

**BASALTIC RING STRUCTURES AS AN ANALOG FOR RING FEATURES IN ATHABASCA VALLES, MARS.** W. L. Jaeger<sup>1</sup>, L. P. Keszthelyi<sup>2</sup>, D. M. Burr<sup>2</sup>, J. P. Emery<sup>3</sup>, V. R. Baker<sup>1</sup>, A. S. McEwen<sup>1</sup> and H. Miyamoto<sup>4</sup>, <sup>1</sup> Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, jaeger@lpl.arizona.edu, <sup>2</sup> Astrogeology Team, U.S. Geological Survey, Flagstaff, AZ 86001, <sup>3</sup> NASA Ames Research Center, Mottfield, CA 94035, <sup>4</sup> Department of Geosystem Engineering, University of Tokyo, Tokyo 113-8656, Japan.

**Introduction:** Basaltic ring structures (BRSs) are enigmatic, quasi-circular landforms in eastern Washington State that were first recognized in 1965 [1]. They remained a subject of geologic scrutiny through the 1970's [2,3] and subsequently faded from the spotlight, but recent Mars Orbiter Camera (MOC) images showing morphologically similar structures in Athabasca Valles, Mars, have sparked renewed interest in BRSs. The only known BRSs occur in the Channeled Scabland, a region where catastrophic Pleistocene floods from glacial Lake Missoula eroded into the Miocene flood basalts of the Columbia Plateau. The geologic setting of the martian ring structures (MRSs) is similar; Athabasca Valles is a young channel system that formed when catastrophic aqueous floods carved into a volcanic substrate [e.g., 4-8]. This study investigates the formation of terrestrial BRSs and examines the extent to which they are appropriate analogs for the MRSs in Athabasca Valles.

**The Odessa Craters:** More than 100 BRSs occur near Odessa, WA [2,3]. These so-called Odessa Craters are defined by annuli 50-500 m in diameter [3]. Inside each annulus, basalt outcrops in discontinuous, concentric ridges and scarps ( $\leq 10$  m high). Topography is variable; some BRSs have central peaks surrounded by moats, but most have crater-like depressions. We collected data at five Odessa Craters: two with central depressions, two with central peaks, and one that is relatively planar.

**Lithofacies.** Basalt outcrops at the Odessa Craters can be subdivided into three lithofacies: country rock (*i.e.*, the solidified crust of the lava flow), autointrusive dikes (*i.e.*, dikes fed from the interior of the lava flow), and central mound material (which occurs only in the two structures with topographically high centers). The concentric ridges and scarps consist of country rock and dikes with narrow basalt columns suggestive of water-cooling [9], while the central mound material has wide columns suggesting slow, subaerial cooling.

**Structural data.** At each of the five Odessa Craters, we recorded the attitudes of basalt columns as trends and plunges. On average, country rock columns plunge steeply ( $\sim 76^\circ$ ) away from the center of the BRS, dike columns plunge moderately ( $\sim 37^\circ$ ) towards the center, and central mound columns have near-vertical plunges ( $\sim 83^\circ$ ) with no obvious pattern in the trend data. Additionally, the plunges of country rock columns change as a function of distance from the

center of the BRS; plunges at the perimeter average  $79^\circ$  and those nearest the center average  $60^\circ$ . Collectively, these data show that the Odessa Craters are axially symmetric structures intrinsic to the basalt and that the Missoula Floods only served to expose these pre-existing structures.

**The Banks Lake Structure.** A broad, funnel-shaped structure in the basaltic cliff face over Banks Lake has been described as the cross-sectional exposure of an Odessa Crater-like BRS [2]. However, due to its inaccessible location, previous researchers studied it telescopically from  $\geq 2$  km. We examined the Banks Lake structure *in situ* and found that the lithofacies present, their spatial distributions, the attitudes of basalt columns, and the positions of autointrusive dikes all support the interpretation that this is a BRS. Additionally, at the center of the structure and near the base of the lava flow that contains it, is a small mound of highly altered, 3-10 cm lava clasts in a matrix of palagonitized glass fragments. This phreato-volcanic construct (*i.e.* rootless cone) forms the core of the BRS.

**Origin of the Odessa Craters.** Previous models for the formation of the Odessa Craters include: the sagging of solid crust into the molten interior of a lava flow [2], and flood-erosion of surficial rootless cones [3]. However, our observation that the rootless cone at the Banks Lake structure occurs at the bottom of the lava flow under  $\sim 55$  m of lava invalidates these hypotheses. We instead propose the following scenario: (1) phreato-volcanic activity disrupted a relatively thin, active lava flow and built rootless cones, (2) the lava flow inflated around the cones, (3) tensile stresses induced by inflation led to concentric fracturing, (4) dikes exploited the fractures and fed lava to the surface filling the funnel-shaped depressions and capping the rootless cones, and (5) subsequent erosive floods excavated the structures.

