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HIGH VOLTAGE MICROSCOPY IN PALEONTOLOGICAL STUDIES - GRAPTOLITES

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Transmission electron microscopy has seldom been used in studies of fossils, and to date, no electron diffraction work has been reported. Because of the limited transmission power of the 100 kV electron microscopes (<1μ), the techniques which have been used to prepare specimens have followed standard biological methods, including ultra-thin sectioning and staining.(1) High voltage electron microscopy on the other hand allows examination of considerably thicker specimens (up to 5μ at 500 kV) and is particularly useful in studying fossils e.g. it is often not necessary to section pieces of the fossil. Minimal preparation is advantageous because materials that have been interred in rocks of the earth's crust for millions of years are commonly brittle and distort or break while being sectioned with the microtome. The present paper describes one of the first in which fossil specimens have been examined directly without following standard biological preparation techniques. All the work was done on the 650 kV Hitachi at Berkeley.

The fossils studied are in a group called the graptolites (see fig. 1a). These have previously been examined at low voltages.(1) The graptolites are an extinct group of colonial organisms that lived from approximately 525 to 375 million years ago. The actual specimens studied are approximately 475 million years old. During their lifetime, they were widely dispersed in large numbers in open seas. Despite an extensive knowledge of the graptolites in the fossil record, nothing is known of the animal that secreted the skeletal parts of the colonies now seen as fossil and little is known of the fine structure of the colony. It is hoped that study of the fine skeletal structures may provide some information on their life activities and biological affinities.

The graptolite colony includes an elongated, bell-shaped shell (the sicula) as the initial part of the colony which is shown in the scanning electron microscope images of fig. 1. The sicula probably housed an individual produced by sexual reproduction. The sicula has upper and lower halves (see figs. 1a,b) which exhibit differences in structure (figs. 2,3). The high voltage electron microscope study to date has shown that the three distinct structural elements of the prosicula are: 1) a thin tissue formed of fibers interwoven to comprise an open mesh (figs. 2a,c); 2) sets of long fibers closely bundled together to form longitudinally-oriented rod-like structures (fig. 2a at A); and 3) a set of fibers joined together to form a band (in weak contrast) that spirals down the length of the prosicula (fig. 2a at B). The diffraction pattern and dark field image (figs. 2b,c) indicate that all three regions are of the same material. The lower half of the sicula (metasicula) is composed of a meshwork of fibers that is similar to but more randomly oriented than that forming the tissue-like structure of the prosicula (see fig. 2a,3a). Superimposed on these fibers is a regularly-layered mesh-work with four-fold symmetry that has a fabric-like aspect (fig. 3a). The faint diffraction spots in fig. 3b indicate that this layer is single crystalline.

Chemical data and microscopic study of the fibers suggest that they are probably formed from large proteinaceous molecules. The diffraction patterns of the fibers in figs. 2b,3b are consistent with this viewpoint. The intensity differences in these patterns reflect possible differences in degree of mineralization due to aging.

(1) W.B.N. Berry and R.S. Takagi J. Paleontology, 44, 117-124 (1970).

