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MAMMALIAN PALEOECOLOGY OF CAVERNE DE LA MINE (QUEBEC, CANADA): ANALYSIS OF AN EARLY HOLOCENE CAVE DEPOSIT

BY

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ABSTRACT

The aim of this study is to analyse a mammalian terrestrial fossil fauna in order to assess the early Holocene fauna of the St. Lawrence - Ottawa valley region. The fossils were excavated from Caverne de la Mine located on the Eardley Escarpment in Gatineau Park, western Quebec, near the city of Ottawa (45°28'18"N, 75°51'01"W). A 70 cm deep excavation was done and the fossil contents of seven excavated levels were recovered. Cranial elements were identified and the minimum number of individuals (MNI) per taxa was tabulated for each stratum. Patterns over time were sought by discerning changing environmental affinities within the fossil assemblage and by comparisons with the fossil assemblage of an overlying portion of the infill and with the modern local fauna. The fossil deposit dated between 5 020 ±70 and 8 230 ±80 B.P. yielded twenty-three taxa among ten mammalian families. Two species, *Dicrostonyx hudsonius* and *Microtus pinetorum*, are not part of the modern local fauna. Today, *D. hudsonius* largely occupies the Ungava peninsula and parts of Labrador, while *M. pinetorum* inhabits areas east of the Mississippi valley and south of the Great Lakes. The fossil assemblage is predominantly made up of taxa having boreal affinities. Southern taxa are progressively more abundant approaching the upper portion of the deposit. Analysis of the fossil assemblage has shown that most species constituting the local fauna were established in the region soon after deglaciation. However, shifting community structure and the presence of extirpated taxa suggest that the local fauna underwent some adjustments since the beginning of the Holocene. The faunal adjustments mirror evolving vegetation cover in the area. As the forest cover shifted from a white birch - jack pine dominated boreal type forest to a closed canopy mixed conifer-deciduous woodland, the local fauna evolved in a similar fashion from a predominately boreal assemblage to a faunal assemblage with increased southern taxa. Species responses to these changes appear to have been individualistic.

RÉSUMÉ

Le but de cette étude est de faire l'analyse d'une faune fossile terrestre des basses terres du St-Laurent et de la vallée de l'Outaouais afin d'évaluer la communauté faunique qui y vivait lors du début de l'Holocène. Les fossiles ont été récupérés dans la Caverne de la Mine située sur l'escarpement d'Eardley en bordure du parc de la Gatineau, dans l'ouest québécois, près de la ville d'Ottawa (45°28'18"N, 75°51'01"O). Les restes fossilifères ont été extraits d'une coupe de 70 cm d'épaisseur. Les éléments crâniens de mammifères ont été identifiés et le nombre minimal d'individus par espèces a été déterminé pour sept niveaux d'échantillonnage. L'analyse statistique de la faune fossile a tenté de rendre évident les changements dans le temps. Le gisement fossilifère s'est formé entre 5 020 ±70 et 8 230 ±80 B.P. Vingt-trois espèces de mammifères ont été identifiés. Deux espèces, *Dicrostonyx hudsonius* et *Microtus pinetorum*, ne nichent pas actuellement dans la région. La distribution moderne de *D. hudsonius* recouvre grandement la péninsule d'Ungava, alors que celle de *M. pinetorum* s'étend sur l'est du continent au sud des Grands Lacs. L'assemblage fossilifère se compose surtout d'espèces ayant des affinitées avec les environnements boréaux. Toutefois, la présence d'espèces australes devient plus importante vers le haut du gisement. L'analyse de la faune fossile démontre que la plupart des espèces qui constituent la faune locale moderne, se sont établies dans la région peu longtemps après la déglaciation. Les variations dans la composition de la faune fossilifère ainsi que la présence d'espèces aujourd'hui absents indiquent que d'importants changements ont eu lieu dans la faune locale au cours de l'Holocène. Les changements fauniques correspondent aux modifications de la flore locale. Lorsque le couvert végétal s'est transformé d'une forêt boréale dominée par le bouleau blanc et le pin gris à une forêt mixte, la faune locale s'est parallèlement transformée d'un assemblage dominé par des espèces boréales à un assemblage d'espèces aux affinités mixtes. Les espèces semblent avoir réagi individuellement aux changements environnementaux.

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1. INTRODUCTION

1.1 Synopsis

Environmental changes associated with the last deglaciation had profound effects on the evolution of biotic communities in North America (Graham and Mead 1987, p. 371). The newly opened landscape north of the Wisconsinan terminal moraine became suitable and accessible for colonisation to species previously displaced southward by continental ice. Within the St. Lawrence and Ottawa valley region, scattered Holocene fossil sites have yielded high quality floral records as well as faunal accounts associated with the Champlain Sea episode. Terrestrial faunal records, however, are virtually non-existent. Consequently, very little is known of the postglacial history of the terrestrial fauna of the St. Lawrence - Ottawa valley region.

Late Pleistocene and Early Holocene fossil sites in North America commonly distinguish themselves from sites yielding more recent material by their composition. In fact, numerous sites located in northeastern USA have revealed faunal assemblages comprised of taxa that are excluded from today's local fauna. Among these are species of arctic tundra and boreal forest environments. Clearly, these species were incorporated into the faunal record because they lived in the proximity of the ice front at the close of the last ice age. Younger fossil assemblages from the same region have shown how these species adjusted their ranges towards higher latitudes in response to changing environmental conditions. As these species colonized the recently opened landscape on Canadian territory, evidence of this primitive or *pre-modern* fauna should appear in the early Holocene fossil record of eastern Canada. While a few fossil sites produced evidence of this early fauna, none have been found to date within the St. Lawrence - Ottawa valley region.

Among the few existing faunal sites in this region, all have produced modern looking fossil assemblages. The Caverne de la Mine fossil site, located in the Ottawa Valley, Gatineau County, western Quebec, yielded a significant fossil assemblage believed to be approximately 5 000 years old. Serving as an efficient trap, the vertical cave accumulated varied and plentiful faunal remains. Analysis of a section of the cave infill revealed a mammal assemblage indistinguishable from the modern local terrestrial fauna. The evidence at this fossil site suggests that the local fauna had attained its modern form by circa 5 000 years ago, as was the case with other regional mid-Holocene sites.

The Caverne de la Mine fossil deposit provides a good opportunity for an early Holocene faunal analysis, given that only portions of the cave infill have been excavated and studied during the initial investigation. The site is ideal for such a study since the remaining material should predate the excavated material overlying it. Moreover, the deposit has thus far been shown to contain a plentiful assortment of faunal remains. Therefore, if the underlying portion of the cave infill maintains its integrity, a faunal assemblage predating the mid-Holocene could be produced. Such a faunal collection would be unique and therefore, valuable in assessing the state of the early Holocene fauna from the St. Lawrence - Ottawa valley region.

1.2 Thesis objectives

Important environmental changes are known to have occurred since the last deglaciation, yet the effects of these changes on the regional terrestrial fauna are not well known. The regional fossil record suggests that the faunal community structure has been rather static since the mid-Holocene. The primary objectives of this study are to produce a faunal list predating 5 000 years B.P., and to assess the impact of evolving environments on the local fauna prior to 5 000 years B.P. by attempting to answer whether or not any differences existed between the early Holocene fauna and the modern local fauna with respect to their terrestrial mammal composition. While answering this question, the study should shed light on the following: the differences manifested

in the fossil record, the timing of the modernization of the local fauna, and the age of the Caverne de la Mine fossil deposit.

The analysis of the fossil assemblage from the Caverne de la Mine lower infill provides a significant source of information regarding the postglacial history of the local terrestrial fauna. The analysis will be beneficial provided that the deposit dates back to the early Holocene and that the infill yields sufficient fossil material.

1.3 Research justification

A paleofaunal analysis of the Caverne de la Mine lower infill is justifiable, given that very little is known of the early Holocene terrestrial fauna of the St. Lawrence – Ottawa valley region. The scarcity of faunal deposits in this area, particularly old ones, is mainly responsible for this lack of information. For the period in question, the marine fauna associated with the Champlain Sea and the flora are relatively well known. The acquired data from this research should therefore contribute greatly to an understanding of the paleofaunal history of the region. Apart from the fossil deposit's uniqueness, its age, fossil potential and accessibility also make the Caverne de la Mine a very attractive site for such a study. Furthermore, cave deposits have long been considered to be ideal paleoecological sites (e.g. Graham 1985b; Ford and Williams 1989; Andrews 1990; Churcher and Wilson 1990; Lowe and Walker 1997).

1.4 Presentation

The thesis is divided in 7 chapters. The first two chapters discuss the objectives of the study and offer a general overview. The following two chapters give a description of the area studied and of the methods and techniques used. Chapter five contains an analysis of the excavations. An interpretation of the results and conclusions are given in the final two chapters.

2. HISTORY OF INVESTIGATION

The ecological communities of the Ottawa Valley are considered to be recent since they do not predate the last deglaciation. Paleoecologists are interested in fossil communities since they offer a window on past environments and on the mechanisms of territorial colonisation since the retreat of the Wisconsinan ice sheet. Because of this interest, a variety of Holocene fossils have been studied in the Ottawa area. Perhaps the most studied fossils beside pollen, are those associated with the Champlain Sea. Despite its brief existence, a large quantity of organic remains have been recovered of a variety of forms which include fish (Harington 1978, 1983; McAllister *et al.* 1981), mammals (Harington 1971, 1972, 1977, 1978, 1981; Harington and Occhietti 1988), molluscs (Rodrigues and Richard 1983, 1985), marine vegetation (Mott 1968; Illman *et al.* 1970) and microfossils (Rodrigues 1986). Interest in regional floral colonisation and successions has also led to the analysis of the pollen from a number of sites in the vicinity of Ottawa. Closest to the study site are those from Pink and Ramsay Lake, both analysed by Mott and Farley-Gill (1981).

Very little is known about the early Holocene terrestrial faunas of eastern Canada. This is due in part to the lack of sites with adequate preservation of fossil material. Most of the few fossil deposits are comprised of only a few specimens. A summary of some of these localities is given by Harington (1978) and by Kurtén and Anderson (1980). Among the most famed early Holocene fossil sites are those which yielded the remains of extinct proboscideans. Fossil occurrences of wholly mammoths (*Mammuthus primigenius*) and American mastodons (*Mammut americanum*) are principally concentrated in southern Ontario (e.g. Ferguson Farm site and Muirkirk site, Kent

County, Ontario; Rostock site, Perth county, Ontario; Verbeke Mastodon, Essex County, Ontario) and represent faunas distinct from modern ones as these taxa are now extinct.

The St-Elzéar Cave deposit located in eastern Quebec is believed to be early Holocene in age (LaSalle and Guilday 1980; LaSalle 1984). The cave talus revealed the fossil remains of some 33 species (table 1). The faunal assemblage produced from the cave deposit includes six mammal taxa that do not actually occur within the Gaspé peninsula and "*...suggests boreal forest conditions at least as severe as those of today, with an indication of nearby tundra conditions during lower level times.*" (LaSalle 1984: 345). The arctic shrew (*Sorex arcticus*), the arctic hare (*Lepus arcticus*), the heather vole (*Phenacomys intermedius*), the Ungava collared lemming (*D. hudsonius*), the yellow-cheeked vole (*Microtus xanthognathus*), and the least weasel (*Mustela nivalis*) generally all inhabit areas north of the deposit today. All of these taxa are particularly abundant in the deepest zone of the cave talus and become sparse or entirely absent in the overlying zones. The St-Elzéar cave fossil fauna represents an assemblage which apparently predates the modern local fauna as it contains taxa which do not occur in the vicinity of the fossil site today. A transition approaching a modern-looking fauna may be perceived throughout the deposit from the oldest zone toward the youngest. Altogether, this fossil fauna serves as a good witness to faunal change, showing how the faunal assemblage of early Holocene differed from the local modern faunal structure.

Middle to late Holocene fossil deposits are more common. Located in the Ottawa valley, the Caverne de la Mine fossiliferous infill yielded a significant fossil fauna (Carrier 1989). Carrier's work on the upper portion of the infill revealed a sizeable fossil assemblage dating back to the last 5 000 years which is indistinguishable from the modern fauna. One amphibian and thirteen mammal species were identified among the 1 677 identified specimens from the upper infill (table 2). Among those most frequently encountered are the American toad (*Bufo americanus*), the big brown bat (*Eptesicus fuscus*) and the raccoon (*Procyon lotor*). A number of land snails have also been recovered. In addition to the faunal material recovered from the deposit, Carrier (1989) noted the presence of two etched and polished raccoon ulnas which he

Scientific name	Common name	Stratigraphic levels Zone 1	Zone 2	Zone 3	Zone 4	MNI
Class Mammalia, order Insectivor, family Talpidae						
Condylura cristata	Star-nosed mole	-	1	-	-	1
Family Soricidae						
Sorex arcticus†	Arctic shrew	-	1	3	6	10
Sorex cinereus	Masked shrew	44	150	311	315	820
Sorex fumeus	Smoky shrew	3	9	17	14	43
Sorex gaspensis	Gaspé shrew	-	1	4	8	13
Sorex palustris	Water shrew	-	-	1	4	5
Sorex hoyi	Pigmy shrew	5	23	52	46	126
Blarina brevicauda	Short-tailed shrew	8	13	41	24	86
Order Chiroptera, family Vespertilionidae						
Myotis lucifugus	Little brown bat	1	2	5	1	9
Order Lagomorpha, family Leporidae						
Lepus americanus	Snowshoe hare	7	3	3	9	22
Lepus arcticus†	Arctic hare	-	-	-	1	1
Order Rodentia, family Sciuridae						
Marmota monax	Woodchuck	11	4	3	4	22
Tamias striatus	Chipmunk	-	-	2	2	4
Tamiasciurus hudsonicus	Red squirrel	1	-	1	3	5
Glaucomys sabrinus	Northern flying squirrel	1	1	3	2	7
Family Cricetidae						
Peromyscus maniculatus	Deer mouse	1	4	10	18	33
Family Arvicolidae						
Clethrionomys gapperi	Red-backed vole	57	235	366	470	1128
Synaptomys cooperi	Southern bog lemming	7	40	19	17	83
Synaptomys borealis	Northern bog lemming	36	125	239	105	505
Phenacomys intermedius†	Heather vole	-	-	22	34	56
Dicrostonyx hudsonius†	Ungava collard lemming	-	-	-	7	7
Microtus pennsylvanicus	Meadow vole	10	48	37	36	131
Microtus chrotorrhinus	Rock vole	116	279	432	383	1210
Microtus xanthognathus†	Yellow-cheeked vole	-	-	-	1	1
Family Zapodidae						
Napaeozapus insignis	Woodland jumping mouse	14	39	37	30	120
Zapus hudsonius	Meadow jumping mouse	1	1	1	-	3
Family Castoridae						
Castor canadensis	Beaver	-	-	-	1	1
Family Erethizontidae						
Erethizon dorsatum	Porcupine	11	2	2	3	18
Order Carnivora, family Ursidae						
Ursus americanus		5	1	1	2	9

Table 1: Mammalian fossil fauna for Caverne de St-Elzéar, Quebec (modified from Lasalle 1994).

Scientific name	Common name	Stratigraphic levels				MNI
		Zone 1	Zone 2	Zone 3	Zone 4	
Family Mustelidae						
Mustela nivalis†	Least weasel	2	1	1	4	3
Gulo gulo	Wolverine	2	1	-	1	4
Order Artiodactyla, family Cervidae						
Alces alces	Moose	7	1	1	2	11
Rangifer tarandus	Caribou	1	-	-	-	1

† Taxa presently not living within the Gaspé peninsula.

Table 1: *continued.*

considered to be primitive human tools, making Caverne de la Mine a possible archaeological site.

The Scarborough Bluffs located on the north shore of Lake Ontario near Toronto, Ontario (Churcher and Karrow 1963), the Hamilton Bay deposit near Hamilton, Ontario (Wetmore 1958; Churcher and Karrow 1963), the McIntyre site in Peterborough county, Ontario (Johnston 1984) and Morrisson's Island 6 archaeological site located on the Ottawa river near Pembroke, Ontario (Clermont and Chapdelaine 1998) are among those closest to the lower Ottawa Valley area. These sites date back 3 000 to 6 000 years B.P. and yielded fossil assemblages mainly made up of extant woodland taxa. Altogether, the regional fossil records agree that a modern faunal community structure was reached by 5 000 years B.P.

Species	Common Name	NISP	MNI
Eptesicus fuscus	Big brown bat	300	13
Bufo americanus	American toad	216	7
Procyon lotor	Raccoon	216	7
Peromyscus leucopus	White-footed mouse	26	5
Ursus americanus	Black bear	22	1
Sciurus carolinensis	Grey squirrel	11	1
Ondatra zibethicus	Muskrat	9	1
Microtus pennsylvanicus	Meadow vole	8	1
Odocoileus virginianus	Deer	8	1
Marmota monax	Woodchuck	6	1
Tamias striatus	Chipmunk	5	1
Erethizon dorsatum	Porcupine	4	2
Sorex cinereus	Masked shrew	4	2
Condylura cristata	Star-nosed mole	1	1
Total		**1677**	**47**

Table 2: Caverne de la Mine upper infill fossil taxa in order of fossil abundance.

3. REGIONAL SETTING

3.1 Study area

Caverne de la Mine is located within the boundaries of Gatineau Park, Gatineau County, western Quebec. More precisely, it is found at 45°28'18" latitude North, 75°51'01" longitude West and at 184 metres above sea level, north of the Ottawa River, approximately 20 km northwest of the city of Ottawa (figure 1). The cave is situated on the Eardley Escarpment in the Kingsmere sector at the southwestern extremity of the park. Caverne de la Mine is located on a ledge of the Escarpment approximately 70 m above the adjacent valley (figure 2).

3.2 Quaternary history

As for most parts of Canada, the Ottawa Valley was often glaciated during the Quaternary and as recently as 12 000 years ago. Continental ice from the last glaciation melted away between 11 000 and 12 000 years B.P. in the region (Dyke and Prest 1987). Deglaciation was quickly followed by the submergence of the isostatically depressed lowlands forming an inland sea to the Atlantic Ocean. Centred along the St. Lawrence and the lower Ottawa river valley, the Champlain Sea submerged land presently reaching 200 m of altitude in the vicinity of Ottawa (Fulton *et al.*, 1987). The sea was only briefly in existence between 10 000 and 12 000 years B.P., before isostatic rebound caused the sea to progressively retreat eastward towards the Atlantic. Numerous marine fossils, such as molluscs and mammals, were left in Champlain Sea deposits which have been studied on several occasions. Following the retreat of the ice and the sea and throughout the Holocene, floral and faunal colonisation gradually transformed the local landscape to its modern form.

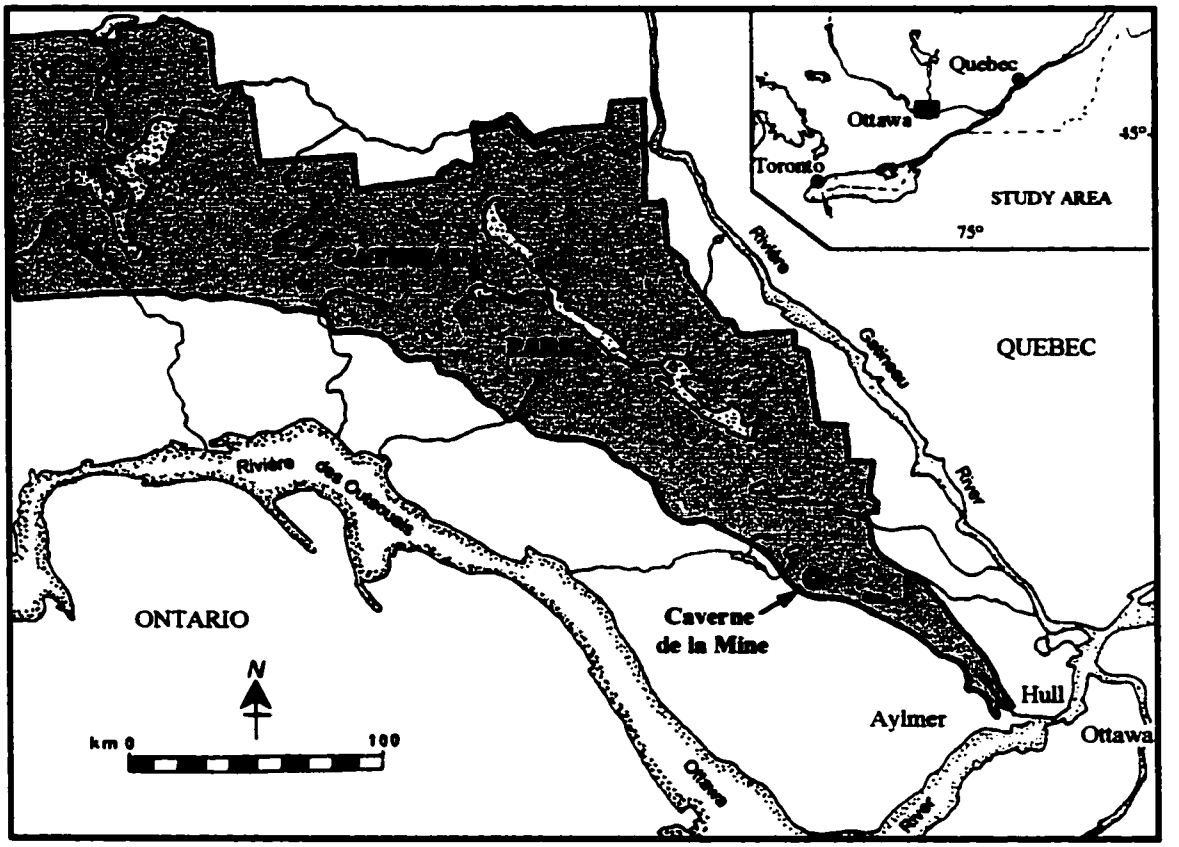


Figure 1: Location of study site, Caverne de la Mine, Gatineau County, Quebec, Canada.

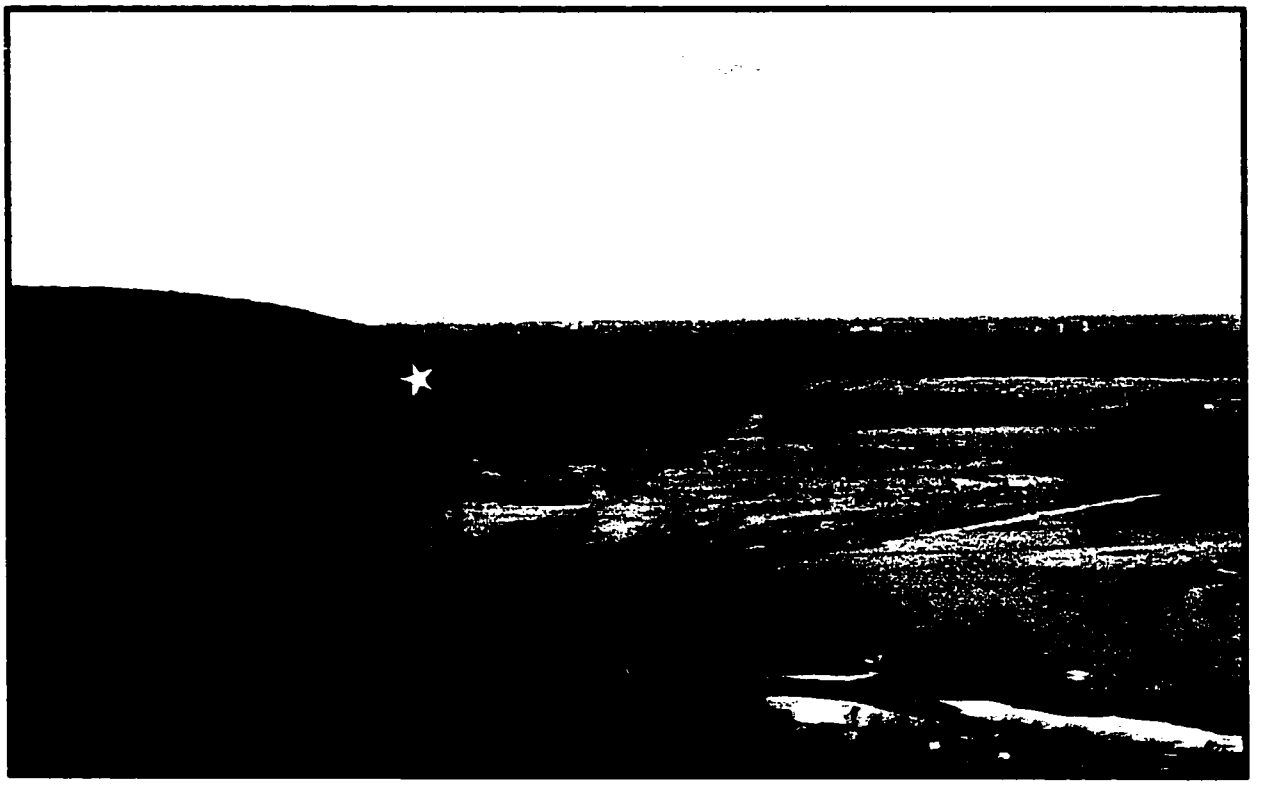


Figure 2: Southerly view of the Eardley Escarpment and the Ottawa Valley as seen from King Mountain. Caverne de la Mine is located on the Escarpment, approximately 70 m above the neighboring lowlands.

3.3 Geology and physiography

The forested landscape of Gatineau Park covers an area of 354.8 km^2. The park lies on the Canadian Shield's Laurentian Plateau where rolling hills and cliffs characterise the surrounding topography. Most of the park's terrain lies between 150 and 300 m above sea level. Precambrian rocks such as gneiss, granite and marble predominate the park's geology (Buckley 1967; Baird 1968; Hogarth 1970; Canada National Capital Commission 1976a). Surface material is most often a thin cover of glacial and glaciofluvial deposits in the form of sands, gravels, tills and erratics (Buckley 1967; Canada National Capital Commission 1976a, 1976b). Champlain Sea sediments such as marine clay and silt are found in low-lying portions of the park (Canada National Capital Commission 1976b).

