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Recognition and geologic implications of potassium metasomatism in upper-plate volcanic rocks at the detachment fault at the Harcuvar Mountains, Yavapai County, Arizona

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INTRODUCTION

Potassium metasomatism of diverse origins has affected volcanic and sedimentary rocks from California to Colorado (Ratte´ and Steven, 1967; Wones and others, 1967; Chapin and Glazner, 1983; Chapin and Lindley, 1986). In southwestern Arizona, mid-Tertiary volcanic rocks that range in composition from basalt to rhyolite may have low Na_2O and anomalously high K_2O content which is indicative of metasomatism (Brooks, 1985a, 1986; Kerrich and others, 1986). Based on their anomalously high K_2O content alone, ash-flow tuffs in the upper-plate of the detachment fault at the Harcuvar Mountains have been referred to as as high-potassium trachytes (Scarborough and Wilt, 1979) and trachytes (Reynolds and Spencer, 1984).

Analytical data are important in resolving the controversy over the magmatic (Shafiqullah and others, 1976) or metasomatic (Brooks, 1985a, 1986) origin of some of the high potassium rocks. Because of the limited number of previous rock analyses (Brooks, 1984) and discordant potassium-argon (K-Ar) and fission-track (FT) dates (some by as much as 7 m.y.) (Scarborough and Wilt, 1979; Brooks, 1985b; Brooks and Marvin, 1985), samples of the upper-plate volcanic rocks (fig. 1) were submitted for analysis.

DISCUSSION

The metasomatic nature of high-potassium volcanic rocks is more easily recognized in the laboratory than in the field, where samples of metasomatised lavas may appear no different than their unaltered counterparts. In thin-section, metasomatic alteration is confirmed by the chalky appearance of plagioclase, alteration of groundmass pyroxene and magnetite to hematite, and patchy replacement of plagioclase by adularia (Chapin and Lindley, 1985). Rock chemistry, particularly a $K_2O:Na_2O > 2$, may indicate metasomatic

