SECONDARY CRATERS AS ABSOLUTE STRATIGRAPHIC MARKERS IN OXIA PLANUM, MARS.

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Introduction: The ESA/Roscosmos ExoMars Rosalind Franklin rover is scheduled to launch in September 2022, and land in the Oxia Planum region of Mars (Figure 1) in June 2023. The main target of the mission are phyllosilicate-rich deposits, estimated to be Noachian (>3.7 Ga) in age [1, 2]. As such, this region likely represents the oldest aqueous environment to be explored in situ.

Although relative ages can be determined from orbital data, absolute ages derived from crater size-frequency distribution (CSFD) studies of small (~<100 km^2) units are susceptible to errors, due to the limited areal coverage [3]. In this study we aim to use secondary craters within the ExoMars landing ellipse to place confident absolute age markers in the stratigraphic framework of Oxia Planum.

Method: We use multiple georeferenced data sets in a GIS environment to map secondary craters, and attempt to identify primary craters. Principally, we use a basemap of a CTX stereo DTM (20 m/px) with accompanying orthoimages (6 m/px), with mosaicked CaSSIS false-color images (4 m/px), all of which are georeferenced to HRSC multi-orbit DTMs [4]. We produced an additional mosaic of 6 stereo CTX DTMs and orthoimages, to extend data coverage, using SocetSet and well-validated methods [5]. Where necessary, we were guided by two separate crater databases: (1) the Mars global large (>1 km diameter) impact crater database [6, 7], and (2) the Mars global small impact crater database [8]. We also incorporated other data sets such as the large, secondary crater population of Mars [9], HiRISE stereo DTMs that we produced as part of the landing site selection process [1], and several databases of rayed craters on Mars [e.g. 10, 11]. To aid primary crater identification, we generated 36 (every 10°) radial lines of 1000 km length for 6 candidate primary craters.

Results: We separate our results into (1) the identification, mapping and analysis of secondary craters, which informs (2) the search for and model age of primary craters.

Secondary Craters. We have identified >300 individual group or clusters of secondary craters across the wider Oxia Planum region. Of these, approximately half appear to be orientated away from the large crater to the north of the Oxia Planum landing ellipse, which also has an additional 88 crater chains pointing radially away from the center of this impact crater. We are in the process of marking the location of possible secondary craters in a ~6800 km^2-sized area surrounding the ExoMars landing ellipse. With ~40% of the area investigated, we have identified ~14,000 craters between 20 and 800 m in diameter for further analysis. We will use the asymmetry of individual craters and ejecta, in conjunction with nonparametric classification methods and machine learning algorithms, in an attempt to confirm or reject their secondary status, and identify primary craters [e.g. 12].

Primary Craters. There are two main craters within ~150 km of the landing ellipses, which are likely to have caused the formation of secondary impact craters within the ellipses themselves. A large (~41 km diameter), unnamed crater (hereafter named '*Northern Crater*') ~125 km north of the center of the landing ellipses has ejecta rays made of secondary craters, as well as widespread clusters of secondary craters that extend over 300 km from the crater rim. The ejecta blanket of this crater is not well defined, but is likely ~6500 km^2. Kilkhampton crater is a 16 km diameter crater that is ~70 km to the south-east of the center of the landing ellipses, with a well-defined ejecta blanket (~1800 km^2) that extends into the ellipses themselves. We carried out crater size-frequency distribution (CSFD) studies at both craters to determine model surface ages for their formation, and by extension, the formation of their associated secondary craters. At Kilkhampton Crater we counted every crater with a diameter >30 m that appeared to have formed on the ejecta blanket. We counted 588 craters, and derive a model surface age of 3.8 ± 0.1 Ga, similar to previous studies [e.g. 13]. At Northern Crater, the poorly defined ejecta blanket required a different approach in the CSFD method. Here we identified those craters that have been partially or fully infilled by ejecta from this impact event, thus providing a minimum age of formation. We counted 28 craters between 1.2 and 11.0 km in diameter, producing a model surface age of 3.9 ± 0.1 Ga.

The direction of crater clusters suggests that primary craters that are >150 km from the landing ellipses are responsible for at least some secondary crater formation in Oxia Planum. One of the most interesting observations is that Oxia Planum could contain both ancient and young secondary impact craters, from Kilkhampton and Northern craters, and Mojave crater respectively. In the case of Mojave crater, previous studies have outlined the number and extent of secondary craters from this impact event,

which is likely to have formed less than ~5 Ma [e.g. 11].

Conclusions and Future Work: Our preliminary results suggest that there are secondary impact craters in the Oxia Planum region, some of which are likely to occur in the landing ellipse itself. There is therefore a good chance that the ExoMars Rosalind Franklin rover will encounter a secondary crater once on the surface.

