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1-31-1988

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Robert B. Warrick  
*Brigham Young University*

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### Recommended Citation

Warrick, Robert B. (1988) "SEM analysis of Utah *Equisetum* stems (Equisetaceae)," *Great Basin Naturalist*. Vol. 48 : No. 1 , Article 8.

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## SEM ANALYSIS OF UTAH *EQUISETUM* STEMS (EQUISETACEAE)

Robert B. Warrick<sup>1</sup>

ABSTRACT.—The Utah taxa of *Equisetum* were observed with the scanning electron microscope to test for taxonomic significance of stem morphology. The four Utah species of *Equisetum* were compared. Stem morphology was shown to be taxonomically significant in most cases. The hybrid *E. x ferrissii*, recognized in the literature as being extant in Utah but heretofore unrecognized in Utah herbaria, was shown to be present in the flora of the state.

Certain species of *Equisetum* have long been difficult to positively identify. Easily keyed species often have intermediate forms with characteristics of two species. This paper attempts to resolve some of these problems by observing stem characteristics, including siliceous tubercle dimensions, position of stomata, and ridge morphology, to test for taxonomic significance.

The stems of *Equisetum* are longitudinally striated, forming a series of furrows and ridges. The two most obvious characteristics of *Equisetum* stems are the stomata and siliceous tubercles. Stomatal arrangement has been used to divide the genera of *Equisetum* into two subgenera (Emons 1986). Stems of *Equisetum* are heavily impregnated with silicon, forming various-sized tubercles. The literature is replete with confusing terms for different-sized tubercles, with little or no uniformity among writers. The tubercles have been called silica nobs, rosettes, bands, bars, bodies, nodules, pustules, spicules, papilla, mamillae, pilulae, etc. (Kaufman et al. 1971, Pant and Kidwai 1968). On all specimens observed, siliceous tubercles were of three sizes. For simplicity, they are designated here as "microtubercles," "mesotubercles," and "megatubercles" (Fig. 1). Microtubercles appear as small white specks, much smaller than the stomata. Mesotubercles are rounded, sometimes coalescing tubercles smaller than the stomata but larger than the microtubercles. Megatubercles, located on the ridges, are larger than the stomata.

### METHODS AND MATERIALS

Ten specimens of each species were observed (where possible) from random locations in Utah. For species not well represented in Utah, specimens from random locations throughout the United States were observed for comparison. All specimens were from dry herbarium mounts located in the Brigham Young University Herbarium (BRY). An attempt was made to observe a section of each stem from the second node below the strobilus. All samples were from mature, fertile stems, with the exception of *E. arvense*, where sections from both fertile and sterile stems were observed.

Samples were prepared for scanning electron microscopy (SEM) by mounting on aluminum stubs with double-sided tape, then carbon coating followed by gold sputter coating (Dawes 1971). Specimens were neither fixed nor critical-point dried before mounting on stubs.

### RESULTS

*Equisetum arvense* L. This species is unique among the species of *Equisetum* found in Utah, being dimorphic, with both fertile and sterile growth forms. The siliceous tubercles of sterile *E. arvense* (Fig. 2) are predominantly microtubercles. Megatubercles are lacking. Mesotubercles may be present either singly or coalescent with other mesotubercles. *Equisetum arvense* is in many ways unique when compared with the remaining

<sup>1</sup>Department of Botany and Range Science, Brigham Young University, Provo, Utah 84602. Present address: Department of Botany, University of Wyoming, Laramie, Wyoming 82071.

