

# The Cretaceous age of the Vinegar Hill silica sand deposit, southern New Brunswick: evidence from palynology and paleobotany

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## ABSTRACT

A small outcrop of quartz (silica) sand has been recognized at Vinegar Hill, near Cassidy Lake south of Sussex, New Brunswick, since the 1980s and extracted for commercial purposes. The deposit overlies Carboniferous rocks and underlies glacial deposits, and its setting is very similar to comparable, confirmed Cretaceous deposits in Nova Scotia. The age of the Vinegar Hill deposit, which appears to be of fluvial origin, has been unconfirmed until the present study. In this study, a general Mesozoic-early Tertiary age is indicated by the identity of a fossil araucarian wood specimen that occurs within the sand, and palynomorphs suggest a late Early Cretaceous, probably Albian, age. The absence of true growth rings in the wood implies a humid subtropical climate characterized by high temperatures, a conclusion consistent with a Cretaceous age because such climates are predicted for that age in the region by global paleoclimate reconstructions. The Vinegar Hill deposit represents the only known outcrop of Cretaceous strata in New Brunswick, but given its economic and scientific interest, a search for similar basins in the province would be worthwhile.

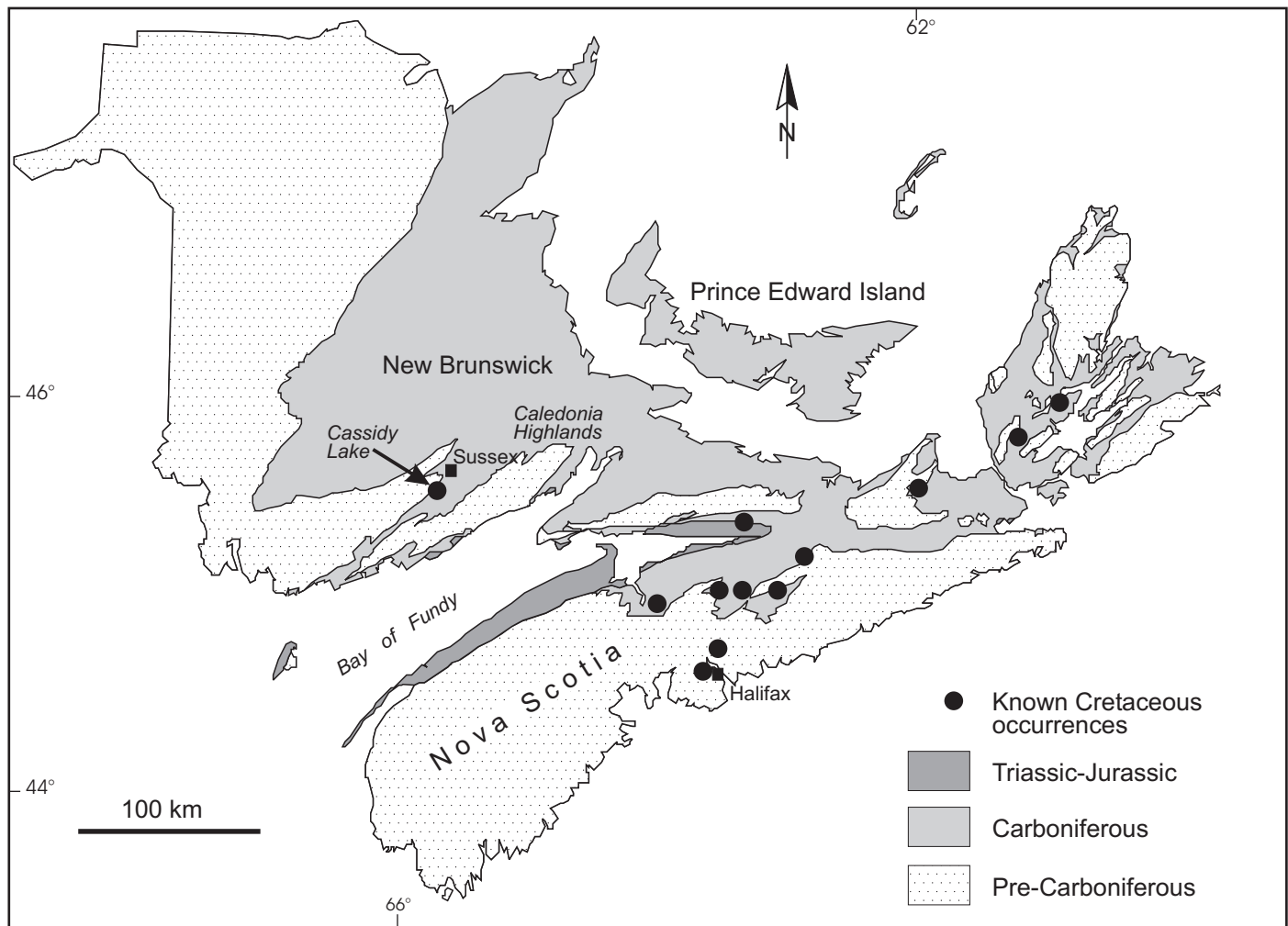
## RÉSUMÉ

Un petit affleurement de sable quartzueux (silice) a été repéré sur la colline Vinegar, près du lac Cassidy, au sud de Sussex, Nouveau-Brunswick, au cours des années 80 et il a fait l'objet d'extraction à des fins commerciales. Le gîte recouvre des roches du Carbonifère et se trouve sous des dépôts glaciaires, dans un cadre semblable aux gîtes crétacés confirmés comparables de la Nouvelle-Écosse. L'âge du gîte de la colline Vinegar, qui semble d'origine fluviale, n'avait pas été confirmé avant la présente étude. L'étude le situe d'une façon générale au Mésozoïque-Tertiaire inférieur en s'appuyant sur l'identité d'un spécimen de bois araucarien fossile présent à l'intérieur du sable; les palynomorphes