Cryoconite Hole Ecosystems in Antarctic Glacier Ice

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Cryoconite holes form as windblown particulates accumulate on the surface of a glacier, are warmed by the sun, and melt into the ice producing a cylindrical basin of liquid water. Organisms released from the melted glacial ice and attached to deposited airborne particulates provide the biological inoculum for these ecosystems. This environment lacks a significant source of allochthonous nutrient input and relies on photosynthesis and nitrogen fixation carried out by the resident algae and cyanobacterial species, which provide assimilateable carbon and nitrogen to the community. Cryoconite holes occur globally in glaciated environments of the Arctic and Antarctic, and are also present in alpine glaciers.

Unlike the open holes found in temperate latitudes, cryoconite holes in the McMurdo Dry Valleys of Antarctica are sealed with an ice lid (up to 30 cm thick) and are frozen solid for the majority of the year. During the austral summer (November-March), the 24 daylight hours and increased temperature enable liquid water to exist, as heat-absorbing sediments in the bottom of a mature cryoconite hole are warmed by solar irradiation, melting a portion of the overlying ice. The austral summer is also a time when new cryoconite holes form, and this process is greatly accelerated by the presence of cracks and depressions within the glacial ice surface, which serve to collect and concentrate sediment. During the few months in which liquid water is present, photosynthetic primary production is possible and these aquatic ecosystems become metabolically active, but are then destined to refreeze and become dormant through the cold, dark winter months.

Interestingly, bacterial species (including cyanobacteria) in cryoconite hole environments are very similar to those found in ecosystems within the permanent ice cover of lakes and in microbial mats (layered groups or communities of microbial populations) of this dry valley ecosystem. This implies that the species within cryoconite holes originate from adjacent terrestrial sources and suggests that similar survival strategies may be in effect in both lake ice and cryoconite holes. Besides the dry valleys of Antarctica, no other ecosystems are known in which nematodes (unsegmented worms), rotifers (multicellular organisms with a wheel-like organ), and tardigrades (“water bears"; small, segmented animals) represent the top of the food chain. Although it is still uncertain if these metazoans are active in Antarctic cryoconite holes, there is evidence that they are preserved in these environments. Some nematode, tardigrade, and rotifer species can enter a dormant resting state in which they are resistant to desiccation and freezing, and then commence metabolism when conditions for growth are favorable.

In addition to the inherent interest of Antarctic cryoconite holes as discrete and unique ecosystems, these environments could function as a biological refuge, serving in reverse to reseed surrounding environments in the summer during glacial melting. Cryoconite hole ecosystems exist and thrive under the harsh conditions associated with an Antarctic desert, and therefore provide a terrestrial analog for plausible past or present environments for life in ice on Mars, and may have been an important haven for life during past ice ages.

(500 words)

Further Reading:

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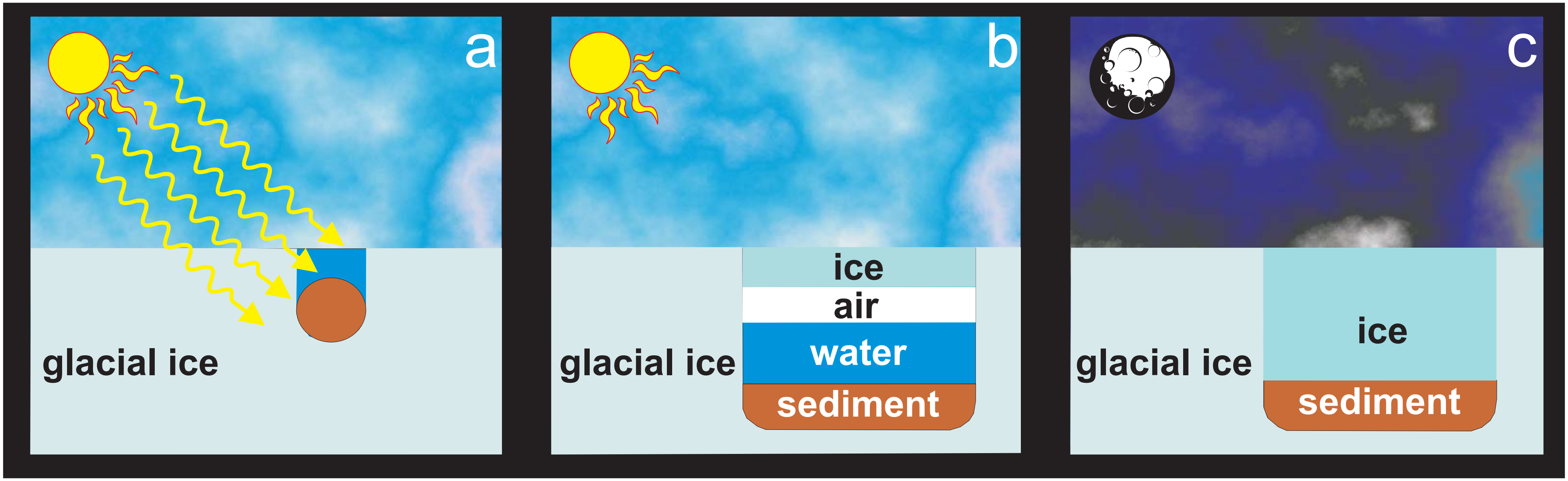

The cryoconite hole environment in the McMurdo Dry Valleys, Antarctica. In summer, particulates blow onto the glacial surface, are warmed by continuous solar irradiation, and produce melt pools within the ice (a). The surface water subsequently freezes (b) and the cryoconite hole becomes completely frozen during the cold, dark winter months (c).

Christner, B.C. Figure for "Cryoconite Hole Ecosystems in Antarctic Glacier Ice"