TRACE-ELEMENT INVESTIGATION OF THE "TURKEY TRACK" PORPHYRY, SOUTHEASTERN ARIZONA

By

James E. Mielke[1]

Geochronology Laboratories, University of Arizona

A rock unit of unusual composition, the "Turkey Track" porphyry, occurs in several localities over a widespread area in southeastern Arizona. The "Turkey Track" is characterized petrographically by large weakly zoned plagioclase laths commonly over an inch in diameter and two pyroxenes or alteration after olivine in a gray to reddish-brown fine-grained glassy groundmass. The "Turkey Track" has been proposed as a correlation guide if it could be established that all "Turkey Track" localities represent one rock unit formed during a short interval of time. An attempt has been made to demonstrate by uniformity of trace-element content coupled with similarities in chemical and mineralogical composition that the "Turkey Track" localities probably do have a common parent. Concurrent K-Ar dating indicates that the "Turkey Track" localities were erupted or intruded penecontemporaneously.

Andesite porphyries that are, or are similar to, the "Turkey Track" are found in several localities within roughly a 75-mile radius of Tucson. These localities include the Desert Museum area, Tumamoc Hill, Sentinel Peak, Black Mountain, San Xavier Mission, Pima district, Mineta Ridge, Happy Valley quadrangle, Saguaro National Monument, Cienega Gap, Davidson Canyon, Kelsey Canyon, Winchester Mountains, Little Table Mountain, Steele Hills, Dos Cabezas Mountains, Fisher Hills, and Fresnal Canyon.

In a previous study of the "Turkey Track" Cooper (1961) proposed use of the porphyry as a correlation guide and presented a fairly comprehensive petrographic and chemical study of several "Turkey Track" localities. Petrographically, he was able to distinguish two separate types of "Turkey Track," one with two pyroxenes, augite and hypersthene, and the other having augite and olivine that has been largely altered to red ferruginous material. Both types are quite similar in other characteristics.

Chemically, these two types seem to be identical and show an average composition close to that of a doreite in Nockold's classification system (Nockolds, 1954). Notable in the chemical composition of the "Turkey Track" is the high alkali content compared to a doreite.

Halva (1961) in working with basalts in southern Arizona noticed a tight grouping of the porphyry samples when plotted as alpha activity versus potassium content. This grouping appeared distinct from other volcanic units in the area, which spread diffusely over the graph and in general had a lower

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[1] Smithsonian Institution, Radiation Biology Laboratory, Washington, D. C.

alpha-ray activity to beta-ray activity from radioactive elements in the rock.

Petrographic studies of each locality revealed no significant difference in mineralogy that could be related to differences in radiometric or chemical composition. For example, the presence of quartz grains in the Desert Museum locality or the alteration after olivine at Sentinel Peak do not indicate significant chemical differences. These differences in mineralogy more likely reflect local differences in pressure and temperature during crystallization of magma bodies of similar compositions. Any apparent differences in chemistry resulting from different mineral assemblages are probably compensated by slight adjustments in the composition of the groundmass. However, as much of the rock is groundmass, its mineralogy is difficult to determine.

Radiometrically, most samples of the "Turkey Track" from widely separated areas fall within a fairly well-defined region when plotted as percent K versus α /mg hr. Although this region of the alpha-beta plot is not completely unique among all porphyritic rocks in the area, it is a significant feature. Most other porphyries fall well outside this region or overlap only its margins. The field in which "Turkey Track" samples plot is definitely distinct from most "basalts" in southern Arizona, which have lower alpha activity. Rocks that overlap the "Turkey Track" field are primarily rhyolitic and andesitic in composition. Rocks of this composition are found to have a wide variation in radiometric characteristics and tend to scatter over much of the graph area. However, as a rough generalization, most rhyolite and andesite porphyries have a lower alpha-beta ratio than the "Turkey Track." Previous investigations have shown that the radiometric variation within a single flow is within or equal to counting error (Sabels, 1960; Halva, 1961). Bikerman's (1962) data indicate that the variation in alphas/mg hr over a single large outcrop area is two or three times counting error. This investigation confirms that of the others and further shows that the variation over several widespread localities of the same or similar rock is again only two or three times greater. It is not at all unreasonable to expect a more widespread radiometric variation over a geographically large area, but the fact that the variation is still not excessive strongly suggests that the "Turkey Track" is all one unit.

