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Morphology and formation ages of mid-sized post-Rheasilvia craters – Geology of quadrangle Tuccia, Vesta

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ABSTRACT

A variety of geologic landforms and features are observed within quadrangle Av-13 Tuccia in the southern hemisphere of Vesta. The quadrangle covers parts of the highland Vestalia Terra as well as the floors of the large Rheasilvia and Veneneia impact basins, which results in a substantial elevation difference of more than 40 km between the northern and the southern portions of the quadrangle. Measurements of crater size–frequency distributions within and surrounding the Rheasilvia basin indicate that gravity-driven mass wasting in the interior of the basin has been important, and that the basin has a more ancient formation age than would be expected from the crater density on the basin floor alone. Subsequent to its formation, Rheasilvia was superimposed by several mid-sized impact craters. The most prominent craters are Tuccia, Eusebia, Vibidia, Galeria, and Antonia, whose geology and formation ages are investigated in detail in this work. These impact structures provide a variety of morphologies indicating different sorts of subsequent impact-related or gravity-driven mass wasting processes. Understanding the geologic history of the relatively young craters in the Rheasilvia basin is important in order to understand the even more degraded craters in other regions of Vesta.

1. Introduction and general geologic setting of quadrangle Av-13

The investigation of the main belt Asteroid 4 Vesta by NASA's Dawn mission (Russell et al., 2012) includes an extensive geologic mapping program. Besides a global geologic map at a scale of 1:500,000 (Yingst et al., 2013) this mapping program consists of the production of 15 geological quadrangle maps at a scale of 1:250,000 (Roatsch et al., 2012; Williams et al., 2014b).

The quadrangle Av-13 called *Tuccia* covers the region between 21–66°S latitude and 180–270°E longitude. The quadrangle represents the transition zone between the topographically elevated Vestalia Terra and the floor of the Rheasilvia basin (see Fig. 1). The Rheasilvia impact structure, whose existence has already been suggested by e.g., Thomas et al. (1997) and Binzel et al. (1997) using data from the Hubble Space Telescope (HST), is centered close to the south pole of Vesta at ~75°S, ~301°E and is approximately 500 ± 20 km in diameter (e.g., Jaumann et al., 2012b; Schenk et al., 2012a). Measuring the crater size–frequency distribution (CSFD) on the relatively lightly-cratered basin floor of Rheasilvia, Marchi et al. (2012) determined a formation time of approximately 1 Ga ago, although this has been questioned by Schmedemann et al. (2012b). Undetected by the HST, Rheasilvia superposes a second large basin with almost the same diameter, which has been named Veneneia. This basin has a diameter of ~400 ± 20 km and its center is located at ~52°S and ~170°E (e.g., Jaumann et al., 2012b; Schenk et al., 2012a). Portions of the floors of both impact structures are located within the Tuccia quadrangle.

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While the Veneneia floor covers only the north-western edge of the quadrangle, Rheasilvia approximately constitutes the southern half of the quadrangle. The exact boundaries of the original basin rims are difficult to determine as they are heavily degraded and modified by landslides and slope slumping, particularly at the southern scarp of Vestalia Terra (see Fig. 1).

Vestalia Terra is a high elevation plateau mainly located in the equatorial mapping quadrangle Numisia (Av-9, Yingst et al., 2013; Buczkowski et al., 2014). The southern edge of Vestalia Terra extends into the Tuccia quadrangle. Here, Vestalia Terra reaches a maximum height of approximately 19.6 km above the Vesta ellipsoid. In combination with the depth of the Rheasilvia basin – of more than 22.4 km in the south-eastern region of the quadrangle – this results in topographic variation exceeding 40 km leading to widespread mass wasting processes such as landslides and slumps, throughout the quadrangle. This complex geologic setting that extends over large parts of the southern hemisphere of Vesta was subsequently modified by mid-sized impact events. In contrast to craters on the heavily-cratered terrains in the northern hemisphere of Vesta (Marchi et al., 2012; Hiesinger et al., 2013), craters on the more lightly cratered floor of Rheasilvia show distinct stratigraphic relationships and, thus, allow for relatively unambiguous analyses of crater morphologies and relative formation ages. The prominent impact craters in quadrangle Av-13, named Eusebia, Tuccia, Vibidia, Galeria, and Antonia (see Fig. 1), offer a rich variety of impact morphologies, erosion types, as well as exposures of dark and bright materials (Kneissl et al., 2013) and, thus, these craters are appropriate candidates to investigate young, mid-sized impact morphologies on Vesta's surface.

2. Methodology

2.1. Database and geologic mapping

Quadrangle Av-13 Tuccia is one of 15 mapping quadrangles of Vesta, with two at the poles, four in the mid-latitude regions, respectively, and five in the equatorial region (Roatsch et al., 2012, see Fig. 2). The presented map (Fig. 3 and SOM) uses the 'Claudia' coordinate system, which is different from the coordinate system used to publish data in Planetary Data System (Li, 2012) that follows IAU coordinate system recommendations (Archinal et al., 2011). Positive longitudes here are offset by 150 degrees from the 'IAU/PDS' system, in the sense that Claudia longitude = IAU longitude −150° (for details see the Coordinate system section in Williams et al., 2014b).

