CRATER CHAIN CLASSIFICATION AND ORIGINS ON RHEA. R. Johnston[1], O. White[2]. [1]Brigham Young University, Provo, Utah 84602 (becky.johnston@byu.edu), [2]Lunar and Planetary Institute, Houston, Texas, 77058 (white@lpi.usra.edu)

Introduction: Crater chains are defined as linear strings of closely spaced, roughly similar-sized, aligned circular depressions, and were first identified on the Moon from Lunar Orbiter and Apollo imagery [e.g. 1, 2], and later on the Galilean moons Ganymede and Callisto from Voyager and Galileo imagery [3, 4]. Lunar chains are interpreted to be formed of secondary impact craters ejected from a primary source crater [5], yet after the impact of the tidally disrupted comet Shoemaker-Levy 9 into Jupiter in 1994, it was postulated that impact of such disrupted cometary fragments into planetary surfaces was another viable mode of formation of crater chains [4]. A survey of crater chains on Ganymede and Callisto yielded 11 chains (or catenae) that could not be linked to any potential source basin, and which were labeled 'anomalous' and considered to be of possible cometary origin [4]. A possible third, endogenic mode of origin is formation through subsidence caused by tectonic activity on the parent body [4]. Identifying crater chains formed by secondary impacts is important for dating planetary surfaces, as distinguishing primary and secondary impacts allows more reliable crater counts to be obtained; determining a cometary origin for a chain allows the properties of the original comet to be deduced [3].

Only a few, putative crater chains have been observed on Saturn's satellites in Voyager imagery [4] and theoretically, the existence of cometary chains formed by a Shoemaker-Levy 9-sized event is unlikely because the periapsis of the orbit that is necessary to achieve tidal disruption of such a comet is actually inside Saturn due to the planet's lower density [4, 6]. However, Cassini orbiter imagery, which became available in 2004, has provided much more extensive coverage of its satellites, and at greater resolution than Voyager, making possible a focused study of crater chains in this system.

This abstract focuses on Rhea, one of the most heavily cratered of the satellites. We have identified crater chains on Rhea and subdivided them into those that can confidently be linked to source basins, and those interpreted to be of a cometary or tectonic origin.

Methods: The initial step involved identifying as many crater chains as possible within the Voyager and Cassini image data sets which include 1032 images, 31 of which are from Voyager. In order for a group of craters to be classified as a chain, four or more craters aligned roughly linearly had to be observed. 66 such chains were identified with a high degree of confidence, and each was catalogued into one of three morphological classes: pearls, grooves, and needles (see Fig. 1). Pearls comprise a chain of discrete, mostly circular impact craters that do not overlap. Grooves are essentially linear troughs, but in which 'bulges' representing individual impacts can still be discerned; Any discrete impact craters in the chain are elongate. Needles are linear troughs with no identifiable individual impacts.

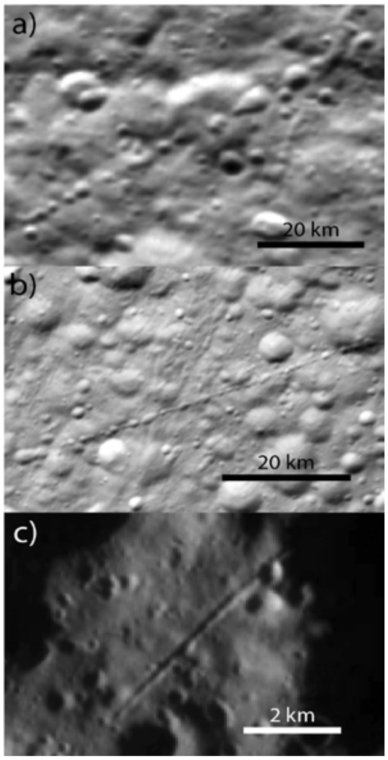

Figure 1. Crater chain morphologies (a) Pearl chain located at 5.5°S, 63.1°W. (b) Groove chain located at 33.5°N, 167.8°W. (c) Needle chain located at 4°N, 45.7°W.

The classification system is subject to image resolution and solar incidence angle. The same chain may appear to have a different morphology in two different images. In such cases, the morphology as it appears in the highest resolution image is recorded.

