FIRST RESULTS OF THE EXPEDITION TO THE HIGHEST LAKE ON EARTH: STUDYING A MARTIAN PALEOLAKE IN BOLIVIA AND THE SURVIVAL STRATEGIES DEVELOPED BY LIVING ORGANISMS. N. A. Cabrol[1] [Email: ncabrol@mail.arc.nasa.gov], E. A. Grin[1], C. P. McKay[2], I. Friedmann[3], G. Chong Diaz[4], C. Demergasso[4], K. Kisse[5], I. Grigorszky[6], R. Ocampo Friedmann[1], M. S. Murbach[2], A. Hock[7], D. A. Fike[8], C. Tambley[4], L. Escudero[4], E. deVore[9], and B. H.Grigsby[10]. [1]NASA Ames/SETI Institute; [2]NASA Ames; [3]NASA Ames/NRC; [4]Universidad Catolica del Norte, Antofagasta, Chile; [5]Hungarian Academy of Sciences; [6] Kossuth Lajos University, Hungary; [7]UCLA; [8] MIT; [9] SETI Institute; [10] Schreder Planetarium/Project ARISE.

Introduction: Between October 16th and November 9th 2002, the first NASA Ames DDF Licancabur multidisciplinary expedition initiated the investigation of the biology and environment for life in the highest lake on Earth located at the summit of the Licancabur volcano (6017 m/20,056 ft) at the boundary of Chile and Bolivia. The low oxygen, low atmospheric pressure, high-UV radiation, average temperature, volcano-tectonic and hydrothermal environment make the site a close analog to Martian paleolakes 3.5 billion years ago. The overall goal of the project is to understand through a series of high altitude scientific expeditions what strategies life is using to defend itself against killer-level UV radiation and environmental extreme conditions at this altitude. Several other lakes are located at 4300 m at the foot of the Licancabur volcano (hereafter named *laguna Blanca and Laguna Verde*). They were also investigated using identical experiments and methods as for the summit lake in order to compare the results and better understand the evolution of survival strategies at transitioning elevations. The lagunas are geothermally heated and many springs provide water at various temperatures. Sources of heat are also suspected for the summit lake as its surface water temperature was measured during the successful ascent at +6°C in a -9°C ambient crater environment (with a wind chill factor of -25°C with a wind blowing almost constantly). Results of this project are expected to provide critical keys to help searching and identifying potential sites for life (extant/extinct) on Mars and developing instruments, experiments and technologies for future missions.

Summary of Science Experiments and Results for the 02 Expedition: The data and samples brought back from the summit lake and the lagunas are currently under analysis at several laboratories at NASA AMES, MIT, UCLA, UCN (Chile), Sergeomin (Bolivia), and in Hungary. It is the first time that the summit lake ecosystem (biota and environment) is subjected to a thorough scientific investigation. We present here the first results of the analysis of the 200 samples of water, sediments and biological material brought back from the 02' expedition and investigate the potential analogies with martian paleolake environments and survival strategies that life could have used on Mars.

Geology: the initial mapping of paleo-shorelines and terraces was conducted for the *lagunas*, leading to the identification of 30 major shorelines and approximately 12 additional minor shorelines. The mapping performed with GPS and Range Finder revealed that Laguna Verde and Laguna Blanca were part of a single massive paleolake system in a closed basin environment likely during the Last Glacial Maximum (LGM). Several distinct but related fields of stromatolites were observed and studied during this expedition, including 1) a vast field (estimated extent >100km^2) of domal, elongate, mushroom, cross and columnar stromatolites at approximately 4360 m; 2) a patchy field of 'encrusting' stromatolites that exhibited radial growth from the surface of lava blocks from an eruption of the volcano Juriques; 3) an isolated cluster of domal stromatolites in Laguna Blanca on an island attached to shore by a sandbar, elevation approximately 4330m; and 4) an isolated cluster of potentially fossil 'mini-stromatolites', approximately 2 to 10 cm in diameter, found in shallow depressions (possible old upwelling regions) on the paleoshore of Laguna Blanca, at approximately 4340m. None of these stromatolites were undergoing active formation (i.e., they were all above the waterline (approximately 4315m)) and some exhibited weathering. The mapping team spent a significant portion of the time investigating this field that is outstanding by (1) its size, (2) its elevation, (3) its diversity, and (4) its possible young age. Although more field work is required to clarify the age issue, current maximum extrapolated from the stromatolitic position with respect to the lagunas would be likely between 10,000 and 20,000 years old. More stratigraphical work will be necessary to verify this first order assessment. Some thin sections have been already performed. There are at least two types of structures: one seems homogeneous in composition, (mainly gypsum?), and the second seems to be a mixture of stages including carbonates (climate changes ?). They appear similar to structures (mushroom-type) produced in present saline lakes, growing up from the bottom and taking advantage of physical irregularities. Some samples, have been selected and cut and studied trough X-Ray Diffraction and imaged through SEM.

