MORPHOLOGY AND AGE OF RHEASILVIA (VESTA), AND EXPECTATIONS FOR LARGE IMPACT BASINS ON CERES. P. Schenk[1] S. Marchi[2], D.P. O'Brien[3], C.T. Russell[4], and C. Raymond[5], [1]Lunar & Planetary Institute, Houston, TX (schenk@lpi.usra.edu); [2]Southwest Research Institute, Boulder, CO; [3]Planetary Science Institute, Tucson, AZ; [4]University of California, Los Angeles, CA, [5]Jet Propulsion Laboratory, Pasadena, CA.

Introduction: The geologic history of asteroid 4 Vesta is dominated by the large impact events Veneneia (D~400 km) and Rheasilvia (D~505 km) near the South Pole [1,2]. Rheasilvia is also stratigraphically the youngest large impact feature on Vesta [2,3]. Reasonable flux models [4] indicate that at least 8±4 similar size basins formed on Ceres. We therefore examine the morphology of Rheasilvia and similar Solar System analogs on small icy bodies, with an eye on predicting crater and basin morphologies on ice-rich Ceres [e.g., 5].

Age and Morphology of Rheasilvia: Rheasilvia basin (RS) is basically a deep bowl-shaped complex crater dominated by a large 22-km-high central massif [2]. The closest morphologic analogs to Rheasilvia are the large basins of Hyperion, Rhea and Iapetus. These basins are remarkably similar to RS in morphology, except are about half as deep, consistent with the generally shallower depths of complex craters on icy satellites [6]. These similarities suggest that the general RS landform is characteristic of large impacts into small bodies, regardless of composition.

The age of formation of RS was initially estimated at 1 Gyr (with ≥20% uncertainties) [2,3]. This has recently been challenged [7] and assigned an age of 3.5 Gyr. The primary evidence for this ancient age is three small sites purported to have relict crater populations dating back to this date (the sites include the ejecta blankets of two later impacts superposed on RS ejecta, and the central peak of RS itself [7]). Close examination of these sites demonstrates that the purported craters that form this population simply do not exist, either as discrete craters or as depressions, negating any evidence for an older age. The argument related to the central peak of RS is that the crater population there is greater than the mean crater density on the crater floor. This argument assumes that the crater density on the floor of RS is uniform, which is not correct. Detailed counts demonstrate that the crater density on the floor varies by a factor of 2 over distances of <100 km, within contiguous geologic units, and can locally be greater than (correctly) mapped on the central peak. The crater statistics of small areas used by [7] are therefore unreliable for local mapping. In addition, the central peak terrain contains only very small craters, whose scaling is affected by terrain properties to a greater extent than the larger craters mapped on the floor of RS, or on proximal ejecta [3,8].

Detailed crater counts of RS now confirm the young age estimated by [2,3] and do not support the putative ancient age proposed by [7], who argue that the younger age indicated by the lower crater density on the floor is due to gigantic post-impact landslides occurring 1-2 Gyr *after* impact. This interpretation is based in part on the large number of unusual arcuate and spiral scarps marking the floor of the basin [2,9].

The arcuate scarps form a distinctive pattern covering all of the floor of RS [10]. These were initially interpreted as fault scarps formed due to inward flow of material during the crater modification stage in the minutes immediately after impact [2]. Similar fault patterns are well documented in eroded terrestrial craters [e.g., 11], and in experiments involving radial compression [cf. 2]. Spiral fault patterns are also observed in the lunar crater King, on the high side of its tilted floor (the side no longer covered by impact melt and debris, which usually obscures such features). On the other hand, no known examples of massive landslides resurfacing entire basin floors *well after the initial impact* have ever been documented on another planetary body: icy, silicate or otherwise.

No relict ancient terrains have been found anywhere within RS. If post-impact landslides have resurfaced all of RS, they would have to have been 100% efficient and landslides are not 100% efficient. Further, RS retains a deep topography consistent with the depths of unmodified smaller craters on Vesta. There is therefore no need to invoke post-impact modification of RS, especially when the fully documented mechanism of prompt radial convergence and floor rebound will produce a pattern similar to the one we observe on Vesta. Crater counts and geologic evidence all point to a relatively young age of formation of RS with minimal post-formation resurfacing (mostly small landslides and regolith development [10]).

