**THE MARS SPHERULE SIZE DISTRIBUTION AND THE IMPACT HYPOTHESIS.** D. Royer[1], D. M. Burt[2], K. H. Wohletz[3], [1]Aix-en-Provence, France, royer.dch@orange.fr, [2]School of Earth and Space Exploration, Arizona State Univ., Box 871404, Tempe, AZ 85287-1404, dmburt@asu.edu, [3]Los Alamos National Laboratory, Los Alamos, NM 87545, wohletz@lanl.gov

**Introduction:** The ubiquitous granule sized spherules called *blueberries*, discovered at Meridiani by the Opportunity rover are thought to be concretions grown in a water environment [1][1]. While widely accepted, this hypothesis does not fit with several observations: the spherules are near perfectly spherical, they are tightly sized around 4 mm, and they occur primarily as single bodies. An alternative hypothesis is their formation in a large meteoritic impact cloud by aggregation or vapour condensation [2]. Previous workers [3] claim that spherical aggregate ejecta only occur along bedding planes unlike Opportunity observations; however, we note that accretionary spherical particles are not restricted to bedding planes in terrestrial ejecta deposits and do resemble the observed distributions of Martian blueberries.

It is recognized that particle size distributions (SD) may contain clues on the nature and origin of the objects. The first aim of this paper is to report on SD measurements from Pancam images and to examine the evolution of the observations along the Opportunity journey from Eagle to Victoria crater. Next, we will examine the ability of the impact modelling to explain the observed shapes.

**Method:** After an earlier series of manual measurements on Pancam images [4], we have devised a semi-automatic method, briefly described here. For each Pancam image, a mask is defined from a representative spherule; this mask includes the spherule body and its shadow. In most of the images that are shot on a smooth terrain - an example is given in Figure 1 - the mask pattern is representative of the spherules of interest through a scaling factor. The mask is translated to the blueberry sites and automatically adjusted in size and place using a matching criterion on the pixel values. A grid is laid on the image to control the sampling. Partially buried or broken blueberries are eliminated either visually or by criterion mismatch. The spherule size is deduced using the measured scaling factor and the image parameters, namely the Pancam elevation angle and the blueberry location in the image. The method has a lower cut-off of 5 pixels, or 1.5 to 2 mm in size. The sample varies between 300 and 900 spherules per image.

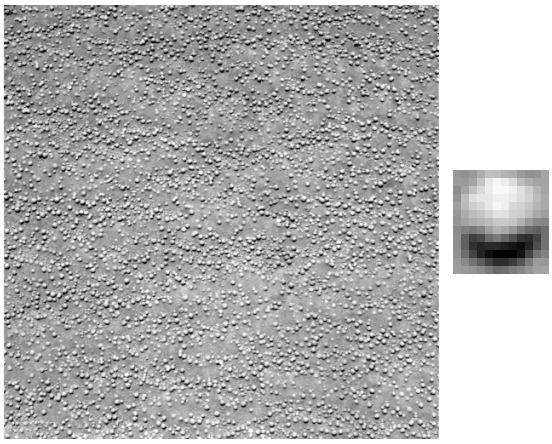

Figure 1. Sol 1071 Pancam image and the blueberry mask (enlarged)

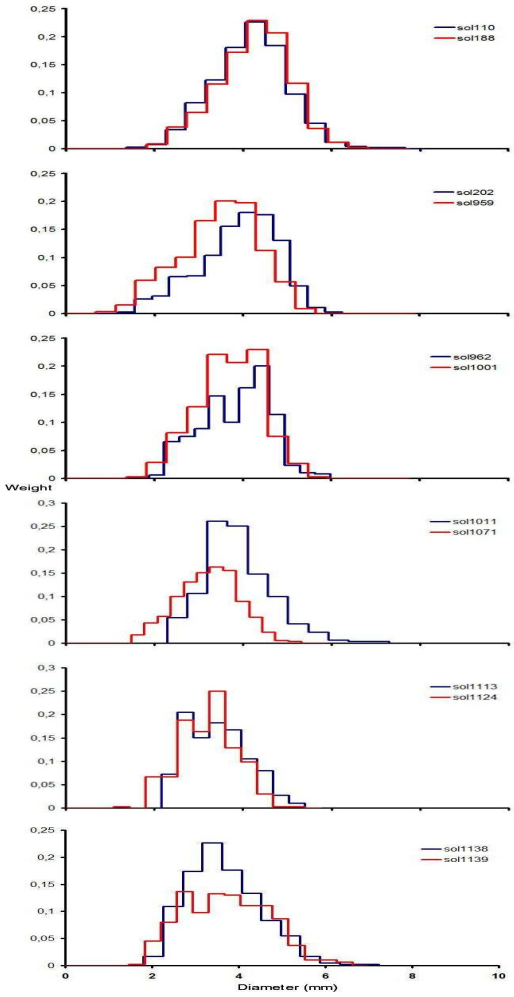


Figure 2. Sol 110-1139 blueberries size distributions as measured on Pancam images, in chronological order

[1] Uniformly sized spherules have also been found in the vicinity of Home Plate, Gusev Crater (first at a locality called King George Island) by the Spirit rover.

