LUNAR PROSPECTOR DATA IMPLY AN AGE OF 4.1 GA FOR THE NECTARIS BASIN, AND OTHER PROBLEMS WITH THE LUNAR "CATACLYSM" HYPOTHESIS P. H. Warren, Institute of Geophysics, UCLA, Los Angeles CA 90095-1567, USA (pwarren@ucla.edu).

Lunar polymict impactite samples have yielded ages that are remarkably clustered near 3.9 Ga, especially for impact melt breccias. This curiously unimodal age spectrum represents one of the most profound discoveries of planetary sample research. It clearly indicates that the rate of cratering (i.e., collisions between the Moon and asteroids and comets) was vastly higher ~3.9 billion years ago than it has been over the last 85% of solar system history. The bombardment history before 3.9 Ga has been most controversial. The relative scarcity of ages >3.9 Ga has led many, in recent years most notably Ryder [e.g., 1,2] to infer a spike in the global lunar cratering rate at ~3.9 Ga. Following Tera et al. [3], this cratering spike concept is somewhat confusingly known as the lunar "cataclysm" hypothesis. A broader, generally accepted hypothesis known as "late heavy bombardment" simply postulates vastly higher, more destructive lunar cratering at ~3.9 Ga, without regard to the spike question. The controversy concerns the degree to which the clustered ~3.9 Ga ages reflect a large-factor and global spike, as opposed to a bump or inflection on a basically monotonic decline in the late-accretionary impact rate.

A key datum in this debate is the inferred age of the Nectaris basin. On photogeologic-stratigraphic grounds, Nectaris is clearly older than Imbrium and Serenitatis; and two-thirds (30 out of 44) of the Moon's still recognizable basins appear even older than Nectaris [4]. Impact melt breccias of Nectaris origin are presumably present among the Apollo 16 samples, acquired ~550 km from the center of Nectaris. Ar ages for Apollo 16 impact melt breccias mostly cluster from 3.87-3.92 Ga, and 3.90-3.92 Ga has become almost canonical as the age of Nectaris [e.g., 4,5]. But as Korotev et al. [6] have noted, the absolute age of Nectaris is unclear.

Lunar Prospector results [e.g., 7,8] indicate a remarkable global-scale heterogeneityin the the concentrations of incompatible elements; these elements are much lower in the broad region of Nectaris,SE of the Apollo 16 site, than in the regions to the N and W where the other basins that potentially contributed impact melt breccias to the Apollo 16 megaregolith. It is instructive, therefore, to compare the ages of Apollo 16 impact melts vs. their contents of incompatible elements. Fig. 1 shows such a comparison, using the frequently determined element K. The data are far from random. The impact melts with low K (filled symbols: K < 430 μg/g) that are most plausibly linked with Nectaris tend to be close to 4.1 Ga. This distribution severely militates against the common interpretation [e.g., 2] that the age of Nectaris is ~3.90 Ga.

The ages of the Imbrium and Serenitatis basins are probably 3.85-3.9 Ga [e.g., 2]. The age of a fourth lunar basin, Crisium, can in principle be constrained using Luna 20 samples. On photogeologic-stratigraphic grounds, Crisium appears similar in age to Serenitatis, i.e., older than Imbrium but younger than Nectaris [4]. Cohen et al. [9] obtained Ar ages for six Luna 20 rocklets and reviewed literature data for 12 others. Swindle et al. [10] found a loose clustering of ages at 3.75-3.90 Ga. Swindle et al. [10] suggested (in a "tentative" way) that the oldest sample in this cluster, 3.895±0.017 Ga, might date the Crisium impact. However, it is not even clear the sample in question is an impact melt breccia (no thin section was made). Also, among the samples dated by Cohen et al. [9], most are in this author's opinion probably either impact melt breccias or annealed impact melt breccias (genuine, pristine "gabbros" seldom have grain sizes of <200 μm like rocklet 2004D; pristine troctolites seldom have grain sizes of <100 μm like rocklet 2004C). Considering all of the 13 or so Luna 20 rocklets that have yielded Ar ages (review: [9]) and are likely impact melt breccias, the data (excluding the 0.52 Ga outlier) show an almost even distribution across the range 3.75-4.19 Ga. In other words, the age of the Crisium impact is not yet constrained beyond being probably within the range 3.8-4.2 Ga. For these and other reasons, the validity of the lunar cataclysm hypothesis remains very much in question.

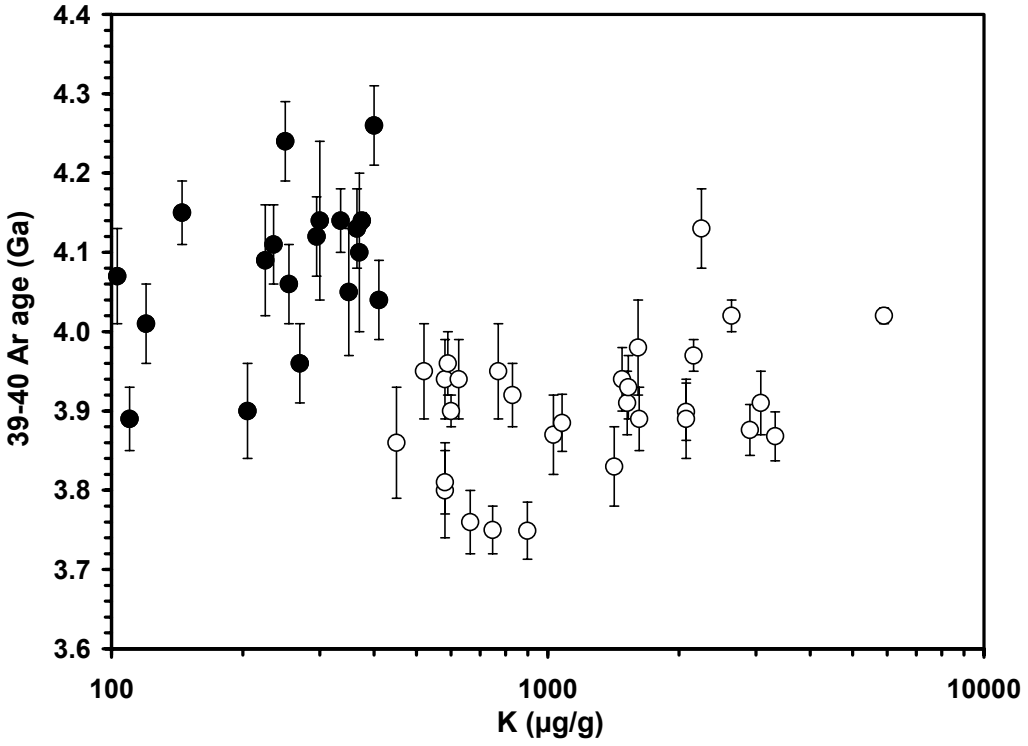

Fig. 1. Bulk-rock potassium vs. ^{39}Ar-^{40}Ar age for 50 Apollo 16 impact melt breccias. Literature data were taken from a variety of sources, most notably Dalrymple et al. [5], and other sources compiled by James [11]. Filled symbols: K < 430 µg/g.

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