At the summit lake, images and photographs were acquired of the shorelines to analyze the evolution of the water level. As part of the geology task, cores were acquired from the shores as well as shallow-water depth sediment and analyzed in laboratory.

Geophysics: The geophysics task was initiated in three major areas: 1) environmental characterization, 2)

biological community analysis, and 3) water chemistry. The environmental characterization includes, measurements of UV flux and soil heat flux. Dataloggers were placed to monitor air temperature, relative humidity, soil temperature, and water temperature over the course of one year. A survey of thermal water input to Laguna Blanca was also made that covered approximately half of the lake's shoreline; 15 individual springs were observed in three major regions. The main observation from this portion of the task was that geothermal fluid input and springing is extremely active. Surface manifestation of thermal fluid upwelling is dependent on coastal geology along Laguna Blanca and Laguna Verde and furthermore, there is a clear relationship between the lakes, their biological communities, and the local geothermal environment. Water and soil samples were gathered for biological community analysis from all sites for Terminal Restriction Fragment Length Polymorphism (TRFLP) analysis, which provides a quantitative means of assessing microbial population structure and diversity. As a part of the microbiological effort, these samples may also be used for analysis and sequencing of 16S rDNA. Finally, in order to understand the geothermal water input to the lagunas and to investigate the presence of hydrothermal circulation in the summit lake, water samples were collected for chemical analysis which employs Ion-Coupled Mass Spectrometry in parallel with Ion Chromatography to analyze elemental concentrations across almost all of the periodic table and also determine concentrations of key anions such as chloride and sulfate. At the summit lake, the geophysics task has prioritized profiling temperature, UV flux, and water chemistry as a function of depth in the lake.

UV Experiment: The goal of this experiment central to the analogy to Mars is to test the effects of UV radiation on periphyton located on sediments. The periphyton includes immobile species that cannot seek refuge from UV radiation unlike sediment-dwelling organisms using vertical migration. Gazer chambers formed by "Acrylite" submersed sheets in shallow water were constructed. The sheets were suspended on four *Acrylite* 12" long rods at ~10 cm above sediment. Each sheet is surrounded by a mosquito nylon screen fixed on the upper part of the pegs and closed by heavy rocks on the sediment. The sheets were anchored to heavy rocks by four nylon ropes. Each station is composed of one 60 x 60 cm x1/8" OP-3 UV filtering UV and one 60 x 60 cm x1/8" OP-3 UV transmitting OP-4 sheet. A total of 4 stations numbered 1 to 4 starting from the refuge are installed on Laguna Blanca at ~20 m offshore and ~100 m from the waves action in shallow pounds. Two are in Laguna Verde, and one station at the summit lake. A preliminary harvest of the underside of the sheets and of the sediments in the gazer chamber was made after 10 days at the lagunas in order to directly compare our results with those of a Canadian study on lakes located at 2200 m elevation. Another harvest will be accomplished by the 03' expedition that will include the summit lake. Samples of water and biomass have been collected in amber bottles at each station (about 50 samples) and analyzed by the biologists. Seven core samples down to 10 cm have been performed in Laguna Blanca and documented through photographs. The first results of this experiment are presented.

Biology: (a) *Organic Geochemical and Microbiological Characterization of Lake Environments*. Shallow water and sediment samples were taken from Laguna Blanca, Laguna Verde, the Warm Hydrothermal Pond, and the summit lake. In addition, deep water samples were obtained from Laguna Verde, and the summit lake. Sediment samples were also obtained from the sulphur- and arsenic-rich Laguna Blanca and arsenic-rich N shore of Laguna Verde. Water and sediment samples are analyzed using Gas chromatograph-Mass spectrometry (GC-MS) to characterize the structure of lipids and photosynthetic/UV-screening compounds such as chlorophyll and carotenoids. The goal is to identify specific adaptations in the structure of these molecules to the high UV environment. The study includes: (i) genetic analyses on DNA extracted from the samples, leading to the sequencing of the genes encoding from the 16S rRNA of organisms present in the samples, (ii) Fluorescent In Situ Hybridization (FISH) to identify quantitatively the communities present in the samples, and (iii) development of arsenic/sulphur enrichment media in order to cultivate arsenic reducing bacteria and sulphur reducing bacteria from the arsenic/sulphur sediments. (b). *Taxonomy*: Abudant samples of the microorganic, bacterial, and algal communities were collected at the lagunas and analyzed to identify the various species living in these environments. Surface water samples and 1-m depth water samples were collected at the summit lake and are subjected to similar analysis. The team also left a slides attached to a float at the summit lake. The slides are separated at regular space interval down to 2-m depth. They will collect the organisms living at various depth in the lake and provide an idea of the distribution of the biological populations in the summit lake. (c) *Water and Sediment Chemistry and Microscopic Characteristics*. A large quantity of water, sediment and soil samples were collected also for chemical and biological analysis at UCN (Chile). They include both samples from the lagunas and the summit lake.

The first results of the sample analyses and expedition field work are presented at this conference.

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