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SCANNING ELECTRONMICROSCOPY OF COLONIZING ROCK SURFACES IN THE FAR NORTH, CANADA

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Abstract: There is little information concerning the reproductive modes of lichens or the nature of available diaspores in natural habitats at northern latitudes. On bare areas, establishment is often extremely slow. This paper reports scanning electronmicroscopy of natural rock substrates in the ablation zone of a valley glacier in Ellesmere Island, Northwest Territories, Canada, a primary bare area of known age in which nearly all of the invading saxicolous species were lichens. Rock surfaces were examined for propagules as well as developing hyphae. The expanse of available substrate was vast, and while many samples contained no evidence of biological entities, spores were frequently encountered, some with associated hyphae. There were no recognizable thallus fragments or isidia in the samples and few structures that appeared to be soredia. Both spores and mycelial growths were most often found in protected microscopic enclaves on the rock, rather than evenly distributed over the entire surface.

1. Introduction

Natural colonization by lichens often takes place within a relatively short period of time. For example, visible thalli appear within two years on pine needles (JAHNS *et al.*, 1979) or *Fraxinus excelsior* twigs (DEGELIUS, 1964). On volcanic deposits such as those on Surtsey Island colonization by lichens took place within three years (KRISTINNSON, 1972). However, in the Far North establishment on bare rock surfaces can be extremely slow in glacier ablation zones, and may not be evident on rocks closer than 100 m to the receding ice nor begin for several decades.

Colonization near large ice masses seems to be retarded by low temperature (FAHSELT *et al.*, 1988), though other considerations could be involved as well. One of the most important factors which determines species establishment is the availability of propagules (LONGTON, 1988). Dissemination of lichens is poorly understood but perhaps few diaspores are able to reach an extensive bare area such as a glacier ablation zone. BAILEY in his review (1976) indicated that many dispersal mechanisms are only effective over relatively short distances.