The samples were subjected to radiometric analysis by alpha and beta counting. Samples were prepared for counting by crushing and sieving to minus 60 mesh. Fines below 300 mesh were not counted.

Alpha activity is an indirect measure of uranium and thorium content in a rock. Other alpha emitters exist in nature, but their normal concentrations are so low that their emission is assumed to be negligible.

Potassium content of the samples was determined from beta activity detected in a lead-shielded anticoincidence counter. Figure 1 is a plot of alpha activity in alphas/mg hr versus percent potassium by beta counting for several volcanic rocks in southern Arizona. In addition to data from this investigation, radiometric data from Taylor (1960), Bikerman (1962), and Halva (1961) are included in the graph. The low potassium values of the Davidson Canyon at Cienega Gap sample and the Pima district sample perhaps are not representative. Both samples appeared highly altered, and potassium has probably been removed. Other samples from the Cienega Gap-Davidson Canyon area plotted within the "Turkey Track" grouping. The Pima district sample showed a very high atmospheric correction when age dated.

A method of three channel gamma scintillation was used to

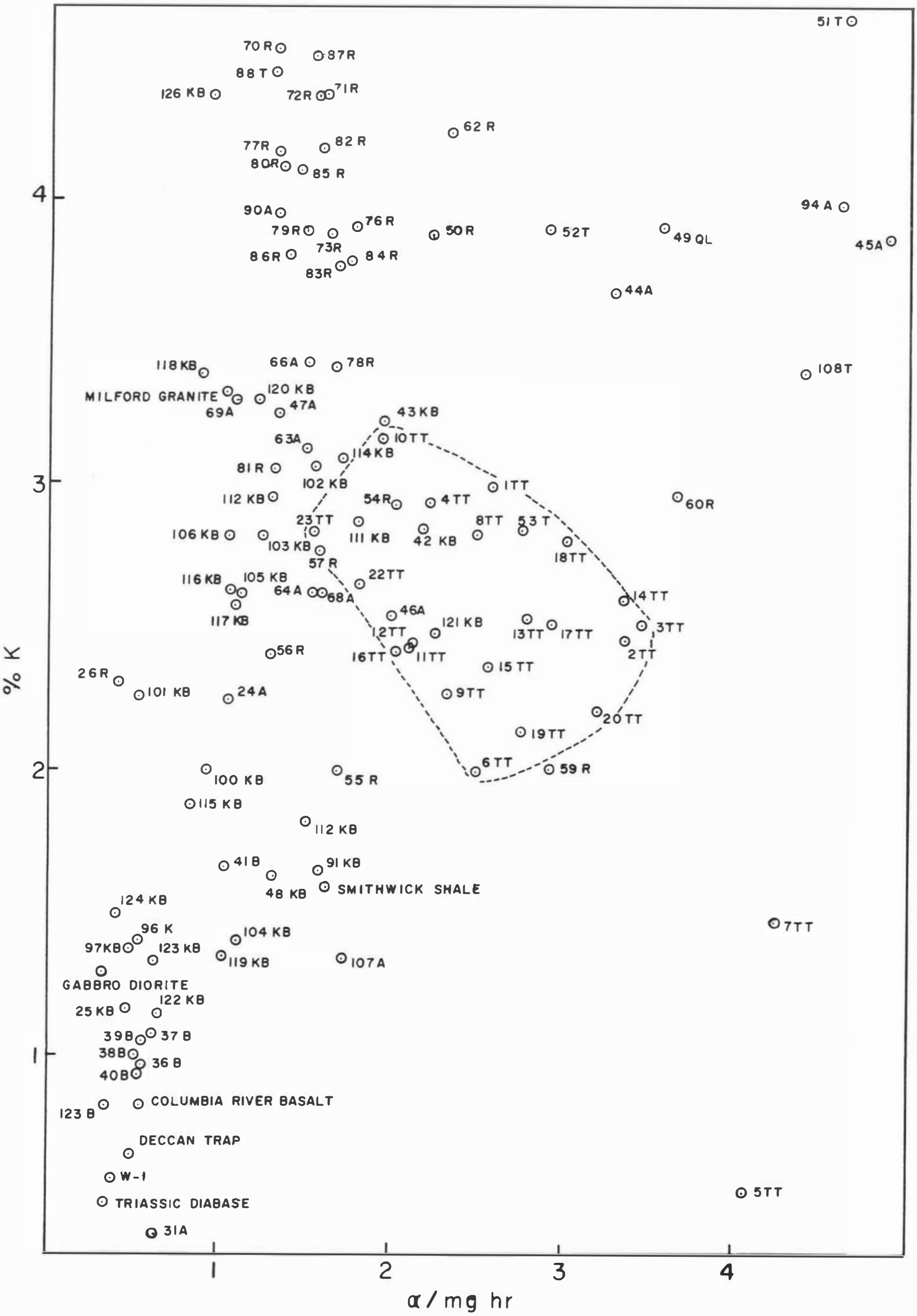

Figure 1. --Alpha activity versus beta activity of southern Arizona volcanic rocks. (Key to this figure appears on p. 93.)

simultaneously determine uranium, thorium, and potassium content. Potassium was determined from a channel centered on the 1.46 Mev K^{40} peak, thorium from the 0.238 Mev Pb^{212} peak in the thorium series, and uranium from a channel at 0.180 Mev, which is a plateau in the uranium series.

Fluorimetric analysis was also used to determine uranium content in the samples. This method served as an independent check on the gamma counting and provided a means of calculating the thorium content from total alpha activity. Agreement of the uranium analyses by fluorimetric and gamma counting is fairly good. In most cases, agreement is within the limits of error. Considering the effort involved in sample preparation for fluorimetric analysis, this certainly emphasizes the potential value of gamma counting for uranium and thorium.