Gatineau Park's most prominent topographical feature is the Eardley Escarpment, located along the park's southern margin. Marking the contact between the Canadian Shield and the St. Lawrence Lowlands, the Escarpment rises to about 200 m above the adjacent valley. The immediate area of the cave is relatively dry, likely due to the Escarpment's significant slope providing adequate drainage. The nearest water bodies are small bogs and marshes located at distant and higher elevations. A few small lakes, such as Kingsmere, Mulvihill and Pink are found within three kilometres of the site.

Caverne de la Mine has formed within a large marble body south of Kingsmere Lake which is part of the Grenville geologic province (Hogarth 1970). According to Dresser and Denis (1976), the crystalline limestone is characterized by a white or grey coloured, medium to coarse grain rock, containing sporadic inclusions of feldspar, pegmatite, granite, gabbro and diorite, as well as other various minerals. The relatively high carbonate contents of the marble, usually over 95% (Frechette 1916; Goudge 1935), makes this rock highly susceptible to erosion, particularly chemical dissolution. A number of karst features, such as caves, sinking streams and springs, are found on the Eardley Escarpment (Carrier 1989).

Caverne de la Mine was formed in a pinkish – white coloured marble containing abundant mineral inclusions, such as mica which was mined to some extant from the upper pit early this century, hence the name of the cave. On the cave walls are found many insoluble mica, gneiss, and quartzite nodules issued from impurities within the original limestone and from an igneous source which was more recently incorporated during metamorphism of the limestone (Dresser and Denis 1946). Soft calcite precipitation similar to mondmilk is also abundant on the cave walls, as it is in many nearby caves (Vigneux 1998).

Caverne de la Mine consists of a rockshelter and a vertical cave comprised of two pits (figure 3 and figure 4). The three metre wide by one metre deep by two metre high rockshelter is a cramped dome-shaped room accessible by two openings on the western and northern sides. From this room, a shallow passage leads a short distance before being obstructed by a heavy breakdown. According to Carrier (1989), this obstructed passage communicates with the vertical cave. A crevice found a few metres outside the rockshelter gives direct access to the first vertical pit, which leads to a small room approximately four metres below. A narrow opening in the floor of this room leads to the second pit. At the bottom of this sub-vertical passage, roughly three metres below, is a cave infill impeding any further exploration of the cave. This sediment plug was found to be highly fossiliferous. A one metre deep section of it has been excavated by Carrier (1989) and its contents analysed. A second section was also excavated underneath, but was not thoroughly analysed. Analysis of the material underlying the second excavation, hereafter referred as the *lower infill* or *lower deposit*, is the principal objective of this study. In the room between both pits is a short but very tight crawlway leading to an elongated room. At the one end of this chamber is an impenetrable vertical crevice which we assume, extends from the surface down to the lower infill.

The processes leading to the formation of caves are generally well known (e.g. Trudgill 1985; Jennings 1985; Ford and Williams 1989). As the numerous springs at the base of the Escarpment attest, subterranean drainage of the plateau toward the adjacent lowlands was mainly responsible for the speleogenesis in the case of Caverne de la Mine. Speleogenesis is

Figure 3: Photograph showing entrances to rockshelter (background) and vertical cave, Caverne de la Mine.

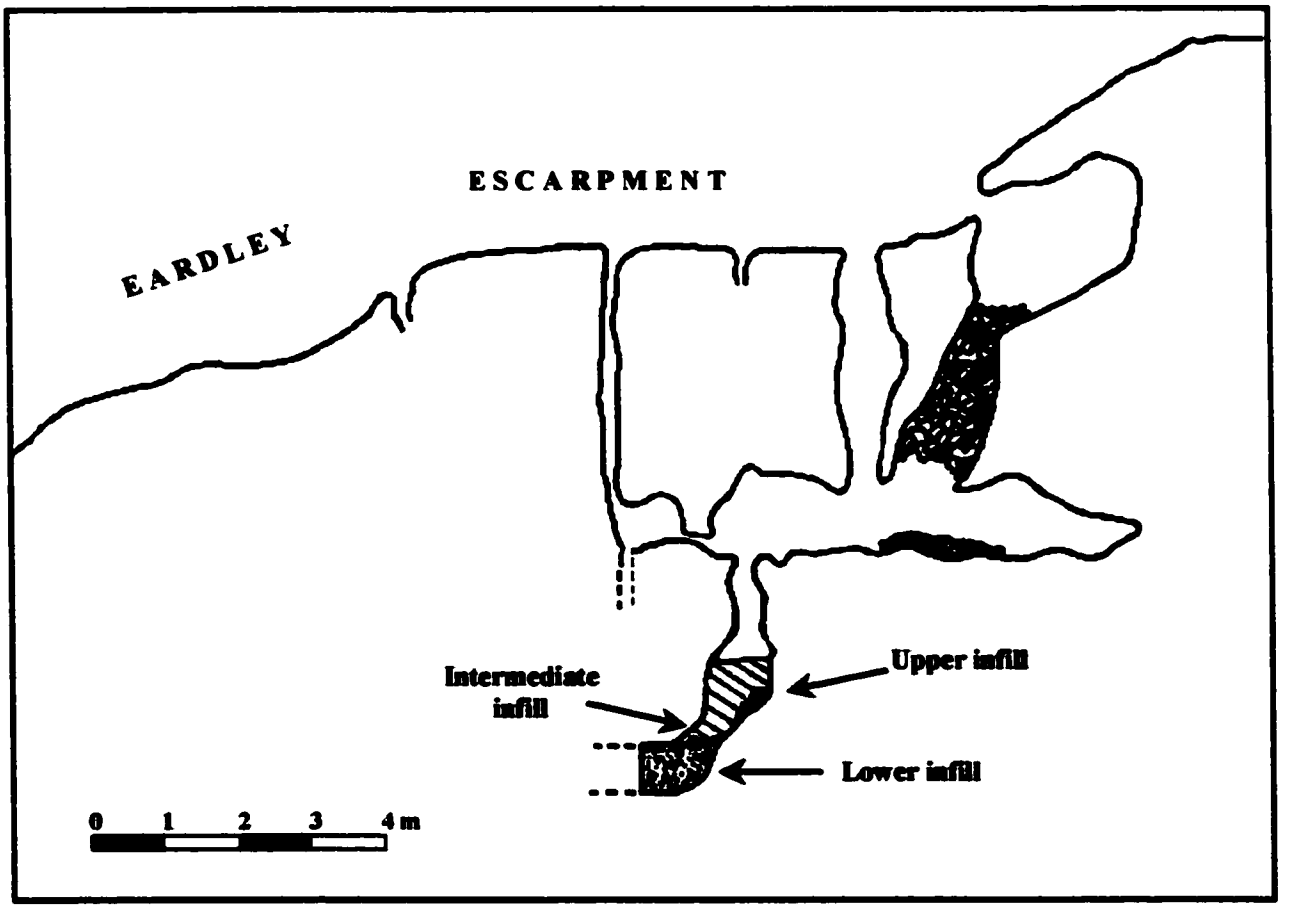


Figure 4: Survey plan of Caverne de la Mine showing location of excavations.

believed to be preglacial as are the nearby Laflèche Caves (Schroeder, unpublished data). During the last ice-age, glacial erosion along the Eardley Escarpment truncated these underground galleries making them accessible from the surface. Today the cave is relatively dry and is therefore considered to be inactive or fossil.

3.4 Climate

The closest permanent weather station to the study site is situated in Chelsea, Quebec (45°31' N, 75°47' W, 112 m). Based on climatic data collected between 1927 and 1990, the region has an annual mean daily temperature of 5.5°C and receives a total of 955.8 mm of precipitation annually (Environment Canada 1993). January is the coldest month and July the warmest with monthly averages of -11.5°C and 20.5°C respectively. Irregular topography, vegetative cover, and exposure contribute to a variety of microclimates inside Gatineau Park, especially along the Eardley Escarpment (Canada National Capital Commission 1976a; Gagnon and Bouchard 1981; Gillet and Catling 1994).

3.5 Ecology

3.5.1 Flora

Gatineau Park is part of the Canadian Zone biotic province as described by Dice (1943). The park's mixed deciduous and coniferous vegetation is characteristic of the middle Ottawa zone of the Great Lakes - St. Lawrence Forest Region [zone L.4c] (Rowe 1959). The Park's vegetation is described in detail by Grandtmer (1966) and by Gillet and Catling (1994). The forest cover surrounding the study area consists predominantly of hardwood taxa such as red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), red oak (*Quercus rubra*), beech (*Fagus grandifolia*), basswood (*Tilia americana*) and white ash (*Fraxinus americana*) . This vegetation association corresponds well to the dry microclimate and the rocky terrain of the Eardley Escarpment (Brunton and Lafontaine 1974; Gagnon 1980; Gagnon and Bouchard 1981).

3.5.2 Fauna

Unlike the vegetation, the local faunal composition may be difficult to assess because of the mobility and the crepuscular lifestyle of certain species. A complete list of mammalian taxa naturally occurring in the Ottawa region was produced by Rand (1945) and recently revised by Sankey (1997). According to the faunal list, 53 taxa presently occur in the region in varying population sizes (table 3).

Taxa	Status	Taxa	Status
Insectivora			
Common shrew (*Sorex cinereus*)	Abundant	Smoky shrew (*Sorex fumeus*)	Uncommon
Pygmy shrew (*Sorex hoyi*)	Rare	Water shrew (*Sorex palustris*)	Very rare
Short-tailed shrew (*Blarina brevicauda*)	Abundant	Hairy-tailed mole (*Parascalops breweri*)	Rare
Star-nosed mole (*Condylura cristata*)	Common		
Chiroptera			
Eastern small-footed bat (*Myotis leibii*)	Very rare	Little brown bat (*Myotis lucifugus*)	Common
Northern long-eared bat (*Myotis septentrionalis*)	Rare	Silver-haired bat (*Lasionycteris noctivagans*)	Rare
Eastern pipistrelle (*Pipistrellus subflavus*)	Very rare	Big brown bat (*Eptesicus fuscus*)	Common
Eastern red bat (*Lasiurus borealis*)	Rare	Hoary bat (*Lasiurus cinereus*)	Uncommon
Lagomorpha			
Eastern cottontail (*Sylvilagus floridanus*)	Common	Snowshoe hare (*Lepus americanus*)	Common
European hare (*Lepus europaeus*)	Rare		
Rodentia			
Eastern chipmunk (*Tamias striatus*)	Abundant	Woodchuck (*Marmota monax*)	Abundant
Gray squirrel (*Sciurus carolinensis*)	Abundant	Red squirrel (*Tamiasciurus hudsonicus*)	Common
Northern flying squirrel (*Glaucomys sabrinus*)	Common	Southern flying squirrel (*Glaucomys volans*)	Uncommon
Beaver (*Castor canadensis*)	Common	White-footed mouse (Peromyscus leucopus)	Abundant
Deer mouse (*Peromyscus maniculatus*)	Common	Southern red-backed vole (*Clethrionomys gapperi*)	Common
Meadow vole (*Microtus pennsylvanicus*)	Abundant	Muskrat (*Ondatra zibethicus*)	Common
Southern bog lemming (*Synaptomys cooperi*)	Very rare	Norway rat (*Rattus norvegicus*)	Uncommon
House mouse (*Mus musculus*)	Uncommon	Meadow jumping mouse (*Zapus hudsonius*)	uncommon
Woodland jumping mouse (*Napeozapus insignis*)	Uncommon	Porcupine (*Erethizon dorsatum*)	Common
Carnivora			
Coyote (*Canis latrans*)	Uncommon	Grey wolf (*Canis lupus*)	Uncommon
Red fox (*Vulpes vulpes*)	Common	Black bear (*Ursus americanus*)	Uncommon

Table 3: List and status of mammals living in the Ottawa district (modified from Sankey, 1997).

Taxa	Status	Taxa	Status
Raccoon (*Procyon lotor*)	Abundant	Marten (*Martes americana*)	Very rare
Fisher (*Martes pennanti*)	Rare	Ermine (*Mustela erminea*)	Common
Long-tailed weasel (*Mustela frenata*)	Uncommon	Mink (*Mustela vison*)	Common
Woverine (*Gulo gulo*)	Very rare	Striped skunk (*Mephitis mephitis*)	Common
River otter (*Lontra canadensis*)	Uncommon	Canada lynx (*Lynx canadensis*)	Very rare
Bobcat (*Lynx rufus*)	Very rare		
Artiodactyla			
White-tailed deer (*Odocoileus virginianus*)	Common	Moose (*Alces alces*)	Rare

Table 3: *continued.*

4. METHODOLOGY

4.1 Overview

Fossiliferous cave deposits are commonly used for paleoecological studies and standard techniques and methodologies have been developed to study them. Various methodologies used in palaeontology and archaeology are discussed in great details by an amalgam of authors in a volume entitled: *Géologie de la préhistoire: méthodes technique et application* (1987) edited by J.C. Miskovsky. Churcher and Wilson (1990) give an overview of techniques used in Quaternary vertebrate analyses. Likewise Graham and Semken (1987) give a thorough overview of the procedures followed for paleoenvironmental studies of Quaternary mammalian faunas. The use of common procedures has made it easier to compare results between similar studies. The analysis of fossiliferous cave deposits generally follows these steps: a) site description and excavation, b) fossil extraction, c) fossil identifications, d) matrix analysis, e) dating, and f) paleoecolgical analysis.

4.2 Excavation and sampling

Four adjacent sections of the cave infill, identified as sections A, B, C and D, were successively excavated from the bottom of the second pit of Caverne de la Mine (figure 5 and figure 6). All the sediment confined between the cave walls was removed in 5 cm increments. Exploratory excavations at the top of section B and of section D were done using 10 cm increments. Approximately 0.5 m^3 of material was excavated from the lower infill. The material was dug out using a gardening trowel and packaged in labelled *Ziplock* type bags. For each stratum sampled, one bag containing approximately 500 g of sediment was reserved for sediment

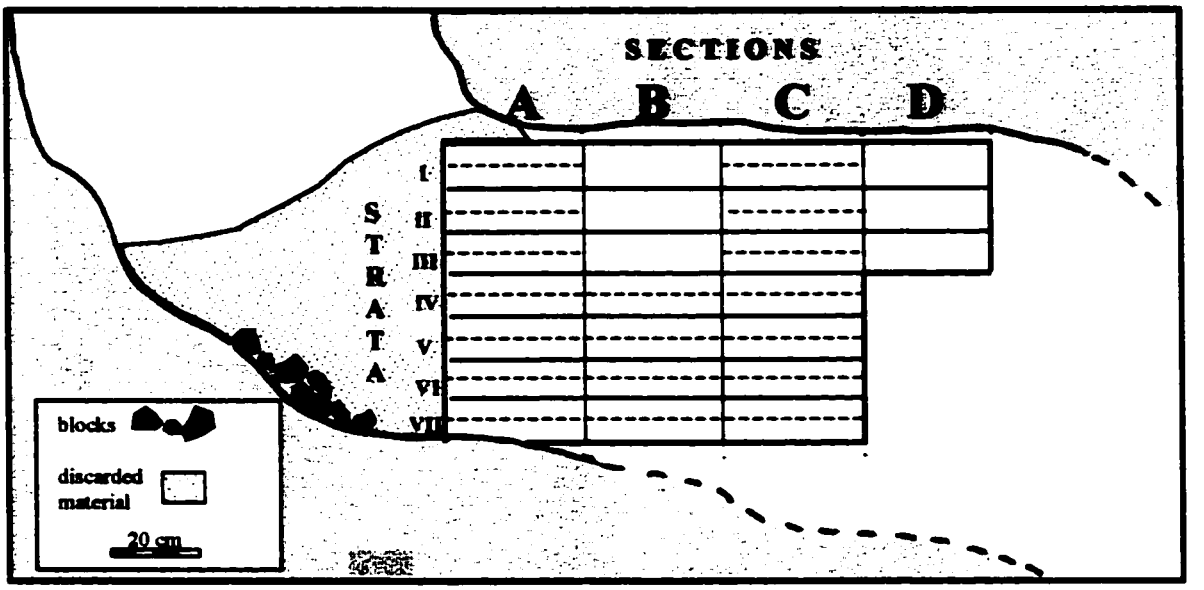


Figure 5: Caverne de la Mine lower infill excavation grid (lateral view).

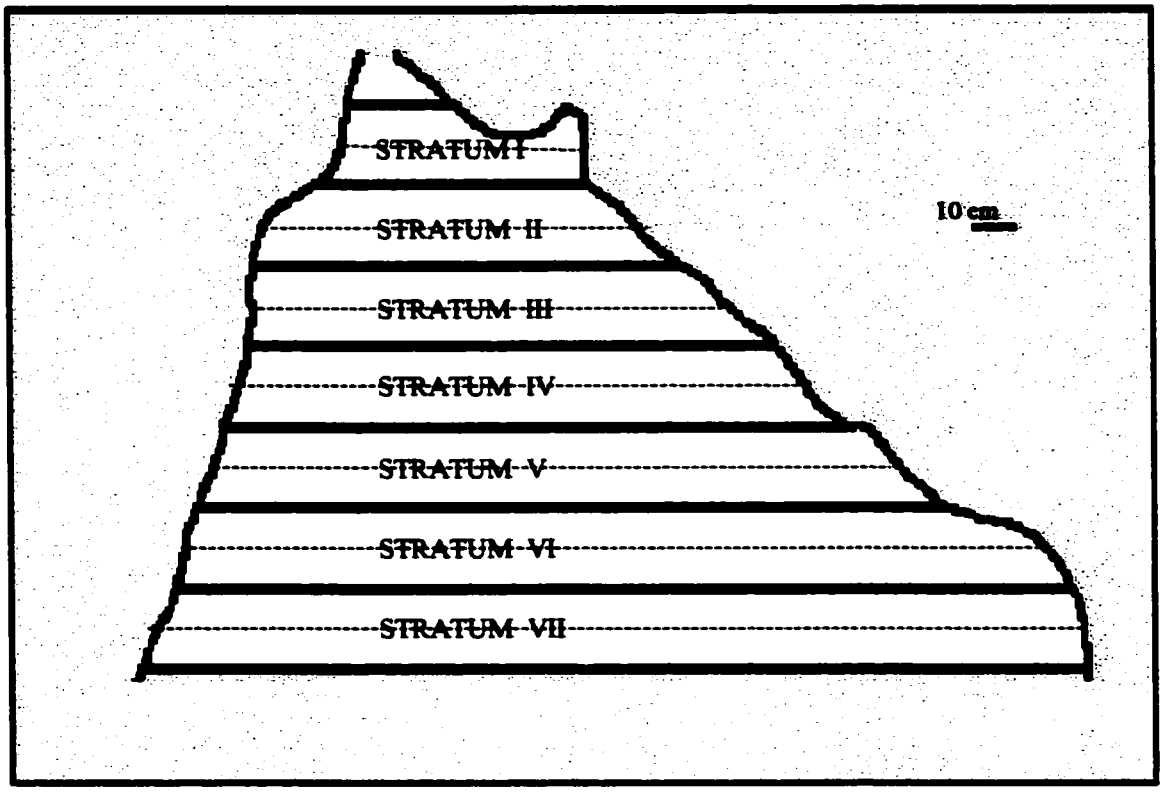


Figure 6: Caverne de la Mine lower infill excavation grid (frontal view).

analysis. Sampling procedures followed are those reviewed by Djindjian (1987) and Lévêque (1987).

4.3 Fossil recovery and cataloguing

All excavated material was brought to the lab for bulk sieving. The sediment matrix from sections A, B and C was dry screened using standard laboratory sieves. Material from section D was wet screened since it was observed that dry screening occasionally damaged the fossil material. Techniques used for fossil recovery were those explained by Hibbard (1949), Guérin and Rage (1987) and Churcher and Wilson (1990). Various sieve sizes were used simultaneously to facilitate fossil recovery from the matrix. To prevent potential loss of microvertebrate teeth, the smallest mesh size used for sieving did not exceed 0.5 mm (Guérin and Rage 1987). Bones, teeth, land snails and charcoal were recovered from the sieved matrix with the help of a pair of forceps, often with the help of a standard laboratory magnifying glass. Items recovered were sorted by type and stored in vials identified by section letter and level number. Specimens to be identified were each assigned an individual catalogue number and stored in separate vessels. Catalogue numbers consist of an infill section letter, an excavation level number, a skeletal element number and a specimen number (for example C-3-4-38). Each level was sieved, picked and catalogued separately to assure stratigraphic control

4.4 Cave infill analysis

4.4.1 Age

As in any paleoecological study, establishing the age of a particular deposit is fundamental. Four samples of wood charcoal recovered from STRATUM I, STRATUM II, STRATUM IV and STRATUM VII were sent to the University of Toronto's IsoTrace Laboratories for AMS radiocarbon dating. Apart from establishing the age of the deposit, results are also used in determining rate of sedimentation and in verifying the stratigraphic sequence for possible mixing caused by processes such as bioturbation.

4.4.2 Colour

Colour measurements are used to describe the general appearance of the matrix. After having been dried, sediment samples of the seven excavated strata were processed at the lab using a Munsell Soil Colour Chart. The colour of each stratum was recorded using the Munsell nomenclature (hue, value and chroma) and corresponding colour description.

4.4.3 Granulometry

Granulometric analysis was performed on approximately 40 to 55 g of raw sediment of the seven excavated strata. Organic matter was eliminated from each sample with 50 ml of hydrogen peroxide (H_2O_2). Samples were wet sieved using 2 mm and 0.063 mm mesh sizes (-1ϕ and 4ϕ) to obtain the relative proportion of gravel (>2 mm), sand (2 mm to 0.063 mm) and fines (<0.063 mm) for each sample.

4.5 Fossil identifications

4.5.1 Vertebrates

Because of the large number of vertebrate specimens recovered from the deposit and the effort required to identify them, only mammalian cranial elements (i.e. maxillae, mandibles and teeth) were identified. These elements are usually well represented in fossiliferous deposits due to their resistant nature, rendering them quite useful in assessing number of individuals present (Chomko 1980; Grayson 1984; Lyman 1994a, 1994b). Moreover, mammalian dentition and skulls are often identifiable to generic or species level which produces a better faunal inventory (DeBlase and Martin 1974).

As for all biological identifications, an adequate comparative reference collection is essential when attempting to work with a faunal assemblage (Chomko 1980). For this study, identifications were done at the Canadian Museum of Civilization using reference specimens of extant taxa collections. Taxonomic identifications were done by direct comparison with the reference collections. Identification keys and guides for mammals (Glass 1973; Kurta 1993), for rodents (Chomko 1980) and for insectivores and bats (van Zyll de Jong 1983a, 1983b) were also

useful. Microfaunal specimens were examined using a Wild-Leitz M5 microscope equipped with a drawing tube. Drawings of some specimens were done at a magnification of approximately 25 times. A micrometer permitted measurements useful in identifying certain taxa. Chomko (1980) describes the methodology most often used for the identification of rodent teeth. He also provides identification characters of representative North American rodents along with drawings and photographs of their dentition. The identification of rodent taxa often relies on the physiognomic characters of their dental pattern. The anterior and posterior loops, triangles, salient and re-entrant angles are especially useful identification criteria (figure 7). For bats, dental formula, skull length (SL), mastoid width (MW), least interorbital width (IOW), length of maxillary tooth row (MTL) and length of P^4M^3 (P4M3L) are criteria often used for their identification (figure 8).

4.5.2 Molluscs

Numerous land snails were recovered from the surface and from the cave infill. Specimens collected from section C were submitted to Dr. E. W. Grimm (For the Biosphere, Environmental Consulting Group) for taxonomic identification. A synoptic list was produced from his inventory.

4.5.3 Charcoal

Charcoal fragments collected from section C of the deposit were submitted to Dr. B. Talon (Centre for Research on Cold Environments, Université Laval) for taxonomic identification. The methodology followed was that described by Thinon (1978, 1988, 1992) and by Talon and others (1998). To facilitate the microspical identification, specimens were washed one at a time by ultrasound to rid the silt and clay covering the samples. Fragments equal to or larger than 2 mm were then examined by microscope equipped with Nomarski interferential contrast. Identifications are based on anatomic properties and by comparison with reference material. In total, 345 charcoal fragments from STRATUM I, STRATUM V and STRATUM VII were used for taxonomic identifications.

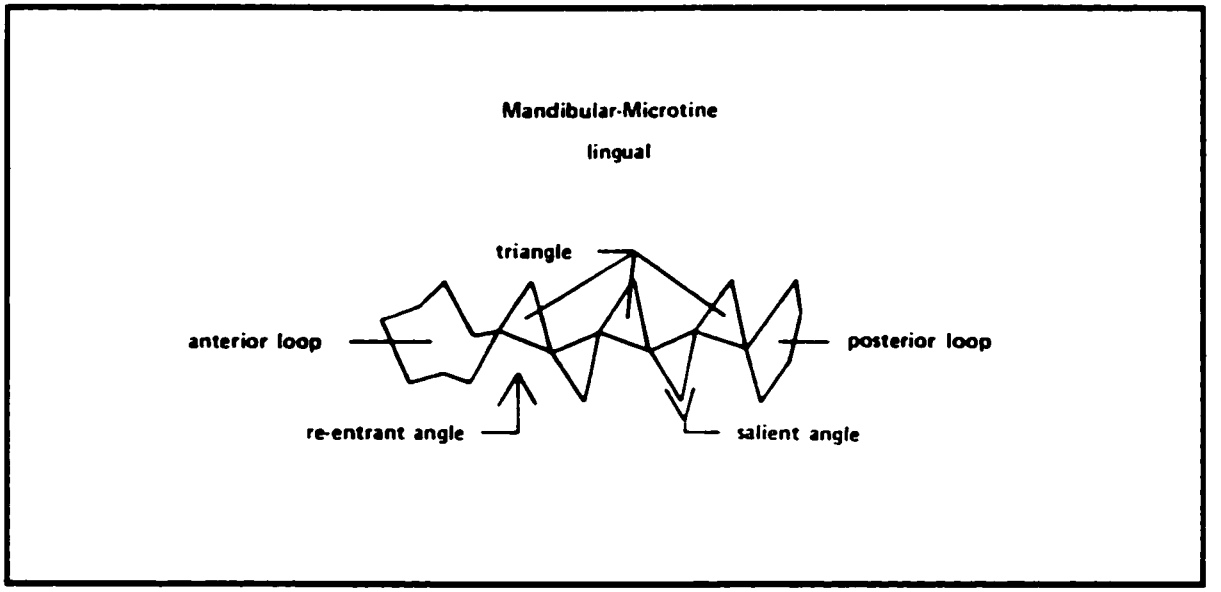


Figure 7: Schematic representation of cusp features on rodent left molars (from Chomko 1980).

