EXTENSIVE SECONDARY CRATERING IN THE EXOMARS LANDING SITE AT OXIA PLANUM, MARS.

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Introduction: The ESA ExoMars Rosalind Franklin (EMRF) rover is scheduled to launch in 2028, and will land in the Oxia Planum region of Mars. The main target is Noachian phyllosilicate-rich deposits [1, 2]. As such, this region likely represents the oldest aqueous environment to be explored in situ.

In this study we have investigated extensive secondary craters within the EMRF landing ellipse, to place absolute age markers in the stratigraphic framework of Oxia Planum, and identify the likely primary source crater(s). We pay particular attention to possible secondary craters from Mojave crater, due to its likely recent formation age [3] and importance as a potential source crater for martian meteorites [4].

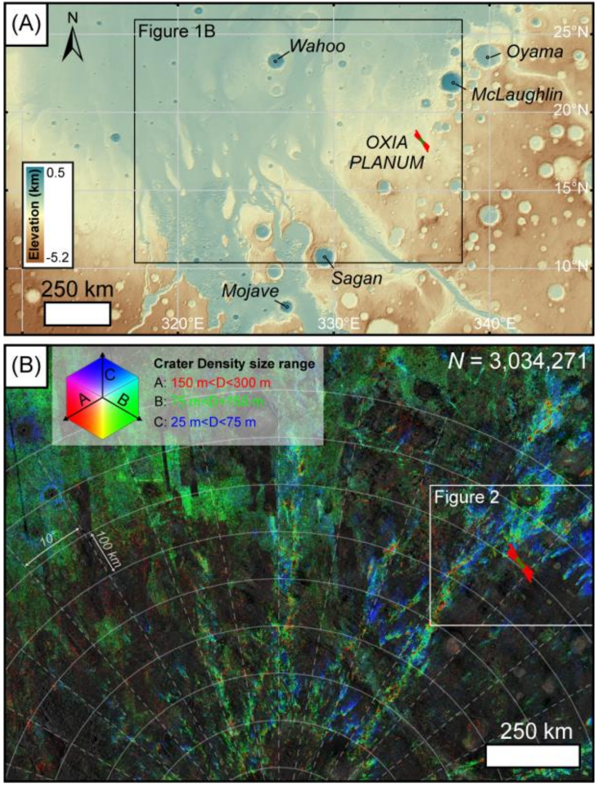

Figure 1. *(A) Context map of the Oxia Planum study region, with 1σ (green) and 3σ (red) landing ellipses for* EMRF. *(B) Density map of the context study region of craters <300 m in diameter, following previous methods of colours representing specific diameter ranges* [1, 2]. *Radial grid centred on Mojave crater.*

Method: We first used the recent Mars catalogue of small impact craters [5, 6] in a large (1.2 x10^6 km^2) 'context study region'. We calculated the density of different diameter ranges of impact craters, using a smaller grid size than previous studies [5, 6] of 1 x 1 km (Figure 1). Next, in a smaller (1 x 10^5 km^2) 'Oxia Planum study region', we manually refined the crater identification through crater addition, deletion, movement, and scaling. We produced a final catalogue with an extra 22,209 craters, totalling 381,584 impact craters. We applied the 'Algorithm for the Secondary Crater Identification'(ASCI) [3] to distinguish between primary and secondary impact craters (Figure 2). Given that the maximum diameter of a secondary crater is 2-5% the respective primary crater, we refined the classification to redefine 57 secondary craters with a diameter >2.9 km (5% of the 57 km diameter of Mojave crater) as primary craters. We then produced a crater size density map of secondary craters for the Oxia Planum study region, from which we identified acute triangle-shaped clusters (or 'cones') of craters. We carried out crater size-frequency distribution (CSFD) studies of previously-identified units in Oxia Planum [1] to determine model surface ages, both with and without secondary craters removed.

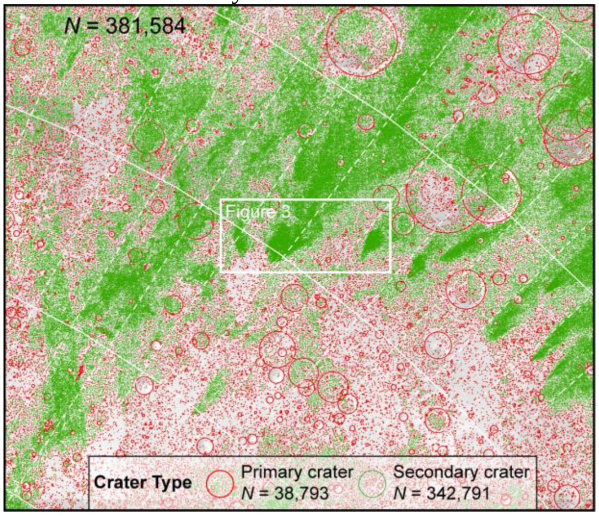

Figure 2. *All craters identified in the Oxia study region. Radial grid centered on Mojave crater, showing distances in 100 km steps, and angles in 2° steps.*

Results: We separate our results into (1) the identification and analysis of secondary craters, and (2) the implications for model ages in Oxia Planum.

