

COSMIC RAY EXPOSURE AGES OF APOLLO 17 SAMPLES AND IMPLICATIONS FOR THE AGE OF TYCHO; R. Arvidson, R. Drozd, E. Guinness, C. Hohenberg, C. Morgan, R. Morrison<sup>1</sup>, and V. Oberbeck<sup>2</sup>, McDonnell Center for the Space Sciences, Washington University, St. Louis, Mo., (1) LFE Corporation, Richmond, Calif., (2) Ames Research Center, Moffett Field, Calif.

A number of authors have proposed that the Central Cluster craters and craters atop South Massif at the Apollo 17 landing site are secondary craters formed by impact of ejecta from the crater Tycho (1)(2)(3). This interpretation is based on similarities in morphology and overall geometry with secondary crater clusters that occur along well-defined rays from Tycho. We have conducted a detailed examination of twenty crater clusters along six well-defined Tycho rays. Within many clusters two distinct units can be defined: (a) An uprange zone characterized by a high density of smaller, well developed craters, and (b) A downrange zone, characterized by larger subdued craters and numerous V-shaped grooves. The downrange effects are presumably related to the debris surge generated by the secondary cratering (3). Our measurements of the twenty clusters indicate that bisectors of well-developed V-shaped grooves lie, within the precision of the measurements, along great circle arcs through the center of Tycho.

Orientations of four V-shaped grooves on Central Cluster (Figure 1) range from S59°W to S53°W (+2°), with a vector mean of S56.5°W (+1°). The great circle arc from Tycho is oriented at S56°W. In addition, orientations of nine V-shaped grooves on the landslide range from S57°W to S53°W (+2°), with a vector mean of S56.2°W (+0.7°). These data lead us to also favor the hypothesis that the Central Cluster craters, the crater cluster atop South Massif, and the landslide are related to impact of ejecta from Tycho.

Cosmic ray exposure ages for rocks and soils collected from stations near or on the landslide and Central Cluster provide constraints on the age of emplacement of these features and thus perhaps on the age of Tycho. The crater Shorty (station 4), which penetrated the slide, seems to be ~ 30 m.y. (4), constraining the age of Tycho to  $\gtrsim$  30 m.y. Analyses of samples collected from the station 2 boulders indicate that the boulders rolled or bounded downhill 45 to 55 m.y. ago, presumably on top of the pre-existing landslide. Tycho's age thus seems to be constrained by this to be  $\gtrsim$  50 m.y.

In Table 1 we list available rare gas exposure data for rock samples collected from stations 0 (LM) and 1, and for station 2 samples not associated with the boulders. Exposure ages for all these samples cluster near 100 m.y., suggesting a large-scale event at that time. The  $^{131}\text{Xe}/^{126}\text{Xe}$  ratio in the spallation-produced Xenon is about 4 for most of these samples, which is consistent with surface irradiation for 100 m.y. Although the apparent clustering of  $^{81}\text{Kr}$ -Kr exposure ages provides the bulk of the evidence for a site-wide event 100 m.y. ago, such an interpretation is corroborated from other sources. It has been suggested, from neutron fluence data, that the meter-thick coarse-grained layer within the Apollo 17 deep drill core (collected near LM) was emplaced as a unit 100 to 200 m.y. ago (5). Modeling of the argon data derived from the coarse-grained layer suggests deposition as a unit ~ 90 m.y. ago (6).

To summarize, most age data point to a ~ 100 m.y. age for the Central Cluster and for the landslide below South Massif. Photogeologic evidence sug-

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gests that the features are related to the impact of ejecta from Tycho, implying that Tycho is also ~ 100 m.y. old. Delineating a firm age for Tycho is of considerable importance, since it provides our only real hope for empirically deriving an impact flux for meter-sized and larger bodies during recent geologic time. However, further age data from stations 0, 1, and 2 are needed before this age can be accepted with certainty. The relationship between the crater Camelot and the Central Cluster needs to be further explored. In this context we note that rare gas exposure ages of rocks collected at station 5 (Camelot) range between 70 and 140 m.y. (4), perhaps suggesting that Camelot is part of Central Cluster. In addition, the origin and age of emplacement of the coarse-grained layer in the Apollo 17 deep drill core needs to be understood. From its location, this layer would appear to be most logically derived from the Central Cluster or, perhaps, from Camelot. Our initial track age of 10 m.y. (7) is incompatible with the scenario described above. However, as described in another abstract (8) it appears that the deep drill material was probably grossly disturbed in sampling or handling, leading to underestimates of our previously reported emplacement age.