**Results:** In Figure 2 we plot the size distributions histograms on a common horizontal scale from sol 110 (plains between Eagle and Endurance craters) to sol 1139 (Cape St-Vincent on Victoria's rim). During the traverse between Endurance and Victoria, the spherules were unevenly distributed and their size smaller, so their measurement on Pancam images was not possible. It is clear from Figure 1 that the SD show an evolution, from left skewed at Endurance to right skewed at Victoria, and that this evolution occurs continuously. This observation is compatible with the idea that different spherule populations lying on different bedding planes may show successively along the rover's traverse, and that near Victoria, the spherules are the weathered remnants of impact ejecta from deep layers [5].

**Modelling and Discussion:** In the following, we have focused our investigation on the modelling of the entire sequence of Figure 1 with the Sequential Fragmentation/Transport model (SFT) that is successful at explaining ejecta size distributions from explosive events [6]. Basically, the SFT model describes fragmentation or accretion and transport of an initial mass whose variation with fragmentation/growth cycles is subject to a power law with an exponent termed *gamma*. SFT method is based not empirically but on first-principle physics. Gamma expresses the distribution's dispersion (standard deviation for normal statistics) and is directly linked to the distribution skewness and kurtosis (peakedness). The reason gamma captures all three parameters, is that from the physics, all three are linked in fragmentation (or aggregation) and transport processes. Notably SFT predicts both lognormal behavior as well as the more widely used Weibull distribution and others used in crushing coal, etc. Thus some physical predictions can be made.

The twelve SD have been analysed with SFT. An optimisation algorithm is used to find the best fits to the data in minimizing the residuals that are the sums of the absolute differences between model and data values. Multiple populations are allowed. The results are in Table 1. Residuals (distribution fraction not predicted by the model) less than 10% are considered as a criterion for a satisfactory agreement. The SD for individual populations produced by the model are all left skewed, in agreement with the observations of sols 110-202. In the sol 959-1138 sequence on Victoria's rim, two populations are needed to meet the residual requirement. The mode values for these two populations, including the four-momomodal distributions, are comprised between 4.1 and 4.7 mm for the main population, and 3.2 and 3.5 mm for the subordinate population. The twin populations that we infer from this analysis may be interpreted as the mixing of different stratigraphic levels by the Victoria impact. In all cases the gamma value is positive, which, according to the physics of the SFT model, means an accretion process. This process may have occurred in earlier impact surge event(s) and covered the whole region. It is important also to note that the high sphericity of the blueberries is well accounted by the accretion / condensation process in a very turbulent cloud environment that spins the accreting particle in such a way to build up concentric layers and promote spherical symmetry.

Table 1

| Sol | Mode (PHI units) | Gamma | Fraction | Residual (%) |
|---|---|---|---|---|
| 110 | -2.28 | 0.4 | 1 | 5.50 |
| 188 | -2.28 | 0.87 | 1 | 9.39 |
| 202 | -2.17 | 0.15 | 1 | 7.60 |
| 959 | -2.13<br>-1.76 | 0.11<br>1.03 | 0.68<br>0.32 | 8.35 |
| 962 | -2.14<br>-1.71 | 0.13<br>0.71 | 0.62<br>0.38 | 4.74 |
| 1001 | -2.24<br>-1.78 | 0.54<br>0.28 | 0.75<br>0.25 | 4.92 |
| 1011 | -2.23<br>-1.81 | 0.20<br>0.96 | 0.81<br>0.19 | 6.74 |
| 1071 | -2.20<br>-1.77 | 0.42<br>0.51 | 0.26<br>0.74 | 6.32 |
| 1113 | -2.10<br>-1.76 | 0.69<br>0.66 | 0.19<br>0.81 | 8.15 |
| 1124 | -2.03<br>-1.78 | 0.09<br>0.64 | 0.16<br>0.84 | 10.37 |
| 1138 | -2.23<br>-1.67 | 0.20<br>0.11 | 0.80<br>0.20 | 3.22 |
| 1139 | -2.23 | 0.16 | 1 | 3.65 |

**Conclusion**: The berry size distributions along the Opportunity path are found to exhibit an evolution from left skewed at Endurance to right skewed at Victoria. The SFT model offers a coherent interpretation of these features, implying an accretion mechanism. Further work is needed with concretion growth models to examine their compatibility with the observed SDs.

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**References:** [1] McLennan S. M. et al. (2005) *Earth & Planetary Science Letters,* 240,95. [2] Burt D. M. et al. (2007), *Lunar and Planetary Science XXXVIII* Abstract # 1922. [3] Grotzinger, J.P., et al., (2007), *Seventh International Conference on Mars* Abstract # 3292. [4] Royer D. et al. (2006), *Lunar and Planetary Science XXXVII* Abstract #1001. [5] Squyres S. W. et al. (2007), *Lunar and Planetary Science XXXVIII* Abstract #1437. [6] Wohletz K. H. et al. (1989), *Journal of Geophysical Research,* 94, 15703.