

Geologic-Hydrologic Investigation of Uzboi Vallis, Northern Argyre Basin

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Introduction: Located at 51°S and 317°E, the Argyre Basin, is one of the most prominent impact basins on Mars [1-4]. Among various scenarios for its geologic evolution, it has been speculated that water might have accumulated within the Argyre Basin to a point where spillover occurred that carved the large northern outflow channel Uzboi Vallis [5-9]. Testing such a hypothesis is complicated by the fact that the timing of the proposed spillover is not well constrained. Most likely, if at all, it occurred very early in Martian history, which left ample time for subsequent modification of the terrain by erosional and depositional processes, as well as by two large impacts, Hale and Bond. On the basis of a detailed investigation of the Argyre Basin with Viking, MOLA and MOC data, evidence for such spillover remained elusive [10]. Here we use data from the High Resolution Stereo Camera (HRSC) and other modern data to re-investigate and map in detail the Uzboi Vallis area in the vicinity of Hale-Bond in order to newly assess the evidence for the putative spillover.

Background: Several outflow channels (Surius Vallis, Dzŕgai Vallis, Pallacopas Vallis), presumably fed by meltwater from the South Pole, empty into the Argyre Basin from the south [11-13]. The large drainage area of the Argyre Basin of $20 \times 10^6 \text{ km}^2$ [14], its location in the vicinity and downslope from regions of ancient polar ice deposits that underwent extensive melting in middle Mars history [11-12], and the three channels that empty into the basin suggest that if there ever were large volumes of water flowing across the surface of Mars, the Argyre Basin might be a good candidate

for the accumulation of water. According to Parker et al. [13], the water would have completely filled the basin during the Noachian and then flowed, in at least two catastrophic flood events, through Uzboi Vallis and the Chryse trough [15-16] towards the northern lowlands. Alternatively, it has been proposed that Uzboi Vallis is of Hesperian age [17-18]. However, as there have been other models that propose a partial fill of the Argyre Basin [10, 19] one of the still open questions is to what extent the basin was filled and whether spillover occurred.

Observations: On the basis of the available imaging data (HRSC, MOC, THEMIS), we made a detailed geomorphologic map of the study area. In the Hale-Bond area, the putative outflow channel Uzboi Vallis is heavily modified by the two impact craters, Hale and Bond. That a putative channel might have existed in the Noachian [e.g., 9, 13] before the impacts of Hale and Bond occurred is only indicated by a valley-like topographic depression that once might have been connected with the channel north of crater Bond.

Hale-Bond area: The modern valley floor in the Hale-Bond area is characterized by relatively smooth terrain between morphologically sharp blocks of eroded ejecta material. In HRSC and THEMIS VIS data, numerous shallow pits are visible on the smooth floor material. Some of these pits may represent older buried impact craters or secondary craters; other irregularly shaped pits are likely collapse pits formed by the removal of ground ice or ground water. Gullies are only present on the inward southward facing slopes of Hale crater but not on the slopes of the eroded ejecta material. Similarly, we did not find evidence for a well-developed drainage system that would empty into the main valley. The Argyre rim, which in the study area is located just north and northeast of Hale crater, represents a water shed with water north of it draining north and water south of it draining south into the Argyre basin. Slopes north of the watershed are on the order of 0.3 degree, and are about 0.4 degree south of it. At the investigated scale, we did not observe features, such as streamlined islands, which would indicate large-scale fluvial flow towards the north as is expected from the putative spillover. Modern Uzboi Vallis dissects the southern rim of crater Bond, but the terrain immediately inside the breach is characterized by a rough, pitted morphology rather than fluvial features (e.g., channels, streamlined islands, etc.), which would be indicative of significant amounts of water flowing north into the crater. A smooth unit is visible on the northern and western floor, opposite modern Uzboi Vallis, the material of which is likely derived from the erosion and modification of the crater wall or eolian input. The northern rim of Bond crater is not breached and does not show evidence for water leaving the crater. On the valley floor between the northern Argyre rim and Bond crater, evidence for small amounts of water consists of a smooth viscous flow unit, not unlike a mud stream, which is located on the valley floor and embays

older hills. A volcanic origin of this unit seems less likely because of the lack of a volcanic vent and the detailed morphology. Along the northern Argyre rim in numerous locations, we found evidence for relatively recent water flowing across the surface and draining into the basin. Throughout the investigated area, eolian dunes are rare and no prominent dune fields are visible at this resolution with the exception of north of Bond to Holden crater.

North of Bond crater: North of crater Bond we see evidence for groundwater sapping in form of stubby valleys with few tributaries and theater-like source depressions. In this region, we see evidence for several events of backward erosion, which over time formed a large theater-like source for modern Uzboi Vallis. To the north, water collects into a well-defined Uzboi Vallis that exhibits flow features, indicating flow to the north.

South of Hale crater: In the Argyre basin southeast of crater Hale, that is east of about 324°E and south of about 36.5°S, the terrain is characterized by numerous well-rounded hills and knobs and a soft, undulating morphology. This is in stark contrast with the terrain immediately southwest of crater Hale and the morphologically sharp rim and central peak of crater Hale. Secondary craters of Hale can be traced for at least 1-2 crater radii to the northeast and northwest, but are missing within the Argyre Basin, either due to an oblique impact from the SE (impact angle < 15°; [20]) or continued erosion and material transport to the basin floor that contributed to the obliteration of Hale secondaries.

Conclusions: From our geologic investigation of the Hale-Bond region we conclude that: (1) besides a valley-like topographic depression visible today, the formation of Hale and Bond erased most evidence for a Noachian ur-Uzboi Vallis through which the putative spillover supposedly occurred; (2) while we can not exclude the possibility that a Noachian-age Uzboi Vallis might have existed, there remains no evidence for water flowing through this ur-Uzboi Vallis towards the north; (3) whether this ur-Uzboi Vallis was formed by a spillover from the Argyre Basin or from sapping/precipitation along the basin rim can not be determined unambiguously; (4) while modern Uzboi Vallis cuts the southern rim of crater Bond, unambiguous evidence for water flowing to the north only occurs north of crater Bond; (5) the northern rim of crater Bond is not breached and its interior does not show evidence for water entering from the south, suggesting that fluvial flow through modern Uzboi Vallis towards the north was limited, if it existed at all; (6) fluvial features visible today, including the section of Uzboi Vallis east of crater Hale, postdate the formation of Hale and Bond, were formed more recently, drain into the basin, and are not related to the proposed drainage of the Argyre Basin during the Noachian; (7) north of crater Bond is a large source region, which empties into a well-defined modern Uzboi Vallis that shows several episodes of

fluvial activity.

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