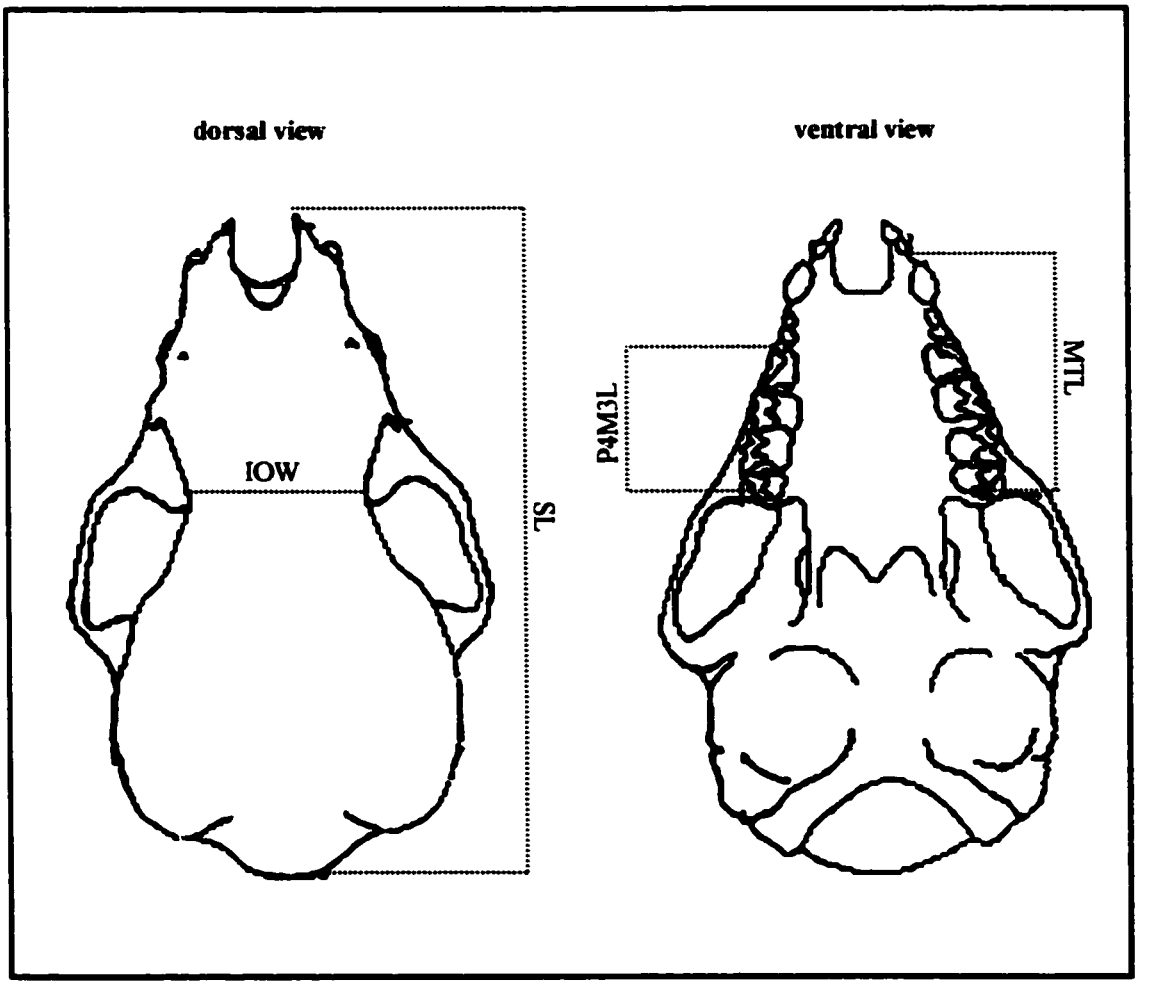


Figure 8: Dorsal and ventral view of bat skull showing useful measurements. SL=skull length; IOW= least interorbital width; P4M3L= length of P^4M^3; MTL= length of maxillary tooth row (modified from van Zyll de Jong 1983b).

4.6 Tabulation

Two commonly used indices were computed to summarize the data: the number of identified specimens (NISP) and the minimum number of individuals (MNI). NISP, an observational unit, is *the number of identified specimens per taxon* [in which] *the taxon may be a subspecies, species, genus, family or higher taxonomic category* (Lyman 1994a:100). Grayson (1984:16) defines a specimen as *a bone or tooth, or fragment thereof.* Cranial specimens are the only ones considered in this study. MNI is a derived unit which expresses *the minimum number of individual animals necessary to account for some analytically specified set of identified faunal specimens* (Lyman 1994a:100) for example, the third right maxillary molar. MNI values were calculated based on identified material for each of the seven 10 cm strata of the lower deposit. Strata sampled at 5 cm intervals were aggregated into 10 cm strata as to obtain a greater number of specimens per stratum. Such level aggregations are valid since only slight differences appear in taxon rank orders between the most divisive approach (NISP) and the aggregated (MNI_{10cm}) approach (see Grayson 1984). A significant Spearman's rank order coefficient (r_s = 0.954) confirms this. Although the use of NISP and MNI as counting units has many weaknesses (Morlan 1983; Grayson 1984), they are by far the most often used measures of faunal abundance.

4.7 Taphonomy

Two fundamental questions that must be answered when analysing fossil assemblages are "Why are these remains here?" and "What agents contributed to their deposition and accumulation?". Assemblages from cave deposits are quite common and the taphonomic processes related to their accumulation have been studied and reviewed (e.g. Andrews 1990; Lyman 1994a, 1994b). The accumulation of skeletal remains inside caves is normally derived from various sources which include the remains of animals frequenting or living in caves, the remains of animals trapped in caves, the remains of predators' prey, and, bones transported to the cave. More often then not, several of these sources simultaneously contribute to the forming fossil fauna of a particular site. Some agents responsible for the accumulation of the fossil

material customarily leave distinguishable physical markings on bones and teeth, such as pitting and fractures, while others do not (Dodson and Wexlar 1979; Korth 1979; Andrews 1990). During the process of their identification, the condition of the cranial material recovered from the Caverne de la Mine deposit was examined. Abnormalities such as breakage, fractures and corrosion were recorded to determine the nature of the accumulation and any post-depositional alterations.

5. RESULTS

5.1 Cave infill analysis

5.1.1 General description

A 70 cm vertical section of the infill was exposed by trenching (figure 9). The deposit accumulated in an horizontal cave passage developed along a vertical fissure in the rock. The triangular-shaped infilled cavity widens from approximately 10 cm at the top of the trench to 110 cm near the bottom. At first sight, the deposit appears to be homogenous. Except for a few angular blocks, it is mostly composed of a fine dark-brown sediment. Organic material such as roots, molluscs and bones can also be seen protruding from the side of the trench. The infill is unstratified apart from a reddish coloured band of sediment located at a depth of 55 to 60 cm, corresponding to STRATUM VI. The band's thickness is about 5 cm across most of the deposit and increases to 12 cm at a protuberance near the right cave wall. This natural stratum was encountered at the same depth throughout sections A, B and C (section D was not excavated to that depth) suggesting that the build-up of the lower infill occurred along a level horizontal plane. The cave floor was reached at approximately 105 cm, after exploratory excavations and probing beyond section D. Numerous angular blocks were encountered at a depth of 85 cm, and a layer of clay, possibly marine, at 90 cm. None of this material has been thoroughly analysed.

5.1.2 Age

Radiocarbon dating from the Caverne de la Mine lower infill was performed on charcoal fragments collected from STRATUM I, STRATUM II, STRATUM IV and STRATUM VII (figure 9). They are as follows: STRATUM I, 5 020 ± 70 B.P. (TO-6854); STRATUM II, 6 020 ± 70 B.P. (TO-6855);

Figure 9: Photograph of the Caverne de la Mine lower infill showing locations of radiocarbon dates.

STRATUM IV, 7 280 ± 60 B.P. (TO-7767); STRATUM VII, 8 230 ± 60 years B.P. (TO-6856). Given the normal chronology of the deposit, internal mixing is not suspected.

5.1.3 Cave infilling rate

The radiocarbon dates provide an idea of the rate at which the fossiliferous matrix infilled the cavity. The 70 cm vertical section of the lower infill was deposited between 5 020 ± 70 and 8 230 ± 60 B.P. Therefore, it took approximately 3 210 years for the sediments to accumulate. This corresponds to an average infilling rate of 1 cm per 46 years or 10 cm per 460 years. These figures are but an overall estimation as the irregular shape of the cave passage would have had an effect on infilling rate. If the deposition rate was constant throughout, the thickness of accumulation for a given period would be less in the lower section where the cave passage is wider.

5.1.4 Colour

The colour of the matrix is quite uniform throughout the seven strata of the lower infill. According to the Munsell Color Charts, the sediment of all the strata is a *very dark brown* colour with the exception of STRATUM VI which is a *dark reddish brown* colour (table 4). STRATUM VI is easily distinguishable *in situ* by its colour (figure 9).

5.1.5 Granulometry

Sufficient granulometric analysis of the lower infill was done to give a fair idea of the make-up of the matrix. The proportion of gravel (>2 mm), sand (2 mm – 0.063 mm) and fines (<0.063 mm) was measured for each of the seven strata (table 4). As the granulometry results reveal, the matrix is primarily comprised of fine sediments, most of which is sand. The granulometric analysis indicates that the relative proportion of sand within each stratum is between 42% and 73% while the relative proportion of gravel is between 2% and 23%, and that of fines varies between 10% and 49%. These results are similar to Carrier's (1989) cave sediment analysis from several sites on the Eardley Escarpment, including the upper infill of Caverne de la

	Colour			Granulometry					
				gravel (>2mm) weight		sand (2-0.063mm) weight		fines (<0.063mm) weight	
	colour code	colour description	initial weight (g)	(g)	%	(g)	%	(g)	%
stratum I	10yr 2/2	Very dark brown	52.15	11.95	22.91	34.43	66.02	5.68	10.89
stratum II	10yr 2/2	Very dark brown	52.23	10.15	19.43	34.85	66.72	6.92	13.25
stratum III	10yr 2/2	Very dark brown	52.19	6.80	13.03	37.79	72.41	7.35	14.08
stratum IV	10yr 2/2	Very dark brown	45.72	10.46	22.88	19.34	42.30	15.81	34.58
stratum V	10yr 2/2	Very dark brown	46.49	6 29	13.53	23.88	51.37	16.02	34.46
stratum VI	5yr 2/2	Dark reddish brown	48.89	4.18	8.55	34.83	71.24	9.78	20.00
stratum VII	10yr 2/2	Very dark brown	42.94	1.10	2.56	20.80	48.44	20.80	48.44

Table 4: Caverne de la Mine lower infill sediment analysis.

Mine. His data showed a consistency in the granulometry of the infills which are characterised by a preponderance of fine sand, as is the case for the lower infill.

The grain size analysis also shows some variability among the seven strata examined (table 4, figure 10). Overall, the sediments become finer with depth as proportions of gravel decrease. The relative proportion of fines augments significantly beneath STRATUM III, mostly at the expense of the sandy fraction. However, a disconformity occurring at STRATUM VI is noticeable where the ratio of sand increases significantly. The distinction is quite apparent as the sediments of this stratum are visibly much coarser than those from the adjacent strata. This disconformity corresponds to the reddish band discussed earlier.

In addition to the differing colour and grain size, the sediments comprising STRATUM VI are also distinguishable from the remaining strata of the lower deposit by their nature. Comparison of STRATUM III with STRATUM VI reveals visible petrographic differences (figure 11). A close examination of the sand fraction of these two strata shows that STRATUM III is rich in mica, gneiss and marble, along with numerous animal remains, with occasional speleothem fragments (figure 11A and figure 11B) whereas STRATUM VI is generally made up of marble and diorite which gives the sediment its distinctive pinkish colour (figure 11C and figure 11D).

5.1.6 Deposit origin

As Carrier's (1989) in-depth analyses reveal, the fossiliferous matrix of the lower infill of Caverne de la Mine is similar to the sediments comprising the upper infill and those of other nearby sites. His granulometric, morphoscopic and petrographic analyses have shown that the bulk of the fine sediments of these infills is comparable to sediments found on the surface. Consequently, he concluded that the cave sediments were mostly derived from the surface and likely correspond to an admixture of till. Rain and meltwater likely permitted surface material to infiltrate through fissures in the rock and be deposited inside the cave. The occurrence of speleothems and angular material within the deposit also suggest that mechanical and chemical

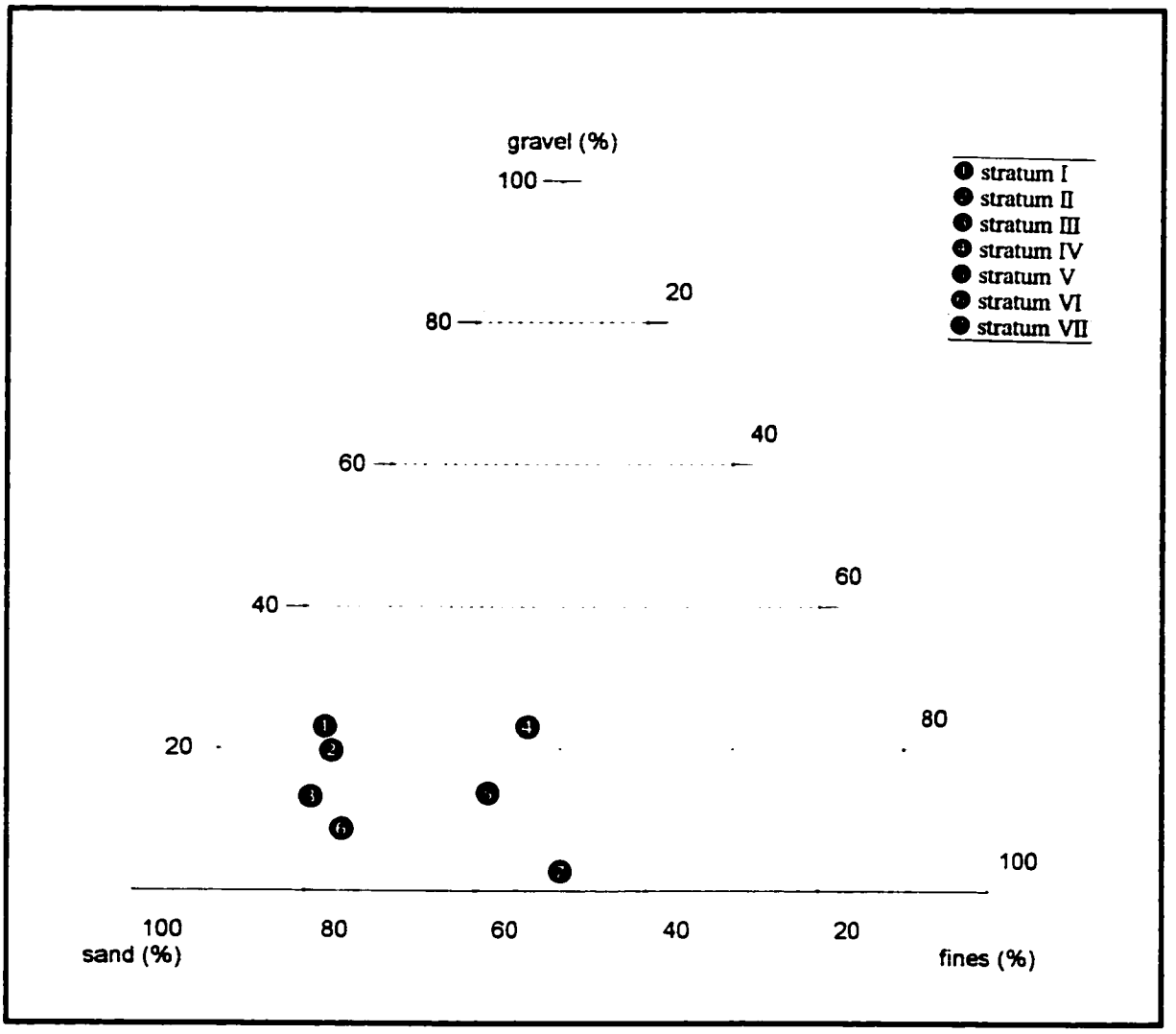


Figure 10: Caverne de la Mine lower infill granulometry.

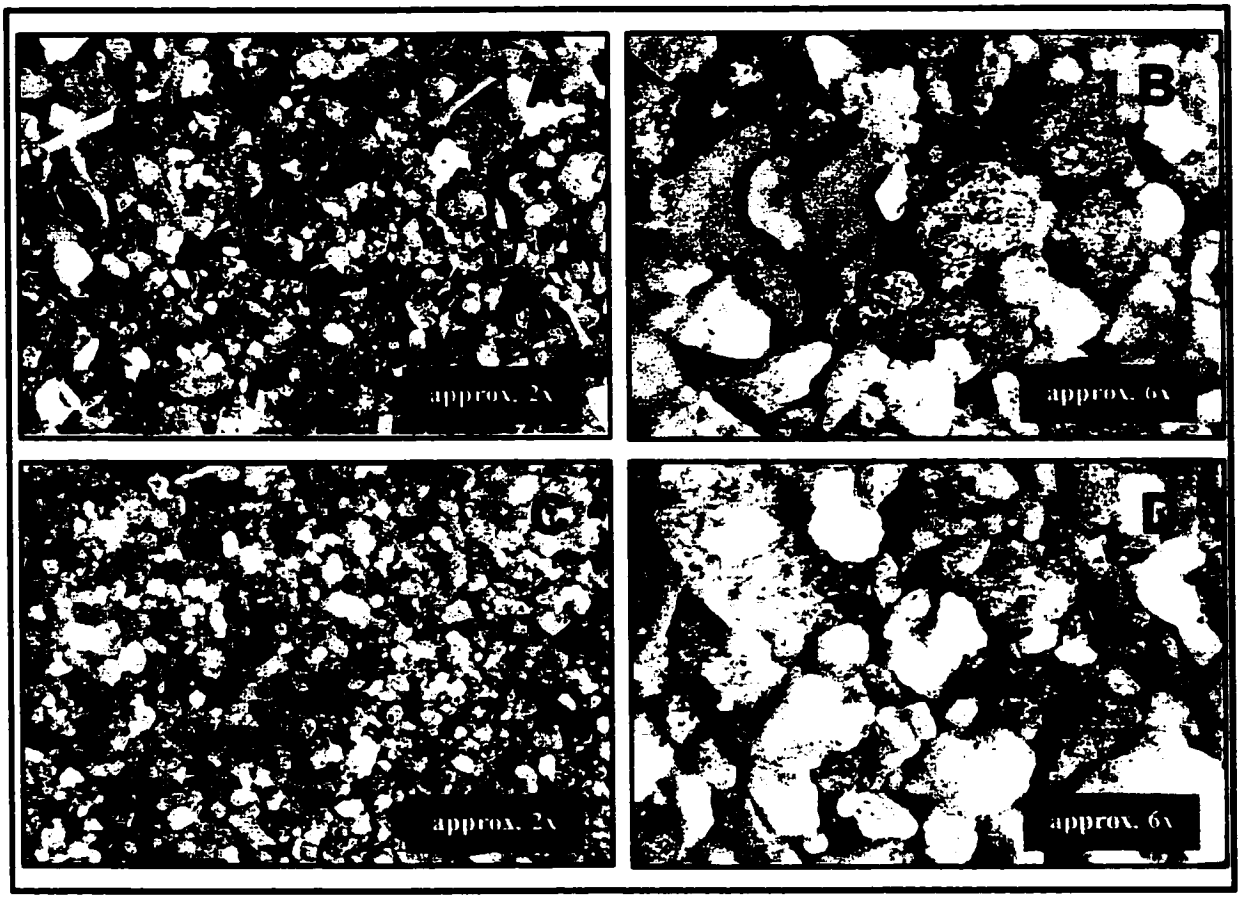


Figure 11: Magnified view of sediments from STRATUM III and STRATUM VI, Caverne de la Mine lower infill.

degradation of the parent rock inside the cave also contributed to the formation of the infill. Undoubtedly, such processes are also responsible for the formation of the lower infill.

As for the occurrence of coarser material at STRATUM VI, it appears that a distinct event took place sometime during the formation of the lower infill. While several hypotheses could be proposed to explain the origin of this material, Carrier (1989) attributed the occurrence of coarse material in three nearby caves to fluvial processes. Likewise, it is imaginable that sometime between about 7 280 and 8 230 years B.P., some material may have been washed inside the cave via one or several of its many openings. Whether this occurred as a result of a widespread climatic event during the early Holocene (e.g. Alley *et al.* 1998; Barber *et al.* 1999) or as a result of a localised event such as an intense rainstorm, it appears that the factors which contributed to the incorporation of the material of STRATUM VI were relatively short-lived.

5.2 Systematic palaeontology

5.2.1 Vertebrates

5.2.1.1 Mammalia

Order: *Insectivora*

Family: *Soricidae*

Sorex fumeus Miller - smoky shrew

Material: D-1-5-26: partial skull.

MNI: 1

Fossil occurrence: STRATUM I.

Distribution: The distribution of the smoky shrew (*Sorex fumeus*) is restricted to eastern North America. Its longitudinal range extends roughly from the north shore of Lake Superior to the coasts of New Brunswick and Nova Scotia while from north to south it extends from the Saguenay River in Quebec to Tennessee and North Carolina.

Habitat: This shrew favours moist environments with abundant leaf litter, logs and mossy rocks such as in the deciduous or mixed woods of the Great Lakes - St. Lawrence and Acadian Forest regions (Banfield 1977; van Zyll de Jong 1983a).

Remarks: This specimen was identified to species using identification criteria provided by van Zyll de Jong (1983a). The nearly complete skull differentiated itself from other Soricini (long-tailed shrews) given several distinctive characteristics such as a broad and relatively flat braincase, infraorbital foramen (opening) situated anterior to the M^1-M^2 interface and wider than long unicuspids. Its superior skull length (>17 mm) distinguishes it from *S. cinereus* which shares similar physical characteristics.

According to Rand (1945) and Sankey (1997), the smoky shrew is uncommon in the Ottawa district. Rand denotes only one record prior to 1945, however Dobbyn (1994) registered its presence in the Ottawa area in his 1900-1969 and 1970-1993 records. The individual recovered from the lower infill remains the lone individual identified thus far from all the excavated material of the Caverne de la Mine infills. The single individual identified confirms the presence of the species in the area at about 5 000 years B.P. Several remains of this shrew (MNI:43) were recovered from all four zones of the Saint-Elzéar Cave talus (LaSalle 1984).

Sorex sp.

Material: A-3-1-46; A-3-1-60; B-1-1-1; B-3-1-121; B-5-1-70; B-5-5-18; C-2-1-32; D-1-1-54; D-1-1-86; D-3-1-156; D-5-1-(92-93): 7 left mandibles, 3 right mandibles, 2 partial skulls.
MNI: 7
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III.

Remarks: These specimens are unmistakably soricids given the distinctive red pigmentation of the teeth caused by the presence of iron in the outer enamel layer (van Zyll de Jong 1983a). Soricini were easily distinguished from Blarini (short-tailed shrews) on the basis of several distinctive cranial properties such as a coronoid process not deflected labially and positioning of

mental foramen located at level or anterior of the protoconid (external cusp) of M_1 (van Zyll de Jong 1983a).

Today, four species of *Sorex* live within the lower Ottawa river valley: *Sorex cinereus*, *S. fumeus*, *S. hoyi* (pygmy shrew) and *S. palustris* (American water shrew). Within the Ottawa district, only *S. cinereus* is considered abundant (present almost everywhere in large numbers) while *S. fumeus* is uncommon (local in distribution), *S. hoyi* is rare (very local) and *S. palustris* is very rare (only a few scattered records). It is very probable that part or all of the unidentified Soricini recovered from the lower infill belong to *S. cinereus*. This species is the most widely distributed of North American soricids as it may be found in a wide variety of habitats.

Apart from the three other taxa, other possibilities could include *S. arcticus* which today inhabits boreal Canada and areas northwest of the Great Lakes. The FAUNMAP Working Group (1994) identified seven late glacial (10 000 - 15 000 years B.P.) fossil sites, extending from northeastern Colorado to central Pennsylvania, where specimens of *S. arcticus* were recovered. Also, ten individuals were recorded the Saint-Elzéar Holocene cave deposit (LaSalle and Guilday 1980; LaSalle 1984). Since the taxon usually has distinct infraorbital canals and postmandibular foramen (van Zyll de Jong 1983a) it was possible to verify if this was the species present in the Caverne de la Mine deposit. None of the specimens exhibited these particular characteristics.

Blarina brevicauda (Say) - short-tailed shrew

Material: A-3-5-9; B-1-1-(2-5); B-3-5-19; B-5-1-(14-15); B-8-1-1; C-1-1-6; C-2-1-4; C-5-1-3; D-1-1-57; D-1-1-87; D-3-1-(150-151); D-3-5-4; D-5-1-94: 10 left mandibles, 5 right mandibles, 3 partial skulls.
MNI: 12
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III, STRATUM IV.

Distribution: This large-sized shrew is found from the Maritimes (except for Newfoundland) to eastern Saskatchewan in Canada and throughout the northern half of central and eastern United States.