laissent supposer qu'il remonterait à la fin du Crétacé inférieur, probablement l'Albien. L'absence de cernes réels dans le bois permet de supposer un climat subtropical humide caractérisé par des températures élevées, une conclusion qui est compatible avec un âge le situant au Crétacé parce qu'on peut déterminer la présence de tels climats dans la région à cette époque au moyen de reconstructions paléoclimatiques planétaires. Le gîte de la colline Vinegar représente le seul affleurement connu de strates du Crétacé au Nouveau-Brunswick, mais vu son intérêt économique et scientifique, il serait intéressant de rechercher des bassins semblables dans la province.

## INTRODUCTION

Outcrops of Cretaceous siliciclastic and lignitic rock occur sporadically but widely in Nova Scotia (Stea and Pullan 2001; Fig. 1), their general age having been proven on the basis of palynology (Stevenson 1959). The Nova Scotia deposits are usually found in faulted basins overlying a range of Carboniferous formations, or in sinkholes within Windsor Group evaporites. Their most distinctive lithological components are silica sands and kaolin clays, both of which have been extracted commercially.

A small deposit of predominantly silica sand is located at Campbell Settlement, 4 km northeast of Cassidy Lake and about 10–15 km south of Sussex, southern New Brunswick (Figs. 1, 2). It was first reported by Lockhart (1983, 1984, 1988) and has since become the subject of commercial extraction by the Atlantic Silica company. In some earlier reports (Venugopal 1994, 1999) this material was referred to as the Cassidy Lake deposit, but was termed the “Vinegar Hill Formation” on the 1:500 000 scale geological map of New Brunswick (New Brunswick Department of Natural Resources and Energy 2000). We refer to it here as the Vinegar Hill deposit.



**Fig. 1** Cretaceous occurrences and general geology of the Maritime Provinces of Canada. This map is based in part on an original in Stea and Pullan (2001). Additional occurrences have been added on the basis of unpublished palynological analyses by one of us (RAF) and E.H. Davies.

