THE TECTONICS OF VESTA. D.L. Buczkowski[1], D.Y. Wyrick[2]., E. Kahn[1], O. Barnouin[1], A. Nathues[3], R.W. Gaskell[4], T. Roatsch[5], F. Preusker[5], C.T. Russell[6]. [1]JHU-APL, Laurel, MD; [2]SwRI®, San Antonio, TX; [3]Max Planck Institute, Katlenburg-Lindau, Germany; [4]PSI, Tucson, AZ; [5]DLR, Berlin, Germany; [6]UCLA, Los Angeles, CA.

Introduction: Framing Camera (FC) images from NASA's Dawn spacecraft revealed the presence of multiple structural features at a variety of scales on Vesta. Analysis of these structures was performed to better understand their genesis.

Models of Asteroid Tectonics: Numerical calculations have indicated that impacts into asteroids could be responsible for the formation of fractures. Axi-symmetric calculations a Stickney-sized impact in a Phobos-like ellipsoid predicts sizes of spall that compare favorably with the spacing of grooves and fractures seen on Phobos [1], supporting the idea that these feature were in fact the result of the Stickney impact [2]. Simulations also indicate that impacts into the flat portion of an elongated ellipsoid generate circumferential fractures perpendicular to the impact normal, while impacts on the curved ends of the asteroid result in fracturing mainly at the antipode [3]. This model is consistent with observations of Ida [3,4] and Eros [5].

Lineated small bodies could alternately be fragments of larger parent bodies on which the structures actually formed. For example, a pre-existing structure throughout most of Eros was found to be consistent with a fabric inherited from a parent body [6]. These putative parent bodies are larger and maybe even differentiated, meaning that their surface structures could possibly be the result of internal processes such as rifting or uplift. Vesta, being large and differentiated [7], is our first opportunity to search for such planetary style tectonism on an asteroid.

Impact-Related Structures: Features observed on Vesta include an equatorial set of wide flat-floor troughs bound by steep scarps, named Divalia Fossae. These 86 linear structures encircle the asteroid for ~240º longitude. Lengths vary from 19 - 380 km and widths are up to 15 km; vertical displacements along the underlying faults range from ~2 up to 5 km.

A second set of large-scale features, the Saturnalia Fossae, extend to the NW at an angle from Divalia. The primary structure is ~390 km long, 39.2 km wide and accommodates up to 4 km of vertical displacement [8]. Shallower walls, rounded edges, infilling and heavy cratering suggest it is an older feature than the Divalia structures. Seven Saturnalia grooves range from 31-212 km long [8].

The orientation of both fossae is consistent with models of giant impact into a differentiated asteroid [e.g. 8-12]. The poles of the two fracture plane sets cluster roughly at the coordinates of the centers of the Rheasilvia and Veneneia basins (Fig. 1). The older Saturnalia features have poles that cluster at 60º ± 10º latitude and 160º longitude, roughly the center of the older Veneneia basin. The Divalia poles cluster at 78º ± 10º latitude [8,13]; the pole longitudes vary, but all poles are on Rheasilvia's central mound. Clustered poles indicate that the fracture planes are similarly oriented and likely share a common formation mechanism [5,6]. Therefore, despite the large scale of these structures, it seems that they are the result of impact.

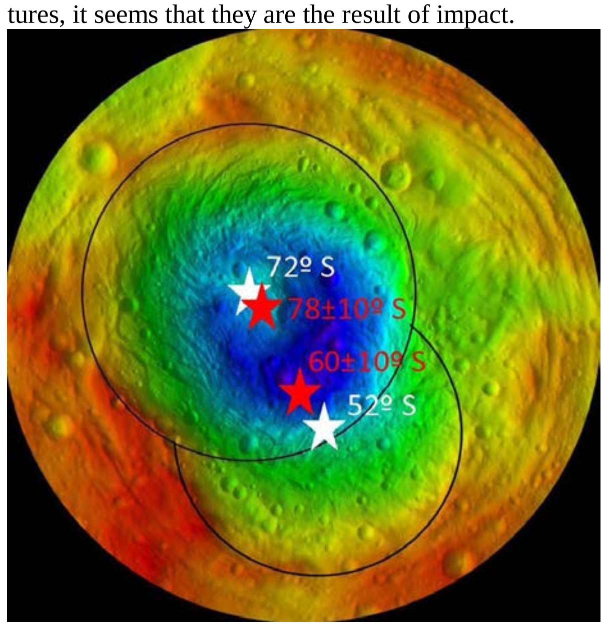

Figure 1. Topographic image of south pole of Vesta. White stars and numbers show latitudes of the centers of Rheasilvia (upper) and Veneneia (lower). Red stars and numbers show the poles of the two sets of fossae.

Possible Non-Impact Structures: The equatorial troughs do not cut the Vestalia Terra plateau (VT), but there are three long pit crater chains (PCCs) observed on its surface [8,14]. PCCs are hypothesized to form when dilational motion on buried normal faults cause overlying material to collapse into the opening portions of the buried fault [15]. The merged pits of the VT PCCs show signs of collapse but distinct fault faces can also be observed [14], suggesting that they are indeed representative of subsurface faulting of the plateau [8].