The geologic mapping was based on a mosaic of Framing Camera (FC) clear-filter imagery derived during the Low Altitude Mapping Orbit (LAMO) of the Dawn spacecraft (Russell and Raymond, 2011; Sierks et al., 2011) (Fig. 2A). The mosaic provided a spatial resolution of 20 m/px. Small gaps in the north-eastern part of the quadrangle were filled with image data from the High Altitude Mapping Orbit (HAMO) with a resolution of 70 m/px (Roatsch et al., 2012). Single LAMO FC clear-filter images with native resolution (>15 m/px) were processed with the USGS Integrated Software for Imagers and Spectrometers (ISIS) (Becker et al., 2012) and used for detailed investigations. Since the albedo of a surface unit is an important property for geologic mapping, we also made use of a mosaic of photometrically corrected FC clear-filter images (70 m/px) obtained during the HAMO mapping phase and provided by the DAWN Team. Multispectral data that was derived from Framing Camera (FC) color filter images (Sierks et al., 2011) was used to map unit boundaries of ejecta blankets and dark material occurrences. Here, we applied Clementine-like color ratio maps (hereafter called color ratio maps) with a resolution of 70 m/px (Fig. 2C). In these composite color maps the red channel is the ratio of 750/440 nm filters, green is 750/920 nm filter ratio and blue is the ratio of 440/750 nm filters (e.g., Le Corre et al., 2011, 2012b; Nathues et al., 2012; Reddy et al., 2012a, 2012b). The red channel shows a steeper visible spectral slope, the green channel is a function of mafic mineral absorption band depth (an indicator for iron abundance, particle size effects, space weathering), and the blue channel is the inverse of the red channel helping to constrain weaker spectral slopes than the average surface (Reddy et al., 2012a, 2012b).

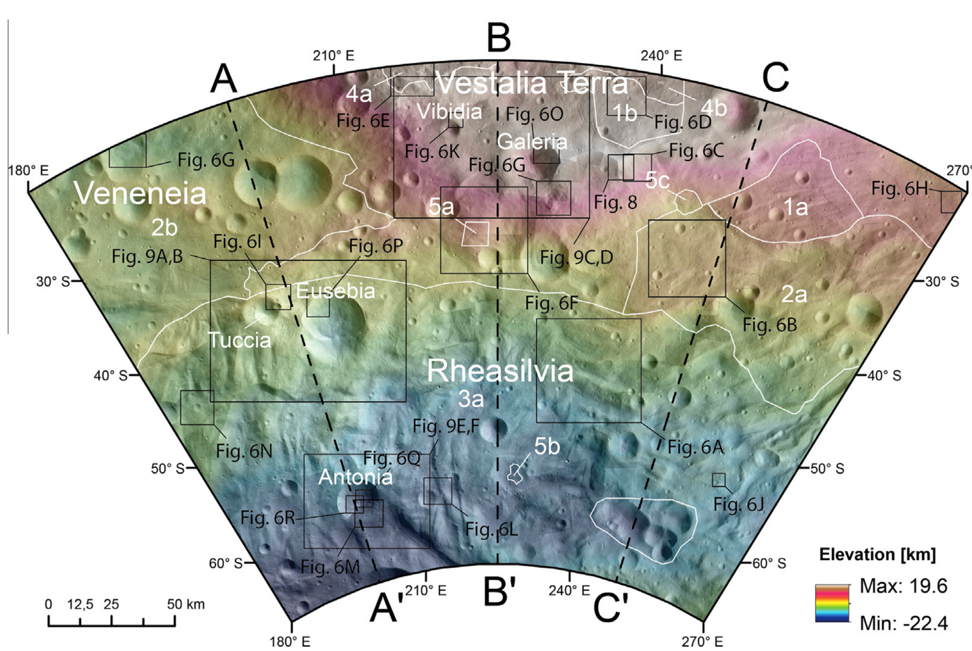

Fig. 1. Overview map of quadrangle Av-13 Tuccia. Black dashed lines denote locations of topographic profiles shown in Fig. 4. Locations of other figures are shown as black solid boxes. White lines denote boundaries of measurement areas used for crater counts shown in Fig. 5. Here, white measurement-area labels correspond to ID numbers given in Table 1 and in the CSFD plots, respectively. Further crater measurement areas are shown in the detailed maps in Fig. 9. Image derived from LAMO FC clear-filter mosaic (20 m/px) overlain by color-coded digital terrain model (DTM); heights refer to a 2-axial reference ellipsoid of 285 × 229 km (radii), Lambert conformal conic map projection with central meridian at 225°E and standard parallels at 30°S and 58°S.