Our results can then be applied in two main ways:

Absolute Stratigraphic Markers. The ability to identify secondary craters in the landing ellipses, and their associated primary craters, will allow us to determine an absolute formation age by dating the primary crater with crater counting methods. This will allow us to use the absolute ages of these secondary craters in any stratigraphic framework of Oxia Planum, across a range of different feature types, both in the run up to, and during, the surface mission.

Target Prioritization. Secondary craters have lower impact velocities than primary craters [e.g. 14], which means that the energy released is also lower. This in turn reduces the opportunity for hydrothermal processes as a result of the impact process for a given crater size, but these secondary craters could still reveal subsurface stratigraphy, information that is crucial in providing context for the drill campaign of the Rosalind Franklin rover. This prioritization must also account for the possibility of investigating a secondary crater that could have formed during a Mars meteorite ejection event [11].

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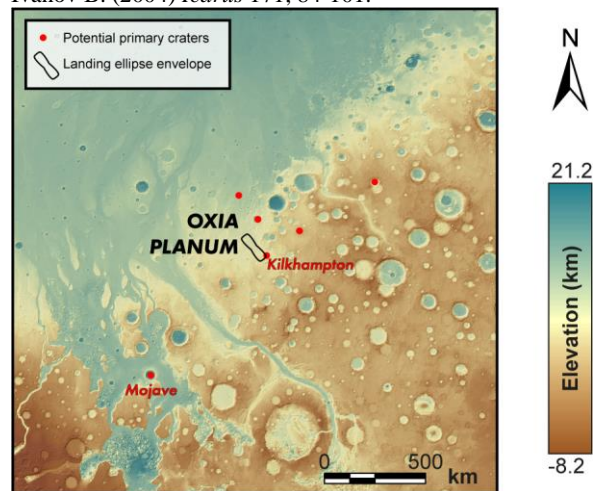

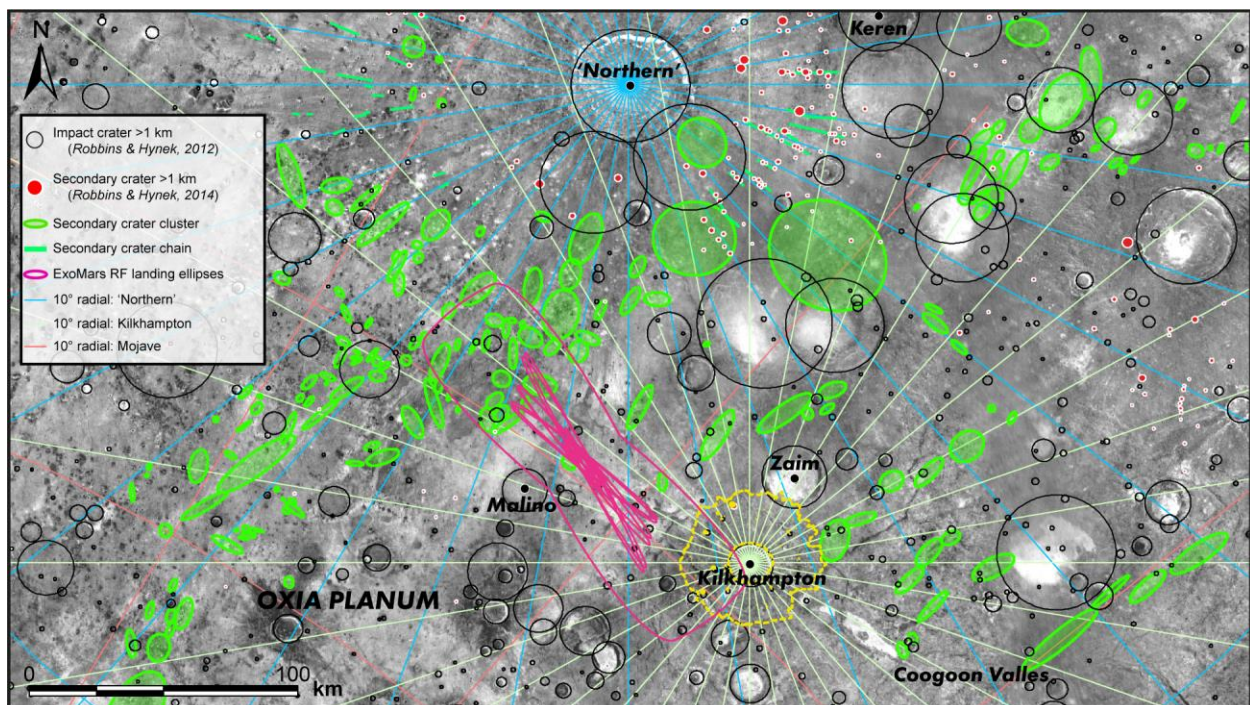**Figure 1.** *Regional context of the Oxia Planum landing site.*

Figure 2. *Preliminary mapping of secondary crater clusters and 10° radial lines from 3 primary crater candidates.*