HOLLOW NODULES IN LACUSTRINE DEPOSITS AS NEW PROXY FOR HABITABLE ENVIRONMENTS ON EARTH AND MARS. R. Bonaccorsi[1,2] L. Baker[3]; C. P. McKay[2]; A. P. Zent[2]; P. R. Mahaffy[4], and D. Willson[2]. [1]SETI Institute's Carl Sagan Center (189, Mountain View CA 94043; rosalba.bonaccorsi-1@nasa.gov); [2]NASA Ames Research Center (M.S. 245-3, Moffett Field CA 94035). [3]Dept. of Geological Sciences, University of Idaho (PO Box 442339, Moscow, ID 83844-2339); [4]NASA Goddard Space Flight Center 8800 Greenbelt Road, Greenbelt, MD, 20771.

Introduction: One intriguing novel sedimentary feature imaged by the MSL Curiosity's Mastcam and MAHLI instruments in Gale Crater are mm-sized circular rimmed hollows nodules (HNs) (Figure 1A), pitting the Sheepbed mudstone of Yellowknife Bay Formation [1,2]. HNs are significantly smaller than the solid nodules within the outcrop, with an external mean diameter of 1.2 mm and an interior one of 0.7 mm [2] Several mechanisms for primary and secondary formation of HNs have been discussed, such as: (1) Diagenetic dissolution of soluble mineral phases; or, (2) Gas bubbles released shortly after sediment deposition due to abiotic and/or biotic reactions and rapid lithification [1-3 and refs. therein].

To date, no terrestrial analogue structures of hollow nodules with similar dimension, shape, distribution, and composition have been described in the literature in support of the gas bubble hypothesis [2].

In an ephemeral pond in Ubehebe Crater, Death Valley Natl. Park, CA., we observed the formation of hollow nodule sedimentary structures (Figure 1B) produced by gas bubbles (Figure 1C) that are strikingly similar to those imaged by the MSL rover (Figure 1A). We propose these as a possible analog for HN formation in the Sheepbed mudstone.

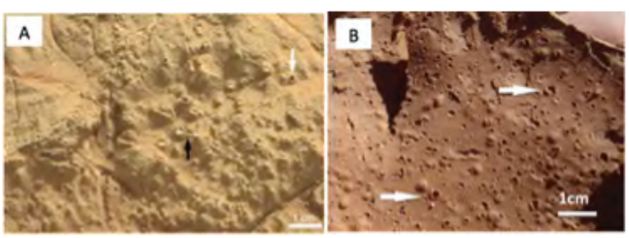

***Figure 1**. HNs (white arrows) imaged by Mastcam-100, sol 159, Yellowknife Bay Site (A). Mini hollows in the dry mud (B) formed by bubbles (C).*

Methods: Ubehebe Crater (UC) surface sediment hollow nodules were sampled and imaged. Powder X-ray Diffractometry (XRD) and Fourier transform infrared spectroscopy (FTIR) were used to identify bulk and clay mineralogy as well as to refine the mineral composition of the structures.

Observations: UC in-situ observations suggest the gas bubbles were generated by low temperature biological activity, perhaps involving formation of iron bearing sulfides, e.g. Fe_2S, within the slightly reducing ephemerally submerged mud; these intra-crater deposits remain otherwise extremely dry for most of the year, i.e., Air_rH ~2-5%; ground H_2O wt%: 1-2%; Summer air/ground T: 45-48ºC/67-70ºC [4-5].

Discussion: Data from the Sample Analysis at Mars (SAM), CheMin, and ChemCam instruments revealed that HNs-bearing mudstone are rich in smectite clay e.g., ~18-20% [6,7] deposited in a neutral to mildly alkaline environment, capturing a period when the surface was potentially habitable [1]. The UC HNs-hosting deposits are also rich in smectite clays (~30%) and occur in an ephemeral shallow freshwater setting [4-5].

Conclusions: If present, surface hollow nodules are easy to find in clay-rich dry lacustrine deposits, so they could represent a new indicator of ephemeral but habitable/inhabited environments on both Earth and Mars. Our terrestrial observations suggest that HNs-rich sites on Mars might be an indicator of ancient biotic activity and thus be the ideal target for future rover and manned missions searching for mineral, sedimentary, and molecular evidence of life.

References: [1] Grotzinger J.P. et al. (2014), *Science 343*, 124277. [2] Stack et al. (2014) *JGR, Planets* 119*343*, 1243480. [4] Bonaccorsi R. et al. (2012) *AGU Fall Meeting*, Abstract #P11B-1839. [5] Bonaccorsi, R. et al. (2014) *AGU Fall Meeting,* Paper #EP53A-3632. [6] McLennan, S.M. et al. (2014) *Science* 343, 1244734. [7] Ming D.W. et al. (2014) *Science*, 343, 1245267.