**The Tokio BRSs:** A second, unnamed population of BRSs lies northeast of Tokio Station, WA. These BRSs are smaller (40-150 m), single-ringed structures with slightly raised rims and considerable loess infill. Autointrusive dikes do not outcrop in the Tokio BRSs, but it is possible that they are buried. The single rings that define the Tokio BRSs consist of basalt that is analagous to the country rock in the Odessa Craters both in terms of its narrowly-spaced joints (an effect of water-cooling) and its outward trending columns (caused by inflation of the surroundings). The "matrix"

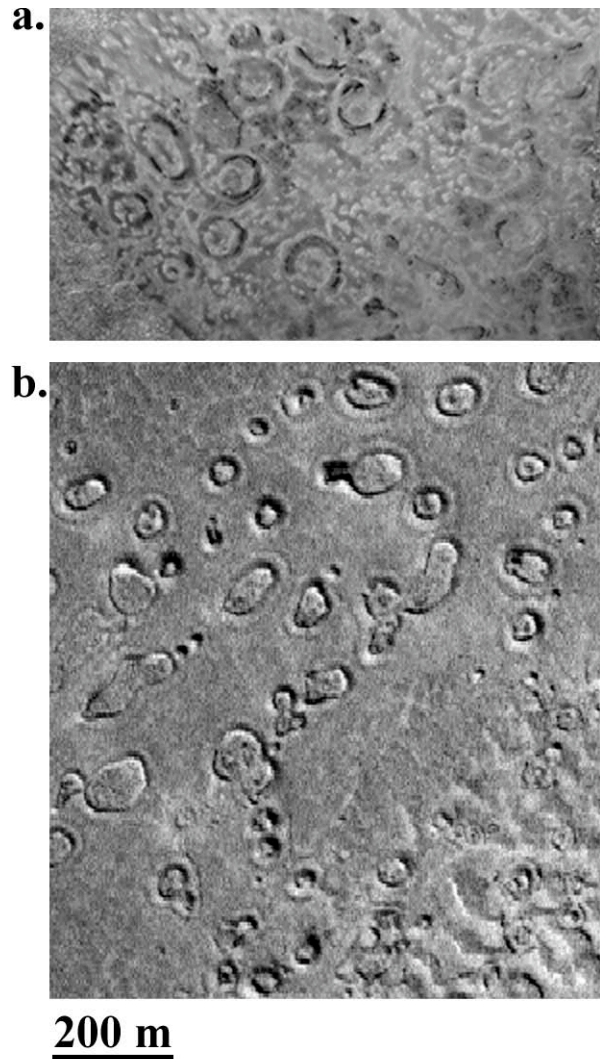
that outcrops between these BRSs is widely-jointed, subaerially-cooled basalt. These findings suggest that, like the Odessa Craters, the Tokio BRSs are sites of localized water-cooling of the lava. Thus, we interpret them as flood-eroded phreato-volcanic structures, but, because of their poor exposure we cannot determine whether lava flow inflation progressed to the point of concentric fracturing and autointrusive dike injection.

#### Comparison to Rings in Athabasca Valles:

Rings similar in appearance to the Tokio BRSs are exposed on the floor of Athabasca Valles, Mars (Fig. 1). The lithostratigraphic unit in which they occur covers much of the channel floor and has been hypothesized to be an ice-rich mud flow [10], flood-deposited sediments [11], or a lava flow [12,13], the latter being most consistent with the observation that the region is rough at radar wavelengths [8]. The MRSs occur in a subsection of this unit that is characterized by patterned terrain. Elsewhere in Athabasca Valles, the patterned terrain was found to have a relatively high thermal inertia consistent with a rocky, dense lithology [8]. Additionally, Keszthelyi et al. [12] interpret nearby terrain with the same pattern as the result of lava ponding between the rafted plates of “platy-ridged” lava flows. Because the unit containing the MRSs fills the valley floor, it must postdate the main channel-cutting phase of the floods. However, geomorphic evidence suggests that Athabasca Valles experienced multiple floods [4,8], and that otherwise pristine lavas on the channel floor were affected by late-stage flooding [8]. Thus, it is likely that the MRSs occur in an analogous geologic setting to the terrestrial BRSs, where aqueous floods eroded into lava flows.

Quantitatively, the MRSs and Tokio BRSs are comparable in diameter, ellipticity and number density. The Odessa Craters, however, are larger, more circular and more dispersed. There are several possible reasons for these differences. Pre-lava emplacement topography, ground water distribution, the extent to which inflation thickens the lava flow, and differential erosion are all factors that could affect the size and/or distribution of BRSs.

**Conclusions:** The BRSs of the Channeled Sca-bland are flood-eroded phreato-volcanic features that formed in inflated basaltic sheet flows. The MRSs in Athabasca Valles are similar in morphology and geologic setting to terrestrial BRSs. If the MRSs formed in the same way as the BRSs, then they are diagnostic of water-lava interactions and, perhaps, inflated lava flows on Mars. We will further test this hypothesis as we continue our larger effort to decipher the interplay between aqueous, volcanic, tectonic, aeolian, impact, and other geologic processes that formed the array of perplexing morphologic features in Athabasca Valles.



**Figure 1.** Comparison of (a) BRSs near Tokio Station, WA, and (b) MRSs in Athabasca Valles, Mars. The scale bar applies to both images. (a) is a low-altitude airphoto reprojected onto a USGS DOQ. (b) is an excerpt from MOC image E10-01384 (3.09 m/pix, illumination is from lower left).

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