Habitat: The short-tailed shrew (*Blarina brevicauda*) thrives in the eastern hardwood forest in areas of high humidity, with deep leaf litter and high humus, yet it may also be found in lower densities in a variety of other environments, ranging from grasslands to bogs (Banfield 1977; van Zyll de Jong 1983a).

Remarks: The short-tailed shrew is easily identified and distinguished from other soricids as noted earlier. The skull of this species is massive with large first and second unicuspids while the third and fourth are smaller. Mandible is stout with mental foramen positioned posterior to protoconid of M_1 (van Zyll de Jong 1983a).

The short-tailed shrew is quite common in the area (Rand 1944; Dobbyn 1994; Sankey 1997) as it is found in a variety of habitats. The species accounts for more than half (63%) of all soricids recovered from the deposit and is present throughout the first four superior strata.

Family: Talpidae

Parascalops breweri (Bachman) - Hairy-tailed Mole

Material: A-1-5-4; B-3-5-38; B-5-5-2; C-2-1-5; D-3-1-149: 1 left mandible, 1 right mandible, 3 skulls.

MNI: 3

Fossil occurrence: STRATUM I, STRATUM II, STRATUM III.

Distribution: Although not greatly abundant, the hairy-tailed mole (*Parascalops breweri*) is found in southern Ontario and Quebec south of a line from the Great Lakes to Quebec City. It is mostly restricted to the New England states, but its southernmost range may reach into the mountains of Virginia and Tennessee.

Habitat: The hairy-tailed mole is restricted to moist sandy soils which facilitates burrowing. Hard and dry soils as well as wet and clay soils are avoided, consequently, soil type may well influence its local distribution (Banfield 1977; van Zyll de Jong 1983a).

Remarks: Molars with well defined W-shaped cusp patterns (dilambdodont) are characteristic of the Talpidae (van Zyll de Jong 1983a). *P. breweri* and *C. cristata* presently occur in the Ottawa area. Both species have distinct-looking cranial and dental morphologies. The small and simple conical teeth of these specimens helped to associate them to *P. breweri*. A third species, the eastern mole (*Scalopus aquaticus*), occurs in southern Ontario, yet its unique dental formula was undetected among the recovered specimens (van Zyll de Jong 1983a).

The hairy-tailed mole is considered a rare species in the Ottawa district with only a handful of confirmed sightings during the last century (Rand 1945; Brunton 1986, 1998). Dobbyn (1994) failed to report a single record for the Ottawa district. The species' apparent scarcity makes the three individuals recovered from the deposit an important find. As with most of the faunal material recovered, the specimens were encountered within the first three superior strata of the deposit. The presence of *P. breweri* specimens in STRATUM III suggests that the species occurred in the area as early as 7 000 years B.P. Its preference for soft soil may have encouraged this species to live in the Gatineau highlands thus avoiding the compact Champlain Sea sediments found at lower elevations. According to Guilday and others (1977), the hairy-tailed mole once had a greater range extension during the Pleistocene. The relative abundance of specimens recovered from the deposit could be attributed to a wider distribution in the past.

Condylura cristata (Linnaeus) - star-nosed mole

Material: A-3-1-65; B-3-1-97; C-5-1-2; D-1-5-(7-8); D-3-1-(146-148): 5 left mandibles. 1 right mandible, 2 skulls.
MNI: 7
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III.

Distribution: The extensive distribution of the star-nosed mole (*Condylura cristata*) covers eastern Canada from central Manitoba to the Atlantic coast. It has the northernmost extension of Canadian moles and reaches treeline in northern Quebec and Labrador. South of the border, the star-nosed mole is found from North Dakota to the northeastern states and the mountains of South Carolina.

Habitat: This mole has a great affinity to moist environments. It commonly lives in areas bordering marshes, meadows and streams where the soil is usually wet (Banfield 1977; van Zyll de Jong 1983a).

Remarks: The species' high skull and slender mandible helped the identification of these specimens.

The star-nosed mole is a fairly common species in the Ottawa district (Rand 1945; Sankey 1997) and its occurrence in the lower infill is no surprise. A single specimen was recovered from the upper infill. Similar to *P. breweri*, it appears that the star-nosed mole was established in the area by at least 7 000 years B.P., based on its occurrence in STRATUM III.

Order: Chiroptera
Family: Vespertilionidae

At least 378 individual bats are represented in the Caverne de la Mine lower infill fossil fauna and their remains appear to be the most common throughout the deposit. The upper infill has also yielded a fair number (Carrier 1989). Unlike the other fossil mammals, bats were found throughout all of the lower infill except for STRATUM VI. Their relatively high numbers suggests that the cave was used by bats as a shelter, undoubtedly for roosting and hibernating. A few live bats were encountered in the lower pit during the excavation operations. Today, eight bat species occur in the Ottawa area.

Complete and partial skulls were easily identified, often to species, using cranial characters as described by van Zyll de Jong (1983b). Bat mandibles were sorted into two categories based on their dental formula. Those having three incisors (I), one canine (C), two premolars (P) and three molars (M) were assigned to *Eptesicus fuscus* based on their large size which is distinctive of the species. Those having three premolars instead of two could not be related to any particular bat species because ten Canadian species share the same mandibular dental formula and similar morphologies. These were noted as *Chiroptera* spp. type A for reference purposes. In all, 603 specimens belonging to this group were collected, corresponding to at least 329 individuals.

A great number of other bat specimens are believed to have been recovered, yet were not identified as bats because of their uncertain identification. Such elements include individual teeth (N=868), fragmented mandibles (N=124) and fragmented maxillae (N=34) which could easily be ascribed to different insectivores.

Myotis septentrionalis (Trouessart) - northern long-eared bat

Material: A-1-5-1; A-2-5-1; A-2-5-7; A-3-5-(13-16); A-4-5-(4-5); B-1-5-(1-2); B-1-5-13; B-1-5-16; B-1-5-18; B-3-5-4; B-3-5-6; B-3-5-8; B-3-5-10; B-3-5-12; B-3-5-42; B-5-5-5; B-5-5-9; C-2-5-1. C-2-5-(12-13); C-3-5-7; C-3-5-(9-10); C-4-5-2; C-6-5-2; D-1-5-9; D-3-5-(6-7); D-3-5-25; D-5-5-8; D-5-5-10; NEP-5-3: 37 complete or partial skulls.
MNI: 37
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III.

Distribution: The long-eared bat (*Myotis septentrionalis*) largely occupies central and eastern North America yet its distribution extends into parts of British Columbia and Northwest Territories. It is well established within the Great Lakes basin.

Habitat: This species is commonly found in woodland environments. It roosts under bark and in tree cavities with a preference for the silver maple. After migration, it hibernates in low densities in caves and abandoned mines (van Zyll de Jong 1983b; Kurta 1995).

Remarks: Only complete or partially complete skulls could be used to identify this species. The remains of *M. septentrionalis* were differentiated from other *Myotis* species by verifying the IOW/MTL ratio (<0.70) and the measurement of P4M3L (<4.2 mm) (van Zyll de Jong 1983b).

Once referred to as Keen's Long-eared bat (*Myotis keenii*), Rand (1945) reported *M. septentrionalis* as not being a very common species in the Ottawa district. This species is known to hibernate in small numbers alongside *M. lucifugus* (little brown bat) and *E. fuscus* in Caverne Laflèche (Rand 1945), less than 20 km east of Caverne de la Mine. *M. septentrionalis* is the second most frequently encountered bat of the lower infill. However, its number is likely to be underestimated considering the many unidentified bat mandibles (*Chiroptera* spp. type A) which could belong to this species. These mandibles were recovered from the same strata as well as the underlying ones (IV, V and VII) making it possible that the bat occurred in the area as early as circa 8 230 years B.P.

Carrier (1989) failed to report the presence of this species among the fossil material he recovered of the upper infill of Caverne de la Mine. In fact, in his report all the bat remains were presumed to belong to *E. fuscus* even though other species evidently occurred in his collection, as one of his pnotographs exhibits (Carrier 1989:56, photo 5.4.F).

Myotis lucifugus (Le Conte) - little brown bat

Material: B-3-5-11; B-5-5-13; D-5-5-1: 3 complete or partial skulls.
MNI: 3
Fossil occurrence: STRATUM II, STRATUM III.

Distribution: *Myotis lucifugus* is a very common bat found over most of Canada from the Pacific to the Atlantic coast and is also widely found throughout the United States. Its northern extension roughly follows the northern limits of the boreal forest.

Habitat: The bat lives in a wide variety of environments yet prefers areas that are wooded and near water. It commonly hibernates and roosts in caves and other natural cavities (Banfield 1977; van Zyll de Jong 1983b).

Remarks: As with *M. septentrionalis*, the identification of this species relied entirely on the measurements of the bat skulls recovered from the deposit. Dental formula, a IOW/MTL ratio superior to 0.7 and a gradually sloping forehead are all characteristic of this species (van Zyll de Jong 1983b).

M. lucifugus is very common in the area today (Rand 1945; Sankey 1997; Dobbyn, 1995). Only three specimens were identified to this species. As with *M. septentrionalis*, the number is likely an underestimate, considering the large number of unidentified bat mandibles that were recovered from the deposit which could be ascribed to this species.

Lasionycteris noctivagans (Le Conte) - silver-haired bat

Material: A-2-5-8: partial skull.
MNI: 1
Fossil occurrence: STRATUM I.

Distribution: The silver-haired bat (*Lasionycteris noctivagans*) is a migratory species which occupies temperate parts of Canada from coast to coast during summer, and is found in nearly all of the United States.

Habitat: This bat inhabits woodlands where it roosts above ground from April to November. Before hibernation, it migrates south of the border where winter temperatures are less harsh (Banfield 1977; van Zyll de Jong 1983b; Kurta 1995).

Remarks: This individual was identified on the basis of its distinctive dental formula and skull morphology.

This migrant species is relatively uncommon in the Ottawa district (Rand 1945). The lone specimen recovered from STRATUM I, is somewhat unusual since this species commonly roosts above ground and hibernates south of the border. What are the circumstances that led this individual to be incorporated to the infill? Several possibilities may be forwarded. For example, the individual may have died at the surface and then was either washed or dragged into the cave, it may have been a preyed upon by predators known to frequent caves such as the great horned owl or even the striped skunk. Although *L. noctivagans* is generally known to hibernate above ground, the individual may also have used the cave for hibernation. This species' northerly hibernating limit reaches only to southern Michigan today (Kurta 1995).

Eptesicus fuscus (Palisot de Beauvois) - big brown bat

Material: A-1-5-2; A-2-5-2;A-2-5-6; A-3-1-26; A-3-1-28; A-3-1-33; A-3-1-38; A-3-5-3; A 4-5-6; A-7-5-1; B-1-5-19; B-1-5-(21-22); B-3-1-35; B-3-1-50· B-3-1-61; B-3-1-77; B-3-1-86; B-3-1-96; B-3-1-(100-101); B-3-1-(105-107); B-3-1-112; B-3-5-23; B-3-5-(39-40); B-5-1-(11-13); B-5-1-21; B-5-1-27; B-5-1-48; B-5-1-48; B-5-1-54; B-5-1-57; B-5-1-59; B-5-1-61; B-5-1-(75-76); B-5-1-101; B-5-5-1; B-5-5-6; B-5-5-10; B-5-5-17; B-7-1-4; B-8-1-3; C-1-1-14; C-1-5-(1-2); C-3-1-13; C-3-1-32; C-3-5-1; C-3-5-18; C-4-1-31; C-4-1-(40-43); C-4-5-5; C-5-1-(29-34); C-5-5-1; C-5-5-6; C-6-1-3; C-8-5-1; D-1-1-11; D-1-1-16; D-1-1-42; D-1-1-63; D-1-1-68; D-1-1-72; D-1-1-76; D-1-1-(84-85); D-1-5-(10-11); D-3-1-26; D-3-1-28; D-3-1-62; D-3-1-(138-145); D-3-5-10; D-3-5-33; D-5-1-62; D-5-1-69; D-5-1-(85-91); D-5-5-(2-5); D-5-5-(16-17); D-5-5-26; D-5-5-30: 19 complete or partial skulls, 7 left maxillae, 10 right maxillae, 42 right mandibles, 37 right mandibles.
MNI: 49
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III, STRATUM IV.

Distribution: The big brown bat is common throughout all of North America. In Canada, it chiefly occupies the southern fringe of the provinces except for Alberta where it extends to the province's northern border.

Habitat: The bat is found within a wide variety of wooded habitats where it usually hunts over meadows and ponds. Trees and rock crevices are used for roosting while caves and mines are used during winter months for hibernation (Banfield 1977; van Zyll de Jong 1983b).

Remarks: This bat species is easily distinguishable from all other Canadian bats by its maxillary dental formula and by its large size.

Remains of *Eptesicus fuscus* were among those most frequently encountered, with 115 specimens recorded and representing at least 49 individuals. Specimens were found in the first four superior strata, with STRATUM II and STRATUM III yielding the most. The species was also recorded from the upper infill (Carrier 1989). *E. fuscus* is commonly found in the Ottawa district today and is known to hibernate in Caverne Laflèche (Rand 1945).

Myotis sp.

Material: A-2-5-(3-4); A-3-5-(1-2); A-3-5-4; A-3-5-6; A-3-5-8; A-3-5-(11-12); A-4-5-(2-3); A-5-5-1; B-1-5-(3-5); B-1-5-7; B-1-5-10; B-1-5-12; B-1-5-15; B-1-5-17; B-1-5-20; B-3-5-(2-3); B-3-5-5; B-3-5-7; B-3-5-9; B-3-5-(14-17); B-3-5-21; B-3-5-(26-27); B-3-5-29; B-3-5-(32-35); B-3-5-37; B-5-5-(3-4); B-5-5-(7-8); B-5-5-12; B-5-5-(14-16); B-5-5-20; B-5-5-22; C-1-5-(3-9); C-2-5-3; C-2-5-7; C-2-5-11; C-3-5-(5-6); C-3-5-(11-13); C-3-5-15; C-3-5-17; C-3-5-(19-20); C-4-5-(3-4); C-4-5-(6-7); C-4-5-(10-13); C-5-5-4; C-5-5-(7-8); C-5-5-10; C-8-5-2; C-9-5-1; C-10-5-1; D-1-5-(12-18); D-1-5-(20-25); D-3-5-5; D-3-5-(8-9); D-3-5-(11-14); D-3-5-18; D-3-5-20; D-3-5-24; D-3-5-26; D-3-5-(29-30); D-5-5-(6-7); D-5-5-9; D-5-5-(12-16); D-5-5-18; D-5-5-20; D-5-5-(22-24); D-5-5-(27-29); D-5-5-32; NEP-5-1: 44 left maxillae, 39 right maxillae, 46 partial skulls.
MNI: 90
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III, STRATUM IV, STRATUM V.

Remarks: All of the above specimens have been assigned to the *Myotis* genus on the basis of the distinct dental formula. Among all Canadian *Myotis* species, only *M. septentrionalis*, *M. lucifugus* and *M. leibii* (small-footed bat) occur in the area today. *M. septentrionalis* and *M. lucifugus* have both been identified from the deposits fossil fauna. *M. leibii* is closely associated with the eastern deciduous forest and its northern limit reaches this area. It is not a very common species, yet was found hibernating at Caverne Laflèche (Rand 1945; van Zyll de Jong 1983b). Consequently, it is possible that this species is present among the *Myotis*

specimens. The species also has the same mandibular dental formula as that of *Chiroptera* spp. type A that have been recovered from the deposit.

Order: Lagomorpha
Family: Leporidae
Leporidae spp.

Material: B-3-4-34; B-8-4-4; C-12-4-(1-2); D-3-4-1: 1 right M^2, 1 right P^2, 3 unidentified teeth.
Fossil occurrence: STRATUM II, STRATUM IV, STRATUM VI.
MNI: 3

Remarks: These specimens consist of individual teeth and are among the few to have been recovered from the bottom portion of the lower infill. These specimens could not be used for generic or specific identification as individual teeth are usually not utilised to differentiate *Lepus* from *Sylvilagus* (Guilday *et al.* 1977).

Among the lagomorphs occurring today in the area are *Lepus americanus* (snowshoe hare) and *Sylvilagus floridanus* (eastern cottontail), the latter reaching the northern limit of its range in the Ottawa Valley. Both species are common in the district. The fossil material recovered from Caverne de la Mine could be of either taxa. Mid-Holocene records of *L. americanus* are known from the nearby Morrisson's Island 6 archaeological site on the Ottawa River (Clermont and Chapdelaine 1998).

Other possibilities include the occurrence of *L. arcticus*. Located south of this arctic species' current range, the St-Elzéar cave deposit produced a record of this taxa (LaSalle and Guilday 1980; LaSalle 1984). Some of the specimens recovered from the lower infill may possibly belong to this species. Although there is a significant size difference between *L. arcticus* and other *Lepus* species, comparisons of the recovered specimens with those from the reference collection did not lead to any specific identifications. Further investigations should be pursued given the depth at which some specimens were found.

Order: Rodentia – Rodents

Family: Sciuridae – Squirrels

Remains of *Tamias striatus* (chipmunk), *Tamiasciurus hudsonicus* (red squirrel) and *Glaucomys sabrinus* (northern flying squirrel) were encountered in the lower infill. All are common sciurids of the Ottawa area today (Rand 1945; Dobbyn 1994). The specimens represent only a few individuals which were recovered between STRATUM I and STRATUM IV. *T. striatus* was present in the upper infill (MNI:1) while *T. hudsonicus* and *G. sabrinus* were not (Carrier 1989). The upper infill also produced remains of *Sciurus carolinensis* (grey squirrel). The three species of squirrels were also found in the fossil fauna of Caverne de St-Elzéar which were concentrated in the older zones of the deposit (LaSalle 1984). *T. striatus* thrives in temperate environments while *T. hudsonicus* and *G. sabrinus* are commonly found in boreal regions.

Tamias striatus (Linnaeus) - eastern chipmunk

Material: B-3-4-53; B-5-4-87; C-3-4-1; C-5-4-7; C-5-5-2; D-3-4-28; D-5-4-1; D-5-4-139: 1 left P^4, 1 left M^3, 1 right M^1, 1 right M^3, 1 left M_3, 1 right M_1, 1 right M_3.
MNI: 2
Fossil occurrence: STRATUM II, STRATUM III.

Distribution: In Canada, the eastern chipmunk is found from southern Manitoba, north to the southern tip of James Bay and east to the Maritimes. Its North American range covers the eastern half of the continent.

Habitat: This animal favours dry hardwood forests offering plenty of refuge in the form of stumps, logs, rocks and banks (Peterson 1966; Banfield 1977).

Remarks: *T. striatus* is easily distinguishable from *Eutamias minimus* (least chipmunk) by its larger size (Chomko 1980).

Tamiasciurus hudsonicus (Erxleben) - red squirrel

Material: C-8-4-2; D-3-4-33; NEP-4-5: 1 left M^1, 2 right M_3.
MNI: 2
Fossil occurrence: STRATUM II, STRATUM IV.

Distribution: The red squirrel is abundant in forested areas throughout all the Canadian provinces and territories with the exception of Newfoundland. In the United States, its distribution extends south of the Great Lakes basin, into the northern portion of the Appalachians and into the Western Rockies.

Habitat: The squirrel lives in a variety of environments yet thrives in the boreal coniferous forest. In mixed and deciduous forests, it prefers cool areas where evergreens are found nearby (Banfield 1977; Kurta 1995).

Remarks: The occurrence of *T. hudsonicus* in STRATUM IV attests the species' presence in the area by 7 280 ± 60 B.P.

Glaucomys* cf. *sabrinus (Shaw) - northern flying squirrel

Material: C-6-4-2; D-1-4-10: 1 left P^4, 1 right M_2.
MNI: 2
Fossil occurrence: STRATUM I, STRATUM IV.

Distribution: The northern flying squirrel is widespread throughout Canada from the Pacific to the Atlantic coast. Its southern extension in the United States reaches well into the Appalachians in the east as well as in the Rockies in the west.

Habitat: The nocturnal squirrel favours a mixed forest where evergreens are abundant as in the boreal forest. It may also be found in pure stands of evergreen and deciduous forests. It may den in tree and branch cavities or in an outside nest perched close to the trunk of a coniferous tree (Banfield 1974; Kurta 1995).

Remarks: *G. sabrinus* is distinguishable from other sciurids by the distinct form of the molars (Chomko 1980). Its more robust-looking molars are used to distinguish it from *G. volans* (southern flying squirrel), its southern counterpart (Banfield 1977). Occurring with *T. hudsonicus* in STRATUM IV, this squirrel appears to also have been established in the area by 7 280 ± 60 B.P.

Famlily: Cricetidae

Peromyscus sp. - Deer Mice

[either ***P.*** cf. ***maniculatus*** (Wagner) - deer mouse

and/or ***P.*** cf. ***leucopus*** (Rafinesque) - white-footed mouse]

Material: A-7-4-2; B-1-1-56; B-1-1-59; B-1-4-(2-3); B-3-1-1; B-3-1-(7-8); B-3-4-14; B-3-4-(35-38); B-3-4-(141-144); B-5-1-1; B-5-1-(8-9); B-5-4-76; B-5-4-89; C-2-1-1; C-2-4-6; C-2-5-(9-10); C-3-4-1; C-3-4-(3-4); C-3-4-10; C-3-5-2; C-3-5-6; C-4-4-(6-7); C-5-4-6; C-6-4-1; C-9-4-(3-5); D-1-1-3; D-1-4-8; D-1-4-17; D-1-4-24; D-1-5-3; D-3-1-1; D-3-1-(7-13); D-3-4-(26-27); D-3-4-(29-31); D-3-4-(34-37); D-3-5-15; D-3-5-32; D-5-1-1; D-5-1-4; D-5-1-6; D-5-1-(8-9); D-5-5-11; NEP-1-1: 10 left mandibles, 11 right mandibles, 5 left maxillae, 4 right maxillae, 4 left M^1, 3 left M^2, 8 right M^1, 4 right M^2, 3 right M^3, 6 left M_1, 2 left M_2, 1 left M_3, 10 right M_1, 3 right M_2, 1 right M_3.

MNI: 26

Fossil occurrence: STRATUM I, STRATUM II, STRATUM III, STRATUM IV, STRATUM V.

Remarks: These specimens are not identified to species since "*P. maniculatus* [deer mouse] can not be distinguished from *P. leucopus* [white-footed mouse] on the basis of dentition" (Chomko 1980:76), nonetheless, they unquestionably belong to the genus *Peromyscus*. Fossil material belonging to this genus is occasionally identified to species based on dental characters, as some species exhibit variations within local demes (e.g. Guilday *et al.* 1977; Semken 1980). However, taxonomic identification is most often based upon modern species distribution and abundance. *P. maniculatus* and *P. leucopus* co-occur in the Ottawa area and are considered to be fairly common species (Rand 1945). Considering this, specimens recovered from the lower infill were not identified beyond generic level. Carrier (1989) catalogued all *Peromyscus* material from the upper infill of the Caverne de la Mine deposit as *P. leucopus*. This species becomes scarce north of Gatineau Park where it reaches its northern limit, whereas *P. maniculatus* is generally

abundant through most of North America. It is most probable that the majority of the *Peromyscus* specimens identified in both the upper and lower infills is that of *P. maniculatus*.

Cranial specimens of *Peromyscus* sp. represent at least 26 individuals accounting for 30.6% of all rodents from the lower infill. Specimens of this genus were collected from STRATUM I through STRATUM V and were most abundant in STRATUM II and STRATUM III, with nine individuals recorded in each level. Members of the genus are today abundant throughout their territory. They are also plentiful in the fossil record which suggests that they were abundant in the past as well (FAUNMAP Working Group 1994). Remains were recovered from numerous late Pleistocene and early Holocene sites in northeastern USA as well as from many Holocene deposits in Ontario. A significant quantity of *Peromyscus* remains would have been expected from the lower infill. It is unfortunate that these are not better identified as both species are excellent paleoenvironmental indicators depicting rather different environments (Graham and Semken 1987).

Family: Arvicolidae

Clethrionomys* cf. *gapperi (Vigors) - southern red-backed vole

Material: A-3-4-(38-39); A-4-4-1; B-1-4-1; B-1-4-5; B-1-4-9; B-1-4-13; B-1-4-18; B-1-4-23; B-3-4-31; B-3-4-43; B-3-4-(46-52); B-3-4-54; B-3-4-221; B-3-1-2; B-3-1-(4-6); B-5-4-(80-84); B-5-4-86; B-8-4-3; C-1-4-1; C-1-4-7; C-2-4-3; C-2-4-5; C-2-1-2; C-3-4-2; C-3-4-(6-9); C-3-5-3; C-4-4-3; C-5-4-2; C-5-4-5; C-9-1-1; C-9-4-1; D-1-1-4; D-1-1-7; D-1-4-1; D-1-4-(4-5); D-1-4-9; D-1-4-(14-15); D-1-4-22; D-1-5-(1-2); D-3-1-3; D-3-1-5; D-3-4-3; D-3-4-11; D-3-4-15; D-3-4-(18-20); D-3-4-(22-23); D-3-4-25; D-5-1-7; D-5-4-12; D-5-4-18; D-5-4-(20-21); NEP-1-2; NEP-1-10; NEP-4-2: 5 left mandibles, 5 right mandibles, 1 left maxilla, 3 partial skulls 6 left M^1, 5 left M^2, 2 left M^3, 5 right M^1, 7 right M^2, 3 right M^3, 9 left M_1, 2 left M_2, 4 left M_3, 10 right M_1, 2 right M_2, 5 right M_3.

MNI: 21

Fossil occurrence: STRATUM I, STRATUM II, STRATUM III, STRATUM IV and STRATUM V.

Distribution: The North American distribution of the southern red-backed vole is mostly restricted to Canada where it is found throughout most parts of the country.

Habitat: This vole prefers coniferous forests of boreal North America but may also be found in hardwood forests in cool areas where stumps and logs are abundant (Banfield 1977; Kurta 1995).

