AGE AND EXTENT OF SMALL, YOUNG VOLCANIC ACTIVITY ON THE MOON. S. E. Braden[1], M. S. Robinson[1], J. D. Stopar[1], C. H. van der Bogert[2], B. R. Hawke[3]. [1]School of Earth & Space Exploration, Arizona State University, Tempe, AZ 85287; (sebraden@asu.edu), [3]SOEST, University of Hawaii, Honolulu, HI 96822; [2]Institut für Planetologie, Westfälische Wilhelms- Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany

Introduction: Small, young volcanic features found throughout the lunar maria [1-3] have units and morphologies similar to those found at Ina, the most well-known example [1,2,4-9]. With Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) images at 0.5-1 meters per pixel, we have identified >50 Ina-style features, including 27 listed by [3] located between 10°S to 40°N and 310°E to 45°E (**Figure 1**). These formations are either continuous areas of smooth and rough units (largest examples are 3-5 km across) or clusters of small rough units (most are ~10-200 m across). Each feature exhibits sharp morphology and few superposed impact craters with diameters (D) >10 m, suggesting a relatively young age. Extending the work of [9], small area crater counts on a subset of these newly mapped Ina-style formations constrain the ages of these features relative to the lunar maria, and determine the range of ages across the population.

Feature	Lat [°]	Lon[°]	NACs	Inc.	Scale*
Sosigenes feature	8.335	19.071	M192824968, M192832116	70	1.2
Ina	18.650	5.300	M113921307	58	0.5
Cauchy feature	7.169	37.592	M1108039362	63	1.2
Tranq. 1	8.891	21.487	M177494593R	70	0.5
Tranq. 2	8.298	21.600	M1108139411	65	1.2

Table 1. *List of features with latitude, longitude, NAC images used, incidence angle, and *image scale in meters/pixel.*

Method: LROC NAC image data (**Table 1**) were processed using Integrated Software for Imagers and Spectrometers (ISIS) [10] and imported into ArcGIS. The smooth (usually topographically higher) and rough (usually topographically lower) units within each Ina-style formation were mapped. Craters on each unit and the surrounding mare were digitized using ArcGIS CraterTools [11]. The measured crater size frequency distrbutions (CSFDs) were plotted with CraterStats2 [12]. Absolute model ages (AMAs) are based on the chronology function and production function of [13] for lunar craters 0.01<D<100 km. AMAs were derived only for craters with D ≥0.01 km, although the NAC resolution allows the measurement of smaller craters.

Observations and Discussion: The AMAs of the smooth units for Ina (area=1.7 km^2), the Sosigenes feature (area=4.5 km^2), and the Cauchy feature (area= 1.3 km^2) are ~33, ~18, and ~58 Ma, respectively (**Figure 2**). These model ages indicate that the volcanic features are younger than the surrounding maria, but not as young as 10 Ma, the suggested maximum age for Ina based on morphology and a single crater in [6]. There are no detected dependencies on incidence angle, which can affect crater count densities [14,15]. Two Ina-style formations in Mare Tranquillitatis cover ≤0.2 km^2 and do not contain enough craters to create meaningful CSFDs. On each of the three smooth units the number of craters with D ≥0.01 km is small, ~230-290 craters. Each unit has different crater densities for craters D ≥10 m, but not for D ≥50 m. Given that all the craters available to count have diameters that depend on strength-scaling, rather than gravity-scaling,

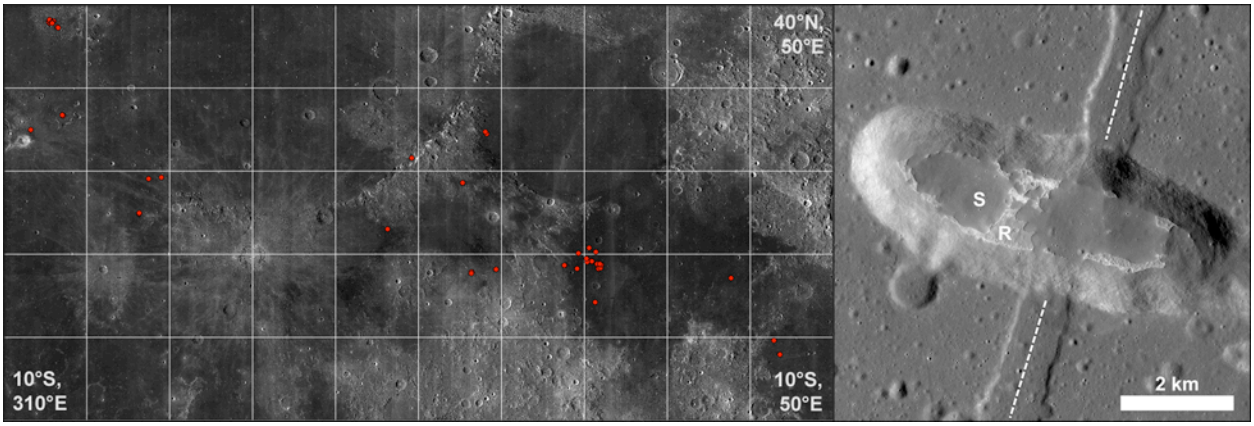

Figure 1. *(left) Extent of >50 young, small Ina-style volcanic features. Each red dot represents either a single feature, or a cluster of small features. Basemap is the LROC WAC 100 m/pixel mosaic. (right) The depression containing the Sosigenes feature crosscuts a smaller northeast-trending graben (dotted white line). "S" and "R" mark examples of the smooth and rough units.*

