pends, for example, on pH and on the molar ratio of the amino acid to copper. Thus, at pH 7 and a fixed copper concentration ($5 \times 10^{-4}M$), arginine, histidine, and histamine at molar ratios of 0.5:1, 1:1, 2:1, and 3:1 relative to copper, possess a marked catalytic action. However, at a molar ratio of 4:1, histidine no longer is catalytically active but histamine and arginine are.

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Fossil Actinomycetes in Middle Precambrian Glacial Varves

Abstract. *Fossil actinomycetes and other bacteria have been found in sulfide minerals from "varved" argillites in the middle Precambrian Cobalt Series of Canada. The fossils consist of branched and unbranched nonseptate hyphae and chains of rod-shaped cells. The presence of actinomycetes is consistent with the theory that the argillites are lacustrine desposits.*

The Gowganda Formation of the middle Precambrian Cobalt Series in southern Ontario and Quebec consists largely of tillites and "varved" argillites. The argillites are probably glacial lake deposits, as indicated by their numerous erratic pebbles and boulders and by their rhythmic stratification (*1*).

The dark gray to bluish coloration of the argillites suggests microbial activity under anaerobic conditions. Additional evidence for this was sought in argillite samples collected in Township 169 and Wells Township, Ontario, where the sediments are gently folded and practically unmetamorphosed. In these rocks were found (i) a lens of erratic sand grains intermingled with and encrusted by chalcopyrite crystals; (ii) a small rosette of pyrite crystals surrounded by concentric zones of pyrite; and (iii) a lens of sand-sized pyrite crystals surrounded by a yellow-brown zone containing smaller, disseminated pyrite crystals; the yellowish pigment is probably limonite formed by oxidation of very fine-grained pyrite. In the absence of evidence for hydrothermal deposition, such clusters of sulfide crystals in dark argillaceous sediments may