In addition to potassium analysis by beta counting, samples were subjected to flame photometry. Flame photometric potassium analyses generally agreed quite well with the beta counting but much less so with gamma counting. This is probably due to the low gamma activity of K^{40} and the generally high background.

In general, the value of radiometric methods of analysis has been demonstrated. Coupled with chemical and petrographic studies these can be useful aids for correlation of volcanic rocks.

Several trace elements were determined by emission spectroscopy using $SrCO_3$ as an internal standard. W-1, G-1, and other USBS rock standards for which trace-element data are available were used to prepare working curves. Values of the elements determined, in most cases, should be treated only as a general order of magnitude. Estimated error in the method is about 25 percent and is lower for some elements than others.

Emission spectroscopic analyses indicated that there is very little real variation in trace-element content among the "Turkey Track" localities. Most of the minor differences that do show up could be attributed to normal variation in the analyses. Cesium, potassium, and sodium tend to show abnormally high concentration in most "Turkey Track" samples. This is interesting, as all three are alkali metals. Cesium content is plotted in figure 2 versus chromium for the "Turkey Track" samples. Included in the graph for purposes of contrast are a granite, G-1; a diabase, W-1; an andesite porphyry, 24A; and a potassium basalt, 25 KB. The average trace-element content of the "Turkey Track" as determined in this investigation is compared with G-1 and W-1 in table I.

The composition of the "Turkey Track" while somewhat unusual is not unrelated to the associated volcanic rocks. Most middle Tertiary "basalts" in southern Arizona that are even more widespread than the "Turkey Track" have many of the same chemical peculiarities. For example, both of these rock types have a high potassium content and a composition similar to a doreite, with the "Turkey Track" being more felsic than the "basalts." Furthermore, the "Turkey Track" commonly forms the base of the volcanic sequence. Consequently, the stratigraphic relationships, similar radiochemical and chemical composition, and similar mineralogy all tend to support the suggestion that the "basalts" and the "Turkey Track" originated in one magma chamber or source area.