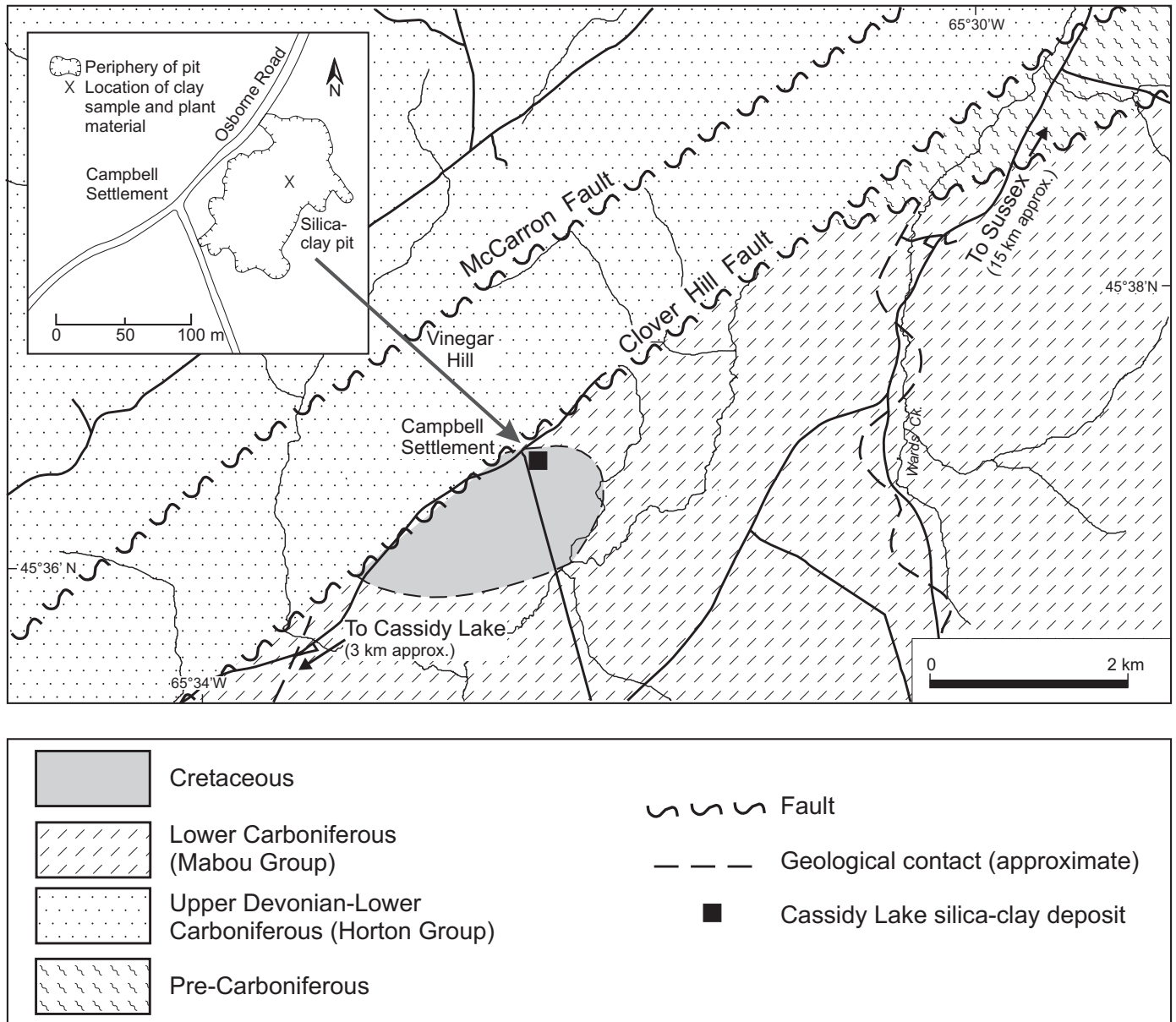
This New Brunswick deposit, because of its similarity of geological setting and lithological content to some Nova Scotia deposits, has been thought to be of Cretaceous age (see, for example, Atlantic Geoscience Society 2001), but this age has not previously been confirmed by direct evidence. Here we present palynological, paleobotanical and paleoclimatic evidence confirming that the Vinegar Hill deposit is of Cretaceous, probably Albian, age. It is thus the first known occurrence of late Mesozoic rocks in the province, the next oldest rocks being Early Jurassic lava flows on Grand Manan Island and dykes of that age in both southern and northern New Brunswick; the next youngest rocks are widespread Quaternary deposits. This is thus a similar stratigraphic succession to that found in mainland Nova Scotia (Stea and Pullan 2001).