the AMAs presented here are more uncertain than if they were based on craters >~1 km [19]. In addition, the sample is small, and the minimum area required to accurately date a surface is not well constrained. Thus, the different apparent AMAs should not be interpreted as distinct ages, but rather a range of minimum ages.

Another approach to estimate the upper bound on the ages of these features is to make comparisons with the onset diameters of equilibrium [16,17] for surfaces with constrained ages. No clear equilibrium population is visible within the smooth unit CSFDs measured. In contrast, small crater counts of Tycho ejecta (area=1.65 km^2) give an AMA of ~85 Ma and show equilibrium populations at crater diameters of <12 m, while CSFDs of the older Copernicus ejecta blanket (area=121 km^2) give an AMA of ~797 Ma and are in equilibrium at D <70 m [18]. Because the CSFDs measured for the Ina-style features are still in production, rather than equilibrium, an upper bound on the age of the Ina-style smooth units is ~100 Ma. For comparison with a much older surface the CSFD for Mare Tranquillitatis near the Sosigenes feature is in equilibrium at D <290 m (AMA ~3.5 Ga).

The young model ages are also consistent with stratigraphic relations at the Sosigenes feature. The east-west oriented depression cross-cuts an older graben, which itself cross-cuts the mare. The smooth, lobate unit within the Sosigenes feature shows no signs of tectonic activity and must be younger than both the surrounding mare and the north-south trending graben (**Figure 1**).

The apparent AMAs from the rough units of Ina (total area 2.2 km^2), the Sosigenes feature (total area 1.1 km^2) and the Cauchy feature (total area 0.9 km^2) were ~4, ~3.5, and ~28 Ma, respectively. The number of total craters on each unit is small, from ~15-60 craters. While the rough units have fewer craters per unit area compared to the smooth units, for craters with D >20-25 m the rough and smooth unit CSFDs overlap. The deficiency of <20-25 m craters suggests a difference in crater retention between the smooth and rough units, possibly due to varying target properties (higher slopes in the rough unit) and/or effects of the local regolith thickness or layering [19,20]. If this interpretation is correct, then the rough units are likely the same age as the smooth units, as suggested by [8].

Conclusions: 1. Many newly discovered Ina-style volcanic features demonstrate their widespread occurrence and provide opportunities for quantitative study. 2. Crater counts of smooth units at three locations give apparent AMAs ranging from 18-58 Ma, which are interpreted as a range of minimum ages, consistent with the sharp morphologic boundaries between the smooth and rough units. 3. Comparisons with small crater equilibrium populations for Tycho and Copernicus ejecta blankets suggest that the smooth units are younger than ~100 Ma. 4. While the rough units have fewer craters per unit area compared to the smooth units, the CSFDs overlap at crater diameters >20-25 m, which indicates a difference in target properties and not age. 5. Stratigraphic relationships at the Sosigenes feature imply that the smooth unit is younger than the mare.

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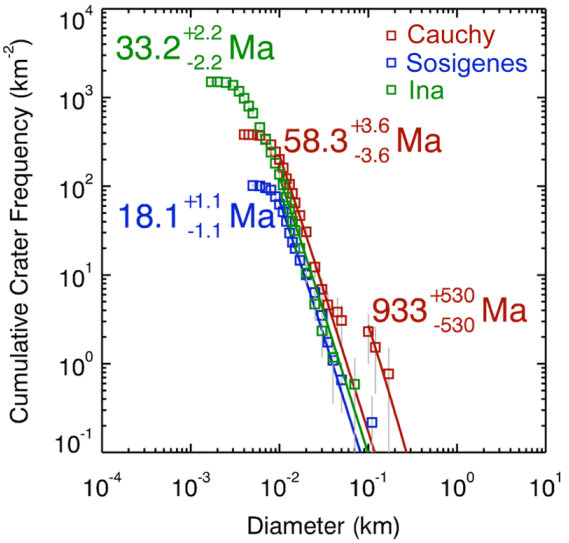

Figure 2. *CSFDs from crater counts on the smooth units within the Cauchy, Sosigenes, and Ina formations give a range of apparent AMAs from 18-58 Ma. Three D>100 m craters give an older model age, however these craters are highly degraded and may have formed before the formation of the Cauchy feature. Statistical error bars shown in gray.*