Within the magma chamber gravitational differentiation could have

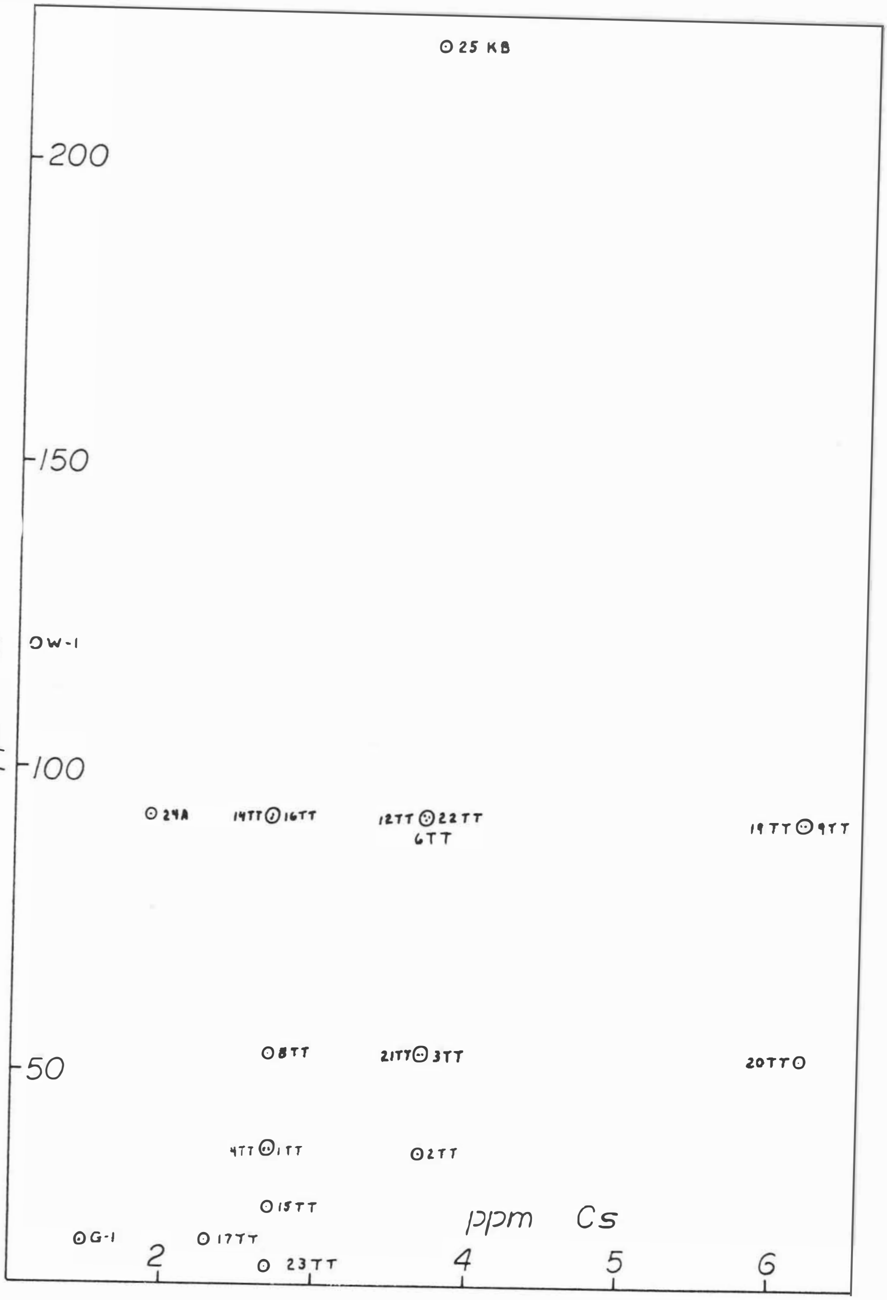

Figure 2. --Cesium versus chromium content.

