RING DIKE STRUCTURES IN THE CHANNELED SCABLAND AS ANALOGS FOR CIRCULAR FEATURES IN ATHABASCA VALLES, MARS. W. L. Jaeger[1], L. P. Keszthelyi[1,2], D. M. Burr[1,2], A. S. McEwen[1], V. R. Baker[1,3], H. Miyamoto[1,3], and R. A. Beyer[1], [1]Lunar and Planetary Laboratory (University of Arizona, Tucson, AZ 85721-0092, jaeger@lpl.arizona.edu), [2]USGS Astrogeology Research Program (Flagstaff Field Center, 2255 N. Gemini Drive, Flagstaff, AZ 86001), [3]Department of Hydrology and Water Resources (University of Arizona, Tucson, AZ 85721-0011).

Introduction: In the Channeled Scabland of eastern Washington, catastrophic Pleistocene floods scoured the surface of the Columbia River Basalts, exposing numerous ring dike structures. These structures are quasi-circular in plan view and typically have raised rims and topographically low centers with respect to the surrounding terrain. They range in diameter from 75-500 m [1]. Some of these structures are comprised of only one ring while others have concentric raised rings or arcuate ridges. The ring dike structures are best exposed near Odessa, Washington where >200 are scattered over an area of ~650 km^2 [2]. All of these structures occur within the Roza Member of the Wanapum Basalt Formation, which was emplaced ~15 Ma. We studied in detail 3 such structures: Amphitheater Crater, Cinnamon Roll Crater, and Wild Garden Crater.

Circular features that are morphologically similar to ring dike structures have been observed on Mars. MOC images show that several hundred are scattered throughout a ~1000 km^2 area in Athabasca Valles (Fig. 1), and another population of circular features is seen in Marte Valles. They are comparable in diameter and areal density to those in the Channeled Scabland, and they occur in a region where young lava flows have been eroded by even more recent catastrophic floods [3]. These features are particularly common within the area studied as a potential landing site for the MER rovers and are juxtaposed with both fluvial and volcanic features. Despite the fact that this area contains some of the most pristine morphology within Athabasca Valles, the origin of the circular features is currently indeterminate.

Possible formation mechanisms for the circular features on Mars include (but are not limited to): (1) rings of fluvial sediments that are deposited around rafts of ice that subsequently sublimed away, (2) ground warping due to mobile ground-ice, (3) eroded rootless cones, and (4) flood eroded and mantled lava. Being able to choose among these (and other) processes is important to understanding the fluvial and volcanic history of Athabasca Valles. Possible analog features involving these processes were examined in Iceland, but none were morphologically identical to the martian circular features. Instead, the ring dike structures in the Channeled Scabland are the most similar in size, shape, and geologic setting. In the following we present new field observations collected from the ring dike structures and discuss new ideas regarding their formation.

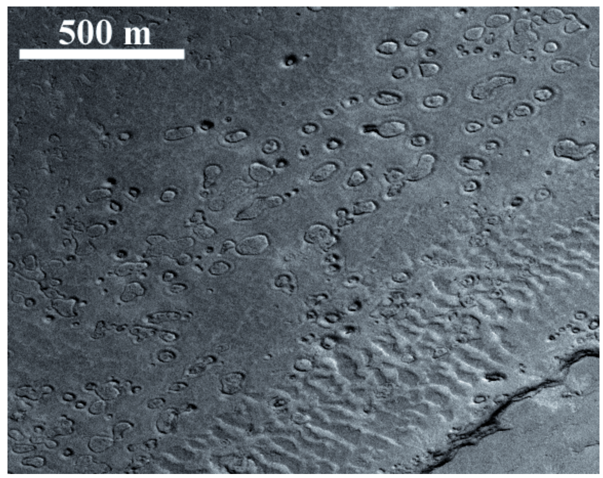

Figure 1. Circular features on the floor of Athabasca Valles, Mars. This is MOC image E10-01384.

Data: The ring dike structures that we observed all occur in entablatures with well-formed columnar jointing, diagnostic of significant water-cooling [4]. The relatively few, small, and very round vesicles are also characteristic of water-cooled lavas. The joints and columns indicate the orientation of the cooling front at the time the lava fractured (when it was ~400-1000ºC). We measured the orientation of these columns at each of the 3 ring dike structures we examined in order to (1) differentiate between dikes and original flow material and (2) reconstruct the deformation history of the lava flow. At all 3 locations we found that subvertically jointed flows were intruded by subhorizonatally jointed dikes.