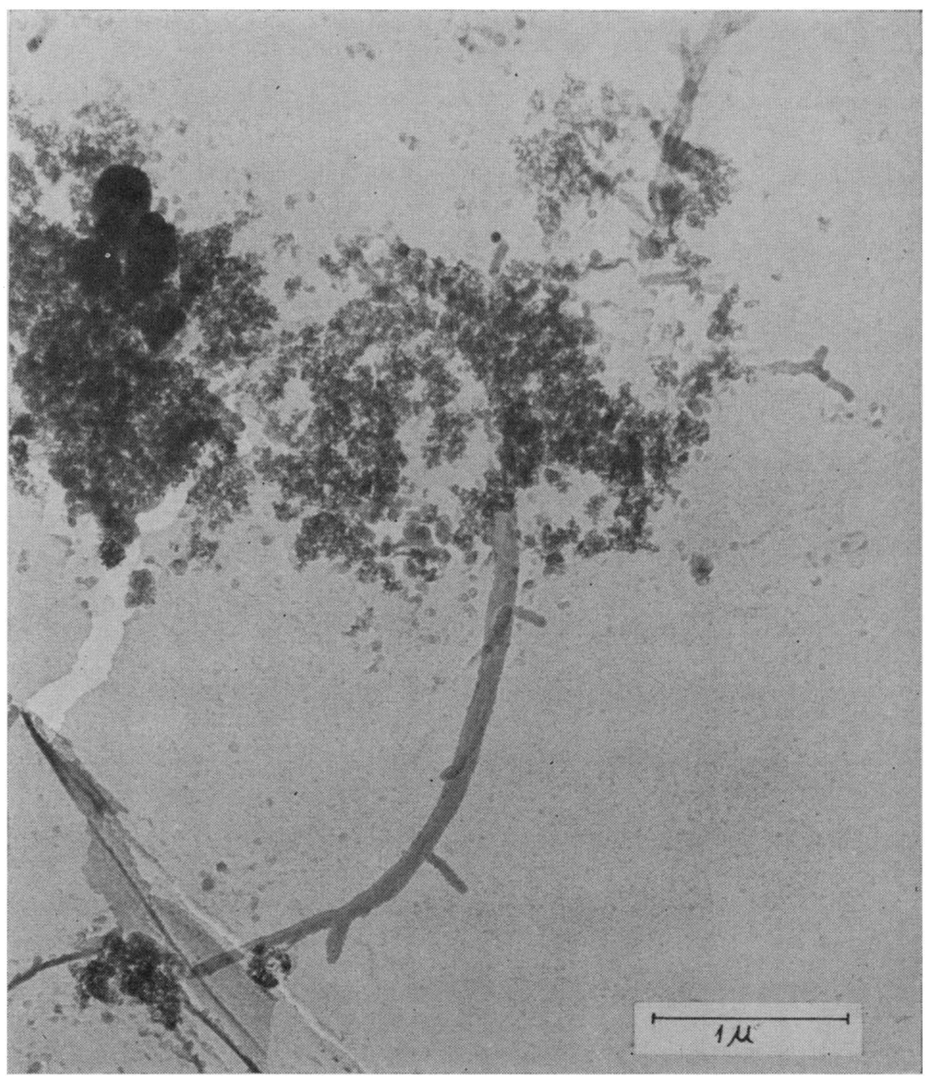

Fig. 1. Hyphae of actinomycete from sulfide crystal (germanium-shadowed carbon replica of cut-and-polished section) (× 25,300).

be attributed to penecontemporaneous production of H_2S by anaerobic bacteria during decomposition of organic remains which were entombed in the sediments. Remains of bacteria may be preserved by inclusion within these sulfide precipitates (*2*).

Sections of the pyrite and chalcopyrite crystals were examined by electron microscopy (*3*). The sections were made by cutting and polishing the crystals or by fracturing them with a hammer. The polished surfaces were coated with parlodion, which was then stripped off and discarded in order to remove any contaminants that might be present. Fresh parlodion impressions were made, and from these, carbon replicas were made, which were shadowed with germanium.

Microorganisms were found which appear to be actinomycetes and other bacteria. The fragments of branching, nonseptate filaments are strikingly similar to the hyphae of present-day actinomycetes (Fig. 1). The thickness of the large hypha in the center of the field is about 0.1 μ. The hyphal fragments are associated with amorphous material (probably organic matter) and with spheroidal bodies similar to spores or cysts. Figure 2 shows a colony of nonseptate, and apparently nonbranching, filaments similar to the hyphae of actinomycetes radiating outward from a mass of amorphous material. The filaments are no thicker than approximately 0.05 μ. Figure 3 shows several chains of crumpled rod-shaped bodies which apear to be bacterial cells (or possibly spores of actinomycetes). The largest cell is about 0.14 μ long and 0.08 μ wide. Some of the cells contain opaque, rounded bodies which may be endospores; the possibility that they are deposits of amorphous sulfides (*4*) is ruled out by their great antiquity, for the sulfides would have crystallized by this time. The various organisms cannot be fungi, for they are much too small. In fact, the actinomycete-like forms are small compared with most contemporary actinomycetes whose hyphae and spores usually have diameters from 0.5 to 1.0 μ; the observed maximum is about 1.5 μ (*5*).

