Breached craters on Mars: Terrestrial analog of downstream erosion, R.A. De Hon. Texas State University, San Marcos, Texas, 78666, dehon@txstate.edu

Rapid outflows of confined water onto an unprepared surface on Mars are termed *catastrophic outflows* [Ref]. The largest catastrophic outflows are presumed to be fed by groundwater discharge to the surface; melting ground ice; or outflow from large Martian lakes [Ref]. Terrestrial carving of the northwest scablands by release of surface water from pluvial Lake Missoula; mid-continent Lake Agassiz: or the topping of Lake Bonneville into the Snake River drainage system provides terrestrial analogs on a scale approaching that of some of the Martian outflows [1-4]. On a much smaller scale, Martian craters were often filled to overflowing. In turn, these craters spilled excess flood waters downstream as smaller outflows. These smaller flows are better matched by terrestrial examples of overfilled reservoirs that discharge by overflow of dams or emergency relief spillways. One such event is the 2002 Canyon Lake (Texas) overflow [5].

Interaction of catastrophic outflows with craters is largely controlled by the relative volume of the discharge and the size of the crater in the path of the flow. Craters may be affected in different ways. (1) An outflow may simply be diverted around a large crater without affecting the interior into the crater. The crater rim is not breached. (2) A large flow compared to crater size may overwhelm the crater, filling the inside, and cascading over the far rim with little restraint. The crater rim is greatly modified, but the rim may not show a breach. Sediment-laden water trapped in the crater deposits a layer of sediment across the entire floor of the crater as a smooth blanket. Or, (3) a lesser flow may top the leading--upstream-- rim; spill into the crater, filling it to overflowing; and spill over the far rim to continuing downslope. In the latter example, the crater may exhibit an upstream breach and one or more downstream breaches as the outflow crests the rim [6]. Depending on the quantity of water and rate of influx, a breached crater may develop a delta during filling which is preserved after the downslope rim is breached. The initial downstream flow, void of entrained sediment, has high erosional capacity.

Canyon Lake is a man-made reservoir on the Guadalupe River on the elevated side of the Balcones Fault Zone. Water release through a 3 m tunnel below the earthen dam controls the conservation lake level at 277 m. The 2002 overflow from Canyon Lake provides an analog of spillover from flooded craters [7, 8]. Flood water was discharged over an emergency spillway. A gorge was cut in a matter of days by spillover following overfilling of the Canyon Lake Reservoir caused by heavy rainfall in the upstream watershed. The emergency 365 m-wide spillway crest level is 287.4 m (10.4 m above pool level). Highest water level during the 2002 incident was 289.7 m msl, or 2.3 m above the spillway. Two times the lake volume went over the spillway in a short period of time.

The rapid discharge excavated a 2.2 km long, 7 m deep, and 12 m wide canyon in the Cretaceous Glen Rose limestone bedrock. Approximately 230,000 m^3 of rock and soil were deposited at the confluence with the Guadalupe River 2.5 miles (4 km) downstream. The rate of the canyon erosion was so rapid that it was limited only by the amount of sediment the floodwaters could carry. Erosion was largely controlled by the spacing of bedding planes and joints. Large blocks averaging 1.5-0.5 m were plucked by the turbulent discharge and deposited in mega-point bars and mid-channel bars. The channel profile consists of many vertical steps as large blocks of limestone were removed along vertical joints.

Although limestone at the Canyon Lake Gorge is softer than basalt, excavation and movement of boulder-size material is more dependent upon jointing and bedding than hardness. Channels originating from breached craters can be expected to be bedrock channels with local depositional bars of boulder-size blocks.

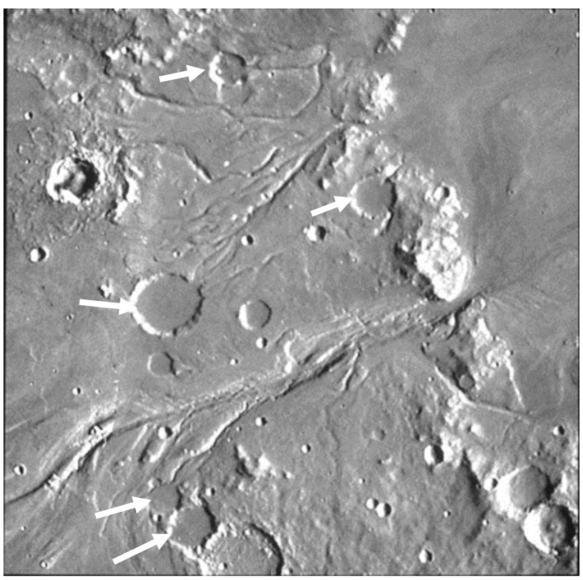

Fig. 1. Lower Maja Valles and Maumee Valles crossing Xanthe Terra. Many channels emerge from once flooded craters.

Overflows from flooded caters are common in the Maja Valles system particularly where the ponded Maja outflow flooded across Xanthe Terra as overland flow prior to channelization [9-11]. Multiple channels of the Maja, Vedra, and Maumee system flow from breached craters along the Lunae Planum—Zanthe Terra margin [Fig. 1]. Downstream flow from these craters is channelized into steep-walled valleys. Terracing along the walls of the exit channels is suggestive of layering within materials underlying Xanthe Terra.

Breached craters with smooth, floor-filling materials indicate that flood waters ponded and suspended sediments settled to cover the crater floor. The flow eventually crested the downslope rim and rapidly carved the downslope channels which merged with other channels. No subsequent inflow was available to build deltas or carve channels across the crater floor. Channels by-passing these flooded craters continued draining of the Lunae Planum impoundment.

References:

[1] Bretz, J.H., (1923) *J. Geol.* **31**, 617–649. [2] Malde, H.E., (1968) *U.S. Geol. Surv. Prof. Pap*. 596, 1–52 (1968). [3] Baker, V.R. & Milton, D.J., (1974) Icarus 23, 27–41. [4] Baker V.R., (2002) *Science* **295**, 2379–2380. [5] Ward, W.C., (2008) *Texas - Geologic and Hydrologic Issues* (Austin Geological Society) 13-28. [6] Goudge T.A., C.I. Fassett, D. Mohrig, (2018) Geology, https://doi.org/10.1130/G45397.1. [7] Klepper E.D., (2018) Texas Parks and Wildlide, July. [8] Lamb M., and M. Fonstad, (2010) *Nature Geoscience* **3**, 477-481. [9] De Hon R.A., (1992) U.S. Geol. Surv. Misc. Inves. Map 2203. [10] De Hon R.A. and E.A.Pani, (1992) Proc. Lunar Planet. Sci. **22**, 63-71. [11] Rice, J.W. and R.A. De Hon, (1996) U.S. Geol. Surv. Misc. Inves. Map I-2432.