Secondary Craters. The larger, context study region contains 3,034,271 impact craters, ranging in size from 29 m to 54.4 km [5, 6]. Of the impact craters in the smaller Oxia Planum study region, we classified 38,793 (10.2%) as primary craters, with 342,791 (89.8%) classified as secondary craters. Our study includes 112 of the 122 impact craters greater than 1 km in diameter previously identified as secondaries in an earlier study [7], of which 49 (44%) we reclassified as primaries, and 63 (56%) we confirmed as secondaries. Our study identified 79 of the 84 impact craters greater than 0.5 km in diameter previously identified as secondaries [5] in our Oxia study region, of which we reclassified 28 (35%) as primaries and confirmed 51 (65%) as secondaries.

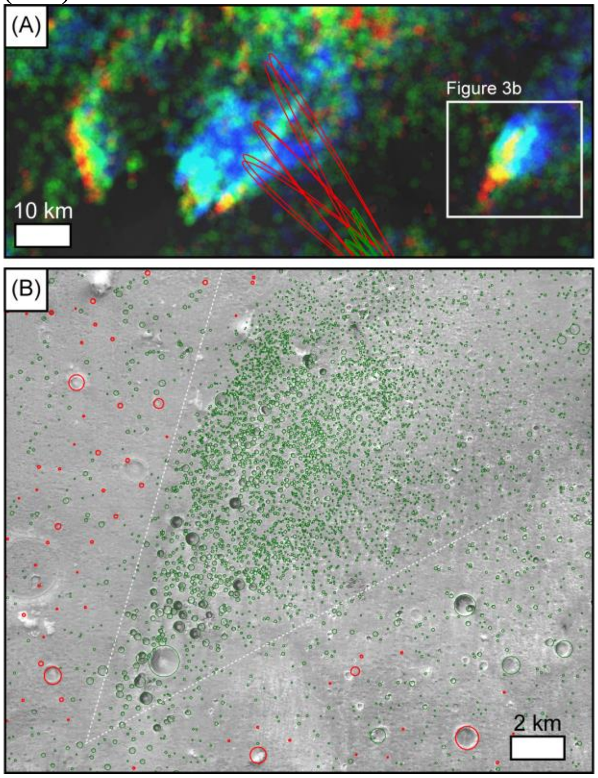

Figure 3. *(A) Distinctive size distribution of secondary craters in acute triangle shapes, using same colour scale as in Figure 1. (B) Example of primary (red) and secondary (green) crater identification and distribution in an acute triangle shape.*

We identified at least 19 separate clusters of craters that occur in cone shapes, typically up to 40 km long and 20 km wide at the distal ends (Figure 3). These cones are oriented radially away from Mojave crater, with the median direction being 225°, similar to the median direction (222°) to Mojave crater. These cones appear to show a distinctive size distribution of craters, with larger craters limited to the proximal (apex) region, and a gradual transition to smaller craters in the distal region. The cones in our Oxia Planum study region are located at distances of ~700 to ~930 km from Mojave.

Model Surface Ages. The removal of secondary craters from CSFD studies does not affect the model surface age of the phyllosilicate units in Oxia Planum. We derive a model surface age of 3.9 Ga for the Noachian layered clay-bearing unit (lNc) of [1] using all our craters, and an identical age when using just our primary craters. This similarity is due to the lack of secondary craters at larger diameters.

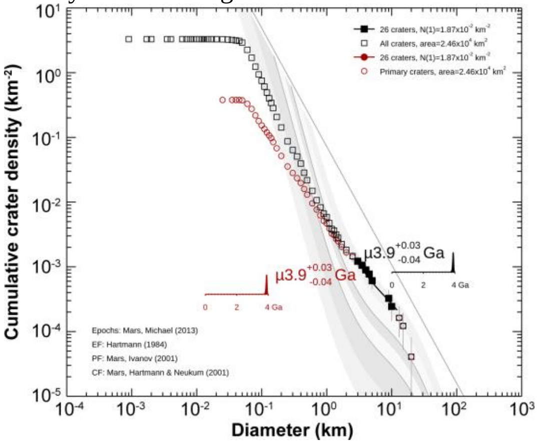

Figure 4. *CSFD and model ages for the Noachian layered clay-bearing unit (lNc) of [1] with and without secondary craters.*

Conclusions and Future Work: Our results suggest that there are extensive secondary impact craters in Oxia Planum, with some in the landing ellipse itself. It is therefore likely that EMRF will encounter secondary craters during surface operations. The direction of small crater clusters strongly suggests that the majority of craters identified as secondaries are sourced from the Mojave impact crater, although larger, older secondary craters from other sources are also present. Given that the Mojave impact is estimated to have occurred 10.1 Ma [3], these secondaries can be used as absolute stratigraphic markers throughout Oxia Planum, particularly in quantifying the rate of recent and active surface processes. These secondary craters will also be important for target prioritization during in situ studies. Our future work will focus on possible mechanisms for the apparent sorting of secondary crater sizes.

References: [1] Quantin-Nataf C. et al. (2021) *Astrobiol.* 21, 345-366. [2] Mandon L. et al. (2021) *Astrobiol.* 21, 464-480. [3] Lagain A. et al. (2021) *Earth Space Sci.* 8, e2020EA001598. [4] Werner S.C. (2014) Science, 343, 1343-1346. [5] Lagain A. et al. (2021) in *GSA Spec. Paper* 550, 629-644. [6] Lagain A. et al. (2021) *Nature Comms.* 12, 6352. [7] Robbins S.J. & B.M. Hynek (2014) *Earth Planet. Sci. Lett.* 400, 66-76.