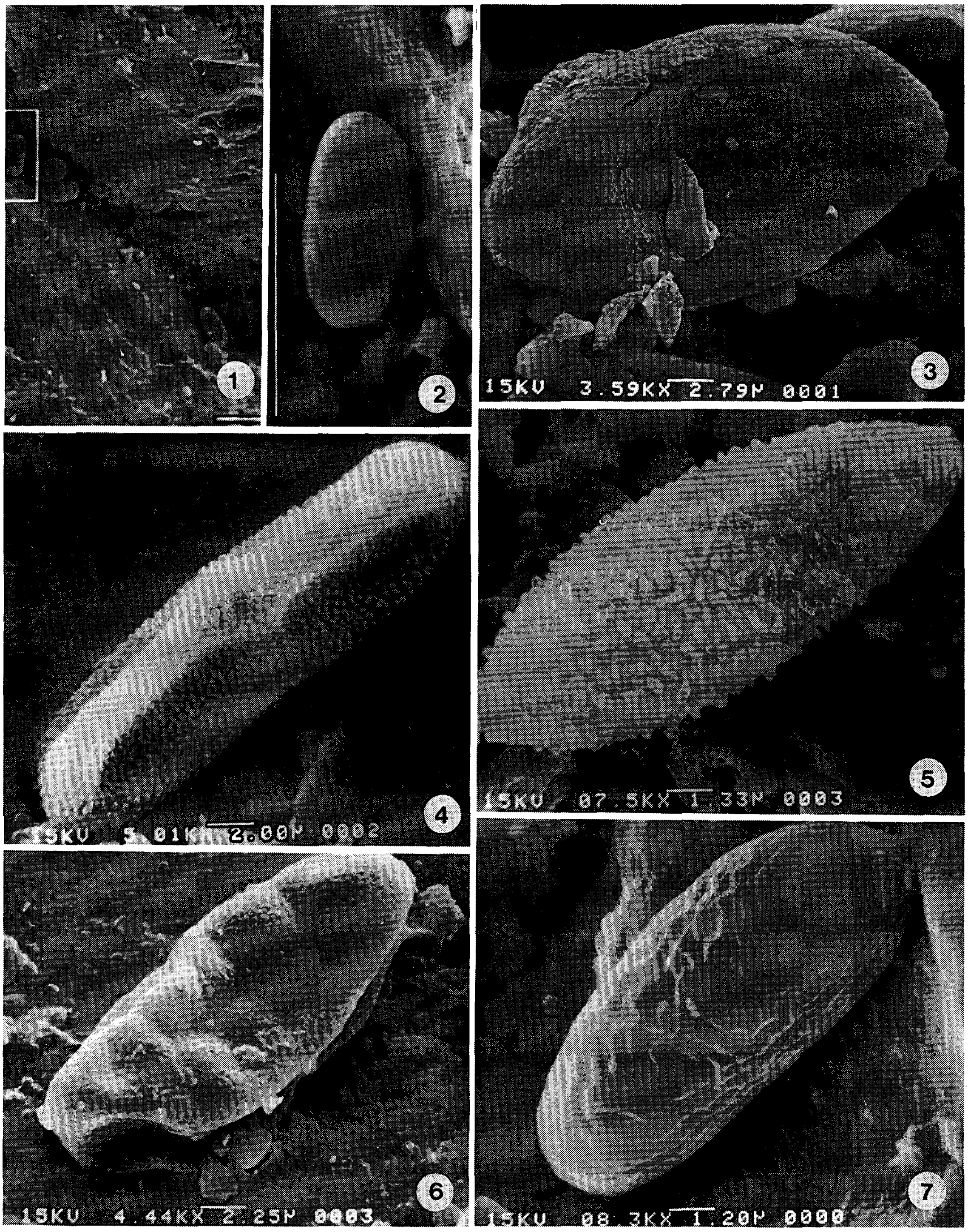
Thallus fragments have been reported in snow samples (DURIETZ, 1931) and in glacial ice (BOND, 1969). However, it is not clear whether this is common throughout the Arctic or whether such fragments could normally be transferred to and retained on rock surfaces. There is little information regarding transport of the various kinds of lichen propagules (BAILEY, 1976) especially in the Arctic. It is believed, however, that light propagules such as spores are more easily transported by wind (BAILEY, 1976;

ALLEN, 1987). In the High Arctic some lichens have vegetative propagules but a large proportion of the fellfield flora is made up of species which do not produce them (FAHSELT *et al.*, 1988). Furthermore, many species in the surrounding tundra are crustose (FAHSELT *et al.*, 1989), have spores but no specialized asexual diaspores and are not subject to fragmentation. Distribution patterns of propagules over natural rock surfaces have not been studied, but establishment takes place preferentially along cracks (FAHSELT *et al.*, 1988).

Establishment of visible lichen thalli was studied in Sverdrup Pass, Ellesmere Island, Northwest Territories, Canada (FAHSELT *et al.*, 1988). While various species of mosses occurred in the pass, bryophytes were less important than lichens in terms of biomass and as colonizers of rock surfaces. There were also very few free-living fungi. Lichens were a more significant component in the landscape, particularly on dry consolidated substrates, were represented by a greater number of species (ms. in preparation) and often were pioneers especially on rock. The present study involved examination of primary bare areas in a glacier fellfield which has been forming since the end of the Little Ice Age. Though limited establishment of lichens has usually begun in such areas, they are termed "lichen-free zones" (EDLUND, 1985) due to their distinctive light-colored appearance in air photos. The earliest invaders of mineral surfaces are probably microbes, but most macroscopic colonizers are lichens. The aim of the study was to determine whether lichen propagules naturally occur on englacial rocks and boulders and, if so, whether they include thallus fragments, specialized vegetative propagules or spores. In the event that disseminules were evident, the intention was to determine whether they were generally distributed on rock surfaces or concentrated in particular microsites.