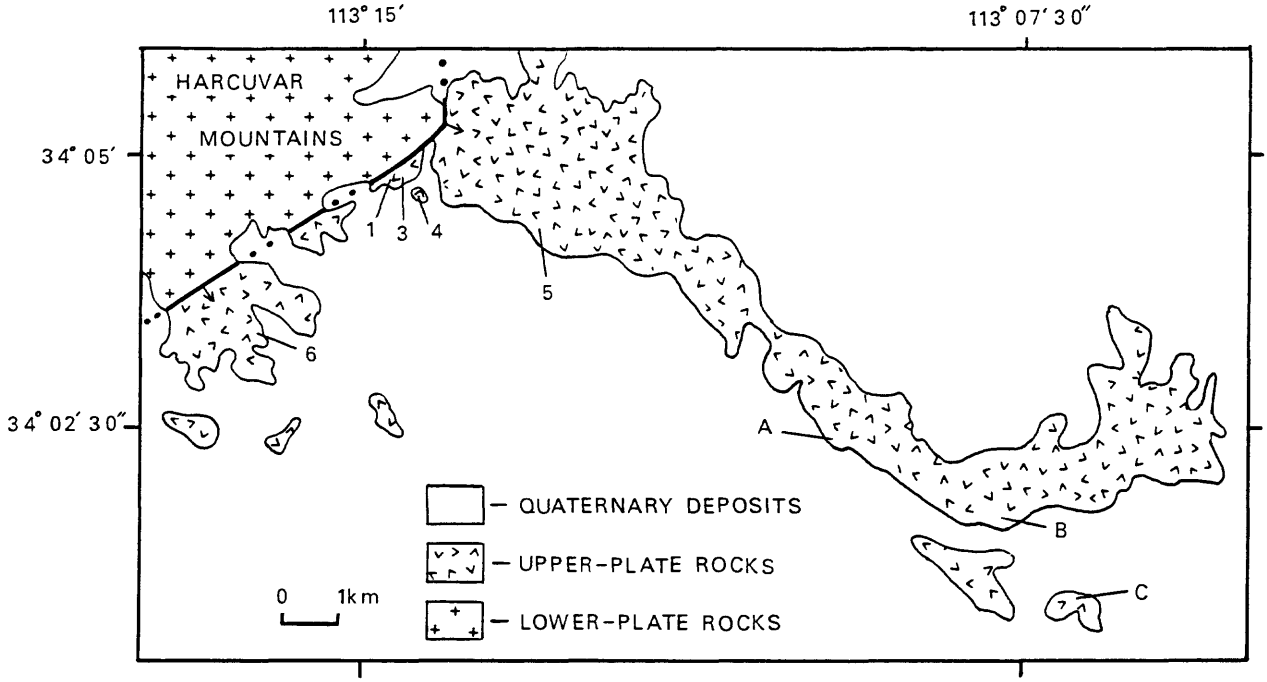

Figure 1.--Locations of analyzed samples of upper-plate volcanic rocks given in Table 1(HM prefix deleted for brevity). Heavy line indicates trace of detachment fault and arrows indicate direction to upper-plate. A=K-Ar site (Scarborough and Wilt, 1979); B=rock analysis site (Brooks, 1984); and C=K-Ar, fission-track, and rock analysis site (Brooks, 1984; 1985b).

alteration. Other indications of metasomatic alteration include the presence of 2-10μm orthoclase as adularia(?), secondary quartz and calcite, propylitic alteration, XRF analyses with a high or erratic LOI, and the absence of leucite as a host phase for the excess potassium.

Potassium content, alone, does not indicate metasomatism. For example, the K_2O content of the ash-flow tuffs from the upper-plate of the detachment fault at the Harcuvar Mountains (HM-1, 3, 4, 5A, 5B; Table 1) is comparable to the K_2O content of the unmetasomatised Topopah Springs tuff of southern Nevada (Lipman and others, 1966). However, metasomatic alteration has reduced the Na_2O content and thereby increased the K_2O:Na_2O of the Harcuvar ash-flow tuffs to as much as 38:

	Harcuvar Mtns. tuff, AZ	Topopah Spring tuff, NV
K_2O wt%	4.3 - 8.6	4.7 - 6.0
Na_2O wt%	0.2 - 1.6	3.7 - 4.4
K_2O:Na_2O	2.7 - 38.0	1.3 - 1.5

An analysis of the Bullard andesite, mapped by Reynolds and Spencer (1984), shows a K_2O content of 4.2 weight percent (HM-6; Table 1). This is only somewhat higher than K_2O contents of 3.2 and 2.1 weight percent given by Taylor (1969) and Gill (1981), respectively, for high-potassium andesites. The low Na_2O of 0.2 weight percent, high K_2O:Na_2O of 21, and high SiO_2 of 70.3 weight percent of this "hand-sample andesite" demonstrate the effects of metasomatism on rock chemistry.

In metasomatised upper-plate volcanic rocks, it is common to find discordant FT and K-Ar dates. Resetting of temperature-sensitive FT dates to 17-18 Ma with respect to K-Ar dates of 24 Ma has occurred in the upper-plate rocks at the Harcuvar Mountains and elsewhere in southwestern Arizona (Brooks and Marvin, 1985; Brooks, 1985c). Therefore, it is unlikely that a single

date, whether FT or K-Ar, from a metasomatised lava gives the true age of eruption.

Because the potassium content of volcanic rocks from southwestern Arizona has been used to establish depth-to-plate reconstructions for the Tertiary (Dickinson and Hatherton, 1967; Lipman and others, 1971; Rowell and Edgar, 1983) it is important to discriminate between analyses of metasomatised lavas and primary potassic lavas. More than just high K_2O content must be considered if analyses of the rocks are to be used in petrology, geochronology, and tectonic modeling. Evaluation of major oxides, K_2O:Na_2O, and petrography indicates that potassium metasomatism has affected the upper-plate volcanic rocks at the Harcuvar Mountains. Therefore, magmatic chemistry should not be inferred from major oxide analyses of these rocks.