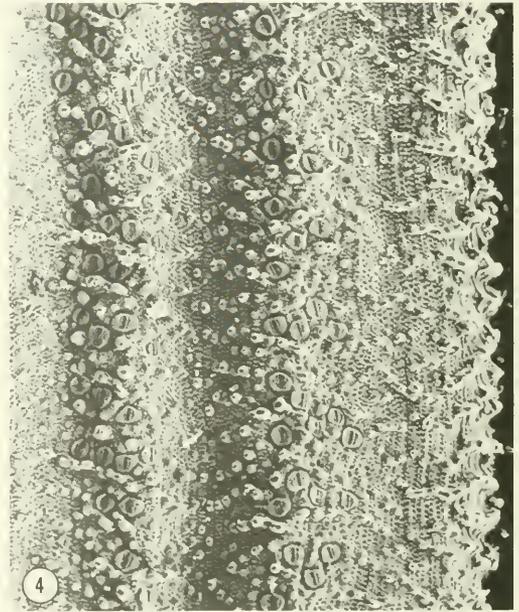
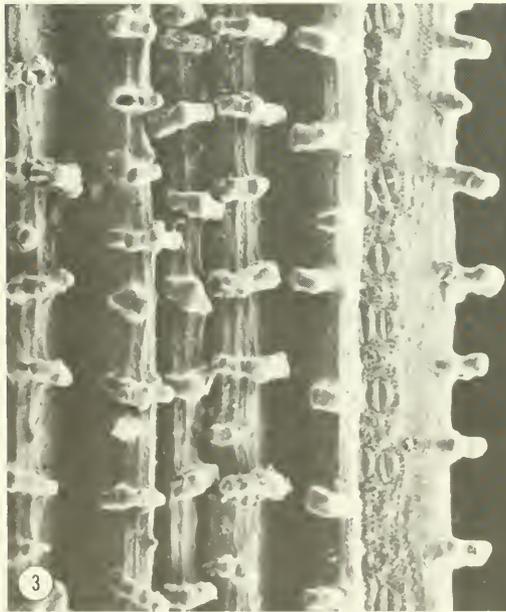
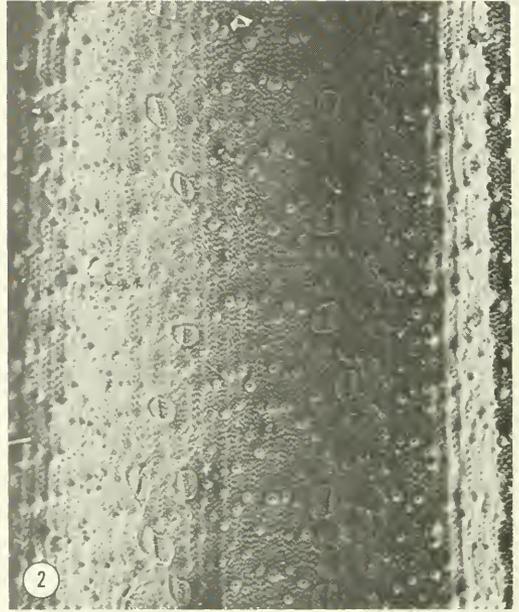
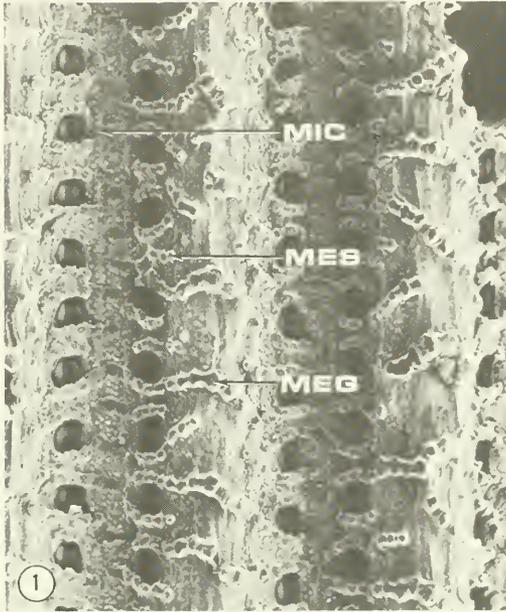


Fig. 1. *Equisetum* stem showing microtubercles (mic), mesotubercles (mes), and megatubercles (meg).

Fig. 2. Sterile stem of *Equisetum arvense* (100X).

Fig. 3. Sterile stem of *Equisetum pratense* from Palmer, Alaska (100X).

Fig. 4. Fertile stem of an atypical *Equisetum arvense* (100X).

species in Utah. The stomata, instead of forming two neat, parallel rows, form uneven, scattered rows, referred to by Hauke (1963) as bands. On specimens observed, bands are often as many as four stomata wide. The stomata are not sunken as in other species, lack a

border of mesotubercles, and are generally taller than wide. Tubercles are altogether lacking on fertile stems.

A species similar in appearance to *E. arvense* is *E. pratense*. Both are dimorphic and somewhat small in stature (Welsh 1974).