2. Materials and Methods

Samples were collected in July 1986 from the central part of a fellfield in Central Sverdrup Pass on Ellesmere Island, in Arctic Canada. In this area where there was sparce visible lichen establishment samples were taken from randomly chosen granite and sandstone rocks which measured 1 m or more in at least one dimension. Samples were removed with a geological hammer at points of weakness in the rock surface. Collections were made south of the glacier 110 to 130 m from the ice front, well within the approximately 180-wide ablation zone which began to develop in the middle of the last century. They were flown to southern Ontario in early August 1986. Where necessary to make them fit aluminum mounts for the microscope, rock samples were trimmed with a diamond saw and subsequently attached with two-sided adhesive tape (J.B. Em, Dorval, P.Q.). Mounted stubs were gold-coated using a Hummer VI Sputterer and then stored over anhydrous calcium sulphate desiccant until SEM analysis. Specimens were microscopically examined at 15 kV on an ISI-DS 130 dual stage scanning electronmicroscope and photographed on Type 55 Polaroid 4″×5″ Land Film. To minimize loss of loose materials specimens were prepared without critical point drying.



Figs. 1–7. Spores on englacial rock surfaces, Severdrup Pass, Northwest Territories, Canada.

Fig. 1. Spores in a trough in granite surface, unusual situation in that four occur together. Scale bar is 13.2 μm.

Fig. 2. One spore from Fig. 1 at 5 × magnification.

Fig. 3. A larger simple spore on coarse-grained sandstone.

Fig. 4. Papillate 2-celled spore on granite.

Fig. 5. Verrucose spore on sandstone.

Fig. 6. Multicellular spore on sandstone.

Fig. 7. Simple spore on granite with reticulate ornamentation.