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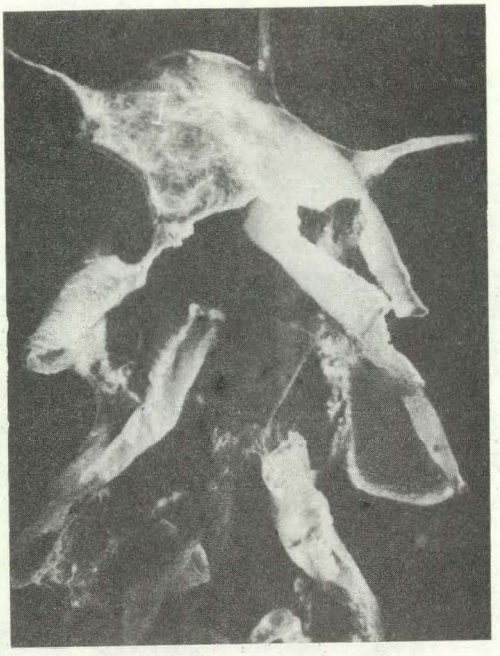
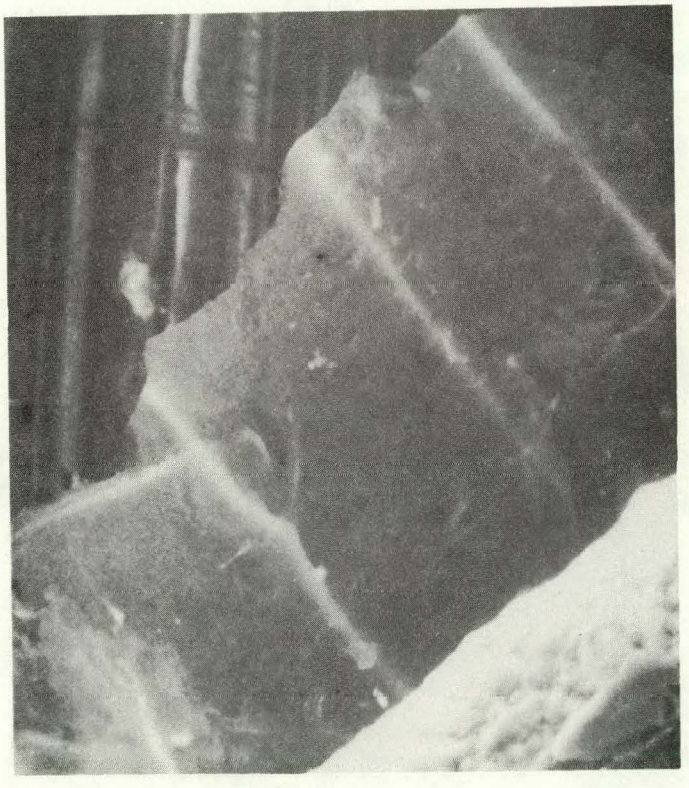
Fig. 1(a) Scanning micrograph of Orthograptus
(b) Scanning micrograph of fragment of metasicula shown in (a) at A.

Fig. 2(a) 650kV transmission bright field image of prosicula shown in 1(a), B.
(b) Diffraction pattern showing rings due to fibres.
(c) Dark field image of region indicated by the aperture in 2(b) of rings reverses contrast of all the fibres.

Fig. 3(a) 650kV transmission bright field image of metasicula.
(b) Diffraction pattern; rings due to fibres, fault spots due to layered structure.



