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Sulfate-Reducing Bacteria and Pyritic Sediments in Antarctica

Abstract. Black lacustrine and marine sediments occur in the McMurdo Sound region of Antarctica. The black color is due to the presence of iron sulfide, precipitated by sulfate-reducing bacteria *(Desulfovibrio)* in the presence of decaying organic matter of algal origin. Viability of sulfate-reducing bacteria in the sediments was demonstrated in the laboratory by culturing in anaerobic liquid media. It is probable that sulfate-reducing bacteria are widely distributed in Antarctica.

The significance of sulfate-reducing bacteria *(Desulfovibrio)* as biological and geologic agents has been widely recognized since the classic work of Beijerinck (*1*) and van Delden (*2*). Numerous investigators have confirmed the significance of these organisms in the geochemical cycle of sulfur, although their quantitative role is not clearly established in either recent or ancient sediments. The ubiquitous presence of sulfate reducers in a wide range of sedimentary environments has been demonstrated in studies of bottom muds from fresh-water, marine, and saline basins. Their temperature tolerance under natural conditions, however, has not been delimited. The presence of sulfate-reducing bacteria as active agents in sedimentary processes under the extreme conditions of the antarctic environment is therefore of interest both with respect to their ecological tolerance and geographic distribution.

Kettle holes are common on the south side of the Wright Dry Valley in the McMurdo Sound region of Antarctica. These holes are located in an area extending westward from the western terminus of the Lower Wright Glacier for about 2 mi (lat. 77°30′S, long. 162°30′E). Small ponds occur in some of the kettle holes, although most of them are dry.

A small saline pond, approximately 25 ft long, 10 ft wide, and 1 ft deep, occurs in one of the kettle holes. The water is impotable and highly saline, as shown in the analysis presented in Table 1. From the values in the table, it can be seen that the salinity of the pond water is approximately four times that of sea water. The principal dissolved salt is sodium chloride. Magnesium chloride, calcium sulfate, magnesium sulfate, and calcium carbonate are also present.

The upper surface of the sediments at the bottom of the pond is light ocherous brown. Immediately below the surface and extending down, however, the sediment is black. Upon drying under oxidizing conditions, the black sediments become gray. Upon addition of dilute HCl to the black sediment, hydrogen sulfide gas is emitted. The black color is due to the presence of iron sulfide, probably of the type described as hydrotroilite ($FeS \cdot nH_2O$), an amorphous, hydrous monosulfide of iron (*3*). The iron sulfide is precipitated by sulfate reduction induced by *Desulfovibrio* in the bottom muds. An energy source for the sulfate-reducing bacteria is readily available from decaying filamentous algae, diatoms, and other microplankton that occur in the pond waters. The existence of a rather complex biocenose, involving the sulfur cycle, under the ecological conditions currently prevailing in the pond is remarkable. In addition to the markedly high salinity of the water, the temperature regime, under which the sediments and their organic fraction are accumulating, is featured by changes from perhaps −60°F in winter to +40°F in summer (*4*).

The presence of living cells of *Desulfovibrio* in the pond sediments under consideration has been demonstrated in the laboratory by culturing in anaerobic sterile liquid media containing lactate as a carbon source. Replicate media were prepared by the use of both tap water and slightly saline water (NaCl). Better growth occurred in the saline medium. Cultures held at room temperature showed a more rapid rate of sulfate reduction than those held at 5°C. The precipitation of iron sulfide, as visually indicated, was used to determine viability of the cultures, and the rate of precipitation was used to indicate the relative rates of sulfate reduction. The laboratory cultures were prepared from samples collected by one of us (R.L.N.) on 9 January 1961. The samples were held under moist, relatively anoxic conditions until 1 February 1961, the time of inoculation of the media, a period of approximately 3 wk.

Table 1. Analysis of a sample of water from a small saline pond in the McMurdo Sound region of Antarctica (*p*H 7.8). (The analysis was made by the Water Analysis Laboratory of Metcalf and Eddy, Boston, Mass.)

Substance	Amount (mg/lit.)
Calcium as Ca	1,130.
Magnesium as Mg	4,890.
Sodium as Na	33,200.
Sulfates as SO_4	16,150.
Chlorides as Cl	58,000.
Bicarbonates as CO_3	330.
Sulfides as S	<0.1
Dissolved solids	132,620.

Pyritic sediments, similar to those described here, occur in other kettle holes in the Wright Dry Valley, on the marine beach on the south side of New Harbor, McMurdo Sound (lat. 77°35′S, long. 163°29′E), in the deposits of Green Lake, Cape Royds, Ross Island (lat. 77°32′S, long. 166°15′E) (*5*), and in a small pond in the elevated marine beaches at Marble Point, McMurdo Sound (lat. 77°26′S, long. 163°46′E). It is probable that further field and laboratory study will demonstrate that sulfate-reducing bacteria and pyritic sediments are widely distributed in Antarctica. It would be of interest to determine the optimum temperature for growth in strains of *Desulfovibrio* occurring in nature under these extreme environmental conditions (*6*).

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6. The field studies by one of us (R.L.N.) were made possible by the assistance of the National Science Foundation.

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