## GEOLOGY

The local geology of the Vinegar Hill deposit is shown in Figure 2 (McLeod *et al.* 1994; St. Peter 1995). The deposit occurs in a down-faulted block on the south side of the Clover

Hill Fault, a major structural break in the immediate vicinity of Campbell Settlement (Venugopal 1994). The fault separates the rocks of the Memramcook Formation (Horton Group) of latest Devonian-Tournasian age from the younger, late Viséan to early Namurian, clastic sedimentary rocks of the Mabou Group (Belt 1965; St. Peter 2001). The putative Cretaceous sediments overlie rocks of the Mabou Group.

Silica sand forms the major constituent of the Cretaceous deposit, but clay is also important (Venugopal 1999). Clay occurs throughout the matrix, where it is admixed with silica flour, and as thin (a few millimetres to 60 cm), horizontal to sub-horizontal, lenticular, poorly stratified horizons interbedded with the silica sand. Locally the layers display crude graded bedding, fining up with discontinuous cross stratification. The grain size distribution of the quartz is generally bimodal, varying from cobbles to pea-sized pebbles in the coarser fraction and gravel to fine flour in the finer fraction. However, locally the quartz grain size displays gradual transition from cobble to flour. The pebbles are sub-angular to sub-rounded and poorly sorted. They are generally coated with rusty sulphidic, hematitic and manganese staining. In part of the sequence, large-scale



**Fig. 2** Geological setting and location of the New Brunswick Cretaceous deposit. The inset shows the outline and precise location of the Vinegar Hill pit. Geological map based on an original by St. Peter (1995).

tabular cross beds are present, suggestive of a braided fluvial setting.

A 1–15 m thick overburden of glacial till and soil, derived largely from Mabou rocks, lies above the Cretaceous deposit and is thickest in the centre of the area. The glacial till consists of a mixture of mostly grey, red and brown volcanic and sedimentary rocks, red silty gravel and minor red to brown clay. The pebbles in the coarser fraction are sub-angular to sub-rounded.

#### METHODS AND SAMPLES

The first sample (Geological Survey of Canada palynological processing number P37213) analyzed palynologically was

collected by one of us (DVV) in 1999. It was obtained from the northeastern part of the pit (see Fig. 2). It is light- to medium-grey, locally-black clay containing plant material. The plant material is medium to dark gray to grayish brown, and may represent the remnants of a tree trunk or branch 10–15 cm in diameter. The material displays partial charcoal appearance and has preserved woody texture. It yielded associated palynomorphs – presumably from sediment surrounding or infilling pores in the wood – as discussed below.

Two of us (RAF and DVV) collected a further 7 samples from the pit in September 2001. All samples were from thin clay or silt lenses within the sands, except for one sample from a block of lignite that was clearly part of a tree trunk, 30–40 cm in length. Its prostrate position in the sand suggests fluvial transport. All 7 samples were processed for palynology, but

only the lignite sample (P37974) yielded palynomorphs. A portion of the lignite was forwarded to the other author (HFL) for analysis.

The palynology samples were processed using standard techniques based on those outlined in Barss and Williams (1973). The palynomorphs were stained using Bismarck Brown dye. Analysis was undertaken using Zeiss Axioplan 2 microscope, Natural Resources Canada number A042033, at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia. The fossil wood (lignite) was examined using a Hitachi S-3200 Scanning Electron Microscope (SEM) at the National Research Council, Halifax, Nova Scotia.

### PALYNOLOGY

The original sample (P37213) examined for palynology yielded very few palynomorphs, the only convincingly in-place spore being a specimen of *Concavisorites toralis* (Fig. 3d). (Full taxonomic names, with authorships, are provided in Appendix 1.) This is a smooth trilete fern spore, the laesurae enclosed within a continuous fold, or kyrtome. Although common in Cretaceous strata, the species is not restricted to that period, so it could not be considered age-diagnostic.

The lignite sample collected on the 2001 visit to the pit (P37974) yielded definitive, though sparse evidence for a Cretaceous age. This sample contained a single specimen of the schizaelean fern spore *Cicatricosisporites* sp. (Fig. 3 a–b) and several specimens of the bisaccate gymnosperm pollen *Rugubivesiculites reductus* (Fig. 3 f–g). The genus *Cicatricosisporites* ranges from the Late Jurassic to the present day, but the form found in the Vinegar Hill material, although not identifiable to species level, resembles typical Cretaceous forms. The genus *Rugubivesiculites* is restricted to the Cretaceous and its base (first appearance datum) is used as a Late Albian marker in offshore eastern Canada (unpublished observations by G.L. Williams and R.A. Fensome). However, it has been found in earlier Cretaceous strata elsewhere (R.A. MacRae, personal communication, 2002). The slide also contained non-diagnostic bisaccate pollen other than *Rugubivesiculites reductus*.

