroxene-plagioclase clots.

8-78ACE-123 Olivine Basalt (Tfob): Phenocrysts of iddingsitized olivine and microphenocrysts of plagioclase in pilotaxitic groundmass of plagioclase, clinopyroxene, olivine, and opaques.

F78-113 Hornblende Rhyodacite (Tfhd): Phenocrysts of biotite, hornblende, plagioclase, and K-feldspar in glassy vesicular pilotaxitic groundmass containing microlites of plagioclase, hornblende, biotite, and opaques.

F78-110 Muscovite Granite (p€g): Medium-grained hypidiomorphic granular texture; contains quartz, microcline and some perthite, plagioclase, muscovite and rare biotite and opaques; plagioclase altered to sericite; micas contain some chlorite alteration.

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