As the PCC Albalonga Catena progresses westward it phases from being a topographically low feature of merged pits into being the topographically high Brumalia Tholus (Fig. 2a,b). Westward of the hill, merged pits are again visible in the slope data (Fig. 2c). Brumalia Tholus may have formed as a magmatic intrusion utilized the Albalonga fault as a conduit to the surface and deformed the overlying rock [16].

Teia crater impacts the northern face of Brumalia Tholus (Fig. 2) and thus its ejecta is likely sampling Brumalia's core material. These ejecta have a distinct smeared and flow-like texture and a distinct false color in the FC color data. VIR shows that while the background VT material is howarditic [17], the Teia ejecta are more diogenitic [18]. VIR also identified diogenite inside small craters on the top of Brumalia Tholus. These identifications of plutonic diogenite are consistent with the hill representing a magmatic intrusion.

Discussion: Brumalia Tholus as a magmatic intrusion requires that Albalonga faulting occurred before volcanism on Vesta ceased >4.4Ga [e.g. 19,20], long before the Rheasilvia impact (1 Ga [21] or 3.6 Ga [22]). While Albalonga faulting could be the result of an earlier impact, it is also possible that it formed by internal magmatic processes.

Dike injection has been shown to sometimes result in overlying graben formation on Earth, Mars and Venus [e.g. 24,25] and so it is possible that the VT faults formed due to diogenitic intrusion into the crust [26]. However, while the orientation of the VT faults suggests they have a common formation mechanism, only Albalonga Catena shows any evidence of magmatic intrusion. This strongly implies that the faults pre-date the Brumalia intrusion, rather than being caused by it.

Instead, the VT faults may have formed due to extension during the upwelling of the plateau, as VT has been theorized to be a fossil magma plume [23]. Then, due to speculated differences in fault depth, only Albalonga was intruded by the deep molten material.

Regardless, either model invokes internal magmatic processes (not impact) in the formation of the observed structures. Thus the VT PCCS may be the first observation of internally-driven faulting on an asteroid.

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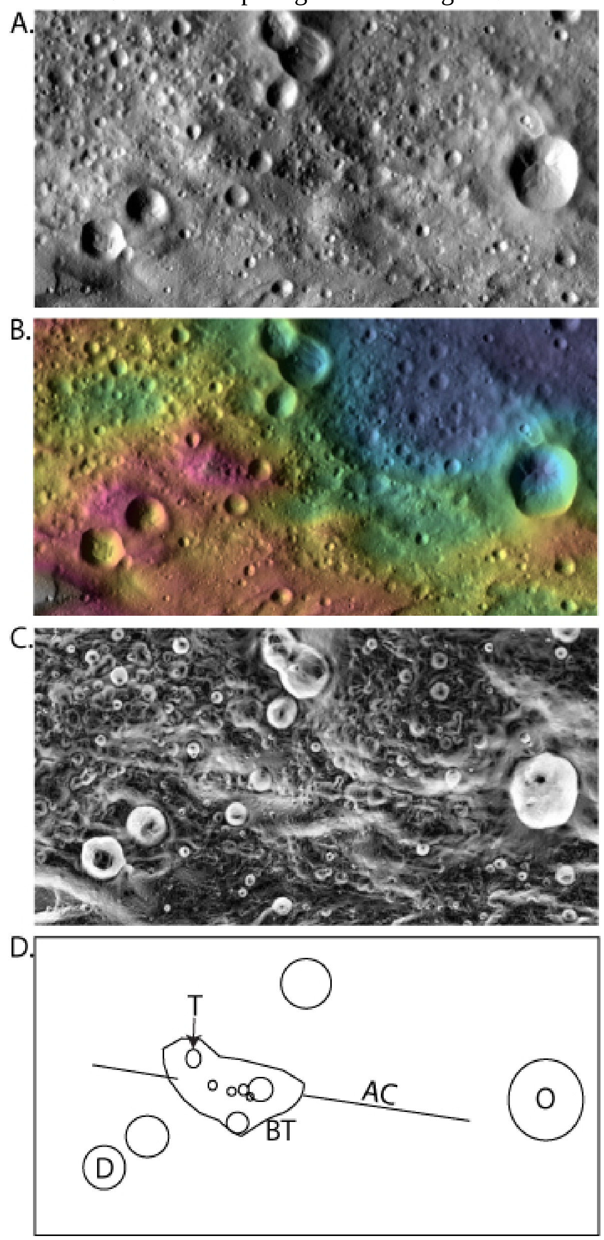

Figure 2. Eastern Vestalia Terra. A) FC mosaic. B) Topography. C) Slope data. D) Sketch map. BT= Brumalia Tholus; AC=Albalonga Catena; T=Teia; O=Oppia; D=Drusilla. Unnamed craters also drawn.