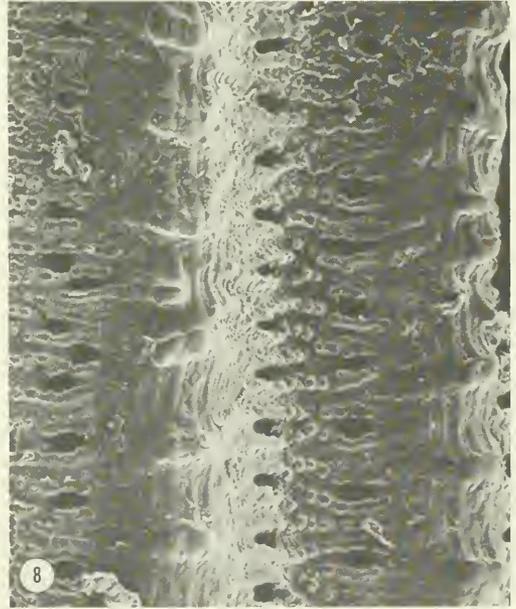
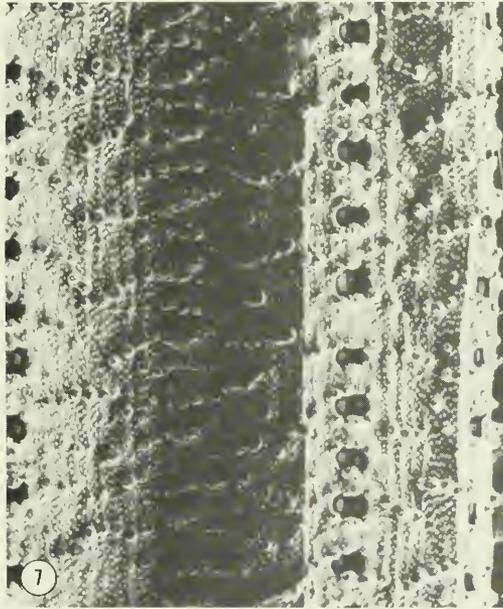
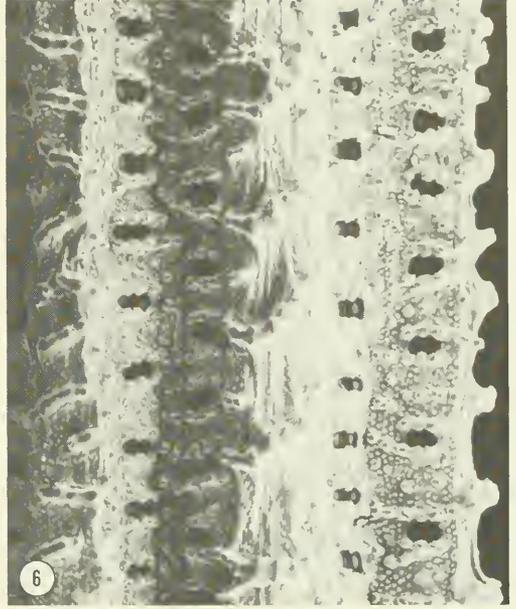
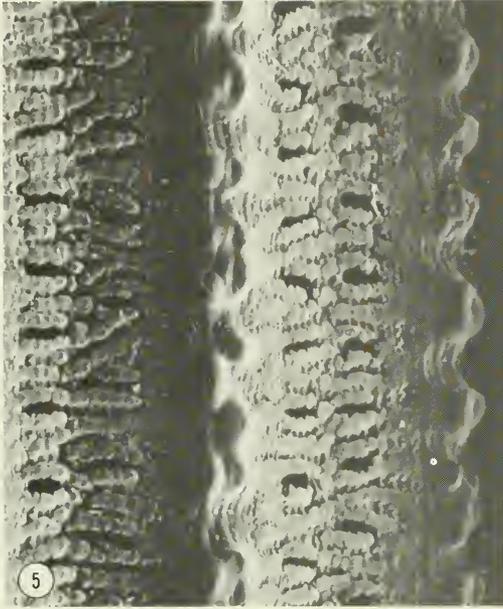


Fig. 5. *Equisetum hyemale* stem (100X).  
 Fig. 6. Immature *Equisetum laevigatum* stem (110X).  
 Fig. 7. Mature *Equisetum laevigatum* stem (100X).  
 Fig. 8. *Equisetum x ferrissii* stem (100X).

