ANCIENT GIANT BASIN/AQUIFER SYSTEM IN THE ARABIA REGION, MARS:

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Introduction: Ancient geologic/hydrologic phenomena on Mars observed through the magnetic data [1,2] provide windows to the ancient past through the younger Argyre and Hellas impacts [e.g., 3,4], the northern plains basement [5], and the Tharsis and Elysium magmatic complexes (recently referred to as superplumes [6,7]). These signatures, coupled with highly degraded macrostructures (tectonic features that are tens to thousands of km-long [8]), reflect an energetic planet during its embryonic development (.5 Ga or so of activity) with an active dynamo and magnetosphere [1,2,6]. One such window into the ancient past occurs northwest of the Hellas impact basin in Arabia Terra. Arabia Terra is one of the few water-rich equatorial regions of Mars, as indicated through impact crater [9] and elemental [10,11] information. This region records many unique traits, including stratigraphy, topography, cratering record, structural character, geomorphology, and geophysical, elemental, albedo, and thermal inertia signatures. We interpret these to collectively indicate a possible ancient giant impact basin that later became an important aquifer, as it provided yet another source of water for the formation of putative water bodies that occupied the northern plains [12,13] and addresses possible water-related characteristics that may be observed at the Opportunity landing site. This basin is antipodal to Tharsis and estimated to be at least 3,000 km in diameter (Fig. 1a,b).

Stratigraphy. The proposed basin region appears to consist of more than 95% Noachian materials with very few outcrops of younger materials [4].

Topography. The proposed Arabia basin is not directly obvious on the high-resolution MOLA topography. However, subtleties include the dichotomy boundary north of the proposed Arabia basin, which is different from other boundary regions. This difference, in part, may be reflective of major fluvial modification during the Late Noachian [14] and resurfacing related to Tharsis-induced water bodies in the northern plains [12,13]. The broad gentle slope (from ~ 0 to –4km) may be indicative of erosion of somewhat laterally consistent geologic materials such as sedimentary basin fill.

The region has been highly degraded and deflated, exposing older features such as exhumed impact craters [15] and old paleodrainages. However, a N-S topographic profile using high-resolution MOLA topography through the central part of the proposed basin region follows the expected slope from Hellas towards the northern plains, but makes a slight upward climb near the northern margin of the boundary (possible basin rim) near the source region of outflow channels [16] that meander and debouch into the northern plains at Deuteronilus Mensae (Fig. 1b).

Impact crater record. As described in a companion abstract [17], high concentrations of multiple layer ejecta morphology craters and craters with central pits are found in the Arabia region. These features are commonly attributed to the influence of subsurface volatiles (ice and possibly liquid water) during crater formation. Craters with these features display a range of preservation states, suggesting that a volatile reservoir has been in place in the Arabia substrate for a substantial fraction of martian history [9].

Structural character. Fewer macrostructures occur within the proposed Arabia basin region when compared to other ancient parts of the highlands (see Figures 1 and 2 of [8]). These include a small number from Hellas when compared to other encompassing regions of the impact basin, a small number possibly associated with the development of the Utopia and Isidis basins, and some that may be related to an extremely ancient phase of plate tectonism [6]. Basement structural control and sediment fill of an ancient basin might help explain the paucity of macrostructures. This hypothesis will be further tested upon completion of the structural mapping of the eastern hemisphere [18].

Geomorphology. One of the largest areas of fretted terrain on Mars occurs along the dichotomy boundary northeast of the Arabia basin [19], with meandering outflow channels sourcing near the proposed northern margin of the basin [16]. These features may be reflective not only of a complex structural fabric associated with tectonism and a rich history of paleohydrologic activity [13], but also an important Arabia basin/aquifer system as noted above.

