BASALTIC RING STRUCTURES AS AN ANALOG FOR RING FEATURES IN ATHABASCA VALLES, MARS. W. L. Jaeger1, L. P. Keszthelyi2, D. M. Burr2, J. P. Emery2, V. R. Baker1, A. S. McEwen1 and H. Miya-
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Introduction: Basaltic ring structures (BRSs) are enigmatic, quasi-circular landforms in eastern Wash-
ington 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 Atha-
basca 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 basalt of the Columbia Plateau. The
gologic setting of the martian ring structures (MRs)
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 investig-
ates 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 annulli 50-500 m in diameter [3].
Inside each annullus, basalt outcrops in discontinuous,
concentric ridges and scarps (≤10 m high). Topogra-
phy is variable; some BRSs have central peaks sur-
rrounded by moats, but most have crater-like depres-
sions. 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
dikes 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 Cra-
ters, we recorded the attitudes of basalt columns as
trends and plunges. On average, country rock columns
plunge steeply (~76°) away from the center of the
BRS, dike columns plunge moderately (~37°) towards
the center, and central mound columns have near-
vertical plunges (~83°) 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° and those nearest the center average 60°. Collect-
ively, 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-
exiting 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 inac-
cessible location, previous researchers studied it tele-
scopically from ≥2 km. We examined the Banks Lake
structure in situ and found that the lithofacies present,
their spatial distributions, the attitudes of basalt col-
umns, and the positions of autointrusive dikes all sup-
port 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 palago-
natized glass fragments. This phreato-volcanic con-
struct (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 sag-
ging 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 ~55 m of lava invalidates these hy-
potheses. 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 exca-
vated 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
analogous 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 Scabland 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.