THE LICANCABUR PROJECT: EXPLORING THE LIMITS OF LIFE IN THE HIGHEST LAKE ON EARTH AS AN ANALOG TO MARTIAN PALEOLAKES. 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], A. Hock[7], D. A. Fike[8], C. Tambley[4], L. Escudero[4], M. S. Murbach[2], 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: The Licancabur volcano (6017 m) hosts the highest and one of the least explored lakes in the world in its summit crater. It is located 22°50' South / 67°53' West at the boundary of Chile and Bolivia in the High-Andes. In a freezing environment, the lake located in volcano-tectonic environment combines low-oxygen, low atmospheric pressure due to altitude, and high-UV radiation (see table). However, its bottom water temperature remains above 0°C year-round. These conditions make Licancabur a unique analog to Martian paleolakes considered high-priority sites for the search for life on Mars.

	Licancabur Summit Lake
Temperature	Day: +5 to - 25°C Night: -25 to -40 °C
Atmospheric Pressure	480 mb (sea level: 1013 mb)
O2 (%)	49% sea level
UV Level	~120 W/m^2/sec

A series of expedition are being supported by NASA to explore the summit lake and other hydrothermal lakes located lower (4300 m) at the foot of the volcano Their investigation will provide (1) critical astrobiological information about the limits of life in this unique extreme environment, (2) scientific clues about potential planetary analogs, and (3) elements to design science mission strategies for planetary exploration. *Our poster presents the project overall goal and objectives and summarizes the results of the first expedition that took place between Oct-Nov 02. It also describes the direction and developments of the project in the coming years.*

Background. Recently, MGS has produced images supporting the hypothesis that environments favorable to life could still be present on Mars. MGS camera captured images of young, possibly current water activity, as shown by the discovery of gullies (Malin and Edgett, 2000), lava flows less than 1Ma old (Hartmann et al., 2000), possibly recent ice-covered lakes in Hellas (Cabrol et al., 2001a,b. Moore and Wilhems, 2001) and current landforms including debris-covered glaciers (Cabrol et al., 2001a, Baker et al., 2001, Baker 2001, Kargel, 2001). The presence of both energy and water in recent (current?) times on Mars significantly improves the probability of finding oases of extant life. However, where the missions should go and what should they look for?

The strategy to increase the chances of mission success in the search for life on Mars implies acquiring the best possible knowledge of terrestrial analog environments prior to missions. Such field assessment helps the statement of hypotheses, the design of relevant instrument payloads and technologies, and provides a reasonable understanding of where to send the probes (whether the probes be rovers, landers, or other scouts). The exploration of terrestrial analogs and the limits of life on our own planet is central to this strategy. In the past 20 years, the boundaries of the known biosphere have been vastly expanded by the continuous discovery of extremophiles. Their habitats include hot springs, shallow submarine hydrothermal systems or abyssal hot-vent systems where microorganisms can be found at temperatures above 100°C. The recent images returned from Mars have helped us to better constrain the main elements that make its current environmental characteristics: recent/current presence of ice, water, thermal energy, and high-radiation surface exposure. The Licancabur project proposes the reconnaissance of a unique terrestrial analog presenting a combination of all these elements in one site. The lake is located in the summit crater of the Licancabur volcano. It is the highest lake in the world and is virtually uncharted.

Exploration Objectives of A Unique Analog. The Licancabur volcano has a well preserved 400-m diameter summit crater with a water lake about 90 m x 70 m. This lake is the absolute highest lake in the world and hosts a planktonic fauna discovered during the 1981 archeological expedition. A high altitude diving expedition in 1984 found the lake temperature to be 6 °C at the bottom (Leach, 1986). Except for this reference, the populations of living organisms hosted by the Licancabur lake and the lacustrine environment remained to date largely unknown. The existence of living organisms in such conditions is of utmost interest in the perspective of the exploration of Mars. This is why the Licancabur project proposes a full-investigation of its environment and biology and that of neighboring lakes in order to better understand their relationship and explore what can be extended to the search for life on the Red Planet.

Starting with the first expedition that took place between 10/02 and 11/02 (see Cabrol et al., this LSPC), the project's objectives are to characterize: (a) the geological, morphological, and limnological environment of the lake, including: the survey of the volcanic structure and crater depression; the search for possible thermal source(s) maintaining the lake bottom waters at positive temperatures throughout the year; the nature and characteristics of the lake sediments and their stratification; the water column distribution and circulation process; and the annual variation of the lake volume; (b) the physical environment, including: annual variations of surface and water temperatures; the annual precipitation; and the variation of UV radiation and oxygen; and (c) the biological environment, including: a survey of living organisms in the lake, their distribution, and origin; their relations to each other in the ecosystem; and their source of energy and nutrients.

Approach. Licancabur and the other lakes at its base require working (sampling and free diving) at an altitude rarely reached by a science team to position data loggers that will collect data over a period of several years. The project is developing a full investigation that encompasses:

Physical Environment: At this altitude and latitude, the UV radiation is extremely high. How does it affect life and what are the survival strategies are important questions to document both to understand better the limits of life on Earth and to envision potential analogies on Mars. The team has positioned networks of UV plates and data loggers and experiments that will provide information about the UV radiation both in and outside the water. Oxygen, air, and water temperature are being also monitored over a period of years.

Geology: A mapping campaign has started during the 02' expedition. It will include a geologic and topographic survey of the crater and that of the lower lakes. One of the most intriguing questions is to understand how the summit lake was capable of resisting evaporation for at least the past 500 years, possibly much more as there are no recorded eruption in historical years. The Atacama is the driest place on Earth and most of the lakes there are receding today. Is the catchment area of the crater large enough to provide a significant watershed and are the few snow precipitation during the year enough to supply the lake? Are there groundwater and hydrothermal sources? The team studies the nature of the rocks, take samples for laboratory analysis and monitor the dynamical processes inside the crater.

Bathymetry and Physics of the Lake: Understanding the depth and topography of the lake bottom is critical. This investigation includes measurements of the variation of the shoreline level as indicators of seasonal or longer cyclic changes. The bathymetry will be important to understand the organization of the ecosystem formed by the lake. If thermal sources are found, it will help visualize their position and extent.

Geophysics: Why does the bottom temperature of the summit lake remain above freezing? Geothermal heating source and hydrothermal circulation? Other processes? The quantification of water and soil temperature gradients is being performed, as well as the study of conductive heat flux through the lake bottom. The investigation also includes basic water chemistry analysis as a function of depth in the lake to determine the presence of thermal water input. This task involves diving for direct observation and sediment collection.

Lake Sedimentology: Shore material, bottom sediments and mud have been sampled for laboratory analysis. This investigation will provide critical information about the composition and grain size of the sediment. It will allow the team to assess sedimentary rates.

Biology: Characterizing the organisms living in the lake and the ecosystem organization is another major objective. It includes: collection of biological samples with plankton nets and other biological material during diving and sampling; search for organisms in the crater, lake shore, and shallow subsurface ground and performing taxonomy and DNA analyses.

Robotics: The region offers an ideal site to develop basic mobility, obstacle navigation, and sample acquisition strategies that could be used in subsequent system designs (e.g., rovers, biolabs, landers, flyers) to explore martian paleolakes and sites of high habitability potential. In 02, the expedition tested MARVIN (Mini-Astrobiology Robotic Vehicle INvestigation), a two-wheeled Mars mini-rover concept. The project is opened to other testing next year.

EPO: The 02 expedition team included an educator who maintained a daily journal and Q&A between students and scientists. About 250 students participated live to the expedition and developed experiments and essays related to the Licancabur project. This effort will be pursued and developed in the coming years.