Where the two overlap in distribution, field identification is difficult by sight alone. *Equisetum pratense* was historically represented in Utah on the basis of a few herbarium sheets, generally collected in the northern part of the state. All were annotated to *E. arvense* previ-

ous to this study, but one specimen collected along the Logan River in Cache County remained slightly enigmatic. This specimen was carefully scrutinized with the SEM (Fig. 3) and compared with a collection of *E. pratense* from Alaska (Fig. 4) and *E. arvense* from Utah

(Fig. 2). As shown in Figure 3, the megatubercles of *E. pratense* are taller than wide and arranged in a very regular pattern along the ridges. The stomata are also grouped into neat rows and mesotubercles are very few in number. When the Logan River collection of "*E. pratense*" was compared with the Alaskan *E. pratense* and a Utah collection of *E. arvense*, it readily correlated with *E. arvense*, albeit with some differences. Unequivocal specimens of *E. pratense* are not currently known from Utah.

***Equisetum hyemale* L.** This species is the most robust of the *Equisetum* taxa occurring in the state, usually possessing an ash gray band near the top of each sheath, and with apiculate cones. The surface characters of *E. hyemale* (Fig. 5) are very distinct. Microtubercles are very few on mature stems. Mesotubercles are numerous but are usually coalesced. Most form short bars running perpendicular to the furrows, with groups of three or four forming borders around the stomata, causing a "doubly sunken" condition (Dayanandan and Kaufman 1973). The stomata are arranged in two even, closely spaced, parallel rows, and are wider than tall. The megatubercles are very prominent on the narrow ridges and appear to form two parallel rows on each ridge. Megatubercles are wider than tall.

***Equisetum laevigatum* A. Br.** This taxon is readily identifiable unless the specimens are small or otherwise depauperate. *Equisetum laevigatum* tends to branch from the caudex, as does *E. variegatum*, whereas *E. hyemale* and *E. arvense* rarely exhibit this feature. Small or immature specimens (Fig. 6) may resemble *E. variegatum* (Fig. 12) and vice versa. The surface characters of *E. laevigatum* (Fig. 7) show the tubercles to be predominantly microtubercles, with megatubercles nonexistent to very few (hence the common name, "smooth scouring rush"). The ridges range from being obscure with no special arrangement of tubercles to prominent with perpendicular bars of small megatubercles. Mesotubercles are scattered throughout, both as single units and as groups coalesced into bars perpendicular to the furrows. Stomata are sunken beneath the epidermis and bordered by three connivent mesotubercles above and below. The stomata are wider than

tall and arranged in widely spaced, parallel rows. The rows tend to be equidistant between the row in the same furrow and the row in the adjacent furrow.

***Equisetum x ferrissii* Clute (= *E. hyemale* x *E. laevigatum*).** This hybrid is widespread in the United States and has been reported for Utah (Hauke 1963, Raven et al. 1981). It should occur frequently since both parents are abundant throughout the state (Welsh et al. 1987). While there are no collections labeled as such, several sheets at BRY look like intermediates between *E. hyemale* and *E. laevigatum* and could possibly be designated as the hybrid *E. x ferrissii* (Fig. 9). Both collections examined appear similar with the SEM. Microtubercles, mesotubercles, and megatubercles are all common. Stomata are deeply sunken and spaced as in *E. hyemale*. Ridge prominence and shape of stomata are about intermediate between the two putative parents.

***Equisetum variegatum* Schleich.** This taxon is poorly represented in the herbaria of the state because of its rarity. Many of the herbarium sheets labeled as *E. variegatum* appear to be misidentified. Only two of the six collections labeled as *E. variegatum* at BRY have cones. From external appearance, five of the six, including the four lacking cones, could very well be immature specimens of *E. laevigatum*. For this reason, several collections of *E. variegatum* from throughout the United States were observed and photographed (Fig. 11) for comparison with the Utah material. Results showed that the collections from outside of Utah, though spaced over 3,000 miles, are strikingly similar to one another in external stem morphology. The ridges are prominent and tend to be as wide as the furrows. Microtubercles are present but not especially common. Mesotubercles are prominent in the furrows but nonexistent on the ridges, while the reverse is true for the megatubercles, thus forming distinct rows on the ridges. The Utah material, however, lacks evident megatubercles. Tubercles on the ridges are borderline megatubercles, appearing more like slightly large coalesced mesotubercles. They are not appreciably larger than the mesotubercles found in the furrows. Microtubercles are much more common in the Utah collection. The only Utah *E. variegatum* which could be

