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LAKE MAGADI, KENYA; A SURVEY OF THE MICROBIAL DIVERSITY AND MICROBIAL BIOMARKERS ASSOCIATED WITH GROWTH OF MICROORGANISMS ALONG ALKALINE GRADIENTS IN A SALINE RIFT VALLEY SYSTEM.

Project Report

Location of the Study: Lake Magadi, Kenya, is an alkaline, "saline pan" lake system, and approximately 100 sq km in size being geographically the southernmost lake within the Rift Valley of Kenya **(Fig1)**. Located approximately 80 miles southwest of Nairobi, the lake contains concentrated brines of sodium carbonate as well as large precipitates of the mineral trona, hydrated sodium bicarbonate carbonate (Na3HCO3CO3•2H2O). The lake water is primarily recharged by a number of saline hot springs (up to 83°C) flowing into the lake's extremely alkaline system (pH values up to ~11). This creates a unique extreme environment, containing both thermal, high saline, and extreme alkaline conditions. Several unique alkaliphilic microorganisms have previously been isolated from this location, including both bacteria and unique phototrophic archaea, which give the lake and its salts a unique pink coloration as illustrated in **Fig. 2 and 3**.

Research Focus: The goal of this fieldwork was to further examine the microbial and metabolic diversity present in this unique alkaline environment, including delving into the bioenergetics of this system. In October 2008, I was fortunate to accompany a team of scientists from NASA's Jet Propulsion Laboratory, Pasadena CA, (Dr. Kevin Hand) and NASA Ames Research Center, Moffet Field CA, (Dr. Lynn Rothschild) for an initial visit to this site as well as other unique sites within Kenya. Currently I am pursuing future collaborations with both utilizing molecular ecology and standard microbiological techniques to begin the characterization of the microbial and metabolic diversity within the highly saline alkaline lake system of Lake Magadi, as well as the associated thermal features of the region. This includes methodologies to look for the presence of a wide variety of microbial metabolic strategies; e.g. aerobic and anaerobic, heterotrophs and chemolithoautotrophs, sulfur and iron respiration, etc. within this extreme ecosystem. I am particularly interested in and I'm focusing on elucidating the degree to which dissimilatory metal respiration is involved in this system.

A wide variety of sites were visited and surveyed and initial samples were collected. Some of these locations were 20 times the salinity of seawater and approached a pH of near 11. In addition some unique structures were discovered in some of the thermal spring sites that were visited, these structure resembled "stromatolites" but appeared to be a surface phenomenon mitigated by a microbial biofilm attached to the surface of the evaporitic deposits within which the spring exists. **(Fig. 4 and 5)**. These are currently being analyzed to identify specific sampling sites of interest for further in depth analysis both on future planned return trips to the region as well as for further analysis in the laboratory.

Significance: Dissimilatory metal respiration, such as sulfate and iron reduction are thought to be two of the earliest forms of respiration to arise on the early Earth. This is based on a wide range of evidence, including phylogenetic analysis of present day sulfate and iron reducers and isotopic mass dependent fractionation of sulfur bearing mineral deposits dating to ~3.47 Gyr. These organisms and their metabolic strategies are an ideal system to consider in the search for life elsewhere. In this fieldwork, I am investigating the existence of dissimilatory metal respiring microorganisms within an extreme high salt alkaline environment. Alkaline environments have become increasingly relevant for consideration as models with respect to Mars, as recent missions have elucidated previously unknown alkaline sites, which overlap with sites that are thought to contain subsurface water. I hope to identify biosignatures produced by these organisms, and investigate the strategies that could be used to identify these signatures, in particularly the long-lived mineralogical signatures, if they existed on or near the surface of Mars or Europa.

Educational Outreach: During my two-week trip to Kenya I had the unique opportunity to become involved in educational outreach through an organization that was previously founded by Dr. Kevin Hand. Cosmos Education, (http://www.cosmoseducation.org/) is an international non-profit organization dedicated to improving science education in developing countries, whose focus is on the role of science and technology in health, the environment and sustainable development. During time between visiting field sites we visited a number of local secondary education schools in the Nairobi area as well as in the rural areas that we visited when the opportunity existed. These visits consisted of discussing science and technology, health and specifically space and space exploration and future careers and career advice with the students at each location. This was one of the most phenomenal aspects of my trip, **(Fig. 6)** I learned a great deal from observing Dr. Hand and Dr. Rothschild during these events as well as participating myself. It reinforced my interests in outreach and in making a personal difference in the world, and I hope to continue to be involved with outreach through all of the friends that I have made in Kenya though this organization in the future.

Future work: Further collaboration is planned with Dr. Kevin Hand and Dr. Rothschild including a return on a second extended expedition to the Kenya currently planned for Fall 2009. This visit will allow us to revisit sites of interest chosen from the initial survey work, such as the geyser rich region of Lake Bogoria (0°15′N 36°06′E), **(Fig. 7)** and will include more detailed *in situ* analysis of the geochemistry of the sites as well as further sample collection, obtaining quantities suitable for chemotaxonomy (mass spectrometry), which will be used to characterize cellular biomarkers (specifically lipids) associated with these unique environments

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Figure 1. Map of Kenya Illustrating the location of Lake Magadi, southwest of Nairobi near the border of Tanzania. (1°52'S 36°16'E)
(http://upload.wikimedia.org/wikipedia/commons/4/49/Kenya-relief-map-towns.jpq)

Figure 2. Lake Magadi, Kenya. The pink coloration is due to the presence of phototrophic *Archaea,* present within the lake and its salts.

Figure 3. A closer look at the pink salts of Lake Magadi.

Figure 4. Stromatolite-like features located within one of the Hot Springs at Magadi.

Figure 5. The striated texture of the surface features of the Magadi hot spring biofilm

Figure 6. Students at a Nairobi secondary school participating in an exercise with COSMOS Education known as "the DNA Dance", where the fundamentals of DNA base pairing are discussed.

Figure 7. Rainbow and geyser located at Lake Bogoria, Kenya. This site was surveyed during our previous trip.