Geophysical information. Arabia Terra is a distinctive province from a geophysical standpoint in that the free-air gravity is relatively uniform when compared with other regions of the southern highlands. It is largely devoid of large topographic and gravitational variations aside from a general sloping to the west and northwest. The lack of a discernable mascon could be the consequence of the basin having formed at a time when the lithosphere was still very thin and the heat flow was high in the earliest part of Mars' history. The excavated cavity resulting from the impact would isostatically adjust and the long-wavelength load created by subsequent deposition within the basin would cause further adjustment with very little elastic support. If deposition rates were high during this early period [15], the basin could have accumulated a substantial volume of material without generating a significant gravity anomaly. As Tharsis began to form and load the opposite hemisphere, Arabia Terra would then begin to bulge in response [20]. This antipodal bulging of the region in response to Tharsis would transition the region from a center of deposition to a region of net erosion.

Magnetic anomalies are observed in this region, although the magnitude is diminished relative to the anomalies in the Terra Cimmeria region [1,2]. The impact would have erased any preexisting magnetic anomalies in the crust as is seen with Hellas and Argyre. If, however, the impact occurred when the dynamo was active, the crust would have a chance to reacquire magnetization. The diminished intensity could indicate that the dynamo was active but in a waning stage. On the other hand, the reduction in magnetic signals may be the result of deep burial by basin infill. Although there is no geophysical manifestation of a large buried impact basin in the gravity or magnetic data (e.g., circular positive mascons as noted for Argyre, but subdued for Hellas), the extreme age of the event may preclude any detectable geophysical signature and may in fact explain the uniform appearance of the gravity.

Elemental, albedo, and thermal inertia information. The proposed Arabia basin region is distinguishable in elemental [10,11], albedo [21], and thermal inertia [22] maps. Odyssey's GRS/NS indicates that the region has a relatively high water ice abundance (5 to 10 % equivalent water content). Whether these ice deposits are related to a larger volatile reservoir within the proposed buried basin region is unclear. It is possible that the basin was a sink for water as well as other deposits, providing a source for active aquifers. Ice may have been deposited more recently in localized cold niches formed by topographic relief [23]. On the other hand, polar surface ice has been proposed to be unstable, sublimate, and be transported to the equator to form an ice "belt" [24]. More recently, results from GCM modeling is consistent with this result, indicating that water ice is stable at the tropics and will migrate there during periods of high obliquity (>45 degrees) [25]. Further, the ice is not uniformly distributed: allowing for vapor diffusion in the regolith, ice preferentially accumulates in regions of low thermal inertia as the diurnal thermal wave does not penetrate as deeply into the regolith as it would in high thermal inertia regions [26]. This is consistent with ice deposition in Arabia Terra, a region characterized by low thermal inertia. High albedo dust and the ice may be a remnant from a past obliquity cycle. If dust accumulation slows the rate at which water returns to the poles at low obliquity, ice may be retained over time scales substantially longer than those required for its emplacement, allowing thick sequences of dust and ice to accumulate [25].

The Odyssey results alone do not indicate to what depth the water ice may extend as it is sensitive only to the top meter or so, but other lines of evidence such as the impact crater record described above indicate the potential of a remaining productive aquifer in the Arabia region.

Implications: Implications of the basin hypothesis include: (1) explaining the unique traits described above, (2) providing another source of water for the putative water bodies that occupied the northern plains [12,13], (3) suggestions of water-related characteristics that may be observed at the Opportunity landing site, and (4) identifying a potential contributor to the development of the long-lived Tharsis superplume[6,7].

