PLANETARY SURFACE DATING FROM CRATER SIZE-FREQUENCY DISTRIBUTION MEASUREMENTS: DIFFERENTIAL PRESENTATION OF DATA FOR RESURFACED UNITS. G.G. Michael, Planetary Sciences and Remote Sensing, Institute of Geological Sciences, Freie Universitaet Berlin, Malteser Strasse 74-100, Haus D, Berlin 12249, Germany.

Introduction: The analysis of crater size—frequency distributions and absolute densities forms the basis of current approaches for estimating the absolute and relative ages of planetary surfaces. Users of the Neukum system of crater dating have conventionally used a cumulative presentation of the data, but because of the recent proliferation of interest in identifying resurfacing ages, it is worth emphasising the utility of the differential presentation of crater data in identifying resurfacing events, and particularly, in distinguishing the signature of short-lived events, such as volcanic flows, from long-lasting effects, such as aeolian erosion.

Discussion: In the Neukum system of surface dating [1], we have conventionally used a reverse cumulative presentation of the crater size--frequency distribution because of its advantage with respect to data noise: the curve rapidly converges to a position on the plot which uniquely corresponds to a model age. The picture is complicated when it is required to interpret a resurfacing event from the data. A resurfacing event causes the removal of craters from the small end of the size--frequency distribution at some time after the unit's formation. If the data are plotted in a reverse-cumulative style, the location of the large-end tail on the plot still corresponds to the formation age of the unit, but the small-end tail no longer corresponds to the time of the resurfacing event: it is offset (upwards) by the relatively older section earlier in the cumulative calculation. This offset can be compensated by an iterative procedure [2], provided that the upper and lower size limits of the resurfaced part of the distribution can be adequately determined. Often, the resurfacing is seen as a step between two portions of the distribution whose curves run parallel to plotted isochrons: in such cases, specifying the diameter range representing the part of the crater population corresponding to the resurfacing is reasonably simple [Fig 1].

In other cases, where the resurfacing process is not short-lived, or where multiple resurfacing events have occurred, it can be difficult to identify appropriate diameter ranges for the correction procedure. Here it is better to examine the population in a differential presentation [3], where portions of the distribution which correspond to isochrons may be seen directly, with abrupt steps between isochron being indicative of short-lived resurfacing events, and more gradual transitions between isochrons indicative of long-acting resurfacing processes.

The differential presentation is similar to the incremental presentation used by Hartmann [e.g. 4], the distinction being that the differential plot is normalised according to the choice of bin-width such that the plot is independent of the binning (aside from statistical effects).

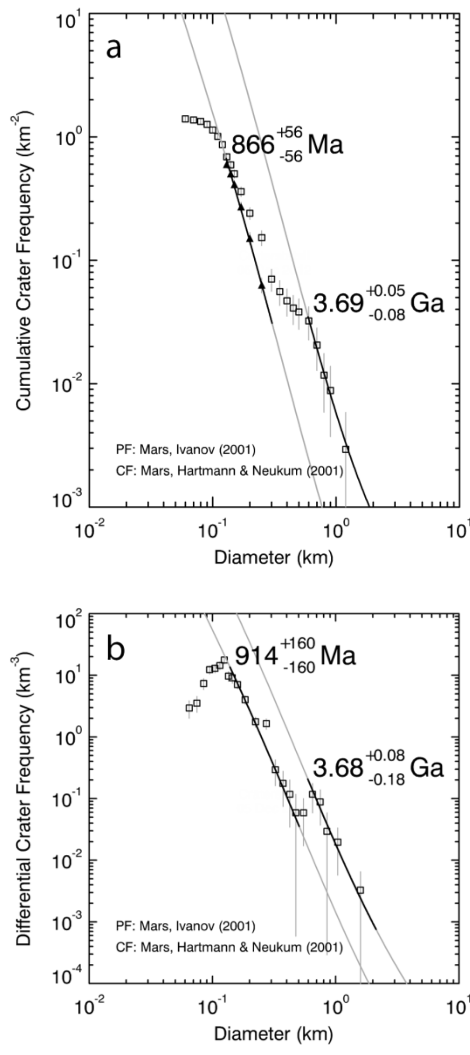

Figure 1. a) Cumulative plot with simple cumulative fit and corrected cumulative resurfacing fit. b) Differential plot with two direct differential fits.

Technical details: A complexity of dealing with a differential plot is the choice of bin-width: if spaced too finely, a real data plot will show empty bins and bins with only a single crater: it is not possible to discern a trend which may coincide with an isochron until the bins begin to encompass a larger number of craters. Conversely, if the bin spacing is overly coarse, the finer structure in the distribution which may relate to resurfacing effects becomes smoothed over, and chronological information may be lost. The optimum choice will depend on the particular dataset at hand: in a recent work we found 10 bins per log-decade to be a good choice (somewhere between the 18/decade of the standard Neukum plot and the ~6.5/decade of a Hartmann-style root-2 binning).

To make use of the differential plot for extracting ages requires having the production functions available in differential form. For a Neukum polynomial, the conversion equation is given in [2]. For the Hartmann system [4], the differential form is

$$F = \frac{H}{D(2^{1/4} - 2^{-1/4})}$$

where H are the incremental values, and D are the geometric bin centres.

An additional consideration is that the binning of an exponential function introduces a bias, since statistically, there will always be more craters close to the left edge of the bin than the right. The effect becomes larger as the bin width increases, and makes a difference of the order of a few percent in model ages for root-2 binning. The bias can be compensated out when fitting a production function, since the slope of the production function is known, according to the following:

$$\frac{F_{bin}}{F} = \frac{\beta^{k/2} - \beta^{-k/2}}{k(\beta^{1/2} - \beta^{-1/2})}$$

where k is the local slope and β is the ratio between adjacent bin boundaries.

Software: These facilities are implemented in the cross-platform software *Craterstats2*, available from http://hrscview.fu-berlin.de/software.html

When fitting an isochron to some portion of the crater distribution, one may select either to make a ‘cumulative fit’ or a ‘differential fit’. The cumulative fit uses the conventional Neukum technique; the differential fit is the exact same procedure but in the differential data space. Note that the data space is distinct from the plot presentation: it is possible to display a differential fit on a cumulative plot and the converse. Fits made in the two approaches should achieve identical results for an ideal dataset. In practice, the data noise will produce small differences between the two, because the data points are weighted differently (in a cumulative plot, a single crater affects more than one data point).

The Hartmann 2004 iteration chronology system for Mars [4] has recently been included in the software, and operates in the same way as the Neukum chronology systems.

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References: [1] Neukum, G, *Meteoritenbombardement und Datierung planetarer Oberflachen*. Habilitation, University of Munich, February 1983. [2] Michael, G.G., Neukum, G., 2010. *Planetary surface dating from crater size-frequency distribution measurements: partial resurfacing events and statistical age uncertainty*. Earth Planet. Sci. Lett. 294, 223–229. [3] Arvidson, R. E. et al., *Standard techniques for presentation and analysis of crater size-frequency data*. Icarus, 1979. [4] Hartmann, W.K., 2005. *Martian cratering 8: Isochron refinement and the chronology of Mars*. Icarus 174 (2), 294–320.