Amphitheater Crater is a multi-ringed structure 220 m in diameter with a rim 20-25 m higher than its center (Fig. 2). The rim is comprised of subvertically jointed basalt and the ridges on the interior are roughly 50% dike material and 50% flow material. The structure of the basalt at Amphitheater Crater is approximately axially symmetric in that it has concentric ridges of original flow material with columns that plunge 52-84º away from the geometric center and dikes with columns that plunge 28-42º towards the center.

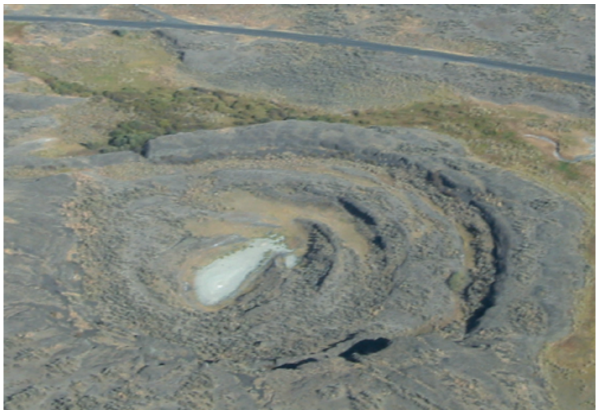

Figure 2. Amphitheater Crater is ring dike structure north of Odessa, Washington. The gray line at the top of the image is a two-lane highway. North is to the upper left.

Morphologically, Cinnamon Roll Crater appears very similar to Amphitheater Crater. However, we find a different pattern in the orientations of its columns. The subvertically jointed material that we infer to be original flow material has columns that mostly (78%) plunge 65-89º towards the geometric center, though we measured a few columns (17%) that did the opposite. We measured the orientations of columns in dikes at only 3 places on Cinnamon Roll Crater and do not find a consistent pattern in their orientation.

We recorded the orientations of columns in both subvertically and subhorizontally jointed material at Wild Garden Crater and found no recognizable pattern. However, in air photos, Wild Garden Crater does not appear to be a circular structure, instead it is a highly irregular depression.

We also examined an outcrop of the Roza Member described by McKee and Stradling [4] in which the source of a dike can be seen in cross-section. The dike is fed from within the entablature of the flow, requiring that it formed while the flow was only partially solidified. Along this same Crab Creek outcrop, there are numerous radiating fans of entablature columns. Some fans radiate downward apparently originating from a point that is above the existing surface, while others radiate upward from meter-scale cavities surrounded by zones of shattered basalt. These fanning columns appear to be associated with small steam explosions. The fan structures are smaller in diameter than the ring dikes we observed, but their columns are oriented similarly.

Formation Models: McKee and Stradling [5] hypothesized that the ring dike structures form by the sagging and foundering of crust over an active lava flow. We hypothesize that they may instead form in one of the following ways: (1) as inflation pits or (2) as fanning joints and fracture zones caused by local water influx.

In the inflation model, a section of the crust fails to inflate with the surrounding sheet of lava. The bending of the lava crust opens cracks along preexisting joints into which dikes of molten lava are injected. The stages of formation by this model are identical to those of the “sag flowout” model of McKee and Stradling [5] except that the lava around the pit rises rather than the center of the pit sinking.

An alternative model places greater emphasis on the fact that these features are only found in water-cooled, columnarly jointed lavas. Like the fanning columns seen at Crab Creek, the ring dike structures may form where steam explosions cause radial jointing and fracturing of the rock. This model is consistent with our observation that subvertical columns can plunge either toward or away from the geometric center of the structure. In all of these models the current ring structure is only exposed after scouring by catastrophic floods.

Conclusions: The morphology, scale, density, and morphologic variability of ring dike structures are similar to the diverse circular features seen in Athabasca Valles. All formation models rely on scouring by catastrophic floods. The possible need for interactions between hot lava and liquid water is intriguing, but needs more study.

References: [1] Baker V. R. and Nummendal D., eds. (1978) *The Channeled Scabland,* 70-72. [2] Mueller M. and Mueller T. (1997) *Fire, Faults, and Floods,* 288 pp. [3] Burr D. M. et al. (2002) *Icarus, 159,* 53-73. [4] Long P. E. and Wood B. J. (1986) *GSA Bull., 97,* 1144-1155. [5] McKee B. and Stradling, D. (1970) *GSA Bull., 81,* 2035-2044.