Remarks: The two Canadian members of the *Clethrionomys* genus, *C. rutilus* (northern red-backed vole) and *C. gapperi*, share similar dental morphologies. Their molars are nearly indistinguishable from one another. Their remains are generally identified to species on the basis of their modern distributions. *C. rutilus* is now confined to the Canada's northern territories while *C. gapperi* is found throughout North America's boreal region. No records of *C. rutilus* are reported from south of the Wisconsinan glacial limits (FAUNMAP Working Group 1994) suggesting that the species likely inhabited the Beringian refugium during the Wisconsinan glaciation. There are many Pleistocene and Holocene records of *C. gapperi* in eastern North America (FAUNMAP Working Group 1994) and the vole today occurs in the area. The specimens recovered from the infill are therefore probably this species. *C. gapperi* is commonly used as an indicator species representing boreal conditions.

Clethrionomys gapperi is a common species in the lower infill accounting for a quarter (24.7%) of the rodents from the lower infill. It is the most prominent taxon of the Arvicolidae family. Remains of the species were recovered from STRATUM I through STRATUM V with a higher number of individuals occurring in the first two superior strata. In significant contrast, the vole was entirely absent from the upper infill. The difference may be attributed to a range adjustment. In fact, the vole's range actually reaches its southern limit in the area *becoming rarer and more local in the southern part* [of the Ottawa] *area* (Rand 1945:125). It is conceivable that its range has extended further south in the past, since it migrated north during the Holocene from its ice age refuge in northern USA. The species would have been more abundant around the fossil site at that time, in turn increasing the probability of entrapment in the cave. Range adjustment among mammalian populations was not uncommon during the Holocene (Handley 1971; Semken 1983).

Synaptomys cooperi Baird - southern bog lemming

Material: A-5-4-1; B-3-1-(3-4); B-3-4-42; C-3-1-2; C-3-4-42; C-4-4-1; D-3-1-4; D-3-1-6 D-5-4-10: 3 left mandibles, 2 right mandibles, 1 left M_1, 2 right M_1, 2 right M_2.
MNI: 6
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III.

Distribution: The southern bog lemming (*Synaptomys cooperi*) is found in east-central North America from the Great Lakes basin to the Maritimes

Habitat: As the vole's name suggests, this vole prefers wet areas where *Sphagnum* is abundant but may also be found in a variety of other forested habitats (Banfield 1977; Kurta 1995).

Remarks: This genus is easily recognisable by its dentition. The maxillary incisors have a pronounced groove lateral of the midline and the cheek teeth have excessively deep re-entrant angles with cementum in the folds (Chomko 1980). The molars of *S. cooperi* and those of *S. borealis* (northern bog lemming) share many similarities yet the mandibular molars are distinguishable from one another. The inferior molars of *S. cooperi* exhibit closed triangles on the buccal sides whereas those of *S. borealis* lack any developed outer triangles. The lower molars of *S. cooperi* also have well developed buccal re-entrant angles while those of *S. borealis* do not (Chomko 1980). Mandibles with molars and individual lower molars recovered from the lower infill belonging the genus *Synaptomys* could be identified to species using these criteria.

S. cooperi has not been reported within the Ottawa district (Rand 1945, Dobbyn 1994) yet the species presumably occurs at very low densities locally in the area as it does throughout its range (Rand 1945; Sankey 1997). At least six individuals were recovered from STRATUM II and STRATUM III making it a relatively significant find. Carrier (1989) did not report the presence of the species in the upper infill.

***Synaptomys* sp.**

Material: B-5-4-78; C-4-4-4; D-1-4-2; D-1-4-11; D-1-4-18; D-1-4-(20-21); D-1-5-5; D-3-4-13; D-3-4-56; D-3-5-2; D-5-4-85: 2 partial skulls, 1 left M^1, 1 left M^2, 3 left M^3, 2 right M^1, 1 right M^2, 2 right M^3.

Fossil occurrence: STRATUM I, STRATUM II, STRATUM III.

Remarks: Skulls and maxillary molars of both members of the genus *Synaptomys* are indistinguishable from one another, therefore, all were assigned to *Synaptomys* sp. Most specimens likely belong to *S. cooperi* since all mandibular molars of the genus are of this species. Moreover, *S. borealis* does not occur presently in the Ottawa valley. Its closest occurrence is near James Bay.

Dicrostonyx hudsonius (Pallas) - Ungava collared lemming

Material: B-8-4-1: left M^1.

MNI: 1

Fossil occurrence: STRATUM IV.

Distribution: The distribution the Ungava collared lemming (*Dicrostonyx hudsonius*) is restricted to the Ungava and Labrador peninsulas.

Habitat: The lemming inhabits dry and rocky terrain during summer and overwinters in vegetated regions capable of sustaining a significant snow cover which protects the species against the cold (Banfield 1977).

Remarks: Two species of the genus *Dicrostonyx*, *D. torquatus* (collared lemming) and *D. hudsonius*, occur in North America today. In a fossil fauna where *Dicrostonyx* is present, molars are commonly used to distinguish the species from one another. The first and secondary maxillary molars of *D. torquatus* exhibit vestigial posterior, internal enamel folds whereas those of *D. hudsonius* do not (Banfield 1977) and the posterior alternating triangles of *D. torquatus* have a concave shape, while those of *D. hudsonius* take a convex form (Chomko 1980). The tooth

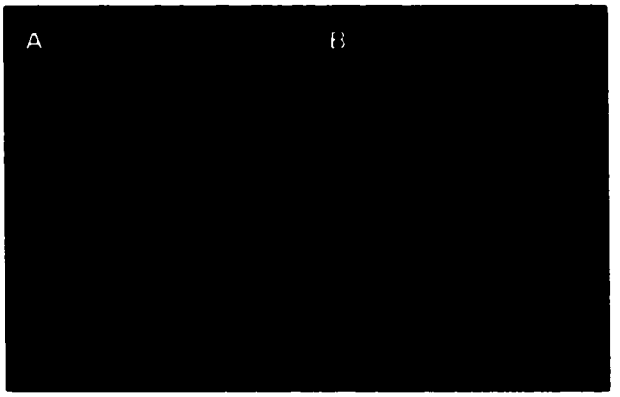


Figure 12: Photograph (A) and drawing (B) showing the occlusal surface of a left maxillary molar (B-8-4-1) of *Dicrostonyx hudsonius* recovered from the Caverne de la Mine lower infill.

recovered from the Caverne de la Mine deposit has the characteristic dental features of *D. hudsonius* (figure 12), and therefore, was identified as a left first maxillary molar of that species.

D. hudsonius does not occur locally today and also has not done so in the recent past according to Rand (1945) and Dobbyn (1994). The species was also not reported from the upper infill. The Caverne de la Mine record is considered a remarkable find and will be analysed and discussed more extensively in further sections of the study.

Ondatra zibethicus (Linnaeus) - muskrat

Material: A-3-4-36; B-1-4-11; B-3-4-33; B-5-5-27; B-5-4-88: 1 right maxilla, 1 left M^2, 1 left M^3, 1 right M^2,1 left M_3.
MNI: 3
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III.

Distribution: The muskrat (*Ondatra zibethicus*) is widely distributed in North America from Alaska to the Gulf of Mexico with the exception of the arid Southwest and the arctic tundra.

Habitat: This semi-aquatic vole is always found close to water bodies. It lives near slow-moving streams, lakes, ponds and marshes where it feeds on aquatic vegetation (Banfield 1977; Kurta 1995).

Remarks: The recovered specimens consist of isolated teeth and a right maxilla holding a third upper molar. The species' dentition is distinctive.

The muskrat is fairly common around Ottawa wetlands today (Rand 1945) and may well also have been in the past. The occurrence of these specimens in the deposit does not necessarily suggest water in close proximity to the cave in the past as the muskrat is at times an extensive wanderer (Guilday *et al.* 1964).

Microtus* cf. *pinetorum (LeConte) - woodland vole

Material: A-3-4-1; A-3-4-47; A-5-4-(2-3); B-1-4-12; B-1-4-14; B-1-4-16; B-1-4-(22-23); B-1-1-62; B-1-4-7; C-2-4-(1-2); C-4-1-1; D-1-1-2; D-1-1-5; D-3-1-(1-2); D-3-4-8; D-3-4-12; D-3-4-(53-55); D-3-4-57; D-3-5-1; D-3-5-3; D-5-1-5: 3 left mandibles, 4 right mandibles, 2 partial skulls, 2 left M^1, 1 left M^2, 1 left M^3, 1 right M^1, 3 right M^3, 3 left M_1, 1 left M_2, 3 right M_1, 2 right M_2, 1 rignt M_3.
MNI: 9
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III.

Distribution: The woodland vole (*Microtus pinetorum*) is found in eastern North America generally east of the Mississippi valley and south of the Great Lakes. In Canada, the species may be found in a few isolated areas in southwestern Ontario and the Eastern Townships of Quebec.

Habitat: This species lives in a variety of habitats, most of them wooded. It is most often found in hardwood forests where beech, maple and oak abound. Habitats with well-drained sandy soils are preferred by this semi-fossorial vole (Banfield 1977; Kurta 1995).

Remarks: Although distinct from other vole species, the molar enamel patterns of *M. pinetorum* and *M. ochrogaster* (prairie vole) are essentially identical. Because of this, the identification of fossil material belonging to these species is most often based on geographic proximity of the modern counterpart (Graham and Semken 1987). Neither species occurs at the fossil site today. *M. pinetorum* today inhabits parts of southern Ontario and Quebec's Eastern Townships whereas *M. ochrogaster* occurs in the Great Plains. The specimens of the Caverne de la Mine deposit were consequently identified as *Microtus* cf. *pinetorum*.

Among the examined material belonging to this species, two specimens, A-5-4-2 and D-3-4-8, display unusual molar occlusal patterns. The two specimens, both left first lower molars (M_1), exhibit confluent first and second triangles (T1-2) in addition of confluent T4-5, which is distinctive of the subgenera *Pedomys* and *Pitymys* (figure 13). Despite their anomalous morphology, both specimens were identified as *Microtus* cf. *pinetorum*. Since confluence of T4-5 is normal for this species, it may be reasonable to suppose that the anomalous confluence of

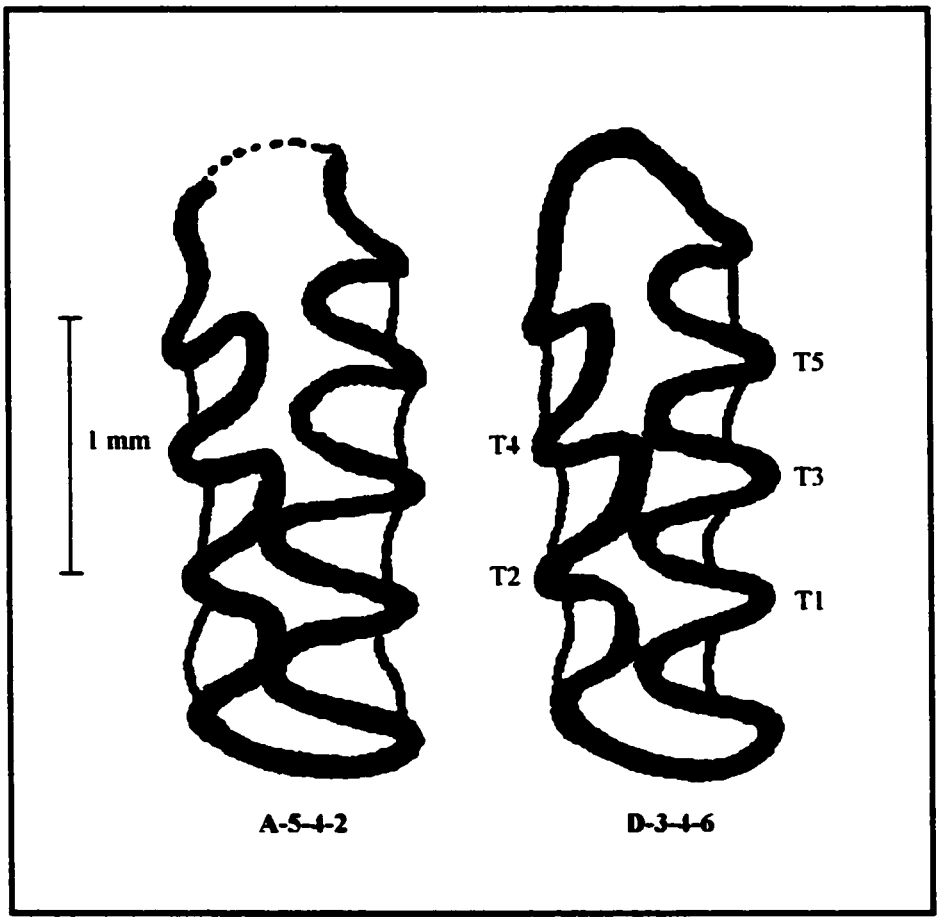


Figure 13: Drawing of two left first mandibular molars with unusual cusp patterns thought to belong to *Microtus pinetorum*.

T1-2 would appear more often in this species that in other species belonging to the genus *Microtus*, whose mandibular first molars usually exhibit tightly closed triangles (R. E. Morlan, personal communication, 1999). This morphotype is unknown from other fossil fauna containing *M. pinetorum* yet the investigation of the fossil material from Duhme Cave in eastern Iowa revealed several specimens displaying a bifurcation of T4 into two smaller salient angles on the first lower molars (Jans 1993).

Remains of *M. pinetorum* in the Caverne de la Mine deposit suggest that the species' range experienced significant adjustments during the Holocene, as this vole does not live in eastern Ontario and western Quebec today. Twenty-seven specimens corresponding to at least nine individuals of this species were recovered from the lower deposit. It is the third most frequent rodent after *Peromyscus* sp. and *C. gapperi*. Despite their relative abundance, remains of

M. pinetorum were limited to the top three strata with STRATUM I yielding the most individuals. Accordingly, the substantial number of individuals recovered from the infill suggests that the species was likely well established within the local fauna. The upper infill does not have any records of this species.

Microtus pennsylvanicus (Ord) - meadow vole

Material: A-10-4-1; B-3-4-40; B-3-4-45; B-7-4-1; B-8-4-2; C-5-4-1; C-7-4-1; D-1-1-6; D-1-4-(6-7); D-1-4-13; D-1-4-19; D-1-4-23; D-1-5-4; D-3-4-4; D-3-4-5; D-5-1-3; NEP-4-1: 2 left mandibles, 1 partial skull, 3 left M^1, 2 left M^2, 3 left M^3, 1 right M^1, 3 right M^2, 1 right M^3, 2 right M_1.
MNI: 8
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III, STRATUM IV, STRATUM V.

Distribution: The meadow vole (*Microtus pennsylvanicus*) is commonly found throughout North America from Georgia and New Mexico to Alaska and Canada's northern territories. It has one of the broadest distributions of North American small mammals.

Habitat: This vole favours moist areas such as meadows and fields benefiting from the cover offered by the tall grasses. It also frequents bogs and marshes and occasionally sparsely forested areas (Banfield 1977; Kurta 1995).

Remarks: The specimens were distinguished from others species of the genus *Microtus* according to morphological characteristics. The M^2 exhibits a fifth rounded posterior loop diagnostic of the species.

M. pennsylvanicus is a common species in the Ottawa area today (Rand 1945; Dobbyn 1994) and seems to have also been in the past. Nineteen specimens were identified to this species in the lower deposit accounting for at least eight individuals. The specimens were recovered from STRATUM I through STRATUM V which correspond to an age of about 5 020 to over 7 280 years B.P. Remains of this species (MNI:1) were also found in the upper infill (Carrier 1989). Not many other fossil records which date to the middle Holocene or earlier are known from eastern Canada. Among these is the Scarborough Bluffs deposit (Churcher and Karrow 1963) and the St-Elzéar Cave deposit (Lasalle and Guilday 1980; Lasalle 1984). Contrarily, numerous fossil records of this species are known from unglaciated eastern North America dating from Pleistocene to recent times (FAUNMAP Working Group 1994). The central Appalachians records have shown that despite the meadow vole's boreal affinities, it was not directly affected by climatic change from boreal late Pleistocene to modern temperate conditions (Guilday *et al.* 1977).

Microtus* cf. *chrotorrhinus (Miller) - rock vole

Material: C-3-4-5; C-9-4-2: 1 left M_1, 1 right M_1.
MNI: 2
Fossil occurrence: STRATUM II, STRATUM V.

Distribution: The rock vole (*Microtus chrotorrhinus*) occurs mainly in eastern Canada. Its range extends from the northern shores of Lake Superior to southern Labrador. South of the border, the species inhabits the Appalachians as far south as Tennessee.

Habitat: As its name suggests, the rock vole dwells in rocky areas such as talus slopes and rocky outcrops that are moist and partly forested (Banfield 1977; Kurta 1995).

Remarks: Molars of *M. chrotorrhinus* closely resemble those of *M. pennsylvanicus* as they both display similar occlusal patterns and are also of comparable size. Two M_1 were tentatively identified as *M.* cf. *chrotorrhinus* upon comparison with the reference material. These two molars exhibited tightly closed triangles and a diversion of the anterior loop toward the labial side which could be attributed to *M. chrotorrhinus* (R. E. Morlan, personal communication, 1999). Unfortunately, none of the vole's distinctive M^3 were found among the fossil material.

The occurrence of *M. chrotorrhinus* in the Ottawa area today is uncertain. While some have included the region within the species' geographic distribution (i.e. Hall and Kelson 1959; Kurta 1995) others have not (i.e. Banfield 1977; Dobbyn 1994). The vole was excluded from both Rand (1945) and Sankey's (1994) Ottawa district mammal checklists. According to the Atlas of the Mammals of Ontario (Dobbyn 1994), the closest known occurrence is in Algonquin Provincial Park, west of the fossil site. The species' presence is sparse within its current range and, because of this, may well have gone unnoticed in the area. The Eardley Escarpment would provide an adequate habitat for this vole with its rock outcrops and talus slopes.

If the identifications are reliable, it appears that the rock vole occurred in the area sometime in the vicinity of 6 020 and 7 280 years B.P. None were found in the upper infill.

Microtus sp.

Material: B-1-4-4; B-1-4-6; B-1-4-10; B-1-4-15; B-1-4-17; B-1-4-(19-20); B-3-4-44; B-5-4-79; C-2-4-4; C-4-4-2; C-5-4-(3-4); C-9-4-6; D-3-4-(6-7); D-3-4-(9-10); D-3-4-14; D-3-4-16; D-5-1-2; D-5-4-2; D-5-4-14:1 left mandible, 1 left M^3, 5 right M^1, 4 right M^2, 1 left M_1, 3 left M_2, 1 left M_3, 1 right M_1, 4 right M_2, 2 right M_3.
MNI: 7
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III, STRATUM V.

Remarks: These specimens exhibit typical dental characteristics of the genus *Microtus*, such as rootless molars and re-entrant angles of approximately equal depth (Chomko 1980), yet could not be identified beyond generic level. Members of the genus presently occurring in the Ottawa area are few and include *M. pennsylvanicus* and possibly *M. chrotorrhinus*.

Family: Erethizontidae

Erethizon dorsatum (Linnaeus) - porcupine

Material: B-1-4-25; C-3-4-26; D-3-4-34; D-3-4-67; D-3-5-35; D-5-4-34: teeth, 1 partial maxilla, 1 right M^3, 2 right P_1, 1 right M_2.
MNI: 3
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III.

Distribution: The porcupine (*Erethizon dorsatum*) is found in most parts of North America.

Habitat: This large rodent prefers habitats which include stands of pine and hemlock but may be found in both deciduous and coniferous woodlands (Banfield 1977; Kurta 1995).

Remarks: The species' teeth are easily distinguished from other rodents. The large molariform teeth have one persistent internal fold and one persistent external fold (Chomko 1950).

The porcupine is a common mammal in the Ottawa area today (Sankey 1997) and its presence in the deposit is no surprise. However, the relatively small number of remains collected (NISP:5) is somewhat surprising since porcupines are known to frequent cave entrances and would be prone to be incorporated into the fossil fauna because of this. The top three strata

yielded remains of the species which indicate that the species has been present in the area since at least 6 020 ± 70 B.P. Remains of the porcupine were also found in the upper infill (Carrier 1989).

Order: Carnivora

Family: Canidae

Canis* cf. *latrans Say - coyote

Material: B-3-4-14; C-3-4-(19-20); C-4-4-18; D-1-4-43; D-1-4-(46-47); D-5-4-30: 1 left I^3, 1 left M^2, 1 right M^1, 1 left P_2, 1 left M_1, 1 right C_1, 1 right P_4, 1 right M_1.

MNI: 3

Fossil occurrence: STRATUM I, STRATUM II, STRATUM III.

Distribution: The distribution of the coyote (*Canis latrans*) covers most of North America with the exception of eastern portions of northern Canada.

Habitat: The coyote is found living in a variety of habitats from alpine tundra to short-grass steppes which explains its continental distribution (Banfield 1977; Kurta 1995).

Remarks: Comparison of these specimens with modern reference specimens of the *Canidae* family revealed that the teeth are proportional to those of *Canis latrans*. They are clearly smaller than those of *Canis lupus* (wolf) and larger than those of the different fox species. The teeth may be comparable to certain subspecies of *Canis domesticus* (dogs) yet the specimens were identified as *Canis* cf. *latrans* since dogs would not be expected in an early Holocene deposit in this region. The recovered specimens were all found in the first three superior strata of the lower infill.

The coyote is considered to be an uncommon species in the Ottawa district (Rand 1945; Sankey 1997). It is believed that the species did not occur in eastern Ontario and Quebec prior to 1900 (Peterson 1966; Dobbyn 1994) however the Caverne de la Mine record suggests that

C. latrans was present in the area between 5 020 ± 70 and 7 280 ± 60 B.P. Remains of this species were not recovered from the upper infill.

Family: *Procyonidae*

Procyon lotor (Linnaeus) - raccoon

Material: A-1-1-10; A-1-4-1; A-1-4-4; A-2-4-(2-4); A-3-4-13; A-3-4-(21-22); A-3-4-2; A-3-4-12; A-3-1-59; A-3-4-2; A-3-4-(5-10); A-3-4-(14-15); A-3-4-(18-20); A-3-4-23; A-4-1-1; A-4-4-6; A-5-4-11; B-1-4-24; B-1-4-(26-28); B-1-4-30; B-3-4-(6-14); B-3-1-120; B-3-4-2; B-3-4-(4-5); B-3-4-15; B-3-4-(18-21); B-3-4-24; B-3-4-29; B-3-5-1: B-5-5-(25-26); B-5-4-(124-128); B-5-4-119; B-5-4-(121-123); C-1-4-41; C-2-4-43; C-2-4-44; C-3-1-41; C-3-4-(21-25); C-3-4-28; C-3-4-31; C-3-4-(36-37); C-4-4-17; C-4-4-(20-21); C-4-4-23; C-4-4-25; C-4-4-17; C-4-5-1; C-1-4-(37-38); C-5-4-14; D-1-1-88; D-1-4-44; D-1-4-(48-53); D-1-1-91; D-1-4-31; D-1-4-(33-34); D-1-4-(36-37); D-1-4-(40-42); D-1-4-44; D-3-4-(58-62); D-3-4-66; D-3-4-(68-70); D-3-5-34; D-3-1-(152-153); D-3-4-63; D-3-4-(71-72); D-3-4-74; D-3-4-(76-77); D-5-4-(31-33);D-5-4-(36-37); D-5-4-39; NEP-4-6: 5 left mandibles, 3 right mandibles, 4 left maxillae, 3 right maxillae, 4 left I^3, 3 left C^1, 3 left P^1, 1 left P^2, 3 left P^3, 6 left M^1, 1 left M^2, 4 left M^3, 2 right M^1, 3 right C^1, 1 right P^1, 6 right P^2, 1 right P^3, 7 right M^1, 2 right M^2, 5 right M^3, 6 left C_1, 5 left P_1, 2 left P_2, 7 left P_3, 2 left M_1, 6 left M_2, 4 left M_3, 5 right C_1, 2 right P_1, 6 right P_2, 4 right P_3, 4 right M_1, 5 right M_2, 4 right M_3.
MNI: 12
Fossil occurrence: STRATUM I, STRATUM II, STRATUM III.

Distribution: In North America, the raccoon is found from southern Canada to Mexico.

Habitat: The raccoon dwells in forested areas generally near water bodies. In the Great Lakes basin, the raccoon is more abundant in Hardwood forests (Banfield 1977; Kurta1995).

Remarks: Apart from individual incisors which could not be specifically identified (with the exception of I^3), the specimens belonging to *P. lotor* were easily identifiable when compared with reference material.

Amounting to 132 specimens, *P. lotor* has the highest NISP value of the lower infill fossil assemblage. This is likely due to the species' greater dental formula (40 teeth as opposed to 16

for small rodents) and to the larger teeth size, which increases their chance of recovery. The species is the fifth most abundant in terms of MNI (along with *B. brevicauda*) with at least 12 individuals represented in the fossil fauna. As with the other larger taxa, the specimens were only collected from the first three strata with STRATUM II yielding the most individuals (MNI:7). The upper infill also produced a significant number of individuals (MNI:7) as remains of the species were recovered from each stratigraphic level (Carrier 1989).

P. lotor is a common species in the Ottawa district and was probably so during the most part of the depositional history of the deposit. Its habit to frequent cave entrances may well have contributed to the relatively high frequency of remains recovered in the deposit.

5.2.1.2 Pisces

The presence of fish in the lower deposit is based on the recognition of characteristic elements within the fossil material such as vertebrae, spines and teeth. The specimens were not inventoried. According to the small size of the specimens collected, the material is tentatively identified as *Cyprinidae* spp. (i.e. minnows). However, because of a lack of reference material, the identification of this assortment was not pursued further. These remains which were recovered throughout the lower infill were most likely introduced by predators such as *P. lotor*. While there are no water bodies in the immediate vicinity of the cave, small ponds and streams likely inhabited by minnows can be found on the higher plateaux less than a kilometre away.