Predicted Basin Morphologies on Ceres: The young age of RS implies that 8±4 large (>400 km) basins will have formed on Ceres [4]. HST results do not reveal any major depressions but partially relaxed basins of the type seen on icy satellites are 2-8 km deep and generally below the HST detection threshold. We must therefore await Dawn arrival in early 2015 to assess large crater populations on Ceres.

Ceres is postulated to be composed of large quantities of water ice [e.g., 5] and may be actively venting water vapor [12]. As such, any impact features may have formed in a water-ice-rich mantle. As impact morphologies are largely (though not completely) controlled by gravity and composition [e.g., 6], it is likely that impact morphologies on Ceres will most resemble those on the ice-rich midsize satellites of Saturn (to which Ceres has similar surface gravity), namely Dione, Tethys, Iapetus and Rhea. Comparison of impact features on Ceres with those on silicate-rich Vesta will also be illuminating if Ceres is ice-rich as surface gravity is also similar on those two bodies.

On midsize Saturnian satellites, complex crater morphologies up to the largest basins >500 km across [with the exception of Odysseus on Tethys] are dominated by large central peaks and minimal rim slumping. Some of these basins have undergone significant relaxation (Fig. 1), resulting in residual topographic rings at the central peak, edge of the central uplift and along the rim [13]. Extensive relaxation has been postulated for Ceres due to the warm surface temperatures, especially near the equator and mid-latitudes, [14,15]. Severe relaxation of craters on active Enceladus also leaves residual circular rim ridges. Relaxation on Ceres may leave topographic rings of this type, distinct from noncircular volcanic features of the type seen on Ganymede and Triton.

Relaxation alters original topography, but impact into warmer ice may also alter the flow of material during formation and produce unusual impact landforms. Examples of this may be found on Ganymede, where palimpsests, penepalimpsests, and anomalous dome craters (which lack rim scarps) have all been interpreted as recording significantly higher heat flow in Ganymede's ancient past, resulting in non-standard impact features [6]. Formation of palimpsest albedo scars, like those on Ganymede [e.g., 6], will require an albedo contrast between Ceres' surface and its shallow interior.

The largest impacts on Ceres may also have formed in both icy shell and silicate mantle. Recent numerical modeling shows that the severe rheologic contrast between these two material may significantly alter the behavior and resulting morphology of large impacts into Ceres [16], if it has an ice-rock layered interior. How this hybrid impact process would alter morphologies is unclear. No obvious signature of this has been identified on the icy Saturnian satellites, but the interior structures of these bodies have not been unambiguously determined (although Tethys is likely to be icy throughout), and differences in topographic signatures on the surface between impact in layered and unlayered targets may or may not be subtle.

Finally, sublimation erosion of landforms similar to what was observed on Callisto [17] may be prevalent on Ceres, where temperatures are higher and albedos lower. In contrast to relaxation, sublimation erosion tends to erode high-frequency topographic features first. All of these processes may be operating on Ceres, but the first priority will be to determine the nature of unmodified impact craters so as to constrain the degree of modification; and Vesta and Dione will be the logical starting points.

While Ceres is expected to have experienced a sizable number of complex craters and at least a few impacts comparable to Rheasilvia and Veneneia on Vesta, the resulting crater morphologies on Ceres are likely to be quite different from those recently observed on Vesta. From icy satellites we expect secondaries and ejecta deposits, but craters are likely to be shallower on Ceres, regardless of whether or not viscously relaxation has further reduced topography. Central peaks will occur at much smaller crater diameters. Sublimation erosion and endogenic activity may further modify impact landforms.

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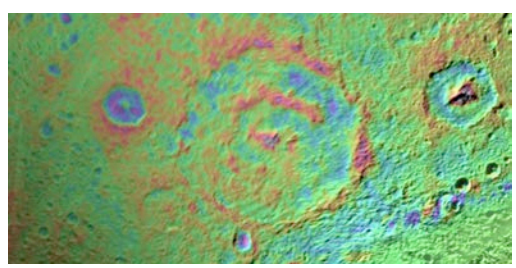

Figure 1. Color-coded topographic map of relaxed Evander basin (D~350 km) on Dione. Total portrayed relief is 3 km. Note prominent central peak in relaxed crater at right.