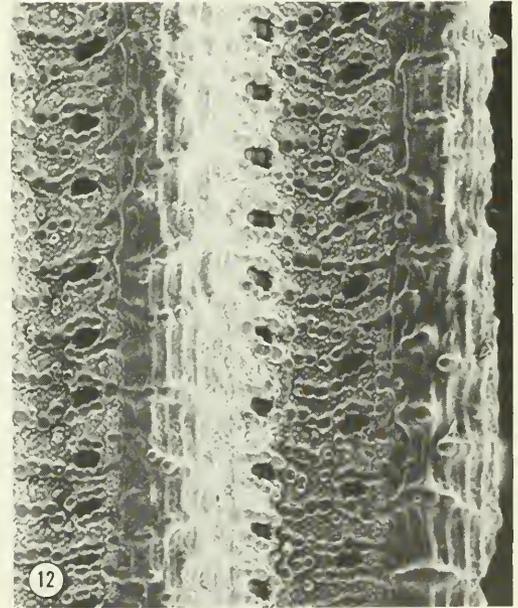
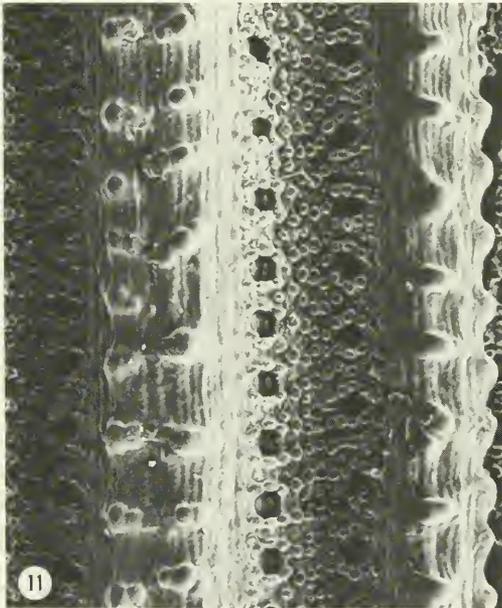
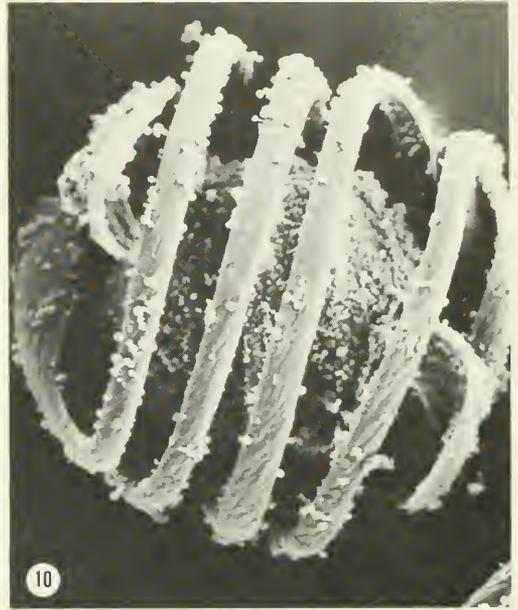
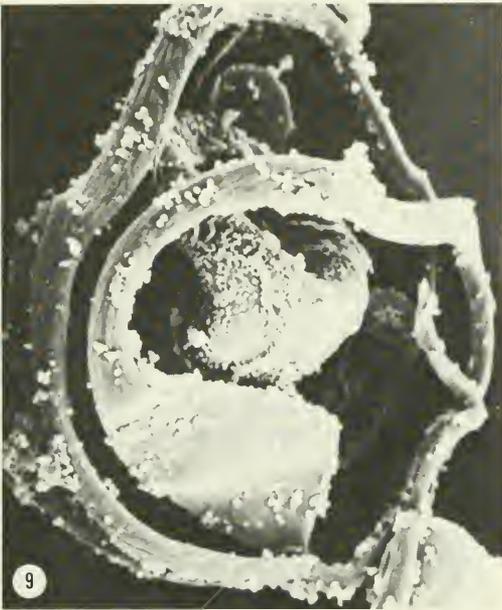


Fig. 9. Aborted spore of *Equisetum x ferrissii* (1,350X).  
 Fig. 10. Developed spore of *Equisetum hyemale* (1,350X).  
 Fig. 11. *Equisetum variegatum* stem from Richland, Washington (100X).  
 Fig. 12. *Equisetum variegatum* stem from Navajo Lake, Utah (100X).

positively identified as such (Fig. 12) was collected near Navajo Lake. This site is only a few miles from Cedar Breaks, the Utah location frequently reported in the literature for this taxon (Cronquist et al. 1972, Hitchcock et al. 1969).

