"Interglacial Beds at Toronto, Ontario"

Paul F. Karrow

Géographie physique et Quaternaire, vol. 44, n° 3, 1990, p. 289-297.

Géographie physique et Quaternaire, 1990, vol. 44, n° 3, p. 289-297, 5 fig., 2 tabl.

INTERGLACIAL BEDS AT TORONTO, ONTARIO

Paul F. KARROW, Department of Earth Sciences and Quaternary Sciences Institute, University of Waterloo, Waterloo, Ontario N2L 3G1.

ABSTRACT Interglacial sediments have been known to occur at Toronto for about a century. There have been two main periods of attention: first by A. P. Coleman in the early twentieth century; and second mostly by the author and co-workers in the past quarter century. Attention was focussed early on the Don Formation because of its rich fossil assemblages. The Don Formation, consisting of gravel, sand, and clay, is commonly 6 to 9 m thick and has been encountered in outcrop only along the DonValley. However, excavations and borings indicate its presence under much of southern Metropolitan Toronto; it may continue northward along the Laurentian River Valley. Its only continuing, accessible exposure has been the Don Valley Brickyard. Early paleontological study emphasized molluscs, wood, leaves, and a few bones, which suggested a climate warmer than present. More recent studies have stressed microfossils, including pollen, diatoms, ostracodes, molluscs, Cladocera, insects, plant macrofossils, and microvertebrates. Altogether about 500 species have been identified, and the list is growing. Climatic indicators show that the Don Formation represents the declining temperatures of the waning half of an interglaciation. Although the Don Formation is beyond the range of radiocarbon dates and is undated, amino acid analysis on wood and shells support assignment to Sangamonian time. The overlying Scarborough Formation clay and sand, and the Pottery Road Formation sand contain mainly cold-climate fossils. These are in turn overlain by Early, Middle, and Late Wisconsinan tills and interbedded lacustrine sediments with corresponding radiocarbon and thermoluminescence (TL) dates.

RÉSUMÉ *Les lits interglaciaires de Toronto, Ontario.* Les sédiments interglaciaires de Toronto, connus depuis environ un siècle, ont fait l'objet de recherches au cours de deux périodes principales; au début du siècle, d'abord, par A. P. Coleman, puis par l'auteur et ses collègues depuis les 25 dernières années. La Formation de Don a d'abord attiré l'attention en raison de ses riches assemblages de fossiles. Cette formation, constituée de gravier, de sable et d'argile, a habituellement de 6 à 9 m d'épaisseur. On ne l'observe que sous forme d'affleurements ici et là dans la vallée de Don. Toutefois, les excavations et les sondages montrent qu'elle est présente à peu près partout dans le sud de la région métropolitaine; elle pourrait se poursuivre le long de la vallée de la Laurentian River. Le seul endroit où l'on puisse l'observer de façon continue est à la Don Valley Brickyard. Les premières études paléontologiques sur les mollusques, le bois, les feuilles et quelques os indiquaient un climat plus chaud que maintenant. Des études plus récentes ont surtout porté sur les microfossiles, dont le pollen, les diatomées, les ostracodes, les mollusques, les Cladocera, les insectes, les macrofossiles de végétaux et les microvertébrés. Jusqu'à maintenant on a identifié 500 espèces. Les indicateurs climatiques montrent que la Formation de Don reflète les températures en baisse de la moitié déclinante d'un interglaciaire. Bien que cette formation ne puisse être datée au radiocarbone, les analyses des acides aminés sur bois et coquillages semblent confirmer son âge sangamonien. L'argile et le sable de la Formation de Scarborough susjacente et le sable de la Formation de Pottery Road renferment surtout des fossiles de climat froid. Ils sont à leur tour recouverts par des tills et des sédiments lacustres interlités datés du Wisconsinien, inférieur, moyen et supérieur.

ZUSAMMENFASSUNG *Interglazial-Betten von Toronto, Ontario.* Das Vorkommen interglazialer Sedimente in Toronto ist seit etwa einem Jahrhundert bekannt. Diese sind während zwei Hauptperioden erforscht worden: zuerst von A.P. Coleman zu Beginn des 20. Jahrhunderts und dann vor allem durch den Autor und seine Mitarbeiter im vergangenen Vierteljahrhundert. Zuerst richtete sich die Aufmerksamkeit auf die Don-Formation wegen ihrer reichhaltigen Fossil-Ansammlungen. Die Don-Formation, die aus Kies, Sand und Ton besteht, ist im allgemeinen 6 bis 9 m dick, und man hat sie nur in Aufschlüssen entlang dem Don-Tal vorgefunden. Indessen zeigen Ausschachtungen und Bohrungen, dass sie fast unter dem ganzen Süden der Stadt-region vorhanden ist, möglicherweise geht sie nordwärts weiter entlang dem Tal des Laurentian River. Ihr einziger zusammenhängender zugänglicher Aufschluss ist der Don Valley Brickyard gewesen. Die erste paläontologische Untersuchung betonte Weichtiere, Holz, Blätter und einige Knochen, welche auf ein wärmeres Klima als gegenwärtig deuten. Neuere Untersuchungen haben Mikrofossile einschliesslich Pollen, Kieselalgen, Ostracodes, Weichtiere, Cladocera, Insekten, Pflanzen-Makrofossile und Mikrowirbeltiere hervorgehoben. Insgesamt hat man ungefähr 500 Spezies identifiziert, und die Liste wächst ständig an. Klimatische Indikatoren zeigen, dass die Don-Formation die sinkenden Temperaturen der dem Ende zugehenden Hälfte eines Interglazial spiegelt. Obwohl die Don-Formation über die radiokarbon-Klassifizierung hinausgeht und nicht datiert ist, stützt die Analyse von Amino-Säure auf Holz und Muscheln die Einordnung ins Sangamonium. Der darüberliegende Lehm und Sand der Scarborough-Formation und der Sand der Pottery Road-Formation enthalten hauptsächlich Fossile kalten Klimas. Diese wiederum werden überlagert von frühen, mittleren und späten Wisconsinium Grundmoränen und zwischengebetteten See-Sedimenten mit entsprechenden Radiokarbon — und Thermolumineszenz (TL) - Daten.

Manuscrit reçu le 11 juillet 1988; manuscrit révisé accepté le 30 mars 1989

INTRODUCTION

Fossiliferous sediments between tills have been known to occur at Toronto, Ontario, for more than a century. Although early references to buried logs and shells are known from the mid-nineteenth century, it was not until late in the century that their paleoclimatic significance was realized. Their stratigraphic position became established at the turn of the century and they became known internationally, partly through being visited by International Geological Congress participants in 1913, guided by A. P. Coleman.

