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PARTICLE TRACK MEASUREMENTS IN LUNAR REGOLITH BRECCIAS. George E. Blanford, University of Houston - Clear Lake, Houston, TX 77058.

The Regolith Breccia Initiative and the recent publication of the Regolith Breccia Workbook (1) make it a particularly appropriate time to review the published track data on lunar regolith breccias. These data are summarized in Table 1.

Particle track measurements have been reported for only 25 (5%) of the regolith breccias in the collection; they have been reported for 16 breccias (30%) of the reference suite (1). No measurements were found in published papers for any Apollo 17 breccias. Unfortunately, many of the track measurements in lunar breccias were made before it was realized what parameters were relevant to measure. The earliest papers emphasized surface exposure ages. Later, when it was understood that regolith breccias retained tracks from the epoch prior to compaction, reports of high track density grains were emphasized. It is not clear from most papers that track density frequency distributions are determined from a random sampling of grains; the earliest papers seem to have immature track density frequency distributions and later papers seem to have mature track density frequency distributions (cf. 10046).

The most frequently reported measurement for the 25 breccias in Table 1 is the maximum surface exposure age of the compacted rock (48% of the published breccia measurements). Information on the nature of the precompaction regolith is given for 9 rocks (36%) and on the nature of the compaction event for 6 rocks (24%).

Realizing that the breccias listed in Table 1 are not likely to be a random sampling of the collection, some general features are nevertheless worth noting. Most of the breccias appear to have simple post-compaction surface exposure histories (89 %). From the few track density frequency distributions (7) that are available and inferring from the relatively low exposure ages of these rocks (75% $\lesssim 10^6$ a), it appears that most of these breccias are very amenable to studies which separate the contemporary surface exposure age from information about the precompaction regolith. Therefore, it is regrettable that regolith breccias seem to have been systematically avoided for the later Apollo missions because of their supposedly complex irradiation histories. If the number of immature-submature precompaction soils (6 out of 10 of the breccias for which appropriate data are available) is representative of many regolith breccias, then we can infer that many regolith breccias may sample the deeper, less reworked materials in the lunar soil and compliment the samples available from the returned cores. The relative immaturity of the precompaction soil is an observation which is consistent with models of regolith breccia formation by subsurface impact compaction. The fact that regolith breccias are more friable than crystalline rocks and metamorphosed breccias

Table 1

Particle Track Measurements in Lunar Regolith Breccias

SAMPLE	EXPOSURE HISTORY†	ORIGINALLY REPORTED DATA: MAXIMUM SURFACE EXPOSURE AGE (a)	METHOD¶	MATERIAL	MAXIMUM SURFACE EXPOSURE AGE** (a)	COMMENTS
10046*	SS		SP	Glass? (h)	1.3×10^6	Immature based on the number of low track density grains (g) Mature track density frequency distribution (k)
10059						Mature track density frequency distribution (k)
12034*			SP	? (j)	2.1×10^7	
14047*	SS	3.4×10^6 (s)	SP	?	1.0×10^6	
14049*	SS					Mature track density frequency distribution (k)
14055*	SS	5×10^4 (s)	SP	?	8×10^4	
14267						Submature track density frequency distribution (k)
14301*	SS	3.4×10^5 (s)	SP	Plagioclase	2.4×10^5	Immature track density frequency distribution (s,x)
		8×10^6 (d)	SD	Plagioclase equivalent?	1.8×10^7	Submature based on % track rich grains (v)
14307*	SS	5×10^6 (y)	SP	Pyroxene	1.4×10^5¶¶	
14315*	MS			Plagioclase		Shock altered, immature based on % track rich grains (v)
14318*	MS			Plagioclase		Shock altered, immature based on % track rich grains (v)
15015*	SS	13 (z)	G	Pyroxene, Glass	35 ± 30	
15086*	SS			Plagioclase		> 90% track rich grains, mature track density frequency distribution (r,x)
15205*	SS	8×10^4 (t)	G	Pyroxene, Glass	$2.2 \pm 1.8 \times 10^5$	Calculated using originally published correction factors
15265*	SS	1×10^6 (c)	ST	?	5×10^5	
15418?						High shock metamorphism (v) Metamorphosed or immature? (x)
15426	SS	5×10^5 (o)	SP	Glass	1.4×10^5	Immature track density frequency distribution (o)
		1.5×10^7 (c)	SD	?	4.3×10^7	

