Crate Chains on Rhea: Impacts from Tidally-Disrupted Comets?

R. Johnston1, O. White2, T. Hoogenboom2, and P. M. Schenk2. 1Brigham Young University, Provo, Utah 84602 (becky.johnston@byu.edu), 2Lunar and Planetary Institute, Houston, Texas, 77058 (white@lpi.usra.edu, hoogenboom@lpi.usra.edu, schenk@lpi.usra.edu)

Introduction

Crate chains are defined as linear strings of closely spaced, roughly similar-sized, aligned circular depressions. Many were designated as simply secondary impacts from the ejecta of initial basin impacts. With the appearance of Comet Shoemaker-Levy 9 in 1992 and its subsequent breakup into the “string of pearls” (seen above), and its impact into Jupiter in 1994, a new process became illuminated as a possible origin for some of the crate chains: tidally disrupted cometary impacts. Previous studies have focused on searching the Jovian system for possible crate chains created by tidally disrupted comets. We expanded the search to the Saturnian system, specifically the icy moon of Rhea. With the arrival of Cassini at Saturn in 2004 there is adequate global coverage at appropriate resolutions to search the surface for crate chains.

Methods

The initial step involved identifying as many crate chains as possible within the Voyager and Cassini image data sets and each was catalogued into one of three morphological classes: pearls, grooves, and needles (see Fig. 1).

The catalogue records the center coordinates, azimuth, length, maximum width, and morphology type of each chain. A scaling law previously applied to lunar secondaries [7] was used to determine the smallest possible size of the primary impactor from the largest crater diameter in the chain: \( D_2 = 0.14D_1^{0.7} \), where \( D_2 \) is the diameter of the largest crater in the chain and \( D_1 \) is the smallest diameter of the primary basin.

Preservation state of the “secondary” and the potential source basin needed to be roughly similar.

Results

• 66 total catalogue chains
• No chains found at the poles
• Most needles were found in higher latitudes
• 80% of the recorded chains are satisfactorily associated with possible source basins and are secondary candidates. Some craters were associated with multiple chains (see Fig. 4 below)
• Anomalous chains do not have any associated basins that are parental candidates
• 13 anomalous chains could potentially have been created by tidally disrupted comet impacts

Discussion

Figure 2. Global distribution of crate chain morphologies on Rhea, superimposed on a digital elevation model. Pearls are green, grooves are red, and needles are blue. The rims of craters >100 km in diameter are highlighted in black. The sub-Saturnian point is located at 0°N, 0°E. The blue area highlights the hemisphere where disrupted cometary impacts are expected based on observations at the Galilean moons [4]. The red areas highlight Cassini coverage obtained at better than 0.2 km/pixel.

Thebeksan Catenae, the red chain, and its groundtrack. The square-like dotted line represents the minimum size basin required to create secondary impacts of Thebeksan’s size. The resulting basin would have covered one full hemisphere of Rhea; a highly improbable occurrence with Rhea presently intact.

Thebeksan Catenae, an anomalous chain centered at 18°S, 175°W, is by far the largest chain catalogued in terms of area (length of 290 km, width of 54 km). It is composed of the large impacts running from SW to NE.

Table 1. Counts and mean values for chain length, width and positive azimuth for the three chain morphologies.

<table>
<thead>
<tr>
<th>Chain Morphology</th>
<th>Count</th>
<th>Mean Length (km)</th>
<th>Mean Width (km)</th>
<th>Mean Azimuth (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearl</td>
<td>50</td>
<td>2.9</td>
<td>56</td>
<td>55</td>
</tr>
<tr>
<td>Groove</td>
<td>10</td>
<td>5.4</td>
<td>50</td>
<td>83</td>
</tr>
<tr>
<td>Needle</td>
<td>5</td>
<td>1.7</td>
<td>61</td>
<td>43</td>
</tr>
</tbody>
</table>

Fig. 3. Histograms of (a) chain length, (b) chain width and (c) chain azimuth for the three chain morphologies.

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References