Natural exposures along the banks of the Don River were supplemented by exposures in brickyard and building excavations. Of these the Don Valley Brickyard (Fig. 1) has been until very recently the only continuing exposure of the Don Formation generally accessible for study; it has been visited on many occasions by field trip groups from various local, national, and international society meetings, university student classes, and numerous individual researchers.

Early recognition and widespread fame have made the Toronto beds a classic interglacial deposit. Nevertheless, considering that most of the study has necessarily focussed on the Brickyard, it is fair to say we still know relatively little about their distribution and more detailed stratigraphy.

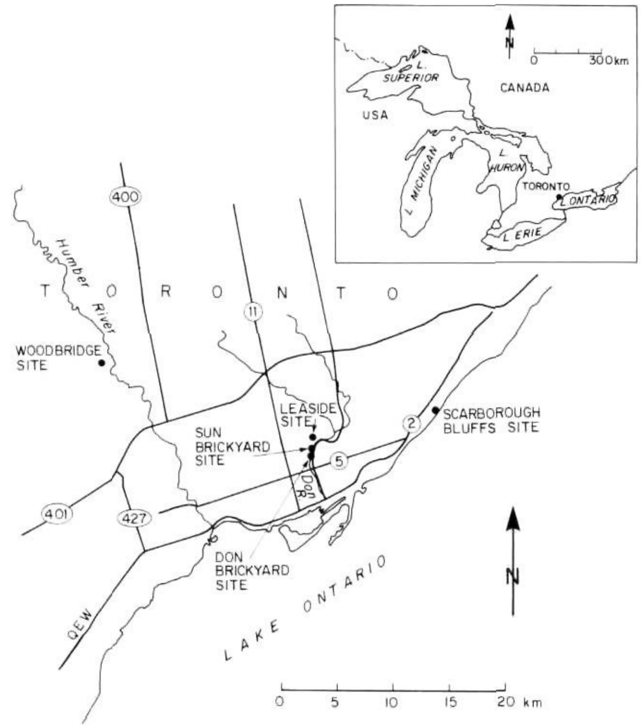

FIGURE 1. Location map showing sites mentioned in the text.
Carte de localisation

HISTORY OF INVESTIGATION

Inasmuch as earlier work on the Toronto interglacial was reviewed and extensively referenced in Karrow (1967, 1969), this paper deals only briefly with early work while emphasizing the results of the most recent studies. Emphasis is placed on the Don Formation as discussed below under "Stratigraphy".

It was the occurrence of obvious fossil remains, principally mollusc shells, wood, and leaves, that aroused curiousity and engaged the attention of early researchers. The rich fossil assemblages were seen to be in sharp contrast to the barren glacial deposits above and below, and led to their interpretation as being of interglacial origin.

The leading name in early study of the Toronto beds was A.P. Coleman, whose published descriptions extend from 1894 to 1941, with the major compilation being his report for the Ontario Department of Mines of 1933. Early in the period of his study it became established that the Scarborough beds overlay the Don beds through the simple approach of hiring a well digger to dig down into the beach at Scarborough Bluffs. Until the present thick layer of fill was placed there in the early 1970's, anyone could duplicate the observation with a hand auger, and under about 5 m of Scarborough clay penetrate sandy layers of the Don Formation, often accompanied by the release of natural gas.

Coleman engaged the help of specialists to identify various fossil remains, which included a few single vertebrate bones (including extinct *Castoroides ohioensis* — giant beaver), and lengthy lists of mollusc and plant species, many indicating a climate warmer than the present. Identification of extinct tree species by Penhallow (Dawson and Penhallow, 1890; Penhallow, 1907) was later disputed (Brown, 1942; Warner, 1984).

After Coleman's death in 1939, there was little new work on the interglacial fossils until Terasmae undertook the first palynological study in the 1950's (Terasmae, 1960). This work, marking the start of a new era of attention to microfossils, applied new names to stratigraphic units, provided photographs of some of the details of the beds, documented vertical variations in pollen assemblages, added many species not previously known to occur, and presented a list of 20 species of diatoms. Terasmae's work showed that the Don beds represented only the later half of an interglacial cycle. Meanwhile, new mapping projects and subway construction contributed to fuller knowledge of the stratigraphy and extent of the interglacial beds (Watt, 1954, 1957, 1968; Karrow, 1967, 1970; Lajtai, 1969).

The author's involvement with the interglacial beds began in 1957 with a first visit to the Don Brickyard with A.K. Watt (Fig. 2). Exposures then were probably similar to those last seen by A.P. Coleman about 20 years before. Given the already extensive lists of known species of fossil plants and animals, it seemed logical to assume that many more species, particularly of groups not yet specifically studied, remained to be identified. Added to this was the growing apprehension during the late 1970's and early 1980's, that access to the exposures at the Don Brickyard might not continue indefinitely, so efforts were intensified to document as completely as possible the total fauna and flora of the Toronto interglacial beds. The status of the Toronto beds as a classic interglacial sequence made future comparisons with other interglacial sites dependant on more complete knowledge.

Thus over the past 25 years, results of several studies by specialists of particular fossil groups have appeared. These will be considered in more detail below, as will the present status of our knowledge of the stratigraphic position, sedimentology, extent, and age of the deposits.

STRATIGRAPHY

Natural exposures of bedrock are few in the Toronto region; they occur mainly west of the city. Bedrock was exposed in the Don Valley Brickyard, and there consisted of striated Ordovician shale of the Georgian Bay Formation. This is overlain by up to a metre of a shale-rich, clayey-sand diamicton known as the York Till (Terasmae, 1960). Excavations elsewhere have revealed associated glaciolacustrine clay and a possible double till layer. These deposits are inferred to be of Illinoian age.

FIGURE 2. Photo of the Don Brickyard (1957). The prominently banded layer is the Don Formation.

La Don Valley Brickyard (1957). La couche en grande partie rubanée représente la Formation de Don.

The overlying non-glacial beds include three named stratigraphic units which are believed, by some scientists, to comprise the interglacial succession at Toronto (Fig. 3). These are from oldest to youngest, the Don Formation, Scarborough Formation, and Pottery Road Formation (Karrow, 1967, 1974). However the author considers that only the Don Formation is truly interglacial — *i. e.* having a climate as warm or warmer than the present. Terasmae (1960) has reported that during the time of deposition of the Don Valley Brickyard beds the climate deteriorated markedly, and that the early part of the interglaciation, which should record rising temperatures, is not represented.