The catalogue records the center coordinates, azimuth, length, maximum width, and morphology type of each chain (See Table 1 for mean values). For each chain, the coordinates of several points along the chain are used to define a small circle that would represent the groundtrack of the path taken by the ejecta, assuming the chain is comprised of secondary impact craters. This path is then scrutinized for potential source craters that overlap with it. Secondary impactors typically occur radially from the original impact, yet in some cases may even occur tangentially to the primary. To account for this, craters are sought that the small circle not only passes through but are near enough, given the standard deviation to be tangential candidates.

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

	Pearls	Grooves	Needles
Count	10	37	19
Length (km)	55	83	43
Width (km)	2.9	5.4	1.7
Azimuth (°)	56	50	61

The likelihood of a primary crater being the source of a chain also depends on the relative sizes of the source crater and the 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: $D_2 \approx 0.14 D_p^{0.77}$, where D_2 is the diameter of the largest crater in the chain and D_p is the smallest diameter of the primary basin. In addition, the calculated value of D_p was relaxed by 80% in order to account for variance in impact crater behavior. The chain should also be sufficiently proximal (taken to be within 90°) of the source basin.

In order for a source crater to be confidently identified, both the small circle fit, scaling law fit and proximity should be satisfied. While a more subjective criterion, the preservation state of the chain and source crater should also be similar. If no qualified candidates exist, the chain is termed anomalous.

Results: The locations of all 66 catalogued chains are shown in Fig. 2. and Table 1 collate statistics for various properties of each chain class.

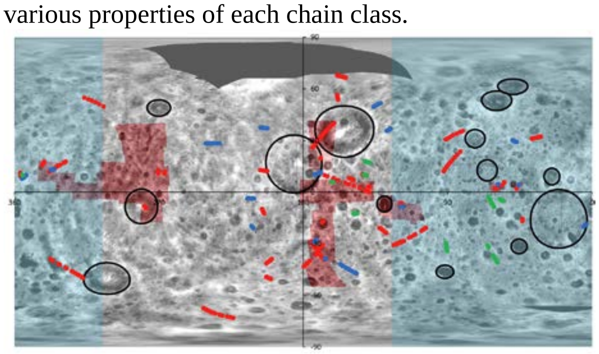

Figure 2. Global distribution of crater chain morphologies on Rhea, superimposed on a digital elevation model. Pearls are green, grooves are red, and needles are blue. The rims of craters >100 km in diameter are highlighted in black. The sub-Saturnian point is located at 0°N, 0°E. The blue area highlights the hemisphere where 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/px.

There were no chains recorded at latitudes of greater than 70°N and less than 72°S. The paucity of chains at the northern pole is influenced by the lack of image coverage in that area. 52% of crater chains recorded lie between 105°W and 215°W, 31% of the moon's surface. In order to determine whether the distribution of chains may be influenced by image resolution, we have begun mapping image resolution across Rhea (red area in Fig. 1). At present we have only mapped the location of coverage better than 0.2 km/px, which is not yet sufficient to state whether image resolution is a factor, but some of the smallest chains have been mapped in very high resolution images (notably at 5°N, 50°W).

Discussion: 80% of the recorded chains are satisfactorily associated with possible source basins and are secondary candidates. Some craters/basins were associated with multiple chains. Anomalous chains do not have any associated basins that are parental candidates. These chains do not have a basin within 90° of the proper scaling to be a source.

All the chains identified as being of cometary origin on Ganymede and Callisto lie within a hemisphere that is shifted ~35° towards the leading hemisphere relative to the sub-Jovian point at 0°N, 0°E (i.e. 55°E to 125°W) as a result of the orbital dynamics of the impacting cometary fragments [3]. If cometary impacts on Rhea are comparable, then out of the 13 chains that are cometary candidates, 9 fall within the cometary zone (blue area in Fig. 2).

More chains were observed on Rhea than expected from the study of the Galilean moons. 16 crater chains were identified on Ganymede and Callisto [4], which have surface areas at least an order of magnitude greater and surface gravities at least 5 times greater than those on Rhea, and which would therefore be expected to display a much higher chain count. Possible explanations for this discrepancy include imagery of Ganymede and Callisto obtained by Galileo and Voyager being less extensive and of inferior resolution relative to Cassini imagery of Rhea.

Future Work: Identification and classification of crater chains on Rhea from the available imagery can be considered complete. Presently, a study of Cassini imagery of Iapetus, another Saturnian moon is in progress. This will refine our understanding of the mechanics of secondary, cometary and otherwise anomalous crater chain formation on the icy Saturnian satellites.

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