TABLE I
COMPARISON OF TRACE-ELEMENT CONTENT

(Values are in parts per million unless otherwise noted. The average for the "Turkey Track" represents 19 analyses of samples from separate localities.)

Element	G-1	W-1	"Turkey Track" average
Ba	1,220	225	1,500
Cs	1.5	1.08	3.7
K (percent)	4.51	.56	2.52
Na (percent)	2.46	1.54	2.6
Ga	18	16	14
Mg (percent)	.24	3.96	1.6
Co	2.2	120	28
Ni	2.1	82	30
Sc	4	43	18
Mn	210	1,300	500
Cu	13	110	42
Cr	22	120	60
Ti	1,400	7,400	8,100
V	21	240	300
Th	52	2.4	19
U	3.7	.52	3.3

created a less dense more felsic fraction of "Turkey Track" composition in the upper portions of the chamber. This material would have been tapped off first followed by the more basaltic fraction. Within the "Turkey Track" slight differentiation is suggested by the mineralogy. Cooper (1961) suggests that the slightly more mafic "Turkey Track" localities represent an original magma from which, by crystal settling in the magma chamber, the more felsic varieties could form.

Although the "Turkey Track" localities appear to be from the same parent, they probably do not represent one eruption from one vent. Rather, they may represent a series of eruptions from several vents or intrusions into several areas, all within the span of a few million years. Evidence for this comes from Damon and Bikerman (this publication), who show that a great number of volcanic and plutonic rocks in southern Arizona formed around the Paleogene-Neogene boundary, 25-30 million years ago. If most middle Tertiary "basalts" in this area formed within this time interval, the "Turkey Track" is even more restricted in time, as it is found near the base of the sequence.

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KEY TO FIGURE 1

A = andesite, B = basalt, KB = potassium basalt, R = rhyolite, T = tuff, QL = quartz latite, TT = probable "Turkey Track." Numbers 1-32 refer to data from this investigation, 35-69 refer to Taylor's data, 70-89 refer to Bikerman's data, 90-126 refer to Halva's data.

Reference Number	Location	Sample Number
1 TT	Hill southwest of San Xavier Mission	JEM 1 63
2 TT	San Xavier Mission	JEM 2 63
3 TT	San Xavier Mission	B 42 60
4 TT	Black Mountain	B 41 60
5 TT	Pima district	RM 2 64
6 TT	Cienega Gap	JEM 3 63
7 TT	Davidson Canyon at Cienega Creek	JEM 11 63
8 TT	Davidson Canyon at Benson Highway	B 50 60
9 TT	Mineta Ridge	JEM 4 63
10 TT	Mineta Ridge	JEM 5 63
11 TT	Mineta Ridge	JEM 6 63
12 TT	Mineta Ridge	JEM 7 63
13 TT	Saguaro National Monument	JEM 10 64
14 TT	Saguaro National Monument	JEM 11 64
15 TT	Tumamoc Hill	CJH 1 2B
16 TT	Sentinel Peak	PED 16 63
17 TT	Desert Museum	PED 2 64
18 TT	Desert Museum	B 55 61
19 TT	Dos Cabezas Mountains	JEM 6 64
20 TT	Dos Cabezas Mountains	JEM 7 64
21 TT	Fisher Hills	JEM 8 64
22 TT	Kelsey Canyon	JEM 9 64
23 TT	Happy Valley quadrangle	JEM 12 64
24 A	Sawtooth Mountains	B 49 60