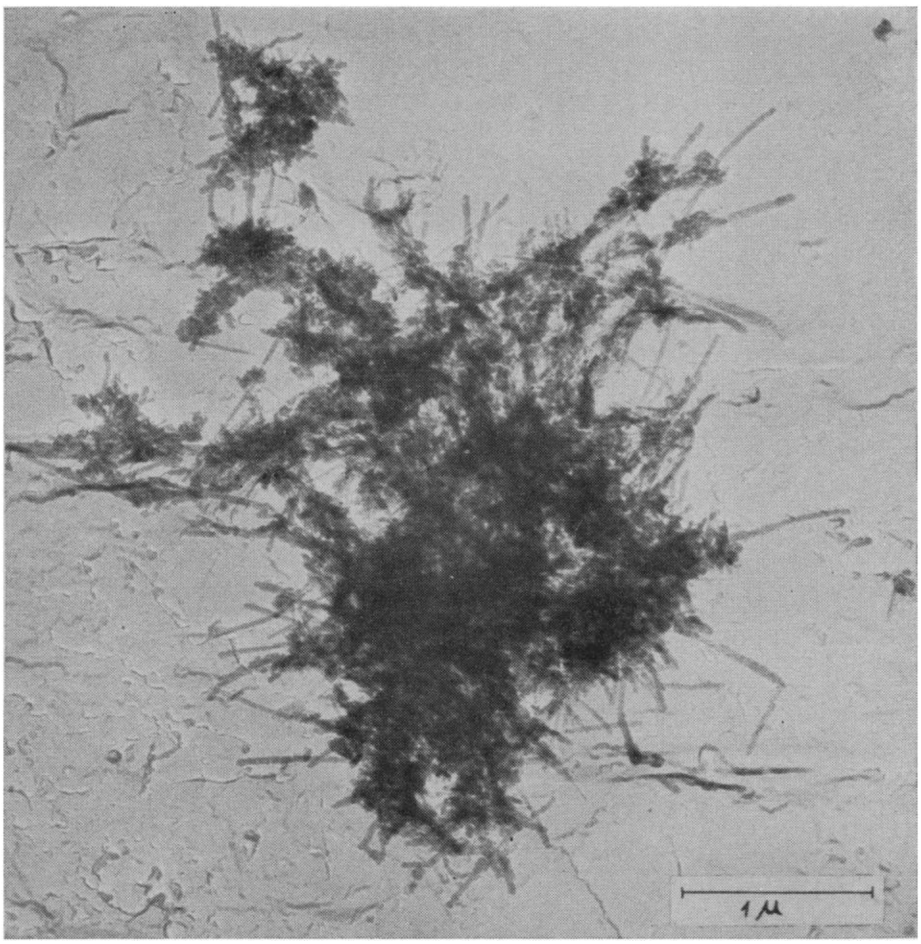

Fig. 2. Colony of filaments similar to the hyphae of actinomycete from sulfide crystal (germanium-shadowed carbon replica of cut-and-polished section) (× 25,300).

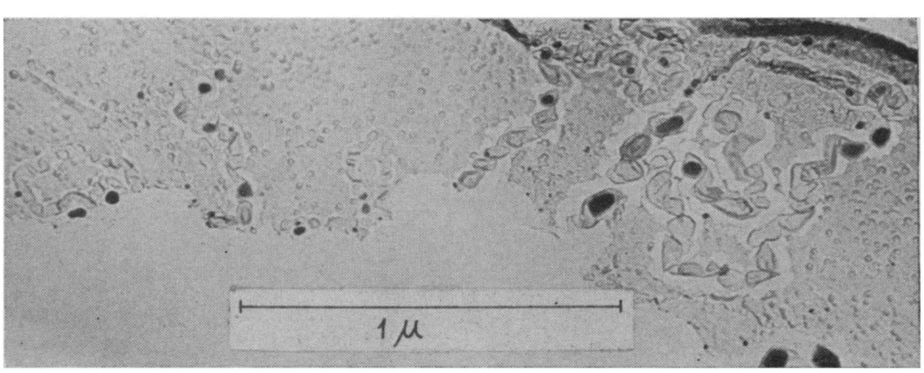

Fig. 3. Chains of bacterial cells (or actinomycete spores) from sulfide crystal (germanium-shadowed carbon replica of fresh fracture surface) (× 49,400).

These organisms should be regarded as genuine fossils rather than contaminants. The chains of cells in Fig. 3 appear to be embedded in the mineral. Moreover, the replica was made from a freshly fractured surface; thus the danger of contamination was minimized. The filaments in Figs. 1 and 2 are not obviously embedded in the mineral, but certain additional considerations testify to their authenticity. For one, the filaments appear to be completely flat, as if they were mere films, whereas a recent microorganism would have a three-dimensional aspect. Also, some of the filaments become thinner and less dense away from the tip, as if they had been planed down when the sections were polished. This effect would probably never be observed in a contaminant; in fact, the reverse would be seen. In addition, a recent contaminant would probably have a more sharply defined outline, and it seems unlikely that a contaminant would appear as disconnected fragments, like the hyphae in Fig. 1.

These findings support the hypothesis that the sulfides in the Gowganda argillites are biogenic, though they have probably been modified by inorganic processes which occurred after deposition. The zonation of the pyrite probably indicates outward diffusion of H_2S from buried centers of microbial activity; in any case, it shows that the pyrite is authigenic rather than detrital. The fact that some, if not all, of the fossil microorganisms apparently belong to the Actinomycetales, which are found chiefly in nonmarine habitats, is consistent with the theory that the argillites were laid down as lake muds, and possibly suggests the existence of soil and a soil microflora on middle Precambrian land surfaces. Contemporary actinomycetes are abundant in lake waters, recent lake sediments, and soil, and they include anaerobic as well as aerobic forms (*5*).