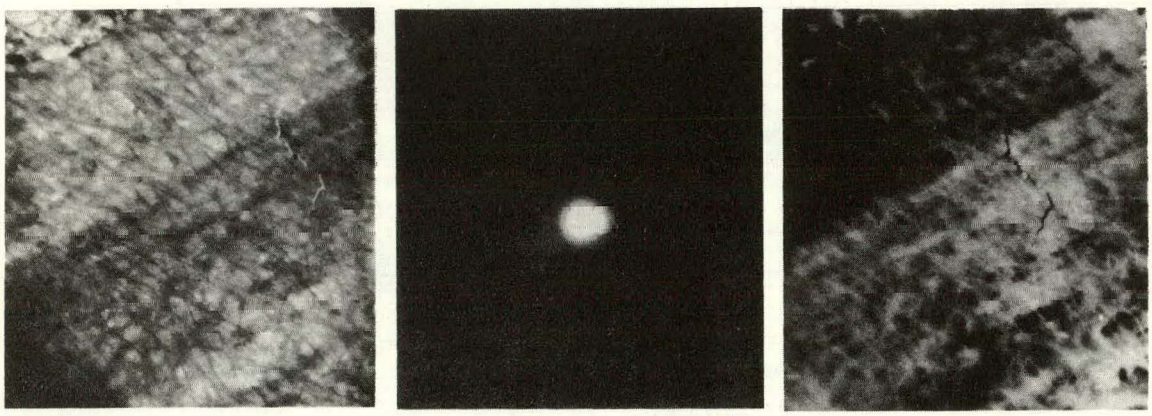
(a) mag = 65X



(b) mag = 1000X

XBB 705-2396

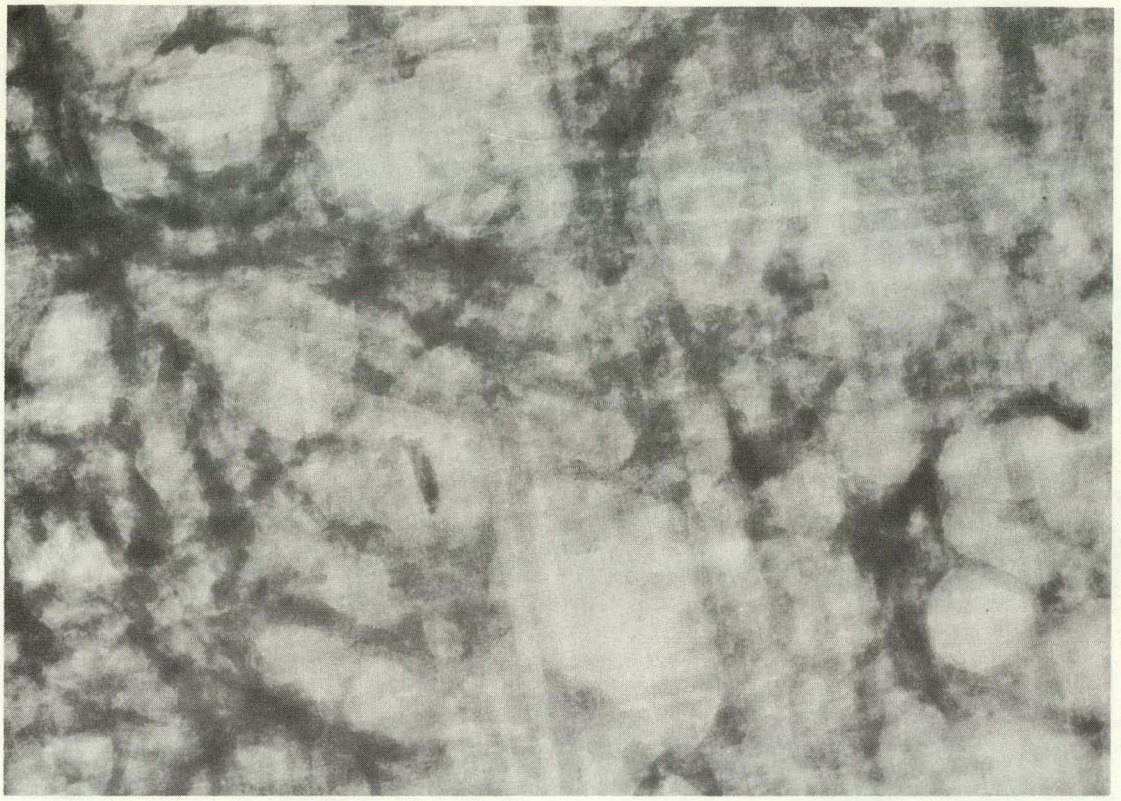
Fig. 1



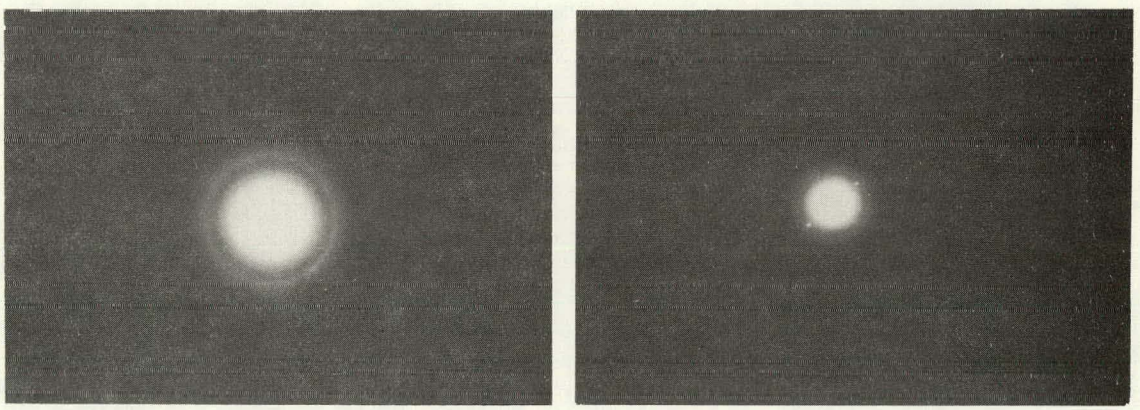
(a) (b) (c)

XBB 705-2394

Fig. 2



(a) mag = 20,000X



(b) mag = 0

XBB 705-2395

Fig. 3

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