Reference Number	Location	Sample Number
25 B	San Bernardino	B 53 60
26 R	Desert Museum	JEM 8 63
31 A	Empire Mountains	JEM 13 64
35 B	Atascosa Mountains basalt 1 bottom	
36 B	Atascosa Mountains basalt 2 bottom	
37 B	Atascosa Mountains basalt 3 bottom	
38 B	Atascosa Mountains basalt 1 top	
39 B	Atascosa Mountains basalt 2 top	
40 B	Atascosa Mountains basalt 3 top	
41 B	Santa Rita Mountains basalt	
42 KB	Tucson Mountains basalt composite	
43 KB	Tucson Mountains basalt top	
44 A	Atascosa Mountains upper andesite	
45 A	Sycamore andesite	
46 A	Santa Rita Mountains upper andesite	
47 A	Shorts Ranch andesite	
48 R	Sycamore spherulitic rhyolite	
49 QL	Quartz latite porphyry	
50 R	Biotite rhyolite	
51 T	Atascosa Mountains tuff	
52 T	Santa Rita Mountains tuff	
53 T	Safford tuff	
54 R	Montana Pk. formation 1 bottom	
55 R	Montana Pk. formation 2 bottom	
56 R	Montana Pk. formation 3 bottom	
57 R	Montana Pk. formation 1 top	
58 R	Montana Pk. formation 2 top	
59 R	Montana Pk. formation 3 top	
60 R	Santa Rita Mountains rhyolite	
61 R	Mustang Mountains rhyolite	
62 R	Cat Mountain rhyolite	
63 A	Ruby Road formation	
64 A	Santa Rita Mountains older andesite	
65 QL	Santa Rita Mountains older latite	
66 A	Tucson Mountains older andesite	
67 R	Pajarito lavas	
68 A	Santa Rita Mountains Cret. andesite	
69 A	Tucson Mountains Cret. andesite	
70 R	Ajo Way section	27-J-1
71 R	Ajo Way section	27-J-3
72 R	Ajo Way section	27-J-15
73 R	Ajo Way section	25-S-6
74 R	Ajo Way section	2-0-5a
75 R	Ajo Way section	2-0-6a
76 R	Cat Mountain section	10-F-2
77 R	Cat Mountain section	10-F-6a
78 R	Cat Mountain section	10-F-10
79 R	Bren Mountain section	15-N-T
80 R	Bren Mountain section	15-N-8
81 R	Bren Mountain section	15-N-14
82 R	East of Cat Mountain	2-N-2
83 R	Near Sweetwater Drive	18-J-2
84 R	Near Sweetwater Drive	18-J-4

Reference Number	Location	Sample Number
85 R	Twin Hills section	17-M-1
86 R	Twin Hills section	17-M-3
87 T	Twin Hills, Safford tuff	17-M-6a
88 T	Twin Hills, Safford tuff	17-M-7
89 R	Gates Pass	3-J-1
90 A	Sasco andesite	
91 KB	Sasco basalt	
92 A	Sawtooth andesite	
93 A	Sawtooth andesite	
94 A	Sawtooth andesite	
95 KB	Picacho intrusive	
96 KB	Tombstone basalt	
97 KB	Tombstone basalt	
98 KB	Sawtooth basalt	
99 A	Tortolita andesite	
100 KB	Tortolita basalt	
101 KB	Galiuro basalt	
102 KB	Black Mesa Top flow	
103 KB	Black Mesa Fifth flow	
104 KB	Black Mesa Fourth flow	
105 KB	Black Mesa Third flow	
106 KB	Black Mesa Second flow	
107 A	Tumamoc andesite	
108 T	Tumamoc tuff no. 1	
109 T	Tumamoc tuff no. 2	
110 T	Tumamoc tuff no. 3	
111 KB	Tumamoc basalt Top flow	
112 KB	Tumamoc basalt Fourth flow	
113 KB	Tumamoc basalt Third flow	
114 KB	Tumamoc basalt Intrusive 2	
115 KB	Tumamoc basalt Intrusive 1	
116 KB	White Mountains basalt no. 1	
117 KB	White Mountains basalt no. 2	
118 KB	White Mountains basalt no. 3	
119 KB	White Mountains basalt no. 4	
120 KB	Mineta basalt	
121 KB	Reddington basalt	
122 KB	San Bernardino basalt no. 1	
123 KB	San Bernardino basalt no. 2	
124 KB	San Bernardino basalt no. 3	
125 B	Carrizo basalt	
126 KB	Catalina Wash no. 1	

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