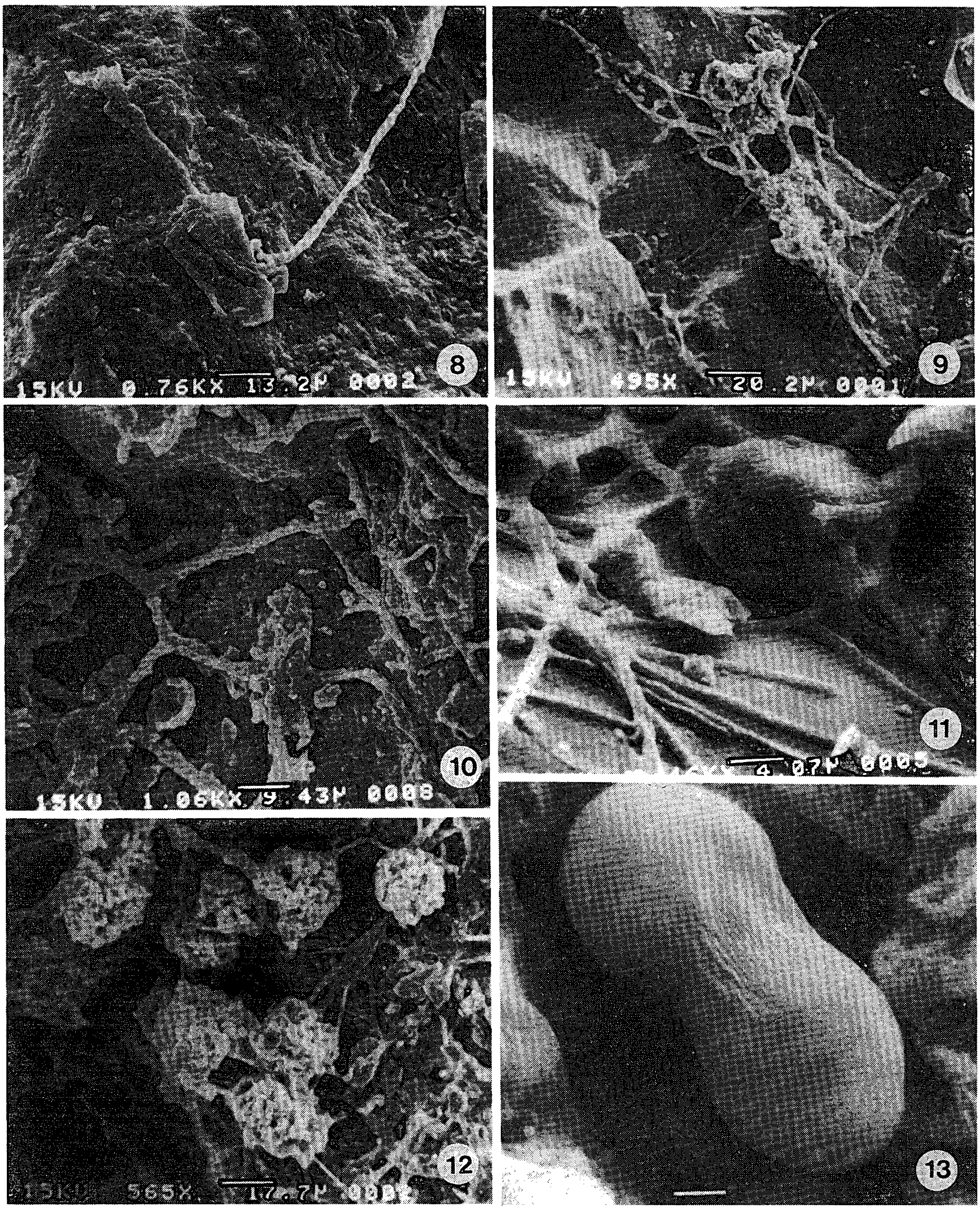


Fig. 8. *Single phypha on englacial granite.*
Fig. 9. *Early stage in the development of hyphal mat on granite rock.*
Fig. 10. *Anastomosing mat of mycelia on granite.*
Fig. 11. *Spore with emerging hyphae contacting hyphae from other sources.*
Fig. 12. *Cellular masses interconnected by mycelia, possibly including algae.*
Fig. 13. *Polaribilocular spore of* Xanthoria elegans *on surface of apothecium. Scale bar is 1.32 μm.*

3. Results

Of the SEM samples studied in detail over a six-month period, nearly half had no evidence of biological structures on them. A few contained structures which appeared to be insect eggs or cell masses resembling the free living fungus, *Lichenothelia*. With respect to propagules the most common were certainly spores, occurring in about 40% of the samples, occasionally as small groups (Fig. 1) but more often singly. Several kinds of spores were found on englacial debris. A common type was simple with a smooth coat (Fig. 2), and others were also simple but much larger (Fig. 3). Some elongated types bore irregular short papillae (Fig. 4) and others were verrucose ornamented (Fig. 5) with polar pore structures. Another type had surface contours suggesting multicellularity (Fig. 6), and among those remaining some were ornamented with low reticulate ridges (Fig. 7), deep reticulate sculpturing or spines. Viability of two spore types was tested on mica strips: one germinated (*Xanthoria elegans*) and one did not (*Umbilicaria virginis*).

Mycelia were observed in several samples either singly (Fig. 8) or as anastomosing networks (Figs. 9 and 10). In some cases spores were seen with hyphal strands apparently emerging from them (Fig. 11). A few samples showed hyphae interconnecting cell clusters (Fig. 12) and spores, and two contained very young thalli with rhizines evident below. Groups of cells, some of which may have involved algae, were observed in association with hyphae.

While many of the rock samples appeared to be smooth or plane, microscopic examination indicated that the surfaces were in fact uneven. Rocks which were perceived as essentially flat frequently supported spores and other structures in slight recesses or microscopic depressions; more spores and hyphal growths were associated with crevices which were deeper.