Table 1.--Analyses of upper-plate volcanic rocks at the Harcuvar Mountains, Yavapai County, Arizona

Field no.	HM-1	HM-3	HM-4	HM-5A	HM-5B	HM-6
Major elements (weight percent, uncorrected) determined by x-ray spectroscopy, analysts, A. J. Bartel, K. Stewart, J. Taggart; $FeTO_3$ indicates total iron reported as Fe_2O_3						
SiO_2	63.0	74.8	77.5	77.2	73.5	70.3
Al_2O_3	9.3	11.6	9.3	10.1	12.8	6.6
$FeTO_3$	1.3	1.2	1.3	1.3	2.2	3.3
MgO	0.3	0.2	0.1	0.3	1.0	0.3
CaO	9.6	0.7	0.4	0.4	0.4	5.6
Na_2O	0.2	0.3	0.3	0.4	1.6	0.2
K_2O	7.6	8.6	6.4	8.4	4.3	4.2
TiO_2	0.1	0.1	0.2	0.1	0.2	0.5
P_2O_5	0.1	<0.1	0.1	<0.1	0.1	0.2
MnO	0.1	0.1	0.7	0.1	0.1	0.2
LOI 900°C	8.0	1.7	1.6	1.3	3.0	5.8
$K_2O:Na_2O$	38.0	28.7	21.3	21.0	2.7	21.0
Trace elements (ppm) determined by ICP method, analyst P. H. Briggs; --, not reported						
Mn	910	720	5300	670	320	1700
Ag	6	3	<2	<2	<2	2
As	<10	20	<10	<10	<10	<10
Au	<8	<8	<8	<8	<8	<8
B	--	--	--	--	--	--
Ba	2000	2300	960	1300	380	550
Be	2	2	1	2	3	<1
Bi	<10	<10	<10	<10	<10	<10
Cd	<2	<2	<2	<2	<2	13
Ce	70	55	170	67	72	28
Co	3	2	5	2	3	58
Cr	2	<1	2	5	7	150
Cu	9	8	7	2	2	14000
Eu	<2	<2	<2	<2	<2	<2
Ga	11	20	15	16	16	8
Ge	--	--	--	--	--	--
Ho	<4	<4	<4	<4	<4	<4
La	61	37	91	34	47	16
Li	22	25	110	37	41	55
Mo	<2	<2	<2	<2	<2	6
Nd	25	27	45	26	28	16
Ni	4	<2	7	3	4	26
Pb	9	39	59	8	<4	180
Sc	<2	<2	<2	<2	3	10
Sn	<20	<20	<20	<20	<20	<20
Ta	<40	<40	<40	<40	<40	<40
Th	9	18	10	15	8	<4
U	<100	<100	<100	<100	<100	<100
V	8	17	23	9	12	62
W	--	--	--	--	--	--
Yb	2	3	2	3	<1	<1
Zn	120	200	270	24	17	1000
Trace elements (ppm) determined by an energy dispersive analyzer Cd^{109} source for Rb, Sr, Y, Zr, and Nb; analyst M. J. Blaskowski						
Rb	193	252	160	210	224	31
Sr	67	154	90	15	27	56
Y	13	32	17	23	17	7
Zr	151	147	143	164	203	32
Nb	12	27	11	29	16	2

Appendix 1.--Locations of samples for analytical data given in Table 1.

Field no.	Latitude N.	Longitude W.
HM-1	34°04'44"	113°14'39"
HM-3	34°04'44"	113°14'33"
HM-4	34°04'40"	113°14'25"
HM-5A	34°04'22"	113°13'04"
HM-5B	34°04'22"	113°13'04"
HM-6	34°03'23"	113°16'12"

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