5.2.1.3 Reptilia

A single right dentary of a snake (Squamata spp.) was recovered from the lower infill. The specimen is of comparable morphology and size as that of the garter snake (*Thamnophis sirtalis*) which is found in the region today. The specimen was not identified.

5.2.1.4 Amphibia

The fossil material of the lower infill of the Caverne de la Mine contains many specimens that clearly belong to amphibians but were not identified further. Carrier (1989) reported the presence of the *B. americanus* in the upper infill, the most numerous vertebrate taxa of that fossil fauna.

5.2.2 Invertebrates

5.2.2.1 Mollusca

Molluscs were plentiful throughout the upper (Carrier 1989) and lower infills of the Caverne de la Mine. Twenty-seven snail species were identified within the lower deposit from a sub sample (>100 specimens) collected from section C. Among this assemblage, 26 are land snails and 1 is a freshwater species. All taxa are among the 46 native terrestrial molluscs known from the Gatineau Park (Oughton 1948; W. Grimm, personal communication, 1998). Surface collection of recent material within the vicinity of the cave uncovered 15 additional terrestrial species.

5.2.3 Flora

Wood charcoal was encountered at all levels of the lower infill. The charcoal fragments of a subset collected from STRATUM I, STRATUM IV and STRATUM VI were identified to generic or specific level. The anthracological analysis revealed at least 16 different floral taxa, all of which are extant in the region. A majority of fragments of the sub sample exhibit the presence of hyphae, which according to Talon (personal communication, 1999), suggests that most charcoals are derived from decaying and fallen timber incinerated during forest fires.

Scientific name	Common name	strata								Tota IMNI	NISP
		I	II	III	IV	V	VI	VII	NEP		
VERTEBRATES											
Class Mammalia											
Order Insectivora											
Family Soricidae											
Sorex fumeus	Smoky shrew	(1)†	–	–	–	–	–	–	–	(1)†	(1)†
Sorex sp.	(Long tailed shrews)	2	3	2	–	–	–	–	–	7	13
Blarina brevicauda	Short-tailed shrew	6	3	2	1	–	–	–	–	12	18
Family Talpidae											
Parascalops breweri	Hairy-tailed mole	1	1	1	–	–	–	–	–	3	5
Condylura cristata	Star-nosed mole	2	4	1	–	–	–	–	–	7	8
Order Chiroptera											
Family Vespertilionidae											
Myotis septentrionalis	Northern long-eared bat	12	19	5	–	–	–	–	1	37	37
Myotis lucifugus	Little brown bat	–	1	2	–	–	–	–	–	3	3
Lasionycteris noctivagans	Silver-haired bat	1	–	–	–	–	–	–	–	1	1
Eptesicus fuscus	Big brown bat	8	20	18	2	–	–	–	1	49	115
Order Lagomorpha											
Family Leporidae											
Leporidae spp.	(Rabits, hares)	–	1	–	1	–	1	–	–	3	5
Order Rodentia											
Family Sciuridae											
Tamias striatus	Eastern chipmunk	–	1	1	–	–	–	–	–	2	8
Tamiasciurus hudsonicus	Red squirrel	–	1	–	1	–	–	–	–	2	3
Glaucomys cf. *sabrinus*	Northern flying squirrel	1	–	–	1	–	–	–	–	2	2
Family Cricetidae											
Peromyscus sp.	Mice	3	9	9	1	3	–	–	1	26	78
Family Arvicolidae											
Clethrionomys cf. *gapperi*	Red-backed vole	6	9	2	1	1	–	–	2	21	78
Synaptomys cooperi	Southern bog lemming	–	4	2	–	–	–	–	–	6	10
Dicrostonyx hudsonius	Ungava collared lemming	–	–	–	1	–	–	–	–	1	1
Ondatra zibethicus	Muskrat	1	1	1	–	–	–	–	–	3	5
Microtus cf. *pinetorum*	Woodland vole	5	3	1	–	–	–	–	–	9	27
Microtus pennsylvanicus	Meadow vole	2	2	1	1	1	–	–	1	8	19
Microtus cf. *chrotorrhinus*	Rock vole	-	1	–	–	1	–	–	–	2	2
Family Erethizontidae											
Erethizon dorsatum	Porcupine	1	1	1	–	–	–	–	–	3	5
Order Carnivora											
Family Canidae											
Canis cf. *latrans*	Coyote	1	1	1	–	–	–	–	–	3	8
Family Procyonidae											
Procyon lotor	Raccoon	3	7	2	–	–	–	–	–	12	132

†Included in *Sorex* sp. count.

Table 5: List of animal and plant remains identified from the Caverne de la Mine lower infill fossil assemblage.

Scientific name	Common name	Scientific name	Common name
VERTEBRATES *cont.*			
Pisces		**Amphibia**	unidentified frogs and/or
Cyprinids spp. (?)	minnows (?)		toads and/or salamanders
Reptilia			
Squamata spp.	unidentified snakes		
MOLLUSCA			
Gastrapoda			
Carychiidae		**Valloniidae**	
Carychium exile	land snail	*Vallonia gracilicosta*	land snail
Pupillidae		**Polygyridae**	
Vertigo ventricosa	land snail	*Euchemotrema fraternum*	land snail
Gastrocopota pentodon	land snail	*Neohelix* sp.	land snail
Strobilopsidae		**Discidae**	
Strobilops labyrinthica	land snail	*Anguispira alternata*	land snail
Strobilops aenea	land snail	*Discus ruderatus*	land snail
Strobilops affinis	land snail	*Discus catskillensis*	land snail
Chochlicopidae		**Helicodiscidae**	
Cochlicopa cf. *lubrica*	land snail	*Helicodiscus parallelus*	land snail
Cochlicopa cf. *nitens*	land snail	*Helicodiscus shimeki*	land snail
Zonitidae			
Glyphyalinia solida	land snail	*Nesovitrea binneyana*	land snail
Glyphyalinia cf. *rhoadsi*	land snail	*Mesomphix inornatus*	land snail
Euconulus fulvus	land snail	*Paravitrea multidentata*	land snail
Striatura ferrea	land snail	*Zonitoides arboreus*	land snail
Striatura exigua	land snail		
Succineidae		**Physidae**	
Succineid sp. indet.	land snail	*Aplexa hypnorum*	freshwater snail
FLORA (from charcoal)			
Acer saccharum	sugar maple	*Picea* sp.	spruce
Acer spicatum	mountain maple	*Pinus banksiana*	jack pine
Betula sp.	birch	*Pinus strobus*	white pine
Empetrum sp. (?)	crowberry	*Taxus* sp.	yew
Fraxinus americana	white ash	*Thuja* sp. / *Juniperus* sp.	cedar / juniper
Fraxinus pennsylvanica	red ash		
Ostrya sp.	ironwood		
Quercus sp.	oak		
Sambucs sp.	elder		
Rosacea spp.	rose family		

Table 5: *continued.*

5.3 Fossil analysis

5.3.1 Data summary

The fossil assemblage of the Caverne de la Mine lower infill is comprised of a variety of organic remains which include vertebrates, land snails and charred vegetation (table 5). Vertebrate remains are most abundant. Together, fish, reptiles, amphibians and mammals constitute the fossil vertebrate fauna, of which mammals appear to be most substantial.

5.3.2 Flora

Mott and Farley-Gill (1981) have shown how the regional flora has evolved over the last 11 000 years by the analysis of the pollen of two sediment cores at Pink and Ramsay Lake from Gatineau Park (figure 14). They have delineated nine pollen assemblage zones which depict the succession of the vegetation from herbaceous tundra of the early Holocene to the present-day mixed deciduous-coniferous forest. The age of the lower deposit (i.e. 5 020 ± 70 - 8 230 ± 60 B.P.) is generally synchronous with assemblage zones 5 and 6 of both palynological profiles and zone 4 at Pink Lake. Zones 6 and 5 date between 5 500 and 9 800 years B.P. for Pink Lake and for Ramsay Lake, between 4 800 and 9 500 years B.P. Zone 6, designated as the ***Pinus* Pollen Zone**, is characterised by a significant increase in jack pine (*Pinus banksiana*) and red pine (*Pinus resinosa*) pollen later followed by a maximum in white pine (*Pinus strobus*) pollen and an abundance of birch (*Betula* sp.) and oak (*Quercus* sp.) pollen. Zone 5, the ***Tsuga canadensis* Pollen Zone**, marks a decline in white pine and an increase in eastern hemlock (*Tsuga canadensis*) pollen while zone 4, **Betula-Quercus Pollen Zone**, marks a general increase of several hardwood taxa. During the period of infilling of the Caverne de la Mine lower deposit, the area's flora was first dominated by a forest of birch and jack pine which was gradually replaced by a mixed conifer-deciduous forest of white pine and other hardwood genera. Following its peak about 6 500 years ago, the white pine began to decline and to be replaced by eastern hemlock.

Analysis of the charcoal assemblage agrees well with the regional pollen record. The fragment count per taxa for STRATUM I, STRATUM V and STRATUM VII shows varying abundances within the assemblage (table 6, figure 15). Among the taxa with the greatest number of

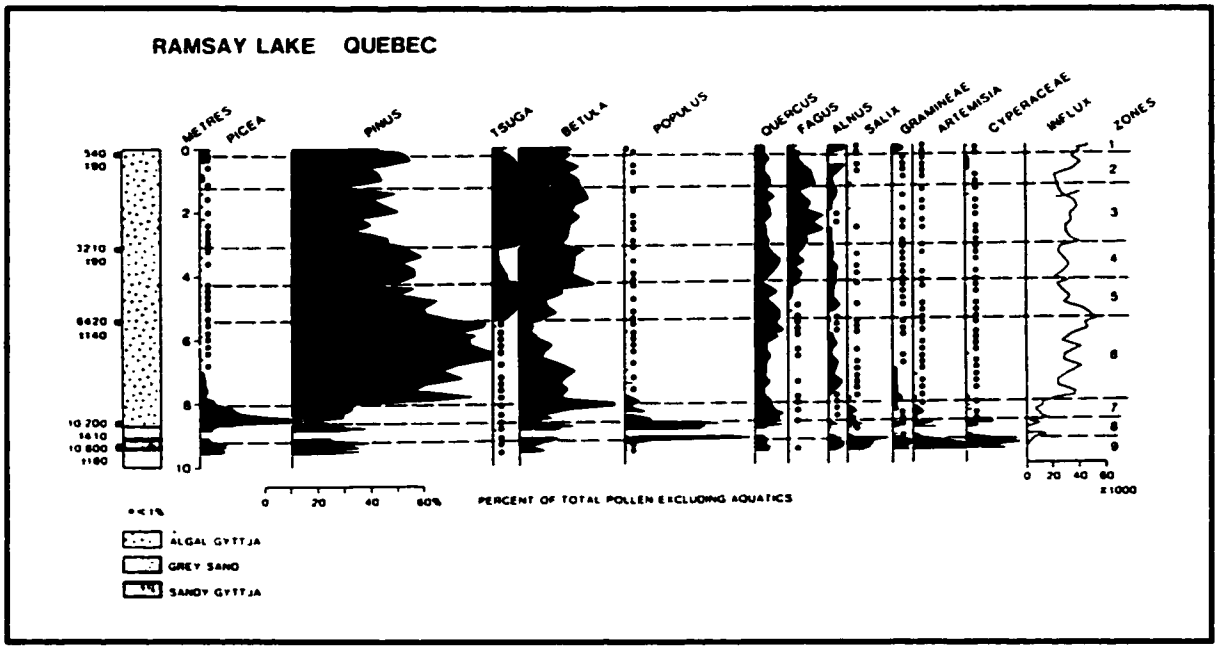


Figure 14: Abbreviated pollen diagram for Ramsay Lake, Quebec. Redrawn from Mott and Farley-Gill (1981) (from Anderson 1988).

taxa	stratum I		stratum V		stratum VII		Total per taxa	
	N	%	N	%	N	%	N	%
Pinus banksiana	1	1.1	22	19.3	8	5.8	31	9.0
P. banksiana (cone scale)	0	0	30	26.3	79	57.2	109	31.6
Pinus strobus	22	23.7	2	1.8	3	2.2	27	7.8
Thuja / Juniperus	8	8.6	6	5.3	3	2.2	17	4.9
Tsuga	5	5.4	2	1.8	0	0	7	2.0
Picea	2	2.2	0	0	0	0	2	0.6
Taxus	1	1.1	0	0	0	0	1	0.3
Quercus	20	21.5	0	0	2	1.4	22	6.4
Betula	0	0	7	6.1	6	4.3	13	3.8
Acer saccharum	19	20.4	0	0	1	0.7	20	5.8
Acer spicatum	3	3.2	0	0	0	0	3	0.9
Rosaceae	1	1.1	38	33.3	29	21.0	68	19.7
Empertum (?)	0	0	1	0.9	6	4.3	7	2.0
Sambucus	0	0	0	0	1	0.7	1	0.3
Ostrya	4	4.3	1	0.9	0	0	5	1.4
Fraxinus pennsylvanica	0	0	1	0.9	0	0	1	0.3
Fraxinus americana	6	6.5	0	0	0	0	6	1.7
others	1	1.1	4	3.5	0	0	5	1.4
Total per strata	93	100.2	114	100.1	138	99.8	345	99.9

Table 6: Relative charcoal abundance per taxon, Caverne de la Mine lower infill.

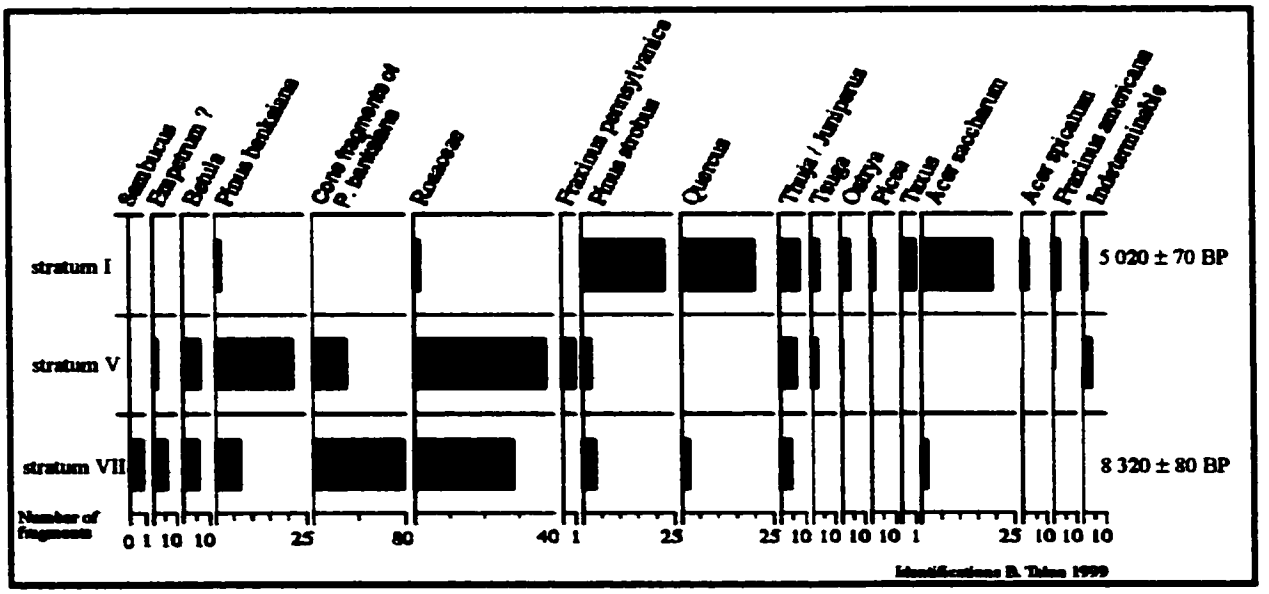


Figure 15: Charcoal diagram, Caverne de la Mine lower infill.

fragments collected are *P. banksiana* and Rosaceae spp. Other notable taxa include *P. strobus*, *Quercus* sp. and *Acer saccharum* (sugar maple). STRATUM VII and STRATUM V are very similar as they contain virtually the same taxa in comparable quantities. Charcoal of *P. banksiana* is most abundant in these two strata along with Rosaceae and *Betula* sp. while charcoal of *P. strobus* and of hardwood taxa, such as *Quercus* sp. and *A. saccharum*, is minimal or not present. The charcoal assemblage of STRATUM I differentiates itself from the other two strata by its abundance of *P. strobus*, *A. saccharum* and *Quercus* sp., very few *P. banksiana* and Rosaceae spp. and absence of *Betula* sp. The charcoal assemblage of the lower infill can therefore be subdivided into two zones according to the visible contrast within the assemblage. The first zone, which combines strata V and VII, suggests that the regional forest cover between 7 280 ± 60 and 8 230 ± 60 B.P. was mainly comprised of jack pine and birch. The second zone, which consists of the charcoal assemblage of STRATUM I, shows a replacement of the jack pine by the white pine and increasing importance of hardwood taxa by 5 020 ± 70 B.P.

Integral analysis of the charcoal assemblage is difficult since an indefinite number of factors have affected the samples from the time the vegetation is consumed by fire to the time the charcoal is analysed in the laboratory. The initial amount of biomass available, scattering, fragmentation and conservation of the specimens as well as sampling bias are some of these influential factors which may affect the relative number of fragments per taxa available for analysis (B. Talon, personal communication, 1999). In spite of these difficulties, examination of the charcoal assemblage of the lower infill provides useful information regarding the integrity of the deposit. The mid-Holocene replacement of the jack pine by the white pine visible in the pollen record, can be discerned in the charcoal record. Also, the charcoal record suggests an increase in hardwood species near 5 000 years B.P. as does the pollen record. The occurrence of these events are in relative synchrony among the fossil sites. The chronological sequence indicates that the Caverne de la Mine lower infill was relatively undisturbed prior to its excavation and shows that the radiocarbon dates attained from the charcoals recovered from the lower infill are both logical and feasible.

5.3.3 Fauna

5.3.3.1 Fossil assemblage

A total of 2 630 mammal specimens from the Caverne de la Mine lower deposit were catalogued of which half (51.4%) were identified to some extent. Twenty three taxa were identified among ten mammalian families and are represented by at least 510 individuals when the entire bat assemblage is considered.

Small mammals are the most prominent taxa of the fossil assemblage both in terms of specimens and individuals. According to Dyck and Morlan's (1995) mammal body size categories, 16 of the 23 identified taxa belong to the lowest rank, which represents animals normally weighing less than 100 g (table 7). The fossil assemblage does not surpass the fourth size category as none of the taxa recovered weigh over 25 kg. The proportion of small-to-large mammals recorded may be attributed to their striking majority in the surrounding fauna. Tumble-in traps are known to generate greater proportions of small sized taxa since their higher densities in the surrounding fauna increase their odds of entrapment (Guilday 1971; Guilday *et al.* 1977). The size of the cave opening may also have played a selective role during the infilling period by filtering out the larger taxa.

Bats ranked first in terms of abundance and their overwhelming numbers are largely responsible for the enriched small mammal fauna. In all, 889 specimens were identified, amounting to at least 378 individuals, overshadowing the abundance of all the other taxa (table 8 and figure 16). Bats alone represent more than half (65.8%) of all identified specimens of the lower infill fossil assemblage and three quarters (74.1%) of identified individuals. Their abundance may be indicative that the cave was inhabited by a large number of bats during the period of its infilling, perhaps even supporting an important colony at one time. An important variety of rodents, including squirrels, mice and voles, also contributed significantly to the fossil assemblage. Among these, *Peromyscus* sp. and *C. gapperi* are the most abundant taxa, represented by 27 and 21 individuals respectively. With the exception of bats, the lower infill fossil assemblage suggests that these two taxa were among the most numerous mammals of the

body size category	animal weight	N	taxa
1	<100 g	16	*S. fumeus, B. brevicauda, P. breweri, C. cristata, M. septentrionalis, M. lucifugus, L. noctivagans, E. fuscus, T. striatus, Peromyscus* sp., *C. gapperi, S. cooperi, D. hudsonius, M. pinetorum, M. pennsylvanicus, M. chrotorrhinus*
2	100 - 700 g	2	*G. sabrinus, T. hudsonicus*
3	700 - 5 000 g	2	Leporidae spp., *O. zibethicus*
4	5 - 25 kg	3	*E. dorsatum, C. latrans, P. lotor*
5	25 - 200 kg	0	N/A
6	200 - 700 kg	0	N/A
7	>700 kg	0	N/A

Table 7: Mammal body sizes, Caverne de la Mine lower infill.

family	species	NISP	NISP (%)	MNI	MNI (%)
Soricidae	*Sorex fumeus* } *Sorex* sp. }	13	0.96	7	1.37
	Blarina brevicauda	18	1.33	12	2.35
	Total	**31**	**2.29**	**19**	**3.72**
Talpidae	*Parascalops breweri*	5	0.37	3	0.59
	Condylura cristata	8	0.59	7	1.37
	Total	**13**	**0.96**	**10**	**1.96**
Vespertilionidae	*Myotis septentrionalis* } † *Myotis lucifugus* } *Lasionycteris noctivagans* }	774	57.29	329	64.51
	Eptesicus fuscus	115	8.51	49	9.61
	Total	**889**	**65.80**	**378**	**74.12**
Leporidae	*Leporidae* spp.	5	0.37	3	0.59
	Total	**5**	**0.37**	**3**	**0.59**
Sciuridae	*Tamias striatus*	8	0.59	2	0.39
	Tamiasciurus hudsonicus	3	0.22	2	0.39
	Glaucomys cf. *sabrinus*	2	0.15	2	0.39
	Total	**13**	**0.96**	**6**	**1.18**
Cricetidae	*Peromyscus* sp.	78	5.77	26	5.10
	Total	**78**	**5.77**	**26**	**5.10**
Arvicolidae	*Clethrionomys* cf. *gapperi*	78	5.77	21	4.12
	Synaptomys cooperi	10	0.74	6	1.18
	Synaptomys sp.	12	0.89		
	Dicrostonyx hudsonius	1	0.07	1	0.20
	Ondatra zibethicus	5	0.37	3	0.59
	Microtus cf. *pinetorum*	27	2.00	9	1.76
	Microtus pennsylvanicus	19	1.40	8	1.57
	Microtus cf. *chrotorrhinus*	2	0.15	2	0.39
	Microtus sp.	23	1.70		
	Total	**177**	**13.10**	**50**	**9.80**
Erethizontidae	*Erethizon dorsatum*	5	0.37	3	0.59
	Total	**5**	**0.37**	**3**	**0.59**
Canidae	*Canis* cf. *latrans*	8	0.59	3	0.59
	Total	**8**	**0.59**	**3**	**0.59**
Procyonidae	*Procyon lotor*	132	9.77	12	2.35
	Total	**132**	**9.77**	**12**	**2.35**
	Total all species	**1351**	**100**	**510**	**100**

† tabulation includes *Myotis* sp. and *Chiroptera* spp. type A fossil specimens.

Table 8: Taxonomic abundance per mammal family, Caverne de la Mine lower infill.

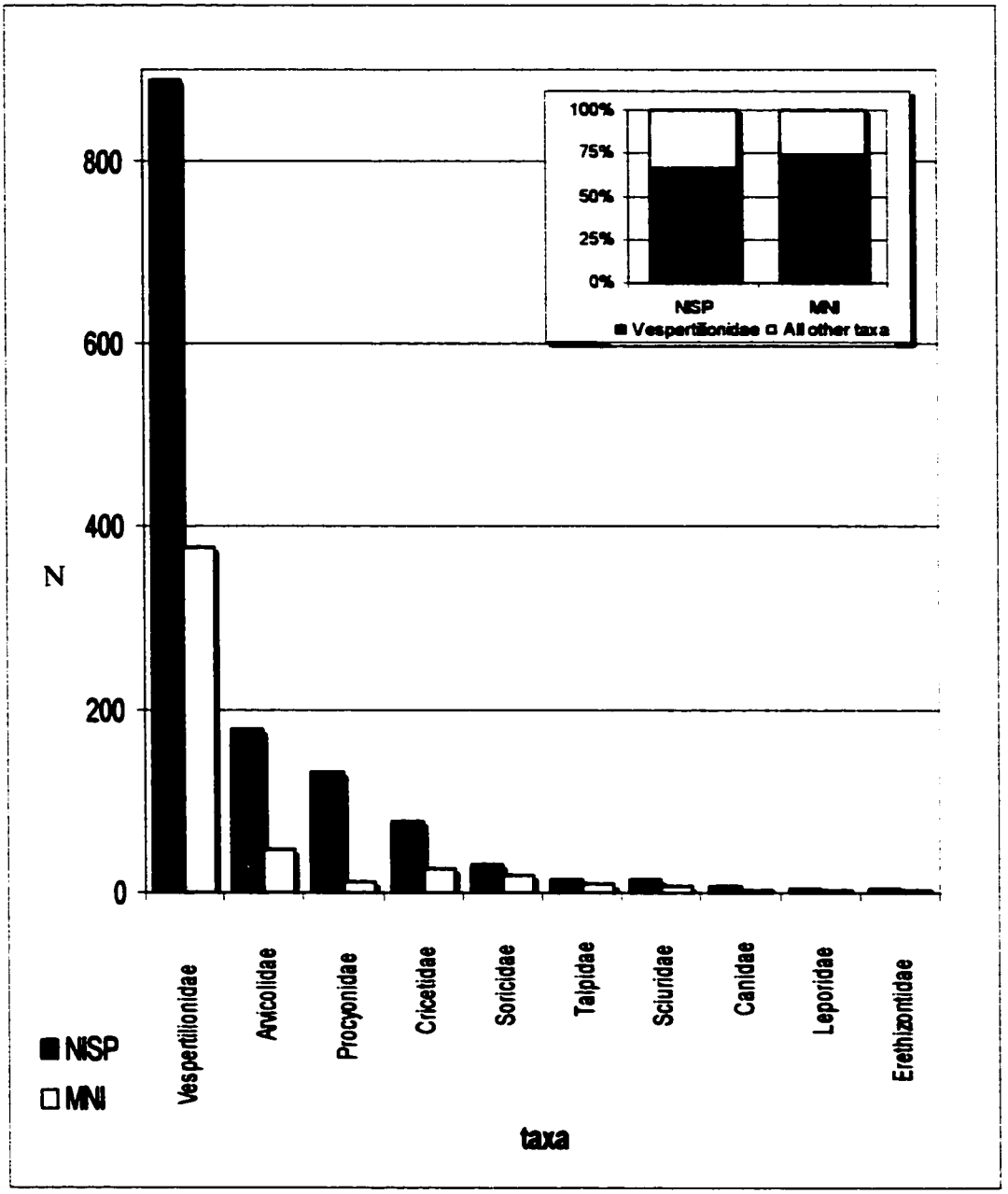


Figure 16: Relative abundance of the ten mammal families represented in the Caverne de la Mine lower infill fossil assemblage.

local fauna during the period in question. The other taxa, including larger species such as the raccoon, are represented by less than a dozen individuals and account for only a small portion of the fossil fauna.

