QUANTITATIVE EFFECTS OF SUN ANGLE VARIATIONS ON CRATER DIAMETER MEASUREMENTS AND LUNAR MARE AGE DETERMINATIONS. R. A. Young, Department of Geological Sciences, SUNY, Geneseo, N.Y. 14454.

Mare ages based on crater measurements often produced conflicting relative age determinations until their refinement by Soderblom and Lebofsky (1), recently reviewed by Moore et al. (2). However, this widely used method normally requires that relatively large areas be used and that care be taken to "map" areas where units of two or more ages are present (2). This necessitates recognition of subtle boundaries prior to analysis. The method has resulted in a great deal of useful age comparison information on the terrestrial planets, within the limitations (2) of the technique. However, many crater distributions in the diameter range from 100-600m may provide significant data on surface or subsurface geology when detailed crater size-frequency plots are available (3,4,5). The successful application of the several different crater analysis techniques in the literature requires that all the various methods produce compatible surface ages, and that any anomalous size-frequency variations near the equilibrium limit be understood (3). The value of detailed crater studies has been demonstrated by the evidence they have provided for lunar volcanism extending to 1.5 AE (5) and 1.0 AE (6) and the implications these young ages have for models of lunar thermal evolution. Mare stratigraphy is another subject which may be advanced by a better understanding of the subtle variations in crater distributions (7).

Young (4) reported on sun angle measurement effects for 100-600m craters that were subsequently investigated by others (3,8). Schultz et al. (3) did not find the effect in craters smaller than 100m, but the results of Boyce and Dial (8), based on a small number of named Apollo site craters, did show that monoscopic diameter measurement discrepancies of nearly 20% do occur.

Continued attempts to quantify monoscopic measurement effects have concentrated on the following:

1) Obtaining individual monoscopic crater diameter measurements on groups of 100 randomly selected, numbered craters on Apollo 2x panoramic photographs by groups of three individuals using the Zeiss Particle Size Analyzer.
2) Comparing the crater diameter variations for each individual crater made by the above method for surfaces photographed at two or more sun angles ranging from 4° to 52° (above the horizon).
3) Photographing a model crater at 5° sun angle increments from 0° to 55° for progressive stages of crater degradation.

Results of these studies show that:

1) There is a significant monoscopic sun angle measurement effect that is predictable in the range of angles from 0° to about 30° but is difficult to define as shadows become less sharp at higher sun angles. Example: A 450m diameter crater can show an apparent diameter decrease of 25% for a sun angle increase of 30° at panoramic photo scales.
2) The sun angle effect disappears at diameters smaller than 180-200m for typical mare surfaces (>3BY), because the majority of these craters have suffered nearly complete rim degradation, as verified by simple stereographic inspection. These observations imply a close relationship between the sun angle effect and the Soderblom erosion model (9) and provide another means of verifying the relative ages of two surfaces. This also explains why Schultz et al. (3) did not encounter the problem in studies of small craters. An adequate sample of craters larger than 500m is not available for a precise determination of the upper limit of any significant sun angle effect. However, much larger craters have proportionately less of their rims eroded by the total postmare impact flux, and their rim crests are generally more obvious, regardless of sun angle differences on photographs.
3) In the 200-600m diameter range, larger mare craters show a proportionately greater apparent diameter change because their rim heights are proportionately less degraded by the postmare flux. In other words, the magnitude of shadow changes is greater as rim magnitude increases. If two craters have a diameter ratio of 1:2, the larger crater has a rim volume nearly eight times greater and thus will produce a proportionately greater apparent sun angle effect for a longer period, since both craters are subjected to the same erosional flux.

4) Laboratory photographic model studies confirm the monoscopic measurement effect and its variation with the degree of crater erosional degradation. The effect is most regular from 0°-25°. At higher sun angles measurements by individuals show increasing scatter as shadows become less distinct and image quality deteriorates. It appears that accurate prediction of the sun angle effect at angles greater than 30° is not practical using either lunar photography or models because of the decreasing ability of individuals to consistently or accurately measure true crater rims. However, this factor may not have caused serious errors in previous studies because the mean values of apparent measured crater diameters at these higher sun angles tend to shift back toward the true diameter, rather than continuing to decrease.

5) This sun angle effect may help explain the anomaly in incremental crater diameter plots observed near the equilibrium limit (3, 4, 5). Larger craters are shifted to smaller apparent diameters (sun effect) so that the smallest interval showing a measurable change is shifted into the next smallest measurement bin containing "smaller" craters not showing a measurable effect. This anomaly is enhanced by an actual increase in crater diameter that may approach 16% as the craters in the equilibrium range are eroded to near the limit of photographic detection. The rate of ballistic transport down crater inner slopes exceeds that down the outer rim slopes, thus gradually displacing the rim-crest position outward.

References:

Figure 1. Results of model studies of sun angle effects. Data averaged for 11 individuals with ranges indicated.