MECHANISMS FOR OVERSPILLING FRESH, YOUNG MARTIAN CRATERS MULTIPLE TIMES, AND ABOVE THE LOWEST POINTS ON THEIR RIMS. A. O. Warren[1], S. A. Wilson[2], E. S. Kite[1], [1]University of Chicago Department of Geophysical Sciences (aowarren@uchicago.edu), [2]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution

Introduction: "Pollywog" craters are one of Mars' most enigmatic recent fluvial features. These craters range from 0.5-15 km in diameter and are characterized by relatively fresh crater rims incised by at least one exit breach channel [1]. The well-preserved crater rims indicate that pollywog incision occurred after the intense fluvial activity of the Late Noachian and Early Hesperian i.e. since 3.5 Ga [1,2] however, these craters lack inlet valleys, so the source of overspilling water must come from within the crater, either as direct precipitation, groundwater, or melt from crater-filling and/or regional ice [1,3,4]. As a result, the filling and overspill hypotheses for pollywogs are an important clue to the climate at the time of their formation, particularly because the latitude distribution of pollywogs and associated Fresh Shallow Valleys is distinct from that of earlier fluvial features on Mars [5]. The climate conditions implied by different overspill hypotheses range from downward freezing of an ice-covered lake during a transition from warmer to colder conditions, to rapid melting of ice sheets in a cold-to-warm transition. Some pollywogs have more than one exit breach (Fig 1), which provide additional information about the crater's overspill history, and therefore the volume(s) of ice and water required to explain the observed outlets.

Crater overspill hypotheses: We propose 4 hypotheses for how water could have breached the rims of pollywog craters (Fig 2). Each of these hypotheses makes distinct morphological predictions for individual pollywogs and their neighbors (Table 1): <u>1. The crater fills to the rim with liquid water</u>, either from precipitation or groundwater flow. This overspill mechanism requires that the breach occurs on the lowest portion of the crater rim. <u>2. The crater fills with ice</u>, and overspilling water forms either as a surface melt pond, or is forced up from the base of the ice body by overpressure from downward freezing. Partial filling of the crater with ice may reduce the volume of surface liquid water required to carve the exit breach [4]. <u>3. The crater is covered by a regional icesheet with liquid water flowing through ice tunnels at the base</u> [3,6]. Although evidence for Amazonian-age wet-based glacial activity has been documented in areas with increased geothermal heat flux [7], pollywogs occur in broad latitude bands in both hemispheres [1,3,4] which would require widespread climate conditions enabling wet-based glaciation in Mars' recent past. <u>4. The crater is partially filled with ice by a rapidly retreating ice sheet</u>, allowing a portion of the crater to fill to the rim with meltwater. This mechanism would be disfavored by two closely spaced pollywogs with breaches with very different azimuths.

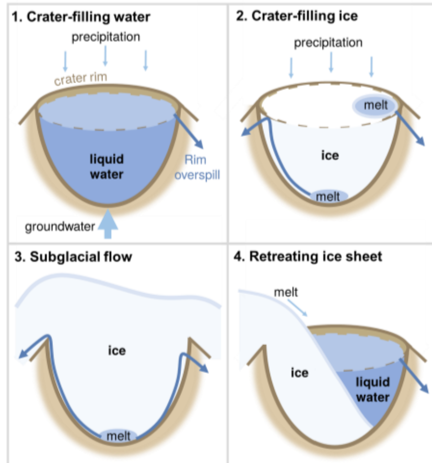

Fig. 2: 4 overspill mechanisms for pollywog craters: 1. Crater fills to rim with liquid water. 2. Ice-filled crater with surface melt pools and/or over-pressured water at base. freezing 3. Channels form through subglacial flow. 4. Retreating ice sheet partially covers crater, melt fills remainder.

Formation of multiple breaches: Surprisingly, several pollywogs have rims incised in multiple locations (e.g. Fig 1). We propose 3 ways that a pollywog could breach in multiple places. These can be related to the crater overspill hypotheses and overall climate context of pollywogs: <u>1. Simultaneous:</u> overspilling water during a single event

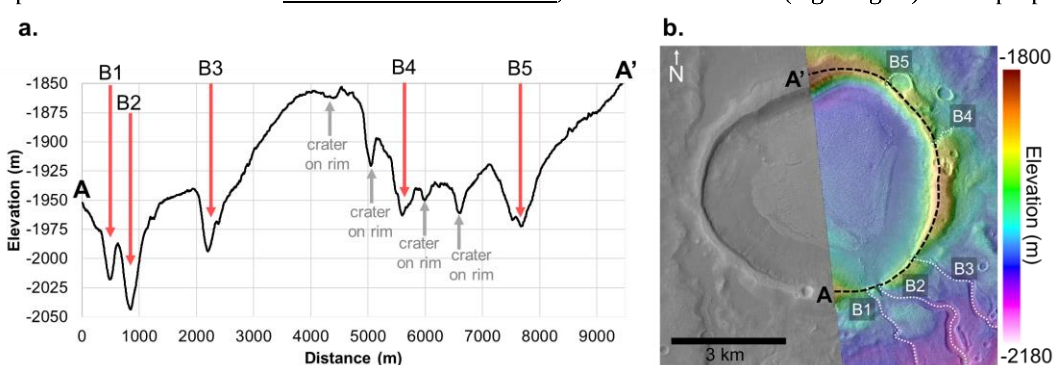

Fig. 1: a. Elevation profile of pollywog crater rim in b showing 5 breaches (B1-B5, red arrows) at different elevations. b. HiRISE DTM (left: ESP_053736_2180, NASA/JPL-Caltech/UArizona) of pollywog at 37.573°N, 21.404°E. Black and white dashed lines trace rim and breaches respectively.