The Scarborough Formation is considered to represent a delta built into a high level lake. Such a lake necessitates glacier ice blocking the St. Lawrence Valley, a fact supported by sedimentological evidence in the Toronto area (Kelly and Martini, 1986). Furthermore the cool-to-cold fossil assemblage (abundant plants) is not indicative of interglacial conditions. Consequently, it is not considered by the author to be part of the interglaciation but rather to be of Early Wisconsinan age. The period of sedimentation may correspond to deep-sea isotope stages 5b or 5d.

The overlying Pottery Road Formation comprises lenticular channel-fill deposits, principally of sand, inset into both the

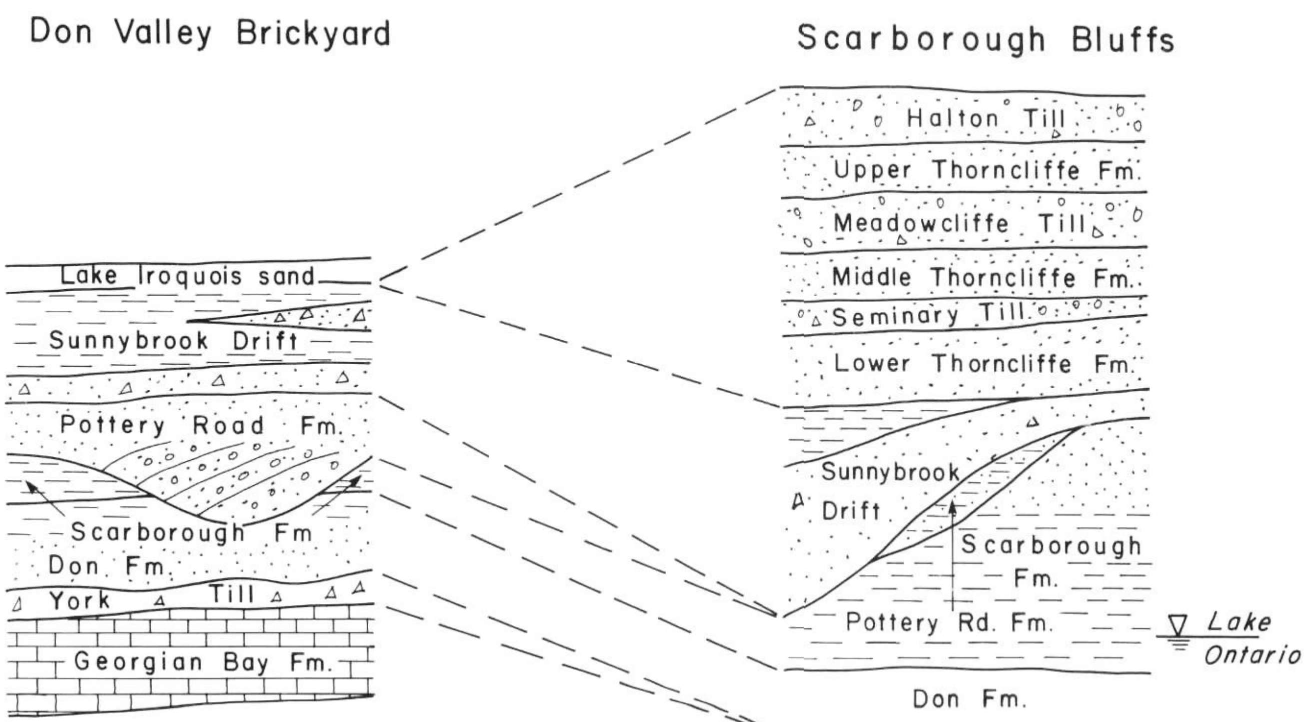

FIGURE 3. Sketches of stratigraphic sequences at the Don Brickyard and Scarborough Bluffs.

Les séquences stratigraphiques à la Don Brickyard et à Scarborough Bluffs.

Scarborough and Don formations. This situation necessitates a lowered Ontario basin lake level and thus an open St. Lawrence Valley. The beds have yielded an intriguing but non-diagnostic mammal-bone assemblage and a limited mollusc assemblage, part of which may be reworked from the older deposits. The climatic affinities and age remain uncertain; the age may correspond to isotope stage 5a or 5c. Correlation with the St. Pierre Interstade of Québec has been suggested (age about 80,000 years).

Above the Pottery Road Formation is a diamicton and rhythmite unit, the Sunnybrook Drift, which is widely recognized in the Toronto area. This was attributed to Early Wisconsinan glaciation by Karrow (1967), an interpretation further supported by Sharpe and Barnett (1985), Gravenor and Wong (1987), and Hicock and Dreimanis (1989) but disputed by Eyles and Eyles (1983) who propose entirely lacustrine and floating ice processes for its deposition. Overlying Thorncliffe Formation sands and clays (Middle Wisconsinan) are of mainly lacustrine and deltaic origin, including two tongues of diamicton (Seminary and Meadowcliffe) considered to be till by Karrow (1967) but lacustrine by Eyles and Eyles (1983). The top of the sequence is formed by the Late Wisconsinan Halton Till, which forms the drumlinized and fluted till plain of the Toronto district. All these major units above the Pottery Road Formation have been well exposed in lakeshore cliffs at Scarborough Bluffs, but shore erosion protective works under construction over the last two decades have greatly diminished the amount of exposure there as slopes have become extensively covered with slump and vegetation.

As a result of these considerations, further discussion in this paper of the Toronto interglacial will deal specifically with the Don Formation and beds believed to be equivalent.

EXTENT OF THE DON FORMATION

The Don Formation is best known and named from its occurrence along the banks of the Don Valley, in what is now central Toronto. Natural exposures have become heavily slumped and vegetated. It has been encountered in excavations (including subways) in downtown Toronto, but these temporary exposures have seldom been described or sampled and generally only indicate the presence of the beds. Long term excavations such as the brickyards along the Don Valley have provided the bulk of the available information, but how representative these relatively small exposures are of the whole formation is unknown.

Subsurface information (engineering borings, gas wells, water wells) indicate similar beds occur deeply buried north of Toronto along the Laurentian River valley (Coleman, 1933; Karrow, 1970; Sado *et al.*, 1983) but little is known about these occurrences other than that shells and plants occur in stratified sands.