A second slide was subsequently made from the first sample (P37213) and a single specimen of the hepatacacean spore, *Zlivisporis* sp. (Fig. 3c) was recovered. Species of the genus *Zlivisporis* (in many previous studies assigned to the genera *Rouseisporites* or *Triporoletes* - see Braman 2001 for a discussion) are characteristically (although not diagnostically) Cretaceous in age. The specimen appears to be of a previously undescribed species, possessing a distal reticulum with very heavy, beaded, double muri.

In the Nova Scotia onshore Cretaceous deposits, cysts of freshwater algae are common (see for example Eisnor, 2002). No distinctive algal cysts were encountered in the two palyniferous New Brunswick samples, although some nondescript bodies may represent algae or fungi (Fig. 3e). Neither

marine palynomorphs nor angiosperm pollen grains were recognized.

### FOSSIL WOOD

In hand specimen, the wood sample from which palynological sample P37974 is derived consists of a brown-coloured, lignitic wood fragment 11.7 cm in length. In cross-section the pronounced curvature of the specimen indicates that it was derived from close to the centre of an axis at least 6.8 cm in diameter. Examined with the SEM, anatomical features are clearly visible. In radial longitudinal section (RLS), 25–30  $\mu\text{m}$  diameter tracheids exhibit uniseriate or biseriata, contiguous bordered pitting (borders: 15  $\mu\text{m}$  diameter, apertures: 7  $\mu\text{m}$  diameter; Fig. 4a). Uniseriate pits are oval, being squashed together, whereas biseriata pits are alternately arranged and circular (Fig. 4b). Cross-field regions possess 2–4 araucarioid pits per field (Fig. 4c–d). Axial parenchyma occurs sparsely. Spool-shaped resin plugs and pronounced checking are also very common locally (Fig. 4e). In tangential longitudinal section (TLS), rays are uniseriate and short (1–10 cells high), being composed of parenchyma, 16  $\mu\text{m}$  wide, 22  $\mu\text{m}$  high, and 90  $\mu\text{m}$  long. In transverse section (TS), rays are up to 1.5 mm long, and spaced 2–8 tracheids apart. True growth rings are entirely absent (Fig. 4f) but, rarely, weakly developed, diffuse “growth zones” may occur, spaced 2–3 mm apart ( $n=23$ ).

Wood with these features is classified as *Araucarioxylon*, a very common Triassic–Recent form genus, which bears a close similarity to the woods of the extant conifer family Araucariaceae (Greguss 1972). Although more material must be collected before a confident species attribution can be made, the Vinegar Hill specimen is closely similar to *Araucarioxylon pseudoparenchymatosum*, a widespread species with an Early Cretaceous to Paleocene range (Falcon-Lang and Cantrill 2001). The absence of spiral thickening and the uniformity of “growth zone” width around the stem circumference suggest that the specimen derived from a vertically-orientated trunk. Applying the biomechanical relationship, determined by Niklas (1994), between trunk diameter and height, the slender araucarian trunk would have supported a tree at least 8 m high.

Araucarian conifers were globally widespread during the Mesozoic, reaching their peak in the Northern Hemisphere in Cretaceous times (Enright and Hill 1995). They became extinct in North America and Europe by the Eocene and today are restricted to a few isolated Southern Hemisphere sites (Enright and Hill 1995). The occurrence of araucarian wood therefore constrains the age of the Vinegar Hill deposit to the Mesozoic–early Tertiary interval. Should the specific identity of the wood be confirmed, the deposit’s range would be further constrained to the Cretaceous–Paleocene. Wood data are thus consistent with the Cretaceous age determination based on palynological evidence, and places a minimum Eocene age constraint on the deposit.