Overspill mechanism		*Breaches must occur at lowest point on rim*	*Breaches on adjacent pollywogs should have similar orientations*	*Breaches must lead downslope*
1	Crater-filling water	✓	✗	✓
2	Crater-filling ice	✗	✗	✓
3	Subglacial flow	✗	✗	✗
4	Retreating ice sheet	✗	✓	✓

Table 1: Comparison of morphological predictions for pollywog overspill mechanisms.

overwhelms the drainage capability of a single breach channel, leading to the formation of a second breach higher on the crater rim (Fig 3), but still close to the rim's lowest point. The water supply rate needed to overwhelm a measured breach can be compared to the maximum water supply rate to the crater under different climate and hydrologic conditions, e.g. energy-limited snowmelt [8], and maximum groundwater discharge through a pressurized aquifer [e.g. 9]. 2. Isolated: Overspill occurs from multiple breaches due to separate pools of melt in the crater separated by crater-filling ice. In this case, breaches need not occur at the lowest point on the crater rim. [4] 3. Sequential: At least two overspill events occur, separated by a hiatus that modifies the lowest point on the crater rim through erosion (disfavored due to the characteristic fresh appearance of pollywog rims) or retreating ice exposes a lower point on the crater rim that can overspill, replacing an earlier breach. In this case, later breach(es) should incise an area of the rim lower than the base of the initial breach (Fig 4).

Future work: We will use Digital Terrain Models (DTMs) [HiRISE] of previously identified pollywogs [2,4,5] to measure pollywog crater rim profiles (e.g. Fig 1) and interpolate pre-breach rim morphology between unincised rim segments. We will then compare these

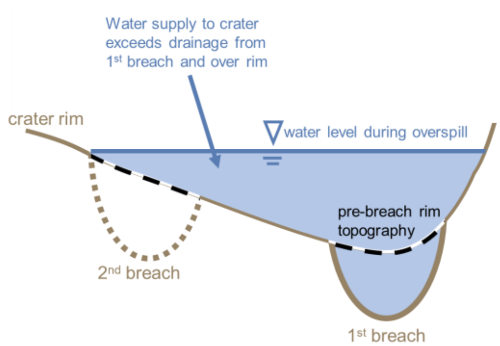

Fig. 3: Sketch (side view) illustrating how multiple breaches could form during a single overspill event where flow through an initial breach and over the crater rim exceed water supply into the crater through precipitation or groundwater flow.

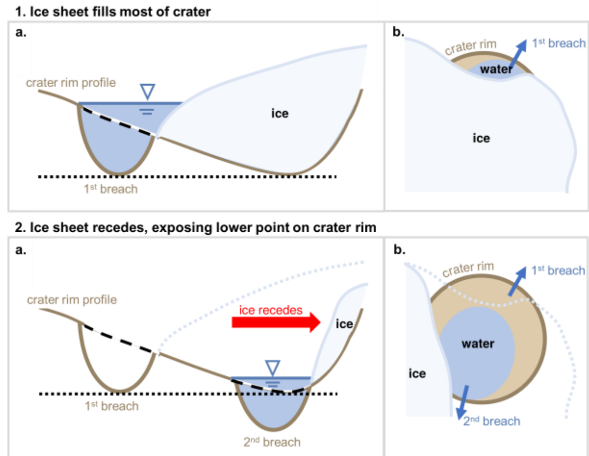

Fig. 4: Sketch illustrating formation of 2 breaches in a crater partially covered by a rapidly retreating ice sheet in a. side view and b. map view.

profiles to predictions made by different hypotheses for pollywog overspill, focusing on 1, 2, and 4 to investigate whether pollywogs can form without wet-based glaciation. Where multiple breaches are present, we will compare relative breach elevations and pre-breach rim profiles to predictions made by each of our 3 multiple breach hypotheses. We will also use pre-breach topography and measured breach geometry to calculate the flow through the lowest breach on the crater rim and over the crater rim up to the level of the next highest breach to calculate the required flow into the crater for multiple breaches to form in a single event and compare this to upper limits on water supply from snowmelt [8] and groundwater discharge [9]. Where HiRISE DTMs are not available, we will use the global blended HRSC DTM to identify what proportion of pollywogs have one or more breaches occurring above the lowest point on the rim. We will use this data to search for patterns in the latitude, longitude, elevation, and size of pollywogs with multiple breaches, and breaches occurring above the lowest point on the rim. Initial results will be presented at the conference.

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