One other occurrence of probably the same age is at the Woodbridge cut, near the northwest corner of Metropolitan Toronto (Fig. 1). There, a few centimetres of clay and sand containing a variety of mollusc shells overlies York Till and underlies peaty sands of cool-climate affinities (correlated with the Scarborough Formation) and several overlying correlatable Wisconsinan tills.

SEDIMENTOLOGY

Gray (1950) studied the Don sediments at the Don Brickyard and concluded that they represented deepening water upward in the sequence. It is evident that the beds are predominantly sand in the lower part, with a basal lag gravel resting on till and clearly representing an erosional unconformity, while the upper part is mainly clay and silt. Contained fossils reflect to varying degrees these lithologic changes, with molluscs concentrated in the lower sand and plant debris in the upper clay.

Further study of the sedimentology at the Brickyard has been carried out by Eyles and Clark (1988); planned studies by the Ontario Geological Survey have been forestalled by a ban on climbing or sampling the Brickyard face following expropriation of the site by the Ontario Government in 1987. Eyles describes sedimentary features and structures he attributes to deposition in a nearshore lacustrine environment subject to episodic storms. Water depths increased from 2 m to about 18 m during its deposition. Karrow (1989) has discussed and supplemented the observations of Eyles and Clark (1988).

AGE AND CORRELATION

The age of the Don Formation is unknown. It is beyond the range of radiocarbon dating; minimum ages have been obtained from the basal Thorncliffe Formation and the Scarborough Formation as well as the Don Formation (Table I). A single date on overlying Sunnybrook Drift has been obtained by the thermoluminescence method (Berger, 1984). All these results are consistent with recent interpretations which assign the Don Formation to the Sangamonian or last interglaciation. It would then correlate with deep-sea isotope stage 5e, with an age of about 125,000 years.

Amino acid analyses of shells showed close similarity between the Don Formation and interglacial beds near Ithaca, New York (E. P. Hare, personal communication about 1973) and were consistent with a last interglacial age. Amino acid analyses on wood have led to a similar conclusion (N. W. Rutter, personal communication, 1980).

Uranium-series dating has been attempted on wood from the Don Formation but proved unsuitable because of detrital

TABLE I

Radiocarbon and thermoluminescence dates relevant to the Don Formation.

Stratigraphic unit	*Material*	*Date*
Basal Thorncliffe Fm.	*plant detritus*	*> 53,000 (GSC-1228; ^{14}C)*
Sunnybrook Drift	*diamicton*	*66,500 ± 6800 (WC-ST;TL)*
Scarborough Fm.	*plant detritus*	*> 54,000 (GrN-4817; ^{14}C)*
Don Fm.	*wood*	*> 46,000 (L- 409; ^{14}C)*

GSC: Geological Survey of Canada   TL: Simon Fraser Univ.
GrN: Groningen, Netherlands
L: Lamont, New York

thorium (letter C. Hillaire-Marcel, Dec. 6, 1984). Uranium-series dating of peat from the Don Formation has been unsuccessful for similar reasons (letter, M. Gascoyne, Sept. 9, 1982). Earlier enquiries about uranium dating of Don Formation shells indicated they too were unsuitable because of extensive alteration (letter, D. Thurber, Aug. 24, 1966).

As a result of the above, the Don Formation remains undated. Other methods with dating ranges greater than radiocarbon, and which are applicable to Don samples, will have to be pursued in the future.

PALEONTOLOGY

It was the obvious fossils in the Don Formation that attracted attention to its study and climatic significance. Shells and plant remains (wood, leaves) were known from earliest times and were the basis for the suggestion that the Don sediments were of interglacial origin. In contrast, the work of the past few decades has emphasized microfossils. About 500 species of fossil plants and animals are now known, and considerable potential remains for discovery of many more species (Table II).

Early study of fossils was apparently based on random collecting, yielding only presence-absence data. Stratigraphic sampling began with the pollen study by Terasmae (1960) and has been a feature of all subsequent research. Most recent work, however, has involved sampling by or for specialist study. The study by Kerr-Lawson (1985), on the other hand, aimed at recovery of *all* recognizable fossil material from a complete column of sediment 0.3 m × 0.3 m in area through the entire Don Formation. This bulk sampling yielded many additional species of molluscs, plant macrofossils, and microvertebrates (particularly fish), and amply demonstrated the value of this approach.

PLANT MACROFOSSILS

This category includes leaves and wood, which were among the obvious remains known to early workers, as well as seeds and other plant parts emphasized in the recent work of Kerr-Lawson (1985) (Table II).

The early work reported by Coleman (1933) included several species of plants native only farther south today, such as Osage orange (*Maclura pomifera*), black locust (*Robinia pseudoacacia*), southern white cedar (*Chamaecyparis thyoides*), chestnut oak (*Quercus muhlenbergii*), iron oak (*Quercus stellata*), and blue ash (*Fraxinus quadrangulata*). Of three supposedly extinct species, two maples (*Acer* spp.) were later reidentified as sycamore (*Platanus occidentalis*) while the third remains uncertain (Warner, 1984). It is commonly not stated what type of plant material was the basis for individual identifications except for the extinct maples for which leaves were illustrated by Coleman (1933).

In the 1960's, workmen at the Brickyard reported finding large logs, but only modest-sized pieces of wood up to 15 cm diameter have been recovered for identification. Several of these were listed by Karrow (1969); they were dominated by decay-resistant species of hardwood.

Kerr-Lawson (1985) lists some 55 plant taxa newly identified from plant macrofossils, principally seeds, in the Don Formation. Among these the most common are submergent aquatic plants such as *Potamogeton*, *Najas*, and *Zannichellia palustris*.

POLLEN

Terasmae (1960) produced the first pollen diagram through the Don Formation., which revealed evidence of declining temperature upward in the sequence (Fig. 4). Hardwood tree pollen dominates in the lower part (about 50% oak (*Quercus*), 15% elm (*Ulmus*), 20% hickory (*Carya*), 10% basswood (*Tilia*), with up to 10% sweetgum (*Liquidambar*), a taxon not native to the area at present). Conifer pollen increases in the upper part (spruce (*Picea*) 30%, pine (*Pinus*) 60%). Pollen from about 30 taxa additional to those previously known were also identified (Table II). Terasmae (1960) estimated that the temperature peak was "at least 5°F warmer than the present mean annual temperature for the Toronto area".