15459		1.0-3.0 x 10^7 (e)	SD	Corrected to Plagioclase	††	
15505*	SS	6 x 10^5 (n)	SP	Pyroxene	3.5 x 10^5	
60255*	SS			Plagioclase		Track annealing characteristics used to comment on thermal history (x)
61175*	SS	2 x 10^7 (p)	SP	Plagioclase	4.4 x 10^7	
66055?						Metamorphosed or immature? (x)
67015						Metamorphosed or immature? (x)
67016		1.5 x 10^7 (u)	G (w)	Plagioclase	5 x 10^5	Mistakenly reported in (u) as 67015
68815	SS		G	Plagioclase	2.4 ± 0.3 x 10^6	Used to obtain a track production curve by (l,aa,bb)

* Reference suite (l).

† SS - single stage, i.e., only one surface is heavily cratered.

MS - multi-stage, i.e., heavy cratering on more than one surface.

¶ SP - A single point measurement using one of three versions of the track production curve determined from the surveyor glass filter (cf. a,i,m,q).

G - A measured track gradient with depth was determined and used with one of the surveyor references given above.

SD, ST - Subdecimeter and Suntan ages - using models and differential energy spectrum reported by (b). Depths are arbitrarily taken at 1 mm for ST ages and 3 cm for SD ages (d).

** Recalculated using the track production profile of (f). Cf. (cc) for a review of the measured lunar track production profiles. Rock densities were taken to be 2.8 g/cm^3. It was assumed that tracks were counted on surfaces perpendicular to the rock surface with an infinite flat surface geometry; these two conditions insure maximum ages. No corrections were made for etchable range or etching efficiencies with respect to plagioclase in which the track production curve was measured. For the SP and G methods the minimum track density model was used [cf. e.g. (h)]. ST and SD ages assume depths of 1 mm and 3 cm, respectively.

†† Insufficient published data to recalculate an age.

¶¶ Published data were incomplete, but a reasonable back calculation appeared to be possible.

a) Barber, et al. (1971) PLSC2, 2705-2714.
b) Bhandari, et al. (1971) PLSC2, 2611-2619.
c) Bhandari, et al. (1972) Apollo 15 Samples, 336-341.
d) Bhandari, et al. (1972) PLSC3, 2811-2829.
e) Bhattacharya, et al. (1975) PLSC6, 3509-3526.
f) Blanford, et al. (1975) PLSC6, 3557-3576.
g) Borg, et al. (1971) PLSC2, 2027-2040.
h) Crozaz, et al. (1970) PLSCA11, 2051-2080.
i) Crozaz and Walker (1971) Science 171, 1237-1239.
j) Crozaz, et al. (1971) PLSC2, 2543-2558.
k) Dran, et al. (1972) PLSC3, 2883-2903.
l) Dust and Crozaz (1977) PLSC8, 2315-2319.
m) Fleischer, et al. (1971) Science 171, 1240-1241.
n) Fleischer, et al. (1973) PLSC4, 2307-2317.
o) Fleischer and Hart (1973) EPSL 18, 357-364.
p) Fleischer and Hart (1974) JGR 79, 766-769.
q) Fleischer, et al. (1975) Nuclear Tracks in Solids, Univ. California Press, Berkeley.
r) Goswami, et al. (1976) PLSC7, 543-562.
s) Hart, et al. (1972) PLSC3, 2831-2844.
t) Hartung and Storzer (1974), PLSC5, 2527-2541.
u) Horz, et al. (1975) PLSC6, 3495-3508.
v) Hutcheon, et al. (1972), PLSC3, 2845-2865.
w) Lal (1977) Phil. Trans. R. Soc. London A 285, 69-95.
x) Macdougall, et al. (1973) PLSC4, 2319-2336.
y) Poupeau, et al. (1972) Apollo 15 Samples, 385-387.
z) Schneider, et al. (1972) Apollo 15 Samples, 415-419.
aa) Walker and Yuhas (1973) PLSC4, 2379-2389.
bb) Yuhas (1974) Ph.D. Thesis, Washington Univ., St. Louis.
cc) Zinner (1980) P.C. Ancient Sun, 201-226.