4. Discussion

Compared to many other environments such as tree bark, moss cushions and even soil, rock and boulders in the High Arctic are subject to a greater degree of cold and desiccation. The nearest weather station to the study site reports an average annual precipitation of 6 cm per year. However, as potential lichen habitat rocks sometimes offer the advantage of being more stable, *e.g.*, the surfaces examined in the present study were probably 60 to 100 year old.

Some microscopic entities which occurred on rocks and boulders were confirmed (A. Henssen, pers. commun.) to be not lichens, but a common species of the free-living fungus, *Lichenothelia*, with a world-wide distribution (Henssen, 1987). However, by far the most frequently-seen structures on rock surfaces were spores. Since saxicolous lichens eventually establish it was expected that some propagules would occur; that many were spores was probably a reflection of the high frequency of apotheciate lichens in the landscape. Since spores which are discharged from nearby asci are often found in groups of eight, the preponderance of single occurrences was considered to be an indication that they were transported from some other location. Winds in the pass travelled primarily along the length of the valley and the distance along the axis of wind movement was at least 300 m from the nearest well-established lichens on unglaciated terrain to the sampled sites. Such long distances suggest that wind was the agent responsible for propagule dispersal. That the most commonly found disseminules were small ones, *i.e.*, spores, also was consistent with transport by wind.

Even though samples were deliberately taken from larger rocks which seem to colonize more readily than small ones (FAHSELT *et al.*, 1988), most appeared to be essentially bare. That SEM revealed so many preparations containing spores is surprising and suggests that distribution must be rather general. Additional rock specimens from the vast expanse of exposed mineral substrate in the ablation zone would probably reveal the presence of other kinds besides those reported here.

Several High Arctic lichen species present in the pass have morphologically distinctive ascospores, *e.g.*, those of *Xanthoria elegans* were bilocular with a constricted central region marked by fine wrinkles (Fig. 13). Some of the fellfield spores (Figs. 1 and 2) resembled those of *Umbilicaria virginis*, another common lichen in the pass. Others were similar to ascospores of the soil lichens, *Solorina crocea* (Fig. 3) or *S. saccata* (Fig. 4), photographed by THOMSON and THOMSON (1984). Due to a lack of information concerning SEM characteristics of the majority of spores sexual lichens in the pass, however, photographed fellfield propagules could not be identified to species.

The marked tendency for spores to be located in depressions or protected places on rock surfaces was similar to that observed by OTT (1987b) who noted that soredia settled into depressions on tree bark. There may be less turbulence in low-lying contours, thus preventing removal by wind. Establishment of young thalli along cracks in High Arctic locations must be partially explained by accumulation of propagules there. Better growing conditions for pre- and post-lichenized hyphae are probably found in these microsites also.

Hyphal growths occurring in protected enclaves on the surface of englacial rocks and boulders sometimes interconnected spores. This was consistent with earlier reports of mycelia from different sources anastomosing or fusing with one another (BAILEY, 1976; OTT, 1987b; JAHNS, 1987; HAGEMAN, 1989) and supported the idea that several propagules might participate in the institution of one single lichen thallus.

It is clear that propagules, particularly spores, were successfully dispersed to the glacial ablation zone under investigation and that many had been retained on the surface of rocks and boulders. Additionally, the kinds of rock surfaces present in the fellfield must have constituted suitable substrate for lichens because similar rocks in unglaciated parts of the pass were densely colonized by lichen species. The delay in establishment was thus not explained either by lack of propagules or inappropriate substrate. The lag in onset of colonization must have been due to the inability of available spores to both germinate and encounter their own normal photobionts or others which might temporarily substitute in a way described by OTT (1987a). Perhaps WILLIAMS' (1975) prediction regarding higher mortality in sexual than asexual propagules is particularly true for lichens. In those environments where sexual species are important as invading species, this may explain why the process of colonization is extremely slow.

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