DIATOMS

Terasmae (1960) also listed 20 diatom taxa from the middle of the unit. More detailed work by Duthie and Mannada Rani (1967) extended the list to 200 taxa (Table II). Varied river mouth assemblages typical of temperate regions were identified, although interpretations were handicapped by limited knowledge of living assemblages.

MOLLUSCS

The other principle fossil group emphasized in early work was the molluscs. Molluscs occur almost entirely in the lower sandy part of the formation. The most obvious molluscs are the large unionid clams, which also were interpreted as indicating warm climates. They occur sporadically and are best

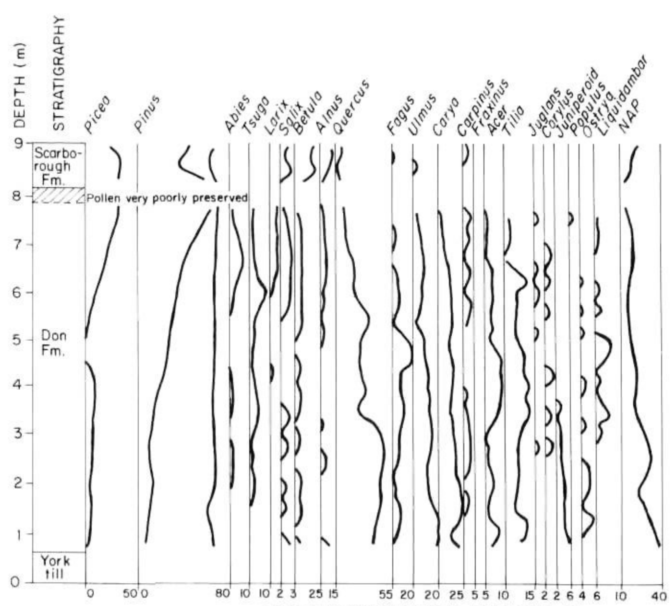

FIGURE 4. Simplified pollen diagram for the Don Brickyard (after Terasmae, 1960).

Diagramme pollinique simplifiée de la Don Brickyard (d'après Terasmae, 1960.

TABLE II

Faunal and floral list for the Don Formation

DIATOMS

Achnanthes clevei
A. clevei rostrata
A. exigua
A. lanceolata elliptica
A. lanceolata cf. *elliptica*
A. lanceolata genuina
A. lorenziana
A. microcephala
A. minutissima pyrenaica
A. ostrupii
A. ostrupii minor
A. peragalli
Amphora
A. exigua
A. gigantea f. *minor*
A. ovalis
A. proteus
Caloneis trochus schilberszkyi
Campylodiscus
C. hibernicus
Cocconeis disculus
C. pediculus
C. placentula
C. placentula intermedia
Coscinodiscus
C. subtilis
Cyclotella
C. glomerata
C. kutzingiana
C. meneghiniana
Cymbella
C. alpine
C. amphicephala
C. aspera
C. caespitosa
C. cistua
C. cistula genuina
C. differta
C. gracilis
C. heteropleura
C. hungarica
C. hustedtii
C. parva
C. parvula
C. prostata
C. purpusilla
C. sinuta laticepts
C. sinuta typica
C. tumidula
C. ventricosa
C. ventricosa paucistriata
Cymatopleura elliptica
Diploneis
D. smithii elliptica
Diatom vulgare
Epithemia
E. hyndmani
E. alpestris
E. argus genuina
E. argus intermedia
E. geoppertiana
E. muelleri
E. turgida
E. turgida verlagus
E. zebra saxonica
Eunotia
E. elegans
E. maior
Fragilaria
F. brevistriata
F. brevistriata linearis
F. brevistriata undulata
F. capucina
F. constricta
F. construens
F. construens binodis
F. construens binodis f. *semigibba*
F. construens subsalina
F. construens genuina f. *typica*
F. construens venter
F. construens venter f. *pusilla*
F. crotonensis prolongata
F. hungarica istvanffyi
F. inflata
F. intermedia
F. lapponica
F. leptostauron
F. leptostauron dubia
F. leptostauron rhamboides
F. nitzschioides
F. pinnata
F. pinnata genuina
F. pinnata hybrida
F. pinnata intercedense
F. pinnata lancettula
F. pinnata turgidula
F. vaucheriae fallax
F. virescens
Frustulia vulgaris typica
Gomphonema
G. acuminatum laticepts
G. acuminatum montana
G. angustatum
G. angustatum productum
G. clevei javanicum
G. constrictum
G. intricatum
G. lanceolatum genuinum
G. montanum genuinum
G. olivaceum
G. parvulum
G. parvulum genuinum
G. parvulum subellipticum
G. pfannkucheae
Gyrosigma attenuatum
Hantzchia amphioxys
H. amphioxys densestriata
Hyalodiscus
Mastogloia
M. lacustris alpina
Meridion circulare
Melosira
M. agassizi
M. canadensis
M. distans nivalis
M. granulata
M. islandica
M. italica
M. undulata
Navicula aberrans
N. anceps
N. anglica subsalsa
N. arata rostrata f. *pusilla*
N. asellus
N. cf. *astutus*
N. atomus
N. biskanterae
N. cf. *biskanterae*
N. capitata
N. cocconiformis
N. cryptocephala exilis
N. dicephala
N. dicephala genuina f. *abiskoensis*
N. elginensis neglecta
N. gastrum
N. grimmei
N. cf. *hassiaca*
N. jaernfelti
N. krasskei
N. menisculus
N. obliqua
N. odiosa
N. pseudocutiformis major
N. cf. *pupula rectangularis*
N. pygmaea
N. radiosa tenella
N. rotula
N. salinarum
N. schonfeldii
N. scutelloides
N. scutiformis
N. tusculoides mayeri
Nitzschia amphibia acutiuscula
N. baltica
N. dissipata
N. dissipata aculea
N. dissipata media
N. frustulum perpusilla
N. fonticola
N. hantzshiana genuina
N. lanceolata minor
N. latestriata minor
N. polaris
N. recta typica
N. solgensis
N. spathulata
N. subtilis glacialis
N. subtilis paleacea
N. thermalis intermedia
N. thermalis minor
Opephora
O. martyi
O. pacifica
Pinnularia
P. viridis cf. *mayeri*
P. balfourina
P. streptoraphae genuina
Rhabdonema arcuatum
Stauroneis kriegeri kriegeri
Staphanodicus
S. astrea
S. astrea minutulus
Stictodiscus johnsonianus
Synedra amphicephala austriaca
S. capitata
S. tabulata obtusa
S. tabulata fasciculata
S. ulna
Surirella
S. ovata
Tabellaria fenestrata
T. flocculosa

