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SPOTLIGHT

LIFE AND DEATH AROUND ACID-SALINE LAKES

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Salt is a contradiction in itself. Halite requires a specific set of environmental conditions for growth, yet it is fairly common. It is extremely soluble, but many well-preserved examples are known from the rock record. It has been used by people for centuries as a food preservative, yet traditionally has been considered a poor fossilizer of other organisms. Recent studies have shown, however, that halite may be an excellent source for microfossils (e.g., Vreeland et al., 2000; Fish et al., 2002; Mormile et al., 2003; Schubert et al., 2005).

A few organisms thrive in and near hypersaline environments. Flamingos, brine shrimp, halophilic algae and bacteria, and even the Death Valley pupfish are well known to most evaporite sedimentologists and saline-lake ecologists. But what life, if any, lives in or near lakes that are not only hypersaline and ephemeral, but also extremely acid? Do these organisms play any role in the unusual chemistry of their environment? Most importantly, do they become preserved in the fossil record?

Natural acid-saline lakes are relatively rare. Two known modern settings, in Western Australia and Chile, host lakes and groundwaters with salinities of 100‰–300‰ TDS (total dissolved solids) and a pH of 1.5–4. There are hundreds of ephemeral, acid-saline lakes, and regional acid-saline groundwater, as well as nearby neutral-hypersaline lakes on the highly weathered Archean rocks of the Yilgarn Craton in the southern part of Western Australia (Mann, 1988; McArthur et al., 1991; Benison et al., 2007). In the Chilean Andes, at elevations of ~4000 and 4200 meters above sea level, there are two shallow acid-saline lakes nestled in a small intravolcanic valley (Risacher et al., 2002; Benison and Gonzalez, 2007). Although geologic processes and acidity sources in Chile and Western Australia are very different, the water chemistry is quite similar. Waters are Na-Cl-Mg-SO_4-rich, and many have very high amounts of Ca, Fe, Al, Si, Br, and Cu, but contain no detectable bicarbonate or carbonate (Risacher et al., 2002; Bowen and Benison, 2006). What kinds of organisms can withstand or even prefer these unusual and complex waters? A good start at answering that question comes from observations in the field.

In Western Australia, it is interesting to compare signs of life at the acid-saline lakes and nearby neutral-saline lakes. Physical sedimentological processes and total salinity are the same here, regardless of pH, so both acid and neutral lakes are shallow, ephemeral, and surrounded by sandflats, sand dunes, and ephemeral channels. The main difference in environment is the lower water pH and high concentrations of toxic (at least to people) constituents in the acid waters that are not present in the neutral waters. The neutral lakes commonly host brine shrimp, are surrounded by a diverse flora, and are frequented by kangaroos, dingoes, spiders, snakes, emus, and other birds. Some slightly alkaline saline lakes even contain gastropods covered by green algae. Other possible microbial habitats include crinkly grey mats at lake shorelines and shallow, subsurface stinky black mats. In contrast, the acid-saline lakes contain no brine shrimp, gastropods, or other macroscopic invertebrates. Kangaroo, dingo, emu, and other bird tracks are noticeably absent. The flora near acid-saline lakes is not diverse and includes only one to two types of eucalyptus trees—most commonly ghost gums and salmon gums—and the ruby salt bush. Evidence of possible microbial communities observed in the field at acid-saline lakes includes small bubbles escaping from the subsurface and filamentous structures and foam along the shorelines (Benison et al., 2005).

Chilean acid-saline lakes also occur in proximity to neutral-saline lakes, which contain brine shrimp, crinkly pink and gray algal mats, and spongy black algal mats. Pink flamingos and small herds of vicuñas, a relative of the llama and alpaca, visit these neutral lakes frequently. The acid lakes seem to support only microorganisms, as suggested in the field by crinkly surface textures under very shallow (<2 cm) surface water.

Kathy Benison grew up along the shore of Massachusetts and, as a kid, loved exploring the rocks, sediment, water, and sea life. Kathy earned a B.S. in Geology and Chemistry at Bridgewater State College, an M.A. in Geology at State University of New York at Binghamton, and a Ph.D. in Geology at The University of Kansas. Under the influence of graduate advisors Bob Goldstein and Tim Lowenstein, she discovered that a combination of fieldwork, analyses of natural samples in the lab, and lab experiments helps her understand relationships among the lithosphere, hydrosphere, biosphere, and atmosphere. She is most interested in deciphering past environments, water chemistry, climate, and life from the clues contained in sedimentary rocks, especially evaporites and red beds. She has been a faculty member at Central Michigan University for eleven years, where she teaches Introductory Geology, Earth History, and Stratigraphy and Sedimentology, and mentors undergraduate researchers. Kathy remains indebted to her husband Chris and three children for allowing her junkets to faraway field locations. Benison would like to acknowledge discussions with collaborators Brenda Beitler Bowen, Melanie Mormile, and Franca Oboh-Ikuenobe. Benison has been funded by the American Chemical Society-Petroleum Research Fund, the National Geographic Society, and the National Science Foundation for her research on acid-saline environments.

