RELATIVE AGES OF LARGE RAYED LUNAR CRATERS - IMPLICATIONS J.A. Grier, A.S. McEwen, P.G. Lucey, R.G. Strom and, M. Milazzo, University of Arizona, Lunar and Planetary Laboratory, 1629 E. University Blvd., Tucson, AZ, 85712.

Introduction: Impacts onto the Earth have had dramatic effects on its biosphere and its surface, but the record of these impacts has been nearly erased by tectonic and weathering processes. To understand the record, we must therefore look to the Moon where a nearly complete record of large cratering events over the past ~ 3 Ga still exists [1]. It has been suggested that large impacts over the last 800 Ma may be preserved in the bright rayed craters found on the lunar surface [2]. Unfortunately the relative ages of these large craters is ambiguous. Certain craters on the Moon have been considered to be "young" because of the presence of "short lived" features such as rays and halos. But some rayed craters are, in fact, much older than the presence of rays around them might suggest. Rays can persist longer if bright highlands material is excavated and deposited onto dark mare. There is some suggestion that the average flux of impactors over the last 1 Ga may have increased slightly [2]. In order to address these and other issues, we are compiling an inventory and analysis of large bright rayed craters on the Moon using the Clementine global mosaic and multispectral color data. As detailed in [3] the relative ages of large craters can be inferred from the spectral estimates of soil maturity, crater and ejecta preservation and morphology, constrained by an absolute age scale provided by craters in the survey which have been radiometrically dated.

Determining Relative Age: The average OMAT profile for each large crater is generated from near- and far-side OMAT mosaics. The profiles clearly fall into three bins based on their relative age. Young - these craters' profiles are characterized by high OMAT values near the rim and very steep dropoffs in OMAT value over a long distance away from the crater. Old - these are craters whose profiles over their ejecta are essentially flat sloped, and indistinguishable from background; their OMAT values at the rim are very low. Intermediate - craters in this bin are in between Young and Old; they have moderate OMAT values at the rim, and their profiles, while somewhat flat, are distinguishable from background some distance away from the crater rim. Profiles for a sample of large craters shows a range of possible values and slopes; clearly the trend is a continuum. The bins suggested above are based on the absolute ages of a few known craters. The radiometric ages known for large craters are listed in Table 1.

Implications:

Tycho and Copernicus: Tycho and Copernicus are approximately the same size, but their OMAT profiles are quite different. Tycho is clearly Young, with a high OMAT value at the crater rim and a steep dropoff in OMAT values as you follow the ejecta away from the crater. Copernicus is on the old side of Intermediate. If its ejecta were any more mature, it would be indistinguishable from background. Copernicus has been radiometrically dated at approx. 810 Ma, so the upper limit of this technique to identify and relatively date large craters must fall at ~ 800 Ma. Tycho is ~ 100Ma. Craters with ejecta both much less and much more mature have been identified.

Aristillus and Autolycus: Both of these craters have been morphologically classified as rayed, due to the nature of their ejecta, Autolycus has been radiometrically dated at about 2 Ga, and Aristillus at 1.3 Ga. These ages seemed in possible contradiction with the supposition that rayed craters are all relatively recent. The OMAT profiles for both of these craters, though, are otherwise indistinguishable from OMAT background values and are very flat. The profiles indicate that the maturity of the ejecta from these craters is much greater than the ejecta of Copernicus, which is consistent with their radiometric ages. It is therefore clear that the presence of rays alone do not imply that a large crater is near or younger than the age of Copernicus.

Lichtenberg: Lichtenberg crater is clearly older than the mare deposit which embays its ejecta [1]. Originally, this was thought to indicate that mare volcanism was active until very recently in lunar history. Lichtenberg has not been radiometrically dated, but its OMAT profile indicates that its ejecta is very mature; more than Copernicus, similar to Autolycus or Aristillus. Lichtenberg and its associated mare deposit are therefore probably older than 1 Ga.

Table 1 - Sample Large Rayed Lunar Craters

Name	*Age*	*D (km)*	*Category*
Tycho	110 Ma	85	Young
Copernicus	810 Ma	93	Intermediate
Aristillus	1.3 Ga	55	Old
Autolycus	2.1 Ga	39	Old
Lichtenberg	undated	20	Old

Names, radiometric ages (where known) and categories for a sample of large rayed lunar craters. All ages from [1] except Autolycus from [4].

Conclusions: It is clear that the technique of determining the relative ages of large craters by the apparent maturity of their ejecta is effective and consistent with known radiometric ages. This relative age determination allows for important conclusions to be drawn about the lunar surface and cratering record.

References: [1] Wilhelms (1987) USGS Prof. Paper #1348. [2] McEwen, Moore and Shoemaker (1996) *JGR*. [3] Grier et *al.*, *LPS XXX*, this volume. [4] Ryder et al. (1991) *Geology*, 19.

Figures - OMAT Profiles for Sample craters. Shown here are crater profiles for a sampling of lunar craters. Aristarchus and Tycho are Young. Kepler's ejecta is clearly more mature than Tycho's, but not as mature as Copernicus', and the overall OMAT values are higher. The OMAT profile for Copernicus is just above background; the limit detectability for immaturity with an average near ejecta OMAT value of 0.24. Kepler and Copernicus are intermediate. While the crater rim of Lichtenberg is still immature due to downslope movement, the average near ejecta OMAT value is about 0.22. This is only slightly higher than the average near rim ejecta value for Autolycus of 0.21. These profiles shown are not averages, but selected cords across the craters and their ejecta. Radial averages should smooth out fluctuations in the profiles and make apparent maturity of ejecta for each crater more straightforward.