COMPARING BINARY SYSTEMS OF THE INNER AND INTERMEDIATE ZONES OF THE ASTEROID BELT P. F. Wren[1] and R. A. Fevig[2], [1]Mars Space Flight Facility, School of Earth and Space Exploration, Arizona State University, 201 Orange Mall, Tempe, AZ 85287 [2]Department of Space Studies, University of North Dakota, Clifford Hall Room 512, 4149 University Ave Stop 9008, Grand Forks, ND, 58202 paul.wren@und.edu

Introduction: A doublet is a pair of impact craters created by the same primary impact event [1]. Doublets have been observed on Earth, the Moon, Mercury, Venus, Mars, Ceres [2,3,4,5,6,7,8,15], and we recently reported the discovery of doublets on Vesta [18].

Doublet crater formation. Originally, doublet crater formation was attributed to a single impactor broken up by either atmospheric disruption [9] or tidal forces [1,10], but further studies showed these processes could not result in sufficient separation to create the observed doublets [11,12]. It is now believed that well-separated binary asteroids are the source of doublet craters [12]. This makes doublets a source of evidence for the prevalence of binary asteroid systems.

Constraining binary asteroid populations. The percentage of asteroids in the near-earth population that are binary is fairly well established at 15%, and doublet craters on Mars, Earth, Venus, and the Moon have been used to confirm this value [2,14]. 144 binary asteroids have been identified in the main belt using ground-based and spacecraft observations [13], but smaller binary systems have likely gone undetected. In a previous study, images of 1 Ceres taken by the Dawn spacecraft were analyzed for the presence of doublet craters [15,16]. These impact features provide evidence for the size and abundance of binary asteroid systems in the intermediate zone of the main belt, down to smaller diameters than previously possible.

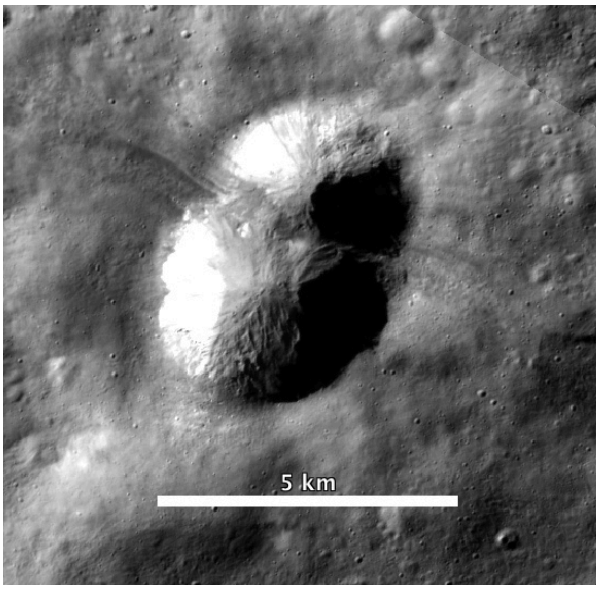

Figure 1: "Pair 1", a very likely doublet crater, featuring both a septum and ejecta lobes. From Dawn Framing Camera image FC0024266 [15].

Recent Vesta study. The authors have subsequently applied the same methods used in the Ceres study to measure the abundance of doublet craters on 4 Vesta [18]. We surveyed 55,218 square kilometers in the Divalia Fossae region of 4 Vesta. 289 craters ≥ 3 km in diameter were identified, constituting 2087 pairs that could possibly be doublets. Four candidate doublets were identified, two of which were considered likely (see Table 1). The best candidate is shown in Figure 1.

Table 1: Candidate Doublets in 1 Vesta in Study Area

Crater Pair	*Longitude*	*Latitude*	*Diameter (km)*	*Separation (km)*	*Impactor Diam (m)*	*Doublet?*
Pair 1	90.500	17.016	3.8	1.87	255	Very likely
	90.703	17.375	3.0		189	
Pair 2	98.557	-18.566	3.7	2.32	247	Likely
	98.192	-18.934	4.5		317	
Pair 3	91.169	-8.560	3.2	2.15	205	Possible
	91.609	-8.734	3.2		205	
Pair 4	57.094	18.703	4.3	4.55	299	Possible
	58.141	18.766	4.4		308	

Comparing inner and intermediate zones. As shown in Figure 2, the Main Asteroid Belt is divided by the most prominent Kirkwood gaps into three zones: Inner, Intermediate, and Outer [17]. 1 Ceres orbits in the Intermediate zone, while 4 Vesta occupies the Inner zone. Examining our new results from 4 Vesta alongside data from our Ceres study allows us to indirectly compare widely-separated binary asteroids from both the Inner

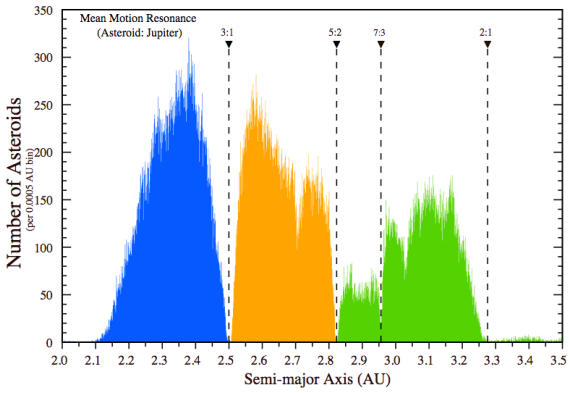

Figure 2: Distribution of Main Belt asteroids between the Kirkwood Gaps. Inner Intermediate Outer Image credit: JPL/NASA.

and Intermediate zones of the Main Belt.

Results of the comparison: On 1 Ceres, 0.7% of impact events in the study area showed evidence of double impacts. On 4 Vesta, we found that 1.4% of the impact events seemed to result from binary asteroid impacts, double the percentage observed on Ceres [18].

Discussion: What are the possible sources of the differing doublet abundances on 4 Vesta and 1 Ceres? Some possible scenarios that would lead to such a difference in observable doublet craters include:

1. Vesta's surface may be older than that of Ceres. Could the lower percentage of doublet impacts on Ceres represent a decline of widely-separated binary asteroids over time?

2. The surface compositions and densities of Ceres and Vesta are quite different. Might the water ice in the crust of Ceres cause the specific evidence for older doublet craters to form differently, and possibly disappear more quickly as a result of surface relaxation over time?

3. If there are more binary asteroids in the Inner Zone than in the Intermediate, could they be the result of a more intense YORP effect, since they are closer to the Sun?

4. Could the additional binary asteroids in the Inner Zone be Mars-crossing asteroids that have been disrupted and formed into binary systems?

Ongoing Work: We intend to begin by investigating the possibility expressed in scenario #1. Using recently-published geologic maps of 4 Vesta and 1 Ceres, we may be able to date the surface areas where we based our studies. If these do not provide sufficient coverage, we will employ crater counting in an attempt to determine the surface ages of our study areas.

We are also interested in looking further into scenario #2. Using hydrocode impact crater simulations (such as iSALE-2D described in [19]), we hope to evaluate possible differences in crater formation morphologies between 4 Vesta and 1 Ceres.

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