References: [1] Acuna M. H. et al. (2001) *JGR*, 106, 23,403-23,417. [2] Arkani-Hamed, Jafar (2003) JGR, 108, 10.1029/2003JE002049. [3] Scott, D.H. and Tanaka, K.L. (1986) *USGS I-Map 1802A*. [4] Greeley, Ronald, and Guest, J.E. (1987) *USGS I-Map 1802B*. [5] Fairén, A.G. and Dohm, J.M. (in press) *Icarus*. [6] Baker, V.R. et al. (2002) A theory of early plate tectonics and subsequent long-term superplume activity on Mars. Electronic Geosciences 7, (<http://lin.springer.de/service/journals/10069/free/conferen/superplu/>), 2002. [7] Dohm, J.M., et al. (2002) *Superplume International Workshop*, Abstracts with Programs, Tokyo, 406-410, 2002. [8] Dohm, J.M., et al. (2002) *Lunar Planet. Sci. Conf.,* XXXIII, #1639. [9] Barlow N.G. and Perez, C.B. (2003) *JGR, 108*, 10.1029/2002JE002036. [10] Boynton W.V. et al. (2002) *Science, 297*, 81-85 [11] Feldman W.C. et al. (2002) *Science, 297*, 75-78. [12] Baker, V. R. (2001). *Nature*, 412, 228-236. [13] Fairén, A.G., et al. (2003) *Icarus*, 165, 53-67. [14] Hynek, B.M. and Phillips, R.J. (2001) *Geology,* 29, 407-410. [15] Malin, M.C. and Edgett, K.S. (2001) *JGR*, 106, 23429-23570. [16] D.H. Scott et al. (1995) *USGS Misc. Inv. Ser. Map I-2461 (1:30,000,000)*. [17] Barlow, N.G. and Dohm J. M. (2004) this volume. [18] Pounders, E. et al. (2002) *Lunar Planet. Sci. Conf.,* XXXIII, #1906. [19] Carr, M.H. (2001) JGR, 106, 23571-23594. [20] Phillips, R.J., et al. (2001) *Science*, 291, 2587-2591. [21] U.S. Geological Survey (1991) *USGS Misc. Inv. Ser. Map I-2179 (1:25,000,000)*. [22] Christensen, P.R. et al. (2000) *JGR*, 105, 9623-9642. [23] Paige, D.A. et al. (2003) *Eos Trans. AGU*, 84(46), C21C-0831. [24] Jakosky, B.M. and Carr, M.H. (1985) Nature, 315, 559-561. [25] Mischna et al. (2003) *JGR*, 108, 10.1029/2003JE002051. [26] Richardson, M.I. (2003) *Eos Trans. AGU*, 84(46), C12C-01.

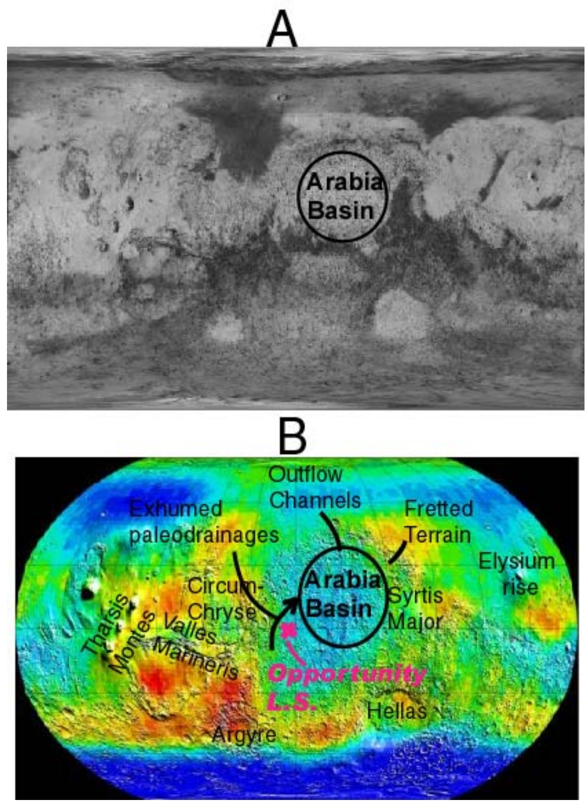

Figure 1. A. Albedo map showing proposed Arabia basin (see [21]). B. Elemental map showing elevated hydrogen [10,11] with major features, including proposed Arabia basin and the Opportunity Landing Site.