7.21 Extirpated taxa

Of the 23 mammal taxa identified from the lower infill fossil assemblage, all are extant today and two, *Dicrostonyx hudsonius* and *Microtus pinetorum* do not presently live in the Ottawa valley. Both extirpated species have not previously been officially reported from this district either in living or fossil form.

D. hudsonius is today restricted to the cold environment of the Labrador - Ungava Bay area. A single specimen belonging to this species was recovered from STRATUM IV which was dated at 7 280 ± 60 B.P. To date, only four other fossil sites yielding remains of *D. hudsonius* are known outside the species' present range (table 9 and figure 17). The fossil record suggests that the lemming's range extended as far south as 38°36' N in West Virginia, 29 400 ±1 700 years ago (Grady and Garton 1981), and existed south of the Wisconsinan ice front perhaps as late as 11 300 years B.P. (Guilday *et al.* 1964). Fossil material of Middle Wisconsinan age was recently uncovered in Michigan (Karrow *et al.* 1997) yet was not identified beyond *Dicrostonyx* sp. The geographic distribution of *D. hudsonius* fossil records suggests that the species once occurred only east of and throughout the Appalachians Mountains (Guilday *et al.* 1964; LaSalle and Guilday 1980; Grady and Garton 1981; Woodman 1982; Mead and Mead 1989). The specimen recovered from the Caverne de la Mine deposit is the first known record recovered west of the Appalachians. This record indicates that the species once occurred west of the mountain range during late stages of its northward migration.

The occurrence of *D. hudsonius* in the Caverne de la Mine deposit is of significant value for the assessment of the species' ambiguous history. Because of the rather sparse fossil record, very little is known on its past distribution and its relationship with *D. torquatus*. Guilday (1963, 1968) and MacPherson (1965) were the first to investigate the Pleistocene and modern

site number on map	site	age and remarks	primary reference
1	New Paris no.4, Pensylvania, USA	11 300 ±1000 (Y-727) on charcoal 4.6 m below datum; 9 540 ±500 (M-1067) on small mammal bones 5.2-6.4 m below datum. *Dicrostonyx* occurs at 6.1 and 6.4 m.	Guilday *et al.* 1964
2	New Trout Cave, West Virginia, USA	17 060 ±220, 28 250 ±850, 29 400 ±1 700 on bone collagen of fragments of several different taxa.	Grady and Garton, 1981
3	Caverne St-Elzéar, Quebec, Canada	Bone material in talus dated at ±5 000 BP. Early Holocene (?).	LaSalle and Guilday 1980; LaSalle, 1984
4	Trou Otis Cave, Quebec, Canada	No dated material Late Pleistocene/Early Holocene (?).	Harington, 1980
✪	Caverne de la Mine, Quebec, Canada	7 280 ± 60 BP (TO 7767) on charcoal from same stratum.	This study

Table 9: North American *Dicrostonyx hudsonius* fossil records.

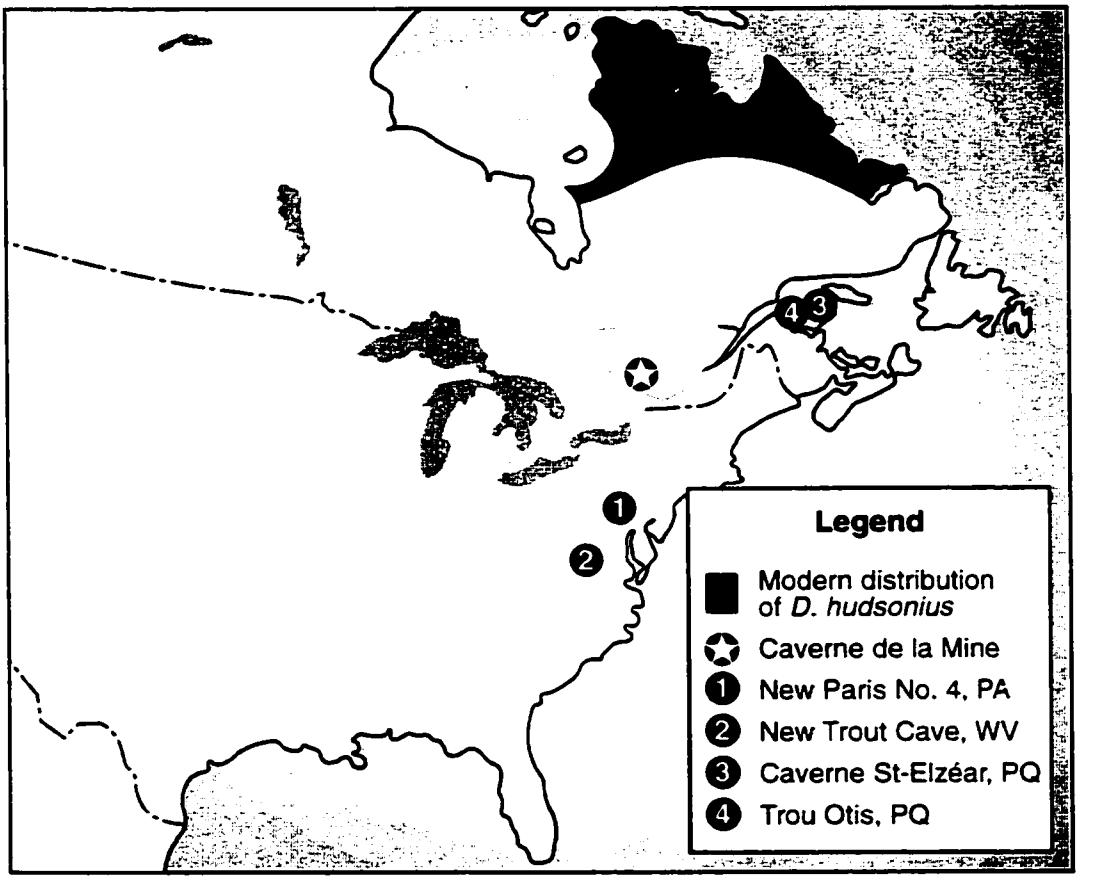


Figure 17: Map showing modern distribution of *Dicrostonyx hudsonius* and location of North American fossil accounts.

distributions of *Dicrostonyx* in North America. MacPherson thought that speciation occurred sometime during the last glacial retreat as the migrating population was segregated into two distinct populations. Yet the fossil record indicates that speciation pre-dated the deglaciation, prompting Guilday (1968) to propose two hypotheses which could account for the state of the genus *Dicrostonyx* in North America prior to the Holocene:

a) A continuous tundra belt existed south of the glacial front inhabited by *Dicrostonyx* in which the population exhibited varying phenotypic characters from more complex in the west to simpler in the east. The population was divided into two distinct entities during deglaciation as the population migrated north and was forced to split by the opening of the Hudson Bay. Hence *D. hudsonius* today inhabits the eastern Canadian arctic while *D. torquatus* inhabits the central and western portions.

b) Both *Dicrostonyx* species were parapatric south of the ice sheet. *D. torquatus* inhabited western regions and *D. hudsonius* the eastern regions, their modern distributions mirroring those of glacial times.

D. hudsonius may have had a much wider distribution in North America during glacial time. In fact Krohne's (1982) genetic work on the genus has shown that karyotypic variations within the genus may not be explained by separate Pleistocene refugia alone. The fossil specimen recovered from Caverne de la Mine also suggests that *D. hudsonius* may have had a more extensive distribution in the past as it shows that the lemming was not strictly confined to the Appalachian Mountains

Fossil records of *Microtus pinetorum* are virtually non-existent north of its present range, which makes this the most northerly known occurrence for this species. Today, the vole is found in hardwood forests south of the Great Lakes. Its closest known modern locality is approximately 175 km south of Caverne de la Mine in Lewis County, northern New York (Hall and Cockrum 1952). The vole was recorded in southern Ontario as part of the Hamilton Bay vertebrate fossil

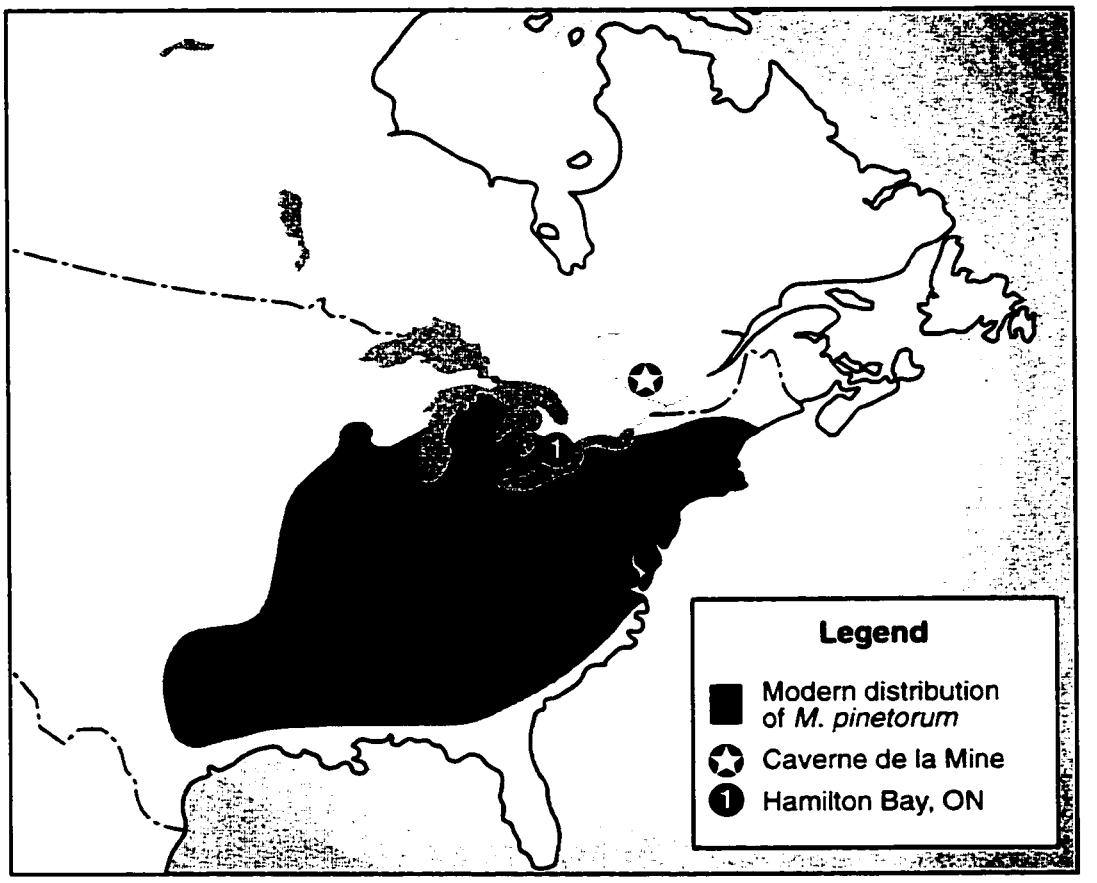


Figure 18: Map showing modern distribution of *Microtus pinetorum* and location of Canadian fossil accounts

fauna (Wetmore 1958; Churcher and Karrow 1963) which is the closest known fossil record (figure 18). The Hamilton Bay deposit is located within the northernmost limits of the species' current range. *M. pinetorum* is a commonly occurring species in fossil faunas of the American northeast.

5.3.3.3 Community analysis

The fossil fauna's area of maximum sympatry (figure 19) consists of 19 of 21 taxa identified to species. It extends throughout the northern portions of the Great Lakes basin and the Appalachians and is largely limited to the eastern section of the Laurentian Mixed Forest. Here, the distributions of northerly occurring species (e.g. *Condylura cristata*, *Tamiasciurus hudsonicus*, *Clethrionomys gapperi*) overlap those of southern ranging species (e.g. *Sorex fumeus*, *Parascalops breweri*, *Tamias striatus*) and those of widespread species (e.g. *Myotis septentrionalis*, *Ondatra zibethicus*, *Canis latrans*). The area of maximum sympatry shows that the fossil fauna of the lower infill is a typical fauna of the Great Lakes region.

The Caverne de la Mine fossil fauna can be subdivided into community associations. Based on their distribution and habitat preferences, Graham (1976) sorted several small mammals according to the faunal units they represent, in which members of the small mammal assemblage of the Caverne de la Mine lower infill fossil assemblage are found (table 10). Widespread species were not classified. Amongst the 14 small mammal taxa recovered from the lower infill that figure in Graham's list, 11 are boreal taxa while three are deciduous or *"southern"* taxa. Accordingly, the Caverne de la Mine lower infill small mammal fossil fauna is principally made-up of taxa associated with boreal environments.

Different habitats are represented by the Caverne de la Mine small mammal fossil fauna. These include forest, moist grassland, wetland and shoreline, and, tundra habitats (table 11). While most taxa are not confined to any one peculiar habitat they have been assigned to those that are most characteristic. The fossil fauna of the Caverne de la Mine lower infill shows varying habitat affinities, yet, the majority of the taxa favour forested habitats.

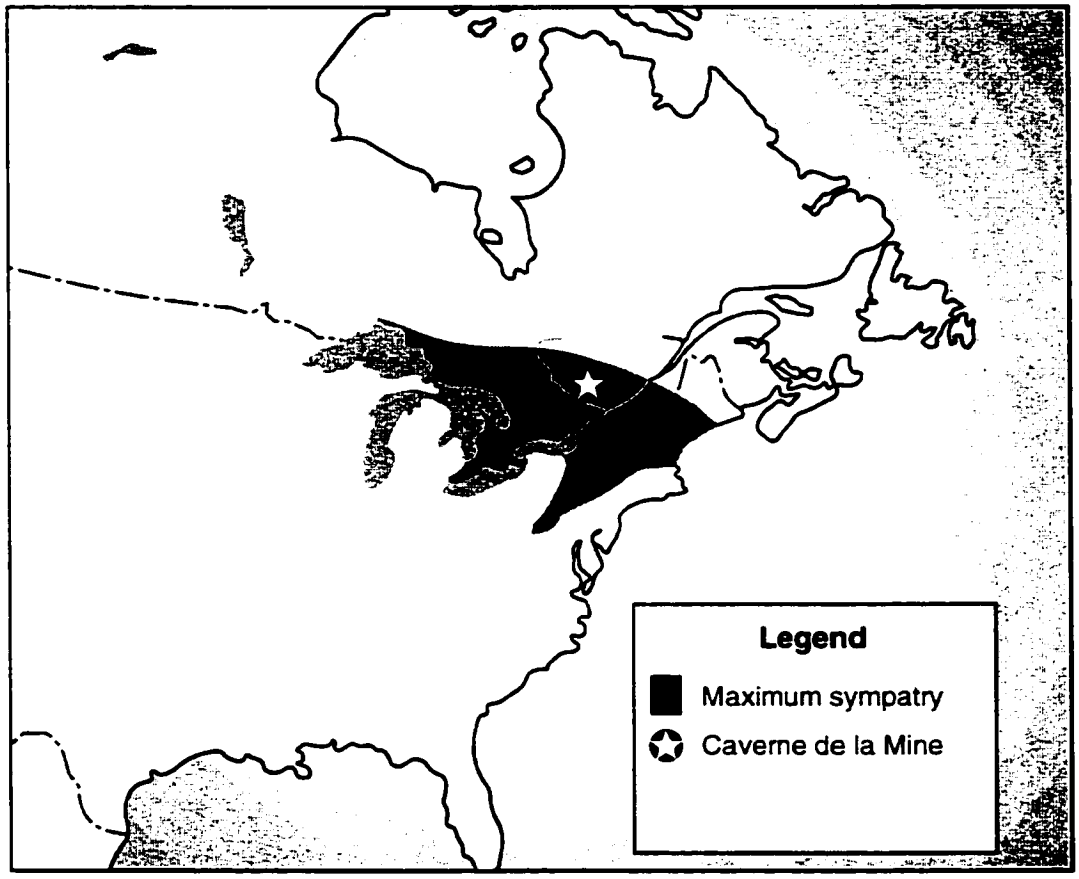


Figure 19: Map showing area of sympatry for mammal taxa recovered from the Caverne de la Mine lower infill.

faunal units	taxa		
Boreal	*Sorex arcticus*	*Martes americana*[‡]	*Phenacomys intermedius*
	Sorex cinereus[‡]	*Mustela erminea*[‡]	***Microtus pennsylvanicus***[†‡]
	Sorex dispar	*Mustela nivalis*	*Microtus xanthognathus*
	Sorex fumeus[†‡]	***Tamiasciurus hudsonicus***[†‡]	***Microtus chrotorrhinus***[†‡]
	Sorex palustris[‡]	***Glaucomys sabrinus***[†‡]	*Zapus hudsonicus*[‡]
	Sorex vagrans	*Neotoma cinerea*	*Napeozapus insignis*[‡]
	Sorex hoyi[‡]	***Dicrostonyx hudsonius***[†]	***Erethizon dorsatum***[†‡]
	Condylura cristata[†‡]	***Synaptomys cooperi***[†‡]	*Lepus americanus*[‡]
	Parascalops breweri[†‡]	*Synaptomys borealis*	*Thomomys talpoides*
	Martes pennanti[‡]	***Clethrionomys gapperi***[†‡]	
Steppe	*Notiosorex crawfordi*	*Pappogeomys castanops*	*Peromyscus difficilis*
	Bassariscus astutus	*Perognathus flavescens*	*Peromyscus pectoralis*
	Mustela nigripes	*Perognathus fasciatus*	*Baiomys taylori*
	Conepatus leuconatus	*Perognathus flavus*	*Onychomys leucogaster*
	Spilogale putorius	*Perognathus merriami*	*Onychomys torridus*
	Cynomys ludovicianus	*Perognathus hispidus*	*Neotoma albigula*
	Citellus variegatus	*Dipodomys ordi*	*Neotoma micropus*
	Citellus mexicanus	*Dipodomys merriami*	*Neotoma mexicana*
	Citellus tridecemlineatus	*Reithrodontomys montanus*	*Microtus ochrogaster*
	Citellus spilosoma	*Reithrodontomys megalotis*	*Lepus californicus*
	Citellus franklini	*Reithrodontomys fulvescens*	*Sylvilagus audubonii*
	Geomys bursarius	*Peromyscus boylii*	*Lepus townsendi*
Deciduous or "*southern*"	*Didelphis virginiana*	*Sciurus carolinensis*[‡]	*Peromyscus leucopus*[‡]
	Blarina brevicauda[†‡]	*Sciurus niger*	*Neotoma floridana*
	Cryptotis parva	*Glaucomys volans*[‡]	*Oryzomys palustris*
	Scalopus aquaticus	*Reithrodontomys humulis*	*Sigmodon hispidus*
	Mormota monax[‡]	*Peromyscus gossypinus*	***Microtus pinetorum***[†]
	Tamias striatus[†]	*Peromyscus nuttali*	*Sylvilagus floridanus*[‡]

[†] taxa present in the Caverne de la Mine lower infill fossil fauna.
[‡] taxa part of the local fauna.

Table 10: Small mammal faunal units (modified from Graham 1976).

habitats	taxa
forest	*Sorex fumeus* *Blarina brevicauda* *Parascalops breweri* *Tamias striatus* *Tamiasciurus hudsonicus* *Glaucomys sabrinus* *Clethrionomys gapperi* *Microtus pinetorum* *Microtus chrotorrhinus*
moist grassland	*Synaptomys cooperi* *Microtus pennsylvanicus*
wetland and shoreline	*Condylura cristata* *Ondatra zibethicus*
tundra	*Dicrostonyx hudsonius*

Table 11: Habitats represented by the Caverne de la Mine lower infill small mammal fauna.

5.3.3.4 Stratigraphic analysis

The fossil abundance is not uniform through time within the cave deposit as the number of recovered remains varies greatly from one stratum to another. Using NISP values as a measure of abundance, the fossil abundance within the lower infill are compared. With an NISP count of 606, STRATUM II yielded the most specimens while STRATUM VI and STRATUM VII recorded the least amount, with only two and one specimens recovered respectively. The fossil abundance within the deposit decreases from top to bottom with 97% of all identified specimens occurring in the three superior strata. Significant diminishment of fossil abundance is visible between STRATUM III and STRATUM IV. Part of the impoverishment below 30 cm can be attributed to the fact that unlike sections A, B and C, section D was not excavated past STRATUM III. To compensate for this and for the unequal volumes of matrix excavated because of the irregular shape of the cave passage, specimen densities were calculated. Expressed in NISP per litre of matrix, the highest densities were recorded in STRATUM I (10.20 NISP/litre) and STRATUM II (10.56 NISP/litre) and the least occurred in STRATUM VI (0.02 NISP/litre) and STRATUM VII (0.01 NISP/litre). As for the fossil abundance, the density of identified specimens per stratum diminishes from top to bottom of the deposit with a sharp decline between STRATUM III and STRATUM IV.

Species diversity also varies among the seven strata of the infill. Unsurprisingly, the strata with high fossil abundance yielded greater species diversity. STRATUM I, STRATUM II and STRATUM III have the highest species diversity with 16, 20 and 17 different species recorded per stratum respectively. Species diversity diminishes progressively below this zone, down to only one species identified in each of the two lowermost strata of the infill.

Varying faunal density, cave accessibility and variable rates of cave infilling are some of several possible factors which could be responsible for the varying degree of fossil abundance and species diversity observed within the deposit. Table 12 gives a summary of the stratigraphic analyses.

	matrix excavated (litres)	fossil abundance (NISP)	relative fossil abundance (%)	fossil density (NISP/litre)	diversity (species/stratum)
STRATUM I	35.49	362	26.99	10.20	16
STRATUM II	57.39	606	45.19	10.56	20
STRATUM III	71.65	331	24.68	4.62	17
STRATUM IV	57.14	24	1.79	0.42	9
STRATUM V	62.5	15	1.12	0.24	4
STRATUM VI	84.13	2	0.15	0.02	1
STRATUM VII	98.77	1	0.07	0.01	1

Table 12: Stratigraphic analysis summary table, Caverne de la Mine lower infill.

5.3.3.5 Faunal change

Change in the composition of the paleofauna is perceivable within the lower infill fossil assemblage. While numbers of taxa decline towards the bottom of the deposit, boreal taxa occur lower than taxa of southern affinities (table 13). Three different boreal species were identified from STRATUM V whereas southern taxa do not occur lower than STRATUM IV. Proportions of southern taxa progressively increase nearing STRATUM I while those of boreal taxa remain relatively steady throughout most of the lower deposit.

The significance of these faunal changes can be depicted by examining the Freeman-Tukey Deviates (**F-TD**) of the fossil fauna (Tukey 1971; Thieling 1973; Semken 1984). Expressed by positive (+) or negative (-) values, the F-TDs are determined by comparing expected counts with actual counts. Derived values offer a weight as well as a direction to any faunal change. Only values above 0.50 are considered to be significant. According to the F-TDs obtained for the Caverne de la Mine lower infill fossil fauna (table 14) the region's fauna experienced some faunal change during the period of cave infilling. The most striking change in relative abundance occurred between STRATUM III and STRATUM IV. Here, both boreal and southern species exhibit a turnover of their relative abundance, going from an over representation (+) in STRATUM IV to an under representation (-) in STRATUM III. In the case of the boreal faunal group, the noticeable turnover corresponds to an amplitude of 3.68 Freeman-Tukey units. A significant increase in bats between STRATUM I and STRATUM III lowered the relative numbers of other taxa within these three strata causing the turnover.

A second important turnover can be seen near the upper portion of the Caverne de la Mine lower infill. While the relative abundance of boreal taxa remains generally constant between STRATUM I and STRATUM II, that of the southern faunal group is significantly increased from –0.78 in STRATUM II to +1.86 in STRATUM I, amounting to a positive increase of 2.64 Freeman-Tukey units. A sharp increase in the number of *Blarina brevicauda* and *Microtus pinetorum* recovered in STRATUM I is responsible for this turnover. In fact, the abundance of these two southern taxa is greatest in STRATUM I, practically doubling the number of individuals recovered from STRATUM II.

faunal units	taxa	strata I	II	III	IV	V	VI	VII
Boreal	*Sorex fumeus*	1	-	-	-	-	-	-
	Condylura cristata	2	4	1	-	-	-	-
	Parascalops breweri	1	1	1	-	-	-	-
	Tamiasciurus hudsonicus	-	1	-	1	-	-	-
	Glaucomys sabrinus	1	-	-	1	-	-	-
	Dicrostonyx hudsonius	-	-	-	1	-	-	-
	Clethrionomys gapperi	6	9	2	1	1	-	-
	Synaptomys cooperi	-	4	2	-	-	-	-
	Microtus pennsylvanicus	2	2	1	1	1	-	-
	Microtus chrotorrhinus	-	1	-	-	1	-	-
	Erethizon dorsatum	1	1	1	-	-	-	-
	Number of species/individuals	**7/14**	**8/23**	**6/8**	**5/5**	**3/3**	**0**	**0**
Southern	*Blarina brevicauda*	6	3	2	1	-	-	-
	Tamias striatus	-	1	1	-	-	-	-
	Microtus pinetorum	5	3	1	-	-	-	-
	Number of species/individuals	**2/11**	**3/7**	**3/4**	**1/1**	**0**	**0**	**0**

Table 13: Stratigraphic abundance of boreal and southern taxa, Caverne de la Mine lower infill.