VASCULAR PLANTS

Abies
Acer carolinianum
A. saccharum
A. saccharinum
A. spicatum
Adiantum
Alnus serrulata
Ambrosia
Artemisia
Asimina triloba
Betula
Botrychium
Carpinus
Caryophyllaceae
Carya ovata
Castanea
Chamaecyparis thyoides
Chenopodiaceae
Clethra alnifolia
Corylus
Equisetum
Eriocaulon cf. *septangulare*
Fagus
Festuca ovina
Fraxinus americana
F. nigra
F. quadrangulata
Gleditsia donensis
Hippuris vulgaris
Ilex
Juglans
Juniperus virginiana
Larix
Liquidambar
Lycopodium
Maclura pomifera
Osmunda
Ostrya virginiana
Picea glauca
P. mariana
Pinus cf. *banksiana*
P. strobus
Planatus occidentalis
Populus balsamifera
P. grandidentata
Potamogeton
Prunus
Quercus alba
Q. macrocarpa
Q. muhlenbergii
Q. rubra
Q. stellata
Q. velutina
Robinia pseudacacia
Rumex
Salix
Scirpus
Selaginella
Sicyos angulatus
Sparganium
Taxus canadensis
Thuja occidentalis
Tilia

Tsuga canadensis
Typha latifolia
Ulmus
Vaccinium uliginosum
Vitis

MOSSES

Drepanocladus capillifolius
Hypnum
Sphagnum

ALGAE

Chara

CLADOCERA

Acroperus harpae
Alona affinis
A. quadrangularis
A. circumfimbriata
A. setulosa
A. barbulata
A. costata
A. rustica americana
A. guttata
A. lapidicola
Alonella excisa
A. exigua
A. nana
A. pulchella
Anchistropus minor
Bosmina (Eubosmina) longispina
B. longirostris
Camptocercus
Chydorus brevilabris
C. piger
C. gibbus
C. faviformis
Daphnia
Disparanola rostrata
Eurycercus (Bullatifrons)
Graptoleberis testudinaria
Kurzia latissima
Leydigia leydigi
Monospilus dispar
Pleuroxus denticulatus
P. trigonellus
P. procurvus
Pseudochydorus globulus
Sida crystallina

COLEOPTERA

Acidota crenata
Anotylus gibbulus
Carphoborus andersoni
C. carri
Chlaenius pensylvanicus
Diatytes criddlei
D. striatulus
Elaphrus clairvillei
E. olivaceus
Hydrobius fuscipes
Leperisinus aculeatus
Nebria lacustris
Oxytelus montanus
Phoeosinus pini
Phloeotribus piceae

TRICHOPTERA

Agrypnia
Brachycentrus cf. *lateralis*
Ceraclea mentiea
Cheumatopsyche
Chimarra obscura
Hydropsyche bifida
H. guttara
H. orris
H. scalaris
H. slossonae
Lapidostoma
Macronema? zebrata
Micrasema
Nectopsyche? diarina
?Polycentropus
Phyacophila? carolina
R.? fuscula
R. melita
Wormaldia

OSTRACODES

Candona caudata
C. rawsoni
Cypria ophthalmica
Cytherissa lacustris
Darwinula stevensoni
Ilyocypris gibba
Limnocythere friabilis
L. paraornata
L. cf. *varia*
L. verrucosa
Paracandona? euplectella
Potamocypris variegata

PELECYPODS

Crenodonta costata
Elliptio dilatatus
Fusconaia flava
Lampsilis ovata ventricosa
L. radiata siliquoidea
Ligumia recta
Obovaria olivaria
Pisidium adamsi
P. casertanum
P. compressum
P. fallax
Pleurobema clava
P. obliquum coccineum
P. obliquum rubrum
Ptychobranchus fasciolare
Quadrula pustulosa
S. rhomboideum
S. striatinum
S. sulcatum

GASTROPODS

Acella haldemani
Amnicola limosa
Goniobasis livescens
G. parvus
Lioplax subcarinata
Physa ancillaria
Pleurocera acuta
P. pallidum
Pomatiopsis cincinnatiensis
Probithinella lacustris
Somatogyrus subglobosus
S. palustris
Succinea cf. *avara*
Vallonia pulchella
Valvata lewisi
V. pulchella
V. sincera
V. tricarinata

VERTEBRATES

Bison
Castoroides ohioensis
Esox
Ictalurus punctatus
Marmota monax
Two species of deer
bear

recovered by general surface collecting; they do not figure prominently in the recently studied bulk samples of Kerr-Lawson (1985).

Coleman's mollusc collections of nearly 40 taxa were restudied by Baker (1931) who applied newer nomenclature and advocated more study. Terasmae *et al.* (1972) reported further nomenclatural revisions as well as a few additional species resulting from more recent surface collecting.

New studies of molluscs were undertaken by Hui in the late 1960's (Hui *et al.*, 1969) but were never completed. Further work on Hui's collections was undertaken by Kalas (1975), but this study was also never completed. Kalas, however, reported the identification of 55 molluscan taxa.

Bulk samples studied by Kerr-Lawson (1985) yielded 11 new records of aquatic gastropod species, 5 new records of terrestrial gastropod species, and 11 new records of sphaeriid clams. The most abundant gastropod species, *Valvata perdepressa*, had not been previously listed, probably as a result of being misidentified. Mollusc assemblages are like those found in the Great Lakes today. Additional subsequent work on pelecypods (particularly the Sphaeriidae) and on oxygen and carbon isotopes in the shells will be reported in a manuscript now in preparation.

OSTRACODES

Ostracodes occur throughout the Don Formation, although, in a similar pattern to that of the molluscs, most abundantly in the middle and lower part. Poplawski and Karrow (1981) reported a dozen species with *Candona rawsoni* and *Candona caudata* as most abundant. The ostracode assemblage was interpreted as indicating combined river and lacustrine environments with a climate similar to the present (Table II).

CLADOCERA

Cladocera were noted by D.G. Frey in samples of Don and Scarborough clay (Frey, 1961) and a systematic study was undertaken by Hann from boreholes at the Brickyard, Leaside, and Scarborough Bluffs (Hann and Karrow, 1984). Taxa recorded give evidence of fluvial environments at Leaside, becoming a shallow lake at Scarborough. The Cladocera from the Don Formation suggest climatic conditions like the present (Table II). One anomalous finding was that basal beds at the Brickyard record colder conditions, which may indicate local preservation of older Don beds not encountered in other studies.