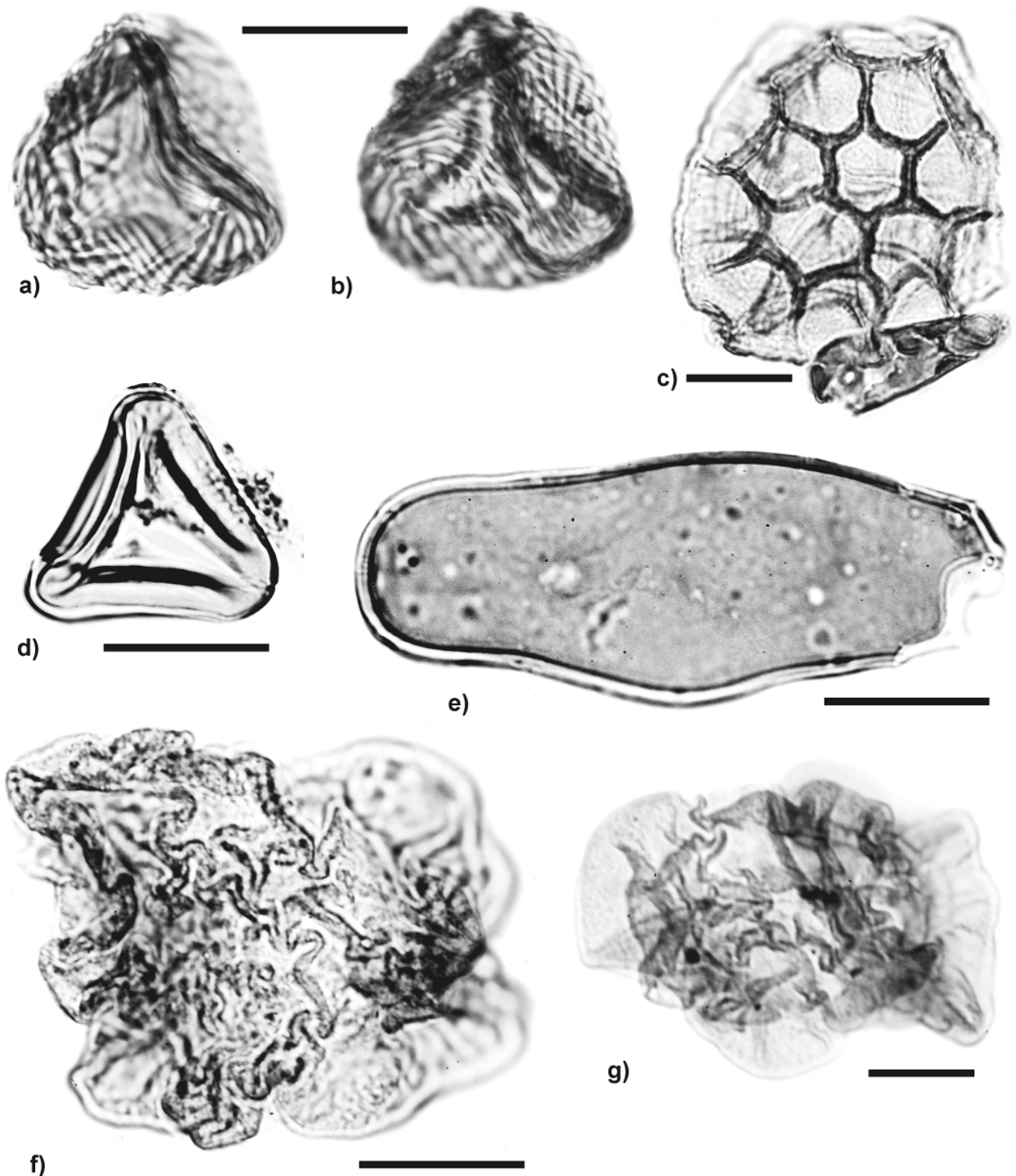