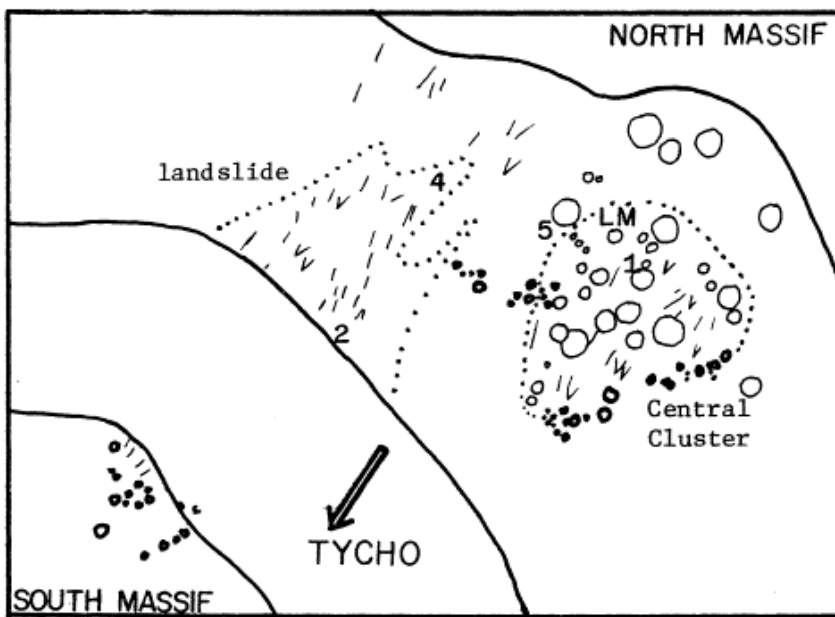
- (1) Muehlberger et. al., 1973, Apollo 17 Prel. Sci. Report, NASA Sp.-330, 6-1 to 6-91.
- (2) Howard, 1973, Science, v. 180, 1052-1055.
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- (4) Arvidson, et. al., 1975, The Moon, v. 13, 259-276.
- (5) Curtis and Wasserburg 1975, The Moon, v. 13, 185-227.
- (6) Dragon, et. al., 1975, Proc. 6th Lunar Sci. Conf., 196-198.
- (7) Crozaz, et. al., 1974, Proc. 5th Lunar Sci. Conf., 2475-2499.
- (8) Crozaz, et. al., 1976, Abstracts, 7th Lunar Sci. Conf.
- (9) Marti, personal communication.
- (10) Kirsten and Horn, 1974, Proc. 5th Lunar Sci. Conf., 1451-1475.
- (11) Morgan, 1975, Ph.D. Thesis, Washington University.

TABLE 1

SAMPLE	AGE(m.y.)	METHOD	REF
70030, LM	116	$^{81}\text{Kr-Kr}$	(9)
70135, LM (Geophone rock)	106	$^{81}\text{Kr-Kr}$	(11)
70215, LM	100	Ar	(10)
71055, STATION 1	110	$^{81}\text{Kr-Kr}$	(11)
72535	107	$^{81}\text{Kr-Kr}$	(11)

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**Figure 1:** Schematic illustration of Central Cluster and the landslide at Apollo 17. LM refers to the landing site, and the other numbers indicate stations discussed in text. The Central Cluster and the landslide complex can be divided into 2 morphologies: a high density of small craters nearest Tycho, and furthest from Tycho, a subdued topography cut by numerous V-shaped grooves. For scale, the crater (Camelot) to the upper right of station 5 is 700 m. in diameter. Sketched from Apollo 17 pan frame 2309.