DISCUSSION

While some researchers doubt that stem characteristics such as those described above are worthy as taxonomic features (Kaufman et al. 1971), others feel that these characteristics

are analogous to the sculpturing of pollen grains and are thus important as diagnostic features (Page 1972, Larouche et al. 1970). These features, based upon this small study of Utah taxa of *Equisetum*, are useful taxonomically, at least for Utah species.

The species *E. arvense* and *E. hyemale* are very distinct and unmistakable when compared with other taxa occurring in the state. These are, however, not easily mistaken for anything else in the field, and it is unlikely that one would ever have to resort to tubercle morphology for identification. It has proven useful, nonetheless, to show beyond doubt that collections labeled as *E. pratense* were mislabeled and that this taxon has yet to be collected within Utah (see also Hauke 1978). It is interesting to note that while the Utah specimen identified as *E. pratense* is most closely allied to *E. arvense*, it does not match that taxon perfectly, possibly accounting for the misidentification. Several mature stems of fertile *E. arvense* from random sites in Utah were examined and no stomata or tubercles were observed. On fertile stems of "*E. pratense*," stomata and tubercles were observed to be as common as on the sterile stems of *E. arvense*. In his monograph of the *Equisetum* subgenus *Hippochaete*, Hauke (1963) states that a considerable amount of variability exists within the species. Others have noted that the horsetails are known to be plants of notoriously plastic morphology (Page 1972). All known taxa of *Equisetum* have  $2n = 256$  (Soltis 1986), a condition adding to the plasticity of this genus. Thus, while different, the Logan River collection of "*E. pratense*" fits into the spectrum of variation for *E. arvense*.

Within Utah, *E. laevigatum* and *E. variegatum* are distinct as mature adults, but when specimens are immature or depauperate, identification becomes difficult and tubercle morphology tends to resemble one another. This would seem to indicate relatedness, but, oddly enough, these are two of the most distantly related taxa in the subgenus *Hippochaete* (Hauke 1963). Since *E. laevigatum* and *E. variegatum* are distinct as mature adults and nearly impossible to distinguish when depauperate or immature, tubercle and stomata morphologies alone are not especially useful for these two taxa within Utah. The one certain collection of *E. variegatum* (Fig. 12) examined with SEM is somewhat distinct

from collections of *E. variegatum* (Fig. 11) from other states. Based solely on tubercle and stomatal characteristics, this collection appears to be intermediate between *E. variegatum* and *E. laevigatum*. Since this specimen readily keys to *E. variegatum* using easily observable external features and looks like other collections of *E. variegatum* from all over the United States, I can only conclude that this specimen is within the range of expectations for tubercle morphology, but that a large enough sample was not examined. Again, the notoriously plastic morphology of this genus must be kept in mind. Inasmuch as the Utah populations represent the southwest extreme of the distribution of this species and are somewhat disjunct, it is not surprising to find this population slightly different from specimens from other states.

Prior to this study, *E. x ferrissii* was unrecognized in the herbaria of the state, though discussed in the literature (Hauke 1963, Hitchcock et al. 1969, Cronquist et al. 1972). Because the two specimens examined are intermediate in stomata and tubercles and also appear intermediate from gross morphological features used in the keys, these collections apparently fall safely within the concept of *E. x ferrissii*. The spores of *E. x ferrissii* all abort, and none are released from the strobilus (Hauke 1963), thus providing one of the best aids for identification (Wagner et al. 1986). Aborted spores from Utah collections of *E. x ferrissii* (Fig. 9) were compared with viable spores of *E. hyemale* (Fig. 10). This verifies the existence of *E. x ferrissii* in Utah.

#### ACKNOWLEDGMENTS

I express gratitude to Jim Allen for technical assistance and patience in preparing the SEM microphotographs and extend thanks to Stanley L. Welsh, Kaye H. Thorne, and W. M. Hess for their reviews and stimulating discussions. All are members of the staff of Brigham Young University.

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