INSECTS

The presence of fossil beetles in the Don Formation was noted as early as 1906 by Coleman. In modern times they were noticed by F. W. Shotton and G. R. Coope on an INQUA field trip to the Don Brickyard in 1965. Extensive faunal lists had long been available for the overlying Scarborough Formation (Coleman, 1933). Work by Anne and Alan V. Morgan commenced in 1970 and is continuing. Some results of the work have appeared (Hammond *et al.*, 1979; Morgan and Morgan 1980; Williams and Morgan, 1977) reporting 15 taxa of Coleoptera (beetles) and 22 taxa of Trichoptera (caddisflies). Large geographical shifts of insect populations are indicated, climate was like the present, and deposition took place near a river mouth in a lake. The Trichoptera were recovered from the clayey upper portion of the Don Formation.

Kerr-Lawson (1985) also recovered a few insect remains in her bulk samples, which added more than eight additional beetle taxa. Their sparseness underlines the difficulty there has been in recovering an adequately representative insect assemblage thus far (Table II). The sedimentary facies available for sampling have not proven particularly suitable for the trapping and preservation of such remains.

VERTEBRATES

Although vertebrates were recorded from the Don Formation early in this century (Coleman, 1907), occurrences have been rare and the faunal list has always remained short (Table II). By 1941, Coleman recorded only groundhog, two species of deer, bison, large bear, giant beaver (*Castoroides ohioensis*, now extinct), and a catfish. Another catfish bone (*Ictalurus punctatus*) and a pike tooth (*Esox* sp.) were recovered in the 1960's (Karrow, 1969; Crossman and Harington, 1970).

Once again the value of bulk sampling was underlined because the samples processed by Kerr-Lawson yielded a comparative wealth of microvertebrate remains, predominantly fish scales and bones. These are being studied by S. L. Cumbaa of the National Museum. Already he has expanded the list of fish taxa to more than a dozen (S. L. Cumbaa, letter Jan. 15, 1987).

A few bits of bone were recovered from the top of the York Till at the Woodbridge site. These have been identified as probable cricetid rodent and? *Gulo gulo* (wolverine) (C. S. Churcher, letter December 19, 1980).

The limited list available so far has told us little of the environment but analysis is continuing.

SUMMARY

The various fossil groups present a reasonably consistent picture of deposition near the mouth of a large river entering a lake in a climate about as warm as or slightly warmer (3°C) than the present. Other groups of fossil remains are known to be present but have yet to be studied. As additional willing specialists are found additional studies will be carried out.

STATUS OF THE BRICKYARD

The Don Valley Brickyard, previously operated by the Toronto Brick Company, provided access for researchers, students, and visitors from around the globe for nearly a century. At least one other brickyard (the Sun brickyard) north of the present one, was briefly described by Coleman (1933) but had been converted to a landfill site by 1957. Natural exposures along the nearby Don River have become slumped and grown over, as well as being extensively concealed by road construction (Bayview extension, Pottery Road, Don Valley Parkway). Thus for the last quarter century the Don Brickyard has been the only continuing point of access to the Don Formation.

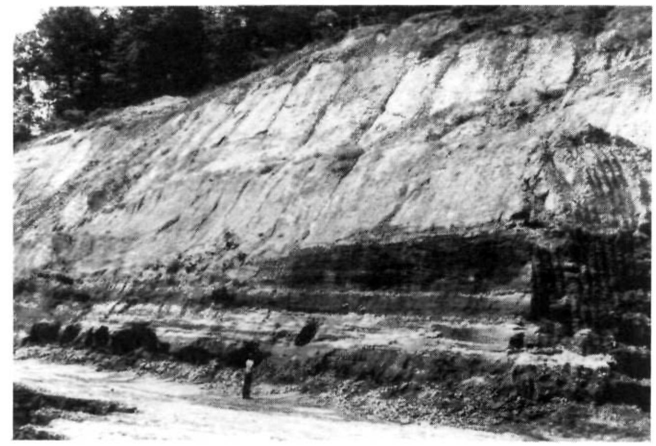

FIGURE 5. Photo of the Don Brickyard (1984).
La Don Brickyard (1984).

The Brickyard was offered for sale for parkland to a government agency, but no action was taken so it was sold to a developer, who proposed to cover the site with a residential development. While held by the developer, access was still provided for research and educational purposes (Fig. 5). After much lobbying by citizens groups concerned about the development and by scientists concerned about the exceptional geology of the site, the property was expropriated by the Ontario government.

Since then, access to the site has been limited, the stated reason being safety. With no active excavation, natural processes are causing slump and vegetation to cover the face. Meanwhile a government committee is considering ways to deal with the site in the future. We can only hope some means will be devised for making the site available for continuing research.

ACKNOWLEDGEMENTS

Many people beyond those cited in the reference list have contributed to the research results summarized here. Foremost to be named is the Toronto Brick Company for cooperating with the scientific community so generously over the years. Torvalley Associates, the subsequent developer, continued this cooperation. Many others among my colleagues have helped with fossil identifications and discussion of the geology on many occasions, and while they cannot all be named, their contributions are here gratefully acknowledged. This paper benefited from comments by A. V. Morgan, B. G. Warner, R. J. Mott, J. V. Matthews Jr., V. K. Prest, and J. Terasmae for which the author is very grateful. Financial and logistical support for the various studies have been provided by the Geological Survey of Canada, National Museum of Natural Sciences, Natural Sciences and Engineering Research Council, Ontario

Geological Survey, and Ontario Ministry of Natural Resources. Drawings were prepared by N. Bahar.

REFERENCES

Baker, F. C., 1931. A restudy of the interglacial molluscan fauna of Toronto, Canada. Transactions Illinois Academy of Science, 23: 358-366.

Berger, G. W., 1984. Thermoluminescence dating studies of glacial silts from Ontario. Canadian Journal of Earth Sciences, 21: 1393-1399.

Brown, R. W., 1942. Supposed extinct maples. Science, 96: 15.

Coleman, A. P., 1984. Interglacial fossils from the Don Valley, Toronto. American Geologist, 13: 85-95.

——— 1906. Interglacial periods in Canada. International Geological Congress, Mexico, Comptes Rendus, p. 1237-1258.

——— 1913. Toronto and vicinity. XII International Geological Congress Guidebook No. 6, Excursion B2 p. 5-34.