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Ostracod "Living Fossils": New Finds in the Pacific

Abstract. *New ostracod "living fossils" have been discovered in samples of Recent marine sediment collected from several Pacific islands. The finds include a male anatomy having several primitive features which, in conjunction with primitive features in the shell, necessitate reconsideration of current opinions on the phylogeny of freshwater ostracods.*

In 1963 "floats" were obtained (*1*) of 58 Recent samples collected (*2*) during 1949 from Saipan, Mariana Islands; and 55 Recent and fossil samples collected (*2*) in 1951 from Onotoa atoll, Gilbert Islands, were later floated (Fig. 1). The Saipan material contained only four specimens, compared with 13 (one fossil) from the Onotoa samples, of a new ostracod genus that both anatomically and in carapace features qualifies as a "living fossil." Close relatives of the new genus belong with it in the dominantly Paleozoic superfamily Healdiacea, which is often a characteristic element in Devonian-Pennsylvanian faunules (*3, 4*).

Subsequent skimming through the literature revealed that in 1890 G. S. Brady recorded from Samoa a Recent species, *Cytherella* (?) *tumida*, evidently belonging to this new genus. Unfortunately Brady's only specimen was destroyed during an attempt at dissection; consequently the species does not appear in his collections (*5*). The species from Onotoa, however, accords with Brady's illustrations and description so closely that I consider it identical with his taxon (*6*).

Distinguishing primitive features include a clustered adductor-muscle scar pattern, poorly developed marginal areas, a five-jointed endopodite of the second antenna, a jointed clasping-type palp on the male fifth limb, setiferous ventral segments on the sixth and seventh limbs, a furca intermediate between Myodocopida and Podocopida types, and probable segmentation in the posterior part of the body (*7*). The carapace is small (in adults, about 0.5 mm in length), often brown but sometimes pallid, smooth, and elongate-ovate in dorsal view; it is further characterized by strong left-valve overlap and a distinct merodont hingement.

In general, the anatomy is Podocopida-like and in some significant details resembles that of Darwinulidae and Cyprididae. For example, the distal mandible endopodite joint is elongate and bears six slender terminal spines, and the seventh limb is a subsidiary walking leg (as in Darwinulidae), while the second antenna exopodite is a small bristle-bearing plate and the furca is well developed as in most Cyprididae. Darwinulidae are predominantly freshwater; Cyprididae are predominantly freshwater except for some primitive genera which are marine or polyhaline.

The warranted inference, that these freshwater groups evolved from marine animals having an aggregate adductor-muscle scar pattern, requires reappraisal of current systems of ostracod classification, although the relation of Darwinulidae to Healdiacea has been suggested on paleontological grounds (*4, 8*).

As yet only a male anatomy has been found among the 17 specimens obtained from Saipan and Onotoa, but I hope that this report will stimulate further collecting or a check of earlier Pacific

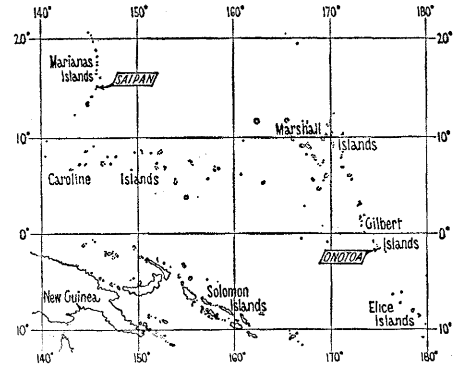

Fig. 1. Pertinent area of the southwest Pacific.

collections, or both. We already know that other ostracod living fossils (Punciidae) occur at its southwestern margin, off northern New Zealand, although only empty valves have yet been found (*9*). Such material is invaluable for the development of a natural classification, which is the principal object of a currently active committee of workers with ostracods (*10*). A more rigorous classification will enhance the already-considerable usefulness of these animals in such diverse economic spheres as oil exploration and development of fisheries.

From another point of view, since ostracods range from Lower Cambrian to Recent, detailed studies of the anatomy and shell of their "living fossils" will provide useful guidelines for any consideration of "protostracans," which were among the pioneer groups of complexly organized animals.

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