Faunal units	taxa	strata																			
		I			II			III			IV			V			VI			VII		
		AC	EN	FTD	AC	EN	FTD	AC	EN	FTD	AC	EN	FTD	AC	EN	FTD	AC	EN	FTD	AC	EN	FTD
Boreal	*S. fumeus*	1	0.25	+1.03	0	0.41	-0.22	0	0.27	-0.03	0	0.03	+0.35	0	0.02	+0.37	0	0.00	+0.41	0	0.00	+0.41
	C. cristata	2	1.77	+0.32	4	2.90	+0.69	1	1.92	-0.50	0	0.24	+0.02	0	0.14	+0.16	0	0.01	+0.39	0	0.01	+0.39
	P. breweri	1	0.76	+0.44	1	1.24	0.00	1	0.82	+0.38	0	0.10	+0.23	0	0.06	+0.30	0	0.01	+0.40	0	0.01	+0.40
	T. hudsonicus	0	0.51	-0.32	1	0.83	+0.37	0	0.55	-0.37	1	0.07	+1.32	0	0.04	+0.34	0	0.00	+0.41	0	0.00	+0.41
	G. sabrinus	1	0.51	+0.71	0	0.83	-0.66	0	0.55	-0.37	1	0.07	+1.32	0	0.04	+0.34	0	0.00	+0.41	0	0.00	+0.41
	D. hudsonius	0	0.25	+0.00	0	0.41	-0.22	0	0.27	-0.03	1	0.03	+1.38	0	0.02	+0.37	0	0.00	+0.41	0	0.00	+0.41
	S. cooperi	0	1.52	-1.24	4	2.49	+0.93	2	1.65	+0.41	0	0.20	+0.07	0	0.12	+0.20	0	0.01	+0.39	0	0.01	+0.39
	C. gapperi	6	4.80	+0.61	9	7.88	+0.46	2	5.22	-1.51	1	0.65	+0.55	1	0.38	+0.86	0	0.04	+0.34	0	0.04	+0.34
	M. pennsylvanicus	2	1.77	+0.32	2	2.90	-0.39	1	1.92	-0.50	1	0.24	+1.05	1	0.14	+1.20	0	0.01	+0.39	0	0.01	+0.39
	M. chrotorrhinus	0	0.51	-0.32	1	0.83	+0.37	0	0.55	-0.37	0	0.07	+0.29	1	0.04	+1.37	0	0.00	+0.41	0	0.00	+0.41
	E. dorsatum	1	0.76	+0.44	1	1.24	0.00	1	0.82	+0.38	0	0.10	+0.23	0	0.06	+0.30	0	0.01	+0.40	0	0.01	+0.40
	Total boreal	**14**	**13.38**	**+0.23**	**23**	**21.99**	**+0.26**	**8**	**14.55**	**-1.86**	**5**	**1.81**	**1.82**	**3**	**1.06**	**+1.45**	**0**	**0.11**	**+0.22**	**0**	**0.11**	**+0.22**
Southern	*B. brevicauda*	6	3.03	+1.48	3	4.98	-0.83	2	3.29	-0.60	1	0.41	+0.83	0	0.24	+0.01	0	0.02	+0.37	0	0.02	+0.37
	T. striatus	0	0.51	-0.32	1	0.83	+0.37	1	0.55	+0.66	0	0.07	+0.29	0	0.04	+0.34	0	0.00	+0.41	0	0.00	+0.41
	M. pinetorum	5	2.27	+1.51	3	3.73	-0.25	1	2.47	-0.85	0	0.31	-0.08	0	0.18	+0.10	0	0.02	+0.38	0	0.02	+0.38
	Total southern	**11**	**5.81**	**+1.86**	**7**	**9.54**	**-0.78**	**4**	**6.31**	**-0.88**	**1**	**0.78**	**0.42**	**0**	**0.46**	**-0.27**	**0**	**0.05**	**+0.33**	**0**	**0.05**	**+0.33**
All other taxa		**101**	**106.81**	**-0.54**	**177**	**175.47**	**+0.13**	**125**	**116.13**	**+0.83**	**11**	**14.41**	**-0.88**	**7**	**8.48**	**-0.43**	**1**	**0.85**	**+0.35**	**1**	**0.85**	**+0.35**

AC: Actual Count EN: Expected Number FTD: Freeman-Tukey Deviate

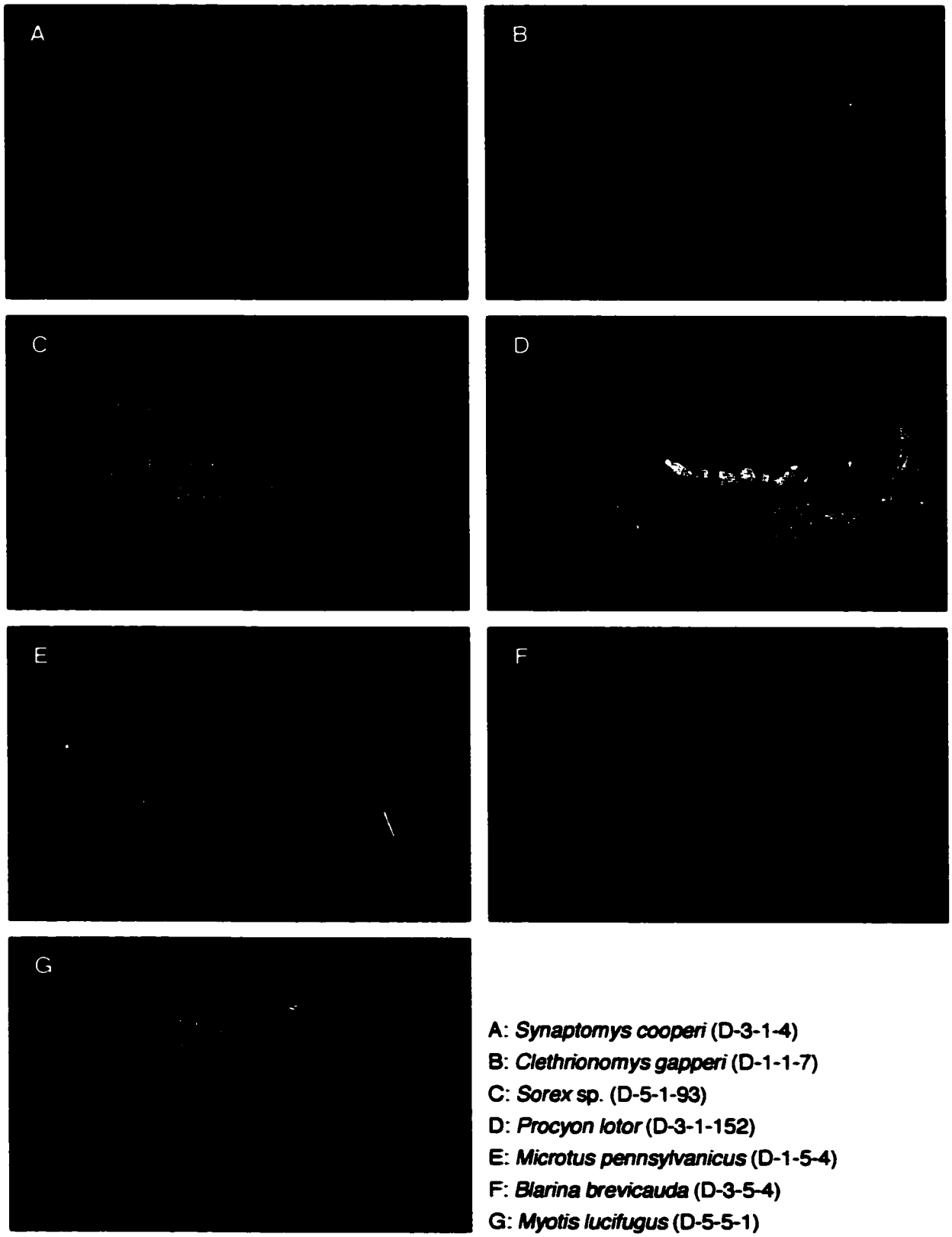
Table 14: Freeman-Tukey deviates for the mammal fossil assemblage from the Caverne de la Mine lower infill.

This marked augmentation in abundance of southern taxa in STRATUM I produces a nearly equal proportion of boreal and southern taxa in terms of minimum number of individuals recovered for this stratum. Southern taxa are outnumbered by only 14:11 in STRATUM I compared to 23:7 in STRATUM II. Overall, proportions have progressively passed from as much as 5:1 in STRATUM IV to 14:11 in STRATUM I. Only the southern faunal unit exhibits such an increase towards the uppermost stratum. This significant increase of the relative abundance of southern taxa in the upper portions of the Caverne de la Mine lower infill suggests increasing densities of southern species in the region's paleofauna at that time.

5.3.3.6 Taphonomic analysis

The cranial specimens of the Caverne de la Mine deposit were examined in search of any evidence of what may have contributed to their accumulation in the cave. It was immediately apparent that the physical state of the specimens differed within the whole fossil assemblage. While some specimens were found to be relatively complete and generally unaltered, others were fragmented and/or exhibited some corrosion. The different conditions of the specimens suggest that the fossil accumulation followed various taphonomic pathways.

The assortment of unbroken and unaltered specimens consists of all possible cranial elements (Figure 20 A to G). Of these, mandibles (A to D) and a large number of isolated teeth account for the most part. A few relatively complete skulls were also recovered (E to G). Represented in this group of specimens are both large and small mammals which include carnivores (D), insectivores (C and F), bats (G) and rodents (A, B and E). The absence of predation marks (specific fragmentation, digestive corrosion) on these specimens suggest that at least part of the fossil assemblage has not accumulated as part of a coprocoenosis. Instead, this collection of specimens appears to be derived from individuals that inhabited the cave or were trapped in it, their remains being incorporated into the deposit after their death. The presence of cave dwelling animals in the fossil fauna, such as bats, and the vertical aspect of the cave making



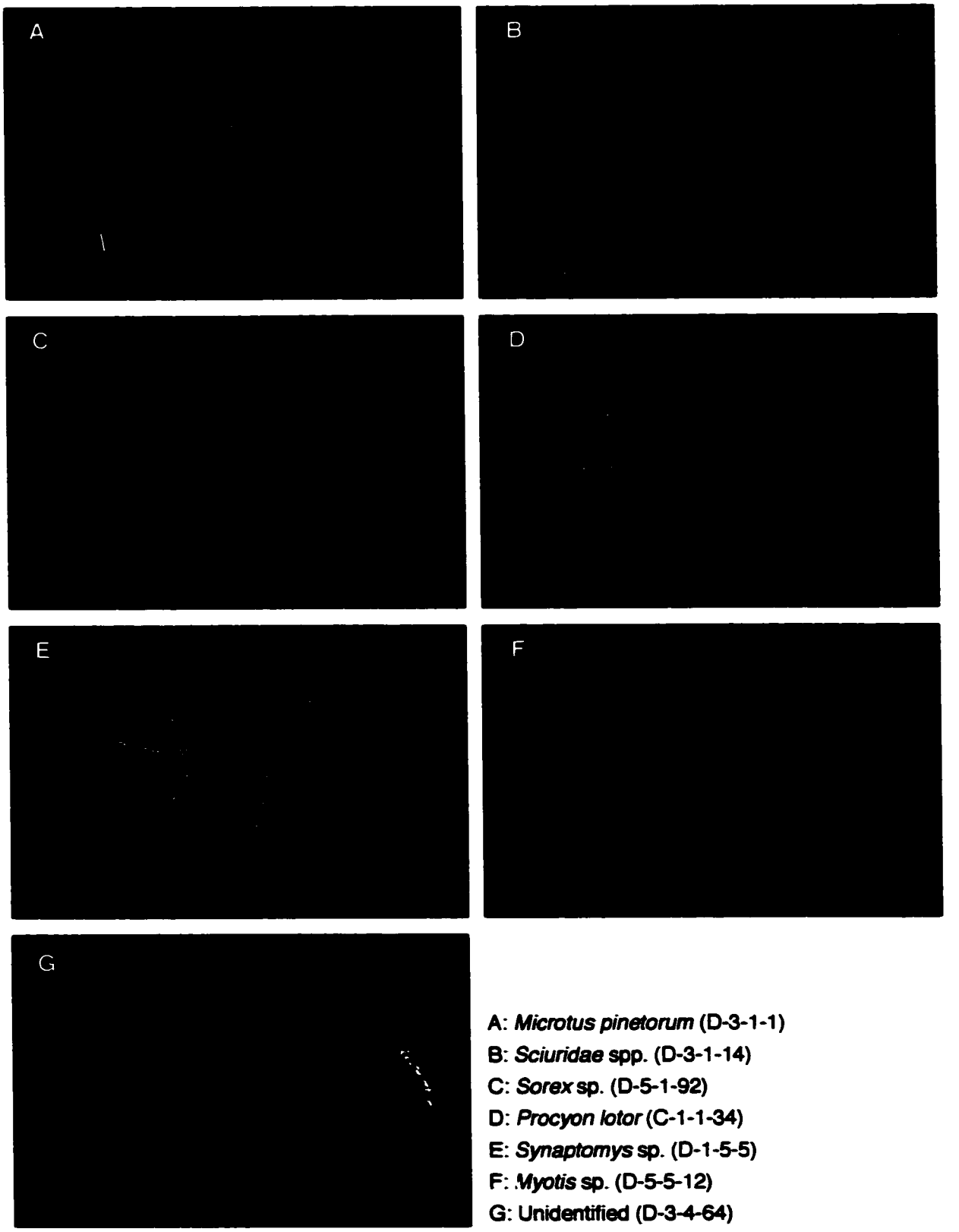
A: *Synaptomys cooperi* (D-3-1-4)
B: *Clethrionomys gapperi* (D-1-1-7)
C: *Sorex* sp. (D-5-1-93)
D: *Procyon lotor* (D-3-1-152)
E: *Microtus pennsylvanicus* (D-1-5-4)
F: *Blarina brevicauda* (D-3-5-4)
G: *Myotis lucifugus* (D-5-5-1)

Figure 20: Photographs of generally complete fossil specimens from the Caverne de la Mine lower infill.

it an effective trap support this hypothesis. The few fragile skulls that were recovered unbroken imply that they were found not far from their initial place of deposition.

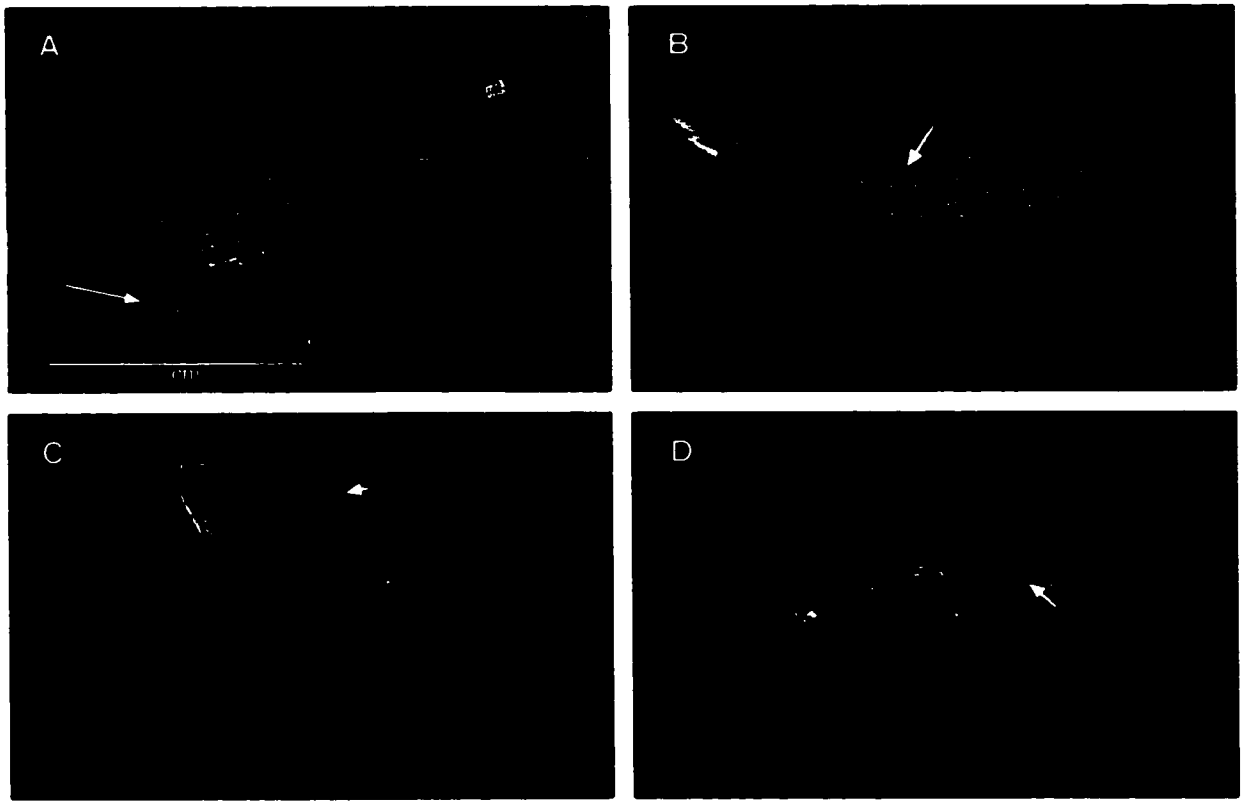
Fragmented cranial material from the fossil assemblage is quite abundant. The fragmented material consists of a variety of cranial elements which includes mandibles (Figure 21 A to G), teeth (G) and skulls/maxillae (E and F). Carnivores (D), insectivores (C), bats (F) and rodents (A, B and E) are all represented in the assemblage of fragmented specimens. Most fragmented specimens exhibit sharp edges along the fracture marks. Such fragmentation may indicate that parts of the fossil assemblage accumulated as a result of predation by carnivores as they are known to produce important quantities of broken bones in their scats (Mellett 1974; Korth 1979; Andrews and Nesbit Evans 1983; Lyman 1994a). Since they are themselves part of the fossil fauna, the raccoon and the coyote could be important predators which contributed to the fragmented remains of the Caverne de la Mine lower infill fossil assemblage. Avian predators such as owls and hawks are also important contributors to small mammal fossil assemblages. However, the regurgitated bones of their prey usually exhibit distinctive breakage and evidence of digestive corrosion such as rounded salient angles on digested rodent molars (Dodson and Wexlar 1979; Korth 1974; Andrews 1990). Diagnostic evidence of this sort was not detected on the Caverne de la Mine small mammal assemblage leading us to believe that the avifauna's contributions to the fossil deposit is either minimal or non-existent.

Post depositional processes may also account for the high number of broken specimens. The fossil assemblage of a cave deposit is subject to corrosion by way of demineralization of the surfaces where the affected specimens exhibit pitting and splitting (Andrews 1990). Such alterations may in turn yield an important quantity of fragmented material to the fossil assemblage which is amplified under processes as compacting and trampling. While pitting was not detected, several specimens from the Caverne de la Mine seem to have sustained some degree of corrosion (Figure 22 A to D). Dissolved surfaces (A and B) and fractures (C and D) are quite visible on both bones and teeth of the larger species. Most alterations are believed to be post-mortem.



A: *Microtus pinetorum* (D-3-1-1)
B: *Sciuridae* spp. (D-3-1-14)
C: *Sorex* sp. (D-5-1-92)
D: *Procyon lotor* (C-1-1-34)
E: *Synaptomys* sp. (D-1-5-5)
F: *Myotis* sp. (D-5-5-12)
G: Unidentified (D-3-4-64)

Figure 21: Photographs of fragmented fossil specimens from the Caverne de la Mine lower infill.



A: *Procyon lotor* (D-3-1-153)
B: *Procyon lotor* (D-1-4-41)
C: *Canis latrans* (D-1-4-46)
D: *Canis latrans* (D-1-4-46)

Figure 22: Photographs of altered fossil specimens from the Caverne de la Mine lower infill.

The taphonomic history of the deposit appears to be somewhat complex. Without an in-depth analysis, it is difficult to determine which agents contributed to the fossil assemblage and in what way. An assessment of the relative abundances of skeletal specimens as described by Lyman (1994a, 1994b) and others would be useful in determining which agents contributed to the fossil assemblage yet this would require a thorough investigation of the entire fossil collection.

5.3.4 Summary

The fossil assemblage of the Caverne de la Mine lower infill is comprised of a variety of organic remains which includes charred vegetation, invertebrates and vertebrates. Of these, vertebrate remains are most abundant. Fish, reptiles, amphibians and mammals constitute the fossil vertebrate fauna of which mammals appear to be most substantial both in terms of diversity and abundance. The mammalian fossil fauna is comprised of some 1351 identified specimens corresponding to at least 510 individuals and is represented by 23 different taxa. Of these, all are extant and two are extirpated. While many types of environments and habitats are represented by the different taxa, the fossil fauna can mostly be associated with a forested boreal environment. The fossil fauna can be characterised as a small mammal assemblage essentially made-up of the remains of an overwhelming bat accumulation. Small rodents are also important contributors to the fossil fauna. Larger taxa are present in limited in numbers, the raccoon being the most prominent of these. Fossil abundance varies and is not homogenous within the deposit. The three superior strata held the most specimens and few were recovered from the lowermost strata. The fossil assemblage shows signs of faunal change during the early Holocene. Boreal taxa are predominant in the lower strata while the superior strata yielded a mixed assemblage of boreal and southern species.

6. DISCUSSION

The early Holocene fossil assemblage recovered from the lower infill exhibits noticeable taxonomic transformations which suggests that faunal change occurred during the period of infilling of the lowermost section of the cave, circa 5 020 - 8 230 years B.P. Based on the species recovered from the lower deposit and their relative abundance, the fossil fauna generally exhibits affinities to boreal environments. However, while boreal taxa prevail over southern taxa throughout the lower deposit, their relative abundance diminishes towards upper portions, where southern taxa become more important. The gradient is even more apparent when both upper and lower excavations are considered. The fossil faunas differ from one another. Unlike the lower infill, the upper deposit yielded a fossil fauna more closely associated with today's local deciduous forest than with boreal environments. The fossil fauna of the upper infill produced five southern taxa (i.e. *Peromyscus leucopus*, *Marmota monax* [woodchuck], *Tamias striatus*, *Sciurus carolinensis*, *Odocoileus virginianus* [deer]) compared to three in the lower deposit, but more significantly, it failed to produce such key boreal taxa as *Clethrionomys gapperi*, which was one of the most often encountered small rodents throughout the lower infill. The fossil fauna of the upper infill is similar to the ecological associations now found in the vicinity of the cave on the Eardley Escarpment. This prompted Carrier (1989) to designate this fossil fauna as typically modern.

The presence of specific taxa within the fossil assemblage bears witness to the changing state of the fossil fauna. This is especially true when the presence of extirpated taxa is considered. Those recovered from the Caverne de la Mine fossil fauna, *Dicrostonyx hudsonius*

and *Microtus pinetorum*, are significant and widely-used indicator species in paleoecological studies.

Well adapted to cold environments, *Dicrostonyx* species have seasonal hypertrophic claws and seasonal colour moults. They are the only North American rodents with such physiological adaptations to cold climate (Banfield 1974). Special importance has been given to fossil sites containing either of the two North American species of *Dicrostonyx* as they were believed to be indicators of tundra environments (Guilday *et al.* 1964; Guilday, 1971; Lundelius *et al.* 1983). The southern extralimital fossil records of the genus prompted Guilday (1968) to state that a tundra belt extending laterally south of the Wisconsinan ice front likely existed during periods of the last glacial age. Similarly, does the presence of *D. hudsonius* in the Caverne de la Mine fossil fauna imply the existence of tundra conditions in proximity of the deposit 7 200 years ago? Mead and Mead (1989) cautioned against using *Dicrostonyx* as a strict tundra indicator in paleoenvironmental reconstructions. They pointed out that fossil faunas which contain *Dicrostonyx* are commonly constituted of species that do not share the same habitats, including tundra, boreal forest, steppe and even deciduous forest, and that the reconstructions may represent "a variety of possibilities, from tundra transition to boreal forest" (Mead and Mead 1989:329). The unusual association of *D. hudsonius* with species that do not share the same habitat today creates associations known as *disharmonious faunas* which are suggestive of contrasting environmental conditions (e.g. Graham 1976, 1985a, 1985b; Graham and Mead 1987; FAUNMAP Working Group 1996). In Pleistocene deposits, such associations represent more equable climates characterised by lesser seasonal extremes which allows for the coexistence of species considered today as being allopatric (Guilday 1967; Lundelius *et al.* 1983; Graham 1985a, 1985b; Graham and Mead 1987).

The fossil records show that non-tundra specific taxa such as *C. gapperi*, *M. pennsylvanicus*, *M. chrotorrhinus* and *Synaptomys* sp. were commonly recovered in significant numbers with *D. hudsonius*. The fossil assemblage of Caverne de la Mine is no exception. STRATUM IV also yielded other species not constrained to tundra environments (table 15). Most

taxa	MNI (stratum IV)	associated environment	sympatric
Blarina brevicauda	1	deciduous forest	No
Eptesicus fuscus	2	widespread	No
Leporidae spp.	1	-	-
Tamiasciurus hudsonicus	1	boreal forest	Yes
Glaucomys sabrinus	1	boreal forest	Locally
Peromyscus sp.	1	-	-
Clethrionomys gapperi	1	boreal forest	Yes
Microtus pennsylvanicus	1	widespread	Yes

Table 15: Mammal species occurring in STRATUM IV alongside *Dicrostonyx hudsonius*, Caverne de la Mine lower infill.

taxa are generally associated with boreal environments and one, *B. brevicauda*, is generally considered as a deciduous forest habitant. Furthermore, *B. brevicauda* and *E. fuscus