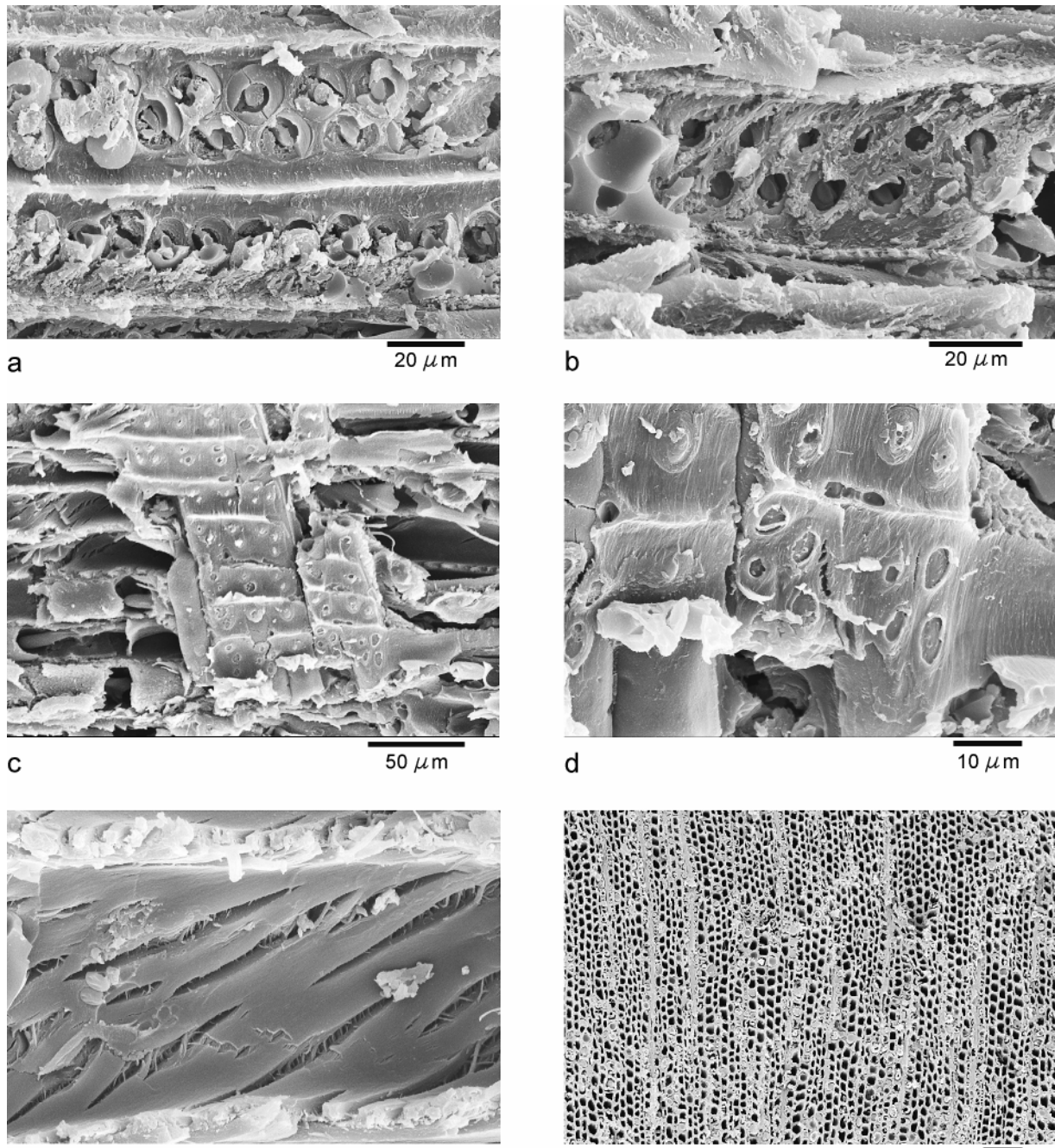