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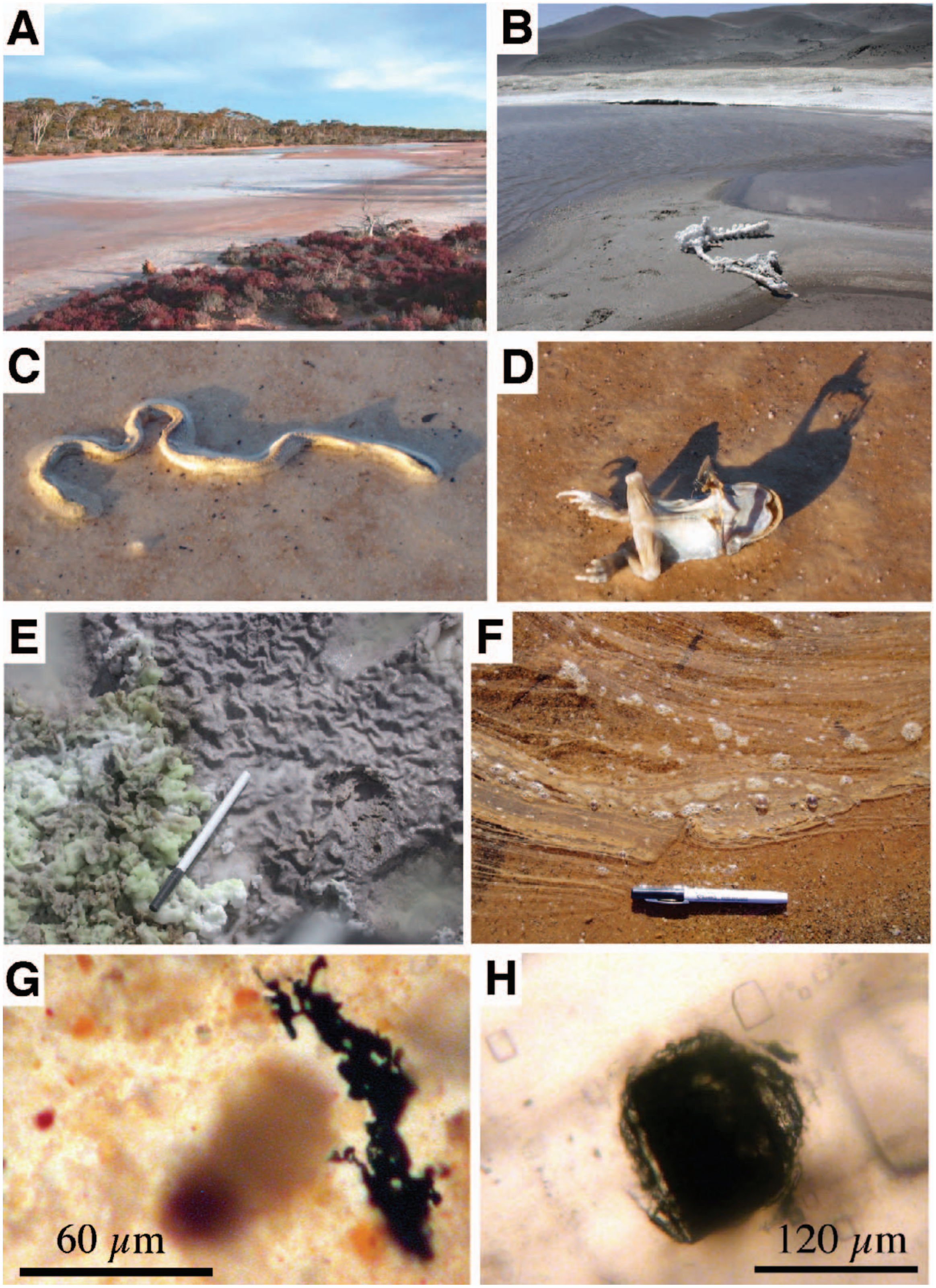

FIGURE 1—Life, death, and fossils around acid-saline lakes. A) Ghost gums and ruby salt bush flank acid lake in Western Australia. B) Vicuña skeleton encrusted in halite and gypsum in Chile. C) Dead snake, and D) dead frog on acid lake sandflat in Western Australia. E) Crinkly cyanobacterial(?) mat in Chile, upon which halite, gypsum, and native sulfur grow. F) Filamentous structures along shore of acid lake in Western Australia. G) Possible microbes (hairy blob) along with small hematite clumps, and H) possible bacterial colony, all trapped in fluid inclusion in acid halite from Western Australia.

Dead organisms are a common sight around acid lakes. Acid lake shorelines and surrounding sandflats are littered with dead vicuña and small birds in Chile and dead frogs, snakes, and sheep in Western Australia (Fig. 1). Tracks and other signs of life at neutral-saline lakes, but not found at acid-saline lakes, suggest that many of these organisms can withstand the high salinity, but not the extreme acidity. Not many dead animals are observed at the neutral lakes, but a great number is found at the acid lakes. Most of the carcasses rapidly become encrusted in halite or gypsum.

Laboratory study is the obvious next step in the characterization of organisms, especially microorganisms, from acid environments. Preliminary laboratory studies suggest at least two novel genera of acidohalophilic bacteria or Archaea at a single Western Australian acid lake (Mormile et al., 2007). Palynological examination shows three unidentified algal types in acid lakes in Western Australia (Story et al., 2007). Petrographic and chemical examination of modern and Permian acid halite and gypsum reveal unusual organic bodies that appear to be remains of various bacteria, Archaea, or fungi (Fig.1; Benison et al., 2008).

Fossilization may be rapid and surprisingly good in acid-saline environments. Halite, along with gypsum, grows rapidly at the surface in hypersaline environments, encasing anything in its path, including beer bottles, rubber tires, sticks, frogs, pollen, and bacteria. Acid environments provide a second key preservative in the fossilization process: iron oxides. In Western Australian acid-saline lakes, hematite precipitates directly from lake waters and from shallow groundwaters. It coats halite and gypsum grains, protecting them against future dissolution by dilute waters. This unusual mode of fossilization, first by rapid entrapment in halite or gypsum, than by iron-oxide coating, allows for organisms to be well preserved at the surface in an oxidative environment. Not only is this another surprising contradiction for salt, but also for red beds!

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