GEOLOGY OF THE ARGYRE BASIN, MARS: NEW INSIGHTS FROM MOLA AND MOC

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Introduction

The Argyre basin is one of the most prominent and best preserved impact basins on Mars. Several geologic histories have been proposed for the evolution of the Argyre basin. One model for the geologic evolution of the Argyre basin involves mainly aeolian deposition [1], another model involves significant volcanic activity [2], a third model calls on the emplacement of mud in large parts of Argyre Planitia in a catastrophic event [3], a fourth model suggests large-scale glaciation [4]. A fifth model suggests that the Argyre basin is completely filled with water during the Noachian [5], a sixth scenario predicts the transport of significant amounts of water to the basin floor during the Hesperian [6]. Each of these models has distinctive geologic implications, predictions and consequences and we use MOLA and MOC data in order to test the plausibility of these hypotheses.

Results

Aeolian deposits in Argyre: From MOLA data we know that the smooth unit Hpl_3 is exposed over a wide range of elevation (about 4 km). This result might be principally consistent with an aeolian formation or modification of this unit because aeolian deposits are not gravitationally confined to lower elevations as lava flows or lacustrine deposits are [7]. MOC images reveal that dunes basically occur on all units associated with the Argyre basin. However, MOC images of the basin floor also indicate that almost every third image of unit Hpl_3 and every other image of unit Hr show rough surface textures that are probably related to deflation and/or sublimation. Prominent ridges in the southern regions of Argyre Planitia were interpreted as dunes [8, 9]. From our investigation of typical dunes in about 100 MOC images of the Argyre region, we see that both terrestrial and martian dunes are too small to be good analogs to these features. Terrestrial dunes often show asymmetric cross-sections with either higher or lower upwind slopes compared to downwind slopes but most profiles across the investigated ridge in Argyre Planitia do not show such an asymmetry of slopes.

Volcanism in Argyre: Unit Hr in Argyre Planitia was thought to be volcanic in origin because ridges were interpreted as wrinkle ridges. However, examining the morphology of typical wrinkle ridges in Lunae Planum and comparing them to the Argyre ridges we find the Argyre ridges to be more sinuous, more braided, and we do not observe a small sharp ridge superposed on a broad ridge [15, 16]. Numerous cross-sections are symmetrical, offsets in elevation between the left and right side of the ridge are smaller and the ridge appears less high than wrinkle ridges studied by [10]. Based on our observations, that is, the surface roughness, the location at the mouth of incoming channels, the absence of source vents, and the characteristics of the ridges exposed on this unit, we conclude that it is very likely that unit Hr in Argyre is largely sedimentary in origin [14].

Mud in Argyre: MOLA data reveal a morphologic feature at the mouth Surius Valles that can be interpreted as a delta [3] formed by a large mud flow. However, the size of this structure is on the order of 30 km and therefore at least ~10 times smaller than the delta envisioned by [3]. In the MOLA data there is no evidence for a delta of the order of 350 km in dimension. Another prediction of [11] is that ridges preferentially formed where the flooding material was dammed by escarpments and that in smooth areas without escarpments only a few, if any, ridges will occur. In the MOLA data we see no evidence for escarpments that might have dammed material. In addition, we see that the most prominent ridges are associated with unit Hr of the geologic map [2], which corresponds to the smoothest and flattest unit in our slope map.

Ice in Argyre: Kargel and Strom [4] postulated a "…vast proglacial lake and deposition of smooth glaciolacustrine plains" in the Argyre basin. However, as they did not map this lake in detail, their prediction is difficult to test rigorously (e.g., with MOLA data). They also argued that a glacier entered the Argyre basin from the south, sculpting Charitum Montes and thereby producing a topography with very steep slopes. They observed that the northern rim was fluvially modified but lacks evidence of glaciation. Therefore, we expect significant differences in the distribution of steep slopes between Charitum and Nereidum Montes. In MOLA data, Argyre is characterized by a very rough annulus with steep slopes of up to 15˚. Slopes are generally steeper in the NW, SW, and SE quadrangle but less steep in the NE. MOLA data show that slopes are largely similar for significant parts of Charitum Montes and Nereidum Montes. From our observations of the ridges in Argyre Planitia we conclude they are most likely eskers, rather than wrinkle ridges.