Fig. 3 Palynomorphs. a–b) *Cicatricosisporites* sp. Slide P37974-01, co-ordinates 16.8x100.3 (England Finder Q43/4). a) Proximal surface of specimen in proximal view. b) Distal surface of specimen in proximal view. c) *Zlivisporis* sp. Slide P37213-02, co-ordinates 19.8x99.9 (England Finder T43/3). d) *Concavisporites toralis*. Slide P37213-01, co-ordinates 15.8x96.9 (England Finder P40/0). e) Algal or fungal body. Slide P37974-01, co-ordinates 15.0x96.2 (England Finder O39/0). f–g). *Rugubivesiculites reductus*. f) Slide P37974-01, co-ordinates 19.7x106.2 (England Finder T49/4). g) Slide P37974-01, co-ordinates 13.2x91.6 (England Finder M34/4). All scale bars 20  $\mu$ m.



**Fig. 4** *Araucarioxylon cf. pseudoparenchymatosum*, all SEM micrographs. a) Biseriate, alternate, bordered tracheid pits, RLS. b) Bordered tracheid pits showing cellular degradation, RLS. c) 1–4 araucarioid cross-field pitting, RLS. d) Close-up of araucarioid cross-field pits, RLS. e) Checking on longitudinal tracheids walls, TLS. f) Absence of distinct growth rings, TS.

#### PALEOCLIMATE

The absence of true growth rings in the araucarian wood implies growth under a humid subtropical climate characterized by high year-round temperatures (Creber 1977). However, weakly developed growth zones and checking features suggest a slight seasonality in rainfall (Schweingruber 1992; Jones 1993), an interpretation supported by charcoal in the Cretaceous lignites of Nova Scotia, if coeval (Stea and Pullan 2001). Similar palaeoclimatic conditions are suggested by the predominance

of silica sand and kaolin clay in the Vinegar Hill deposit. Both lithologies represent the products of paleoweathering under warm, humid climates and, in the modern world, significant kaolin accumulations are restricted to tropical and subtropical regions (Leeder 1999).

Collectively, these data support a Cretaceous age for the Vinegar Hill deposit because the results of global paleoclimate reconstructions (which integrate paleobotanical and sedimentological information with computer modeling) suggest that eastern Canada was subject to a humid subtropical

climate during Cretaceous time (Valdes *et al.* 1996; Paleomap 2000). During the Jurassic time the regional paleoclimate was arid subtropical while during Tertiary times it was temperate (Paleomap 2000).

## DISCUSSION AND CONCLUSIONS

The Vinegar Hill quartz (silica) sand deposit overlies Carboniferous rocks and underlies glacial till deposits. Its similarity in lithology and setting to confirmed Cretaceous deposits in Nova Scotia has previously led to speculation of its Cretaceous age, but direct evidence has been previously unavailable. A microscopic analysis of the wood sample found at Vinegar Hill suggests a Mesozoic-Early Tertiary age, and the palynomorphs, although sparse, specifically confirm a Cretaceous date. The presence of *Rugubivesiculites*, the absence of angiosperm pollen and comparison with the Nova Scotia deposits suggest a late Early Cretaceous, probably Albian, age. Although the sedimentology of the Vinegar Hill deposit is beyond the scope of this study, general facies characteristics suggest a fluvial environment, and this interpretation is supported by the occurrence of only terrestrial fossils in the deposit.

In terms of stratigraphic nomenclature, given its similarity to the deposits of essentially identical age in Nova Scotia, the Vinegar Hill deposit should probably be referred to the Chaswood Formation (formally defined by Stea and Pullan 2001) rather than the "Vinegar Hill Formation" (New Brunswick Department of Natural Resources and Energy 2000).

The Vinegar Hill deposit is so far the only known example of its kind in New Brunswick, but given its economic significance and scientific interest, a search for similar basins in the province would be worthwhile. In their paper on the Nova Scotia Cretaceous basins, Stea and Pullan (2001) concluded that such deposits "... are undoubtedly more widespread throughout the drift-covered Carboniferous and Triassic basins of Nova Scotia." They noted that the best potential for such basins would be on the down-glacier side of horst blocks, where the deposits would have been relatively protected from glacial erosion. The setting of Vinegar Hill deposit (Fig. 1) fits this prediction, and there may be good potential for similar deposits in parallel settings elsewhere in New Brunswick.

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## APPENDIX 1 TAXONOMIC NAMES MENTIONED IN THE TEXT

- Araucarioxylon cf. pseudoparenchymatosum* (Gothan 1908)  
Krausel 1925
- Cicatricosisporites* Potonié and Gelletich 1933
- Concavisporites toralis* (Leschik 1955) Nilsson 1958
- Rouseisporites* Pocock 1962
- Rugubivesiculites* Pierce 1961
- Rugubivesiculites reductus* Pierce 1961
- Triporoletes* Mtchedlishvili in Mtchedlishvili and Samoilovitch 1960
- Zlivisporis* Pačtová 1961