——— 1933. The Pleistocene of the Toronto region. Ontario Department of Mines Annual Report, Vol. 14, pt. 7,69 p.

——— 1941. The last million years. University of Toronto Press, Toronto, 216 p.

Crossman, E. J. and Harington, C. R., 1970. Pleistocene Pike, *Esox lucius* and *Esox* sp., from the Yukon Territory and Ontario. Canadian Journal of Earth Sciences, 7: 1130-1138.

Dawson, J. W. and Penhallow, D. P., 1890. On the Pleistocene flora of Canada. Geological Society of America Bulletin, 11: 311-334.

Duthie, H. C. and Mannada Rani, R. G., 1967. Diatom assemblages from Pleistocene Interglacial beds at Toronto, Ontario. Canadian Journal of Botany, 45: 2249-2261.

Eyles, C. H. and Eyles, N., 1983. Sedimentation in a large lake: a reinterpretation of the late Pleistocene stratigraphy at Scarborough Bluffs, Ontario, Canada. Geology, 11: 146-152.

Eyles, N. and Clark, B. M., 1988. Last interglacial sediments of the Don Valley Brickyard, Toronto, Canada, and their paleoenvironmental significance. Canadian Journal of Earth Sciences, 25: 1108-1122.

Frey, D. G., 1961. Developmental history of Schleinsee. Verh. International Verein. Limnol., 14: 271-278.

Gravenor, C. P. and Wong, T., 1987. Magnetic and pebble fabrics and origin of the Sunnybrook Till, Scarborough, Ontario, Canada. Canadian Journal of Earth Sciences, 24: 2038-2046.

Gray, A. B., 1950. Sedimentary facies of the Don member of the Toronto Formation. M. A. thesis, University of Toronto.

Hammond, P., Morgan, A. and Morgan, A. V., 1979. On the group *Anotylus*, and fossil occurrence of *Anotylus gibbulus* (Straphylinidae). Systematic Entomology, 4: 215-221.

Hann, B. J. and Karrow, P. F., 1984. Pleistocene paleoecology of the Don and Scarborough Formation, Toronto, Canada, based on cladoceran microfossils at the Don Valley Brickyard. Boreas, 13: 377-391.

Hicock, S. R. and Dreimanis, A., 1989. Sunnybrook drift indicates a grounded early Wisconsin glacier in the Lake Ontario basin. Geology, 17: 169-172.

Hui, H. T., Fernando, C. H. and Karrow, P. F., 1969. Mollusca of the Toronto interglacial. American Zoologist, 9: 615-616.

Kalas, L. L., 1975. Malacological evidence of interglacial environments at Toronto; Ontario, Canada; a quantitative approach. Program and Abstracts, Quaternary Non-marine Peleoecology Conference, p. 12.

Karrow, P. F., 1967. Pleistocene geology of the Scarborough area. Ontario Department of Mines, Geological Report 46, 108 p.

——— 1969. Stratigraphic studies in the Toronto Pleistocene. Geological Association of Canada Proceedings, 20: 4-16.

——— 1970. Pleistocene geology of the Thornhill area. Ontario Department of Mines Industrial Mineral Report 32, 51 p.

——— 1974. Till stratigraphy in parts of southwestern Ontario. Geological Society of American Bulletin, 85: 761-768.

——— 1989. Discussion of "Last interglacial sediments of the Don Valley Brickyard, Toronto, Canada, and their paleoenvironmental significance" by N. Eyles and B. M. Clark. Canadian Journal of Earth Sciences, 26: 1078-1082.

Kelly, R. I. and Martini, I. P., 1986. Pleistocene glaciolacustrine deltaic deposits of the Scarborough Formation, Ontario, Canada. Sedimentary Geology, 47: 27-52.

Kerr-Lawson, L. J., 1985. Gastropods and plant macrofossils from the Quaternay Don Formation (Sangamonian Interglacial), Toronto, Ontario. M. Sc. thesis, University of Waterloo, Waterloo, Ontario, 201 p.

Lajtai, E. Z., 1969. Stratigraphy of the University subway, Toronto, Canada. Geological Association of Canada Proceedings, 20: 17-23.

Morgan, A. V. and Morgan, A., 1980. Faunal assemblages and distributional shifts of Coleoptera during the late Pleistocene in Canada and the northern United States, Canadian Entomologist, 112: 1105-1128.

Penhallow, D. P., 1907. Contributions to the Pleistocene flora of Canada. American Naturalist, 41: 443-452.

Poplawski, S. and Karrow, P. F., 1981. Ostracodes and paleoenvironments of the late Quaternary Don and Scarborough Formations, Toronto, Ontario. Canadian Journal of Earth Sciences, 18: 1497-1505.

Sado, E. V., White, O. L., Barnett, P. J. and Sharpe, D. R., 1983. The glacial geology, stratigraphy, and geomorphology of the north Toronto area: a field excursion, p. 505-517. *In* W. C. Mahaney (ed.), Correlation of Quaternary Chronologies. York University, Toronto.

Sharpe, D. R. and Barnett, P. J., 1985. Significance of sedimentological studies on the Wisconsinan stratigraphy of southern Ontario. Géographie physique et Quaternaire, 39: 255-273.

Terasmae, J., 1960. A palynological study of Pleistocene interglacial beds at Toronto, Ontario. Geological Survey of Canada Bulletin, 56: 23-48.

Terasmae, J., Karrow, P. F. and Dreimanis, A., 1972. Quaternary stratigraphy and geomorphology of the eastern Great Lakes Region of southern Ontario. 24th International Geological Congress Field Excursion Guidebook A42, 75 p.

Warner, B. G., 1984. The identity of *Acer pleistocenicum* Pen. and *A. torontoniensis* Pen. from the Don Formation (Sangamonian Interglaciation) at Toronto, Ontario. Ontario Field Biologist, 38: 11-16.

Watt, A. K., 1954. Correlation of the Pleistocene geology as seen in the subway with that of the Toronto region, Canada. Geological Association of Canada Proceedings, 6 (2): 69-81.

——— 1957. Pleistocene geology and ground-water resources of the township of North York, York County. Ontario Department of Mines Annual Report, 64 (7), 64 p.

——— 1968. Pleistocene geology and groundwater resources, township of Etobicoke. Ontario Department of Mines Geological Report 59, 50 p.

Williams, N. E. and Morgan, A. V., 1977. Fossil caddisflies (Insecta: Trichoptera) from the Don Formation, Toronto, Ontario and their use in paleoecology. Canadian Journal of Zoology, 55: 519-527.