Water in Argyre: We performed several tests such as looking for terraces or possible shorelines, investigation of the surface roughness, flooding models, and estimation of water volumes required to fill the basin to different levels. Provided that the distribution of water during the Noachian is governed by the effort to reach hydrostatic equilibrium as proposed by [12], that an ocean in the northern lowlands existed at these times, and that Argyre was simultaneously filled with water, then we expect to find "shorelines" in the Argyre basin at about the same elevation as Contact 1 and 2 [12]. MOLA data show that all of the investigated shoreline positions (Contact 1 and 2) are below the elevation of the outflow channel of Argyre basin. If we assume that the basin is largely unmodified since that time and that the distribution of water in the martian crust is correctly modeled by the hydrostatic model of [12], water would flow below the surface toward lower regions rather than accumulating in Argyre to a level where flow through Uzboi Valles could occur. If the channels that are associated with the Argyre basin are early Noachian to Noachian, we face the problem of where the water came from. *Parker et al.* [5] proposed meltback of a Noachian polar ice cap but [13] only found evidence for a Hesperian retreat of the ice cap. Head [6] proposed a second model that involves water in the evolution of Argyre basin. However, there are significant differences between this model and that of [5] concerning the timing and the amount of existing surface water in Argyre basin. In the model of [6] a large polar cap existed during the early Hesperian. Meltback of this ice cap could have generated large amounts of water that accumulated in the Argyre basin. Based on volume estimates of [13] which are based on a 3 km thick ice cap that covered the entire area of the Dorsa Argentea Formation, ~6.63 x 10^6 km^3 of water could have been released. However, taking into account that the ice thickness very likely decreased toward the margins of the ice cap, that the ice cap contained up to 50% sediments, that not all of the melt water ended in the Argyre basin, that large amounts of ice never underwent melting but sublimed, and that large amounts of water are still stored in the pore space of the Dorsa Argentea Formation, we calculated that there is probably not enough water to completely fill the Argyre basin due to meltback of a Hesperian polar cap. We argue that partly filling the Argyre basin with water derived from polar cap meltback is more likely and is also consistent with Hesperian channels cutting far down into the basin.

Conclusions

Based on our investigation we conclude that (1) the Argyre basin went through a complex geologic history with several geologic processes contributing to its current appearance; (2) glacial and fluvial/lacustrine processes followed by aeolian modification were probably most important in the evolution of the interior of Argyre basin; (3) we cannot rule out that unit Hr once was an important component of the floor of the Argyre basin, but on the basis of the new data the area previously mapped as Hr appears to be covered with sediments, a situation similar to that in the northern lowlands [14]; (4) ridges in Argyre Planitia are most likely eskers [e.g., 15, 16]; (5) based on the occurance of these esker-like features, a model in which the floor of Argyre was covered by ice seems to be a reasonable hypothesis; (6) there is evidence for significant amounts of water having ponded in the Argyre basin in its past history, but compelling evidence for complete fill has not yet been found; (7) it is unlikely that Uzboi Valles drained the basin to the north, because the basin would have to be completely filled with at least 1.79 x 10^6 km^3 of water and this is not consistent with current hydrologic models or other observations; (8) there is a drainage divide east of crater Hale suggesting that water south of it actually flowed into the basin and carved a prominent channel down to the basin floor; (9) Uzboi Valles is of Noachian age but there is no evidence for any meltback of a Noachian south polar cap in order to provide enough water for a complete fill of the basin; (10) the amount of water that can be produced by meltback of a Hesperian south polar ice cap is probably insufficient to completely fill the Argyre basin. Large amounts of water that ponded in the Argyre Basin would have sublimed, evaporated or migrated into the substrate rather than flowing through an outflow channel to the north. On the basis of our investigation, we propose that in Hesperian times the south polar ice cap underwent melting and that significant amounts of the meltwater entered the Argyre Basin through the channels in the south in order to form a lake. This lake very likely froze over and stagnant retreat of the ice left esker-like ridges on the Argyre floor. Aeolian activity probably was important throughout the geologic evolution of the Argyre Basin and aeolian redistribution and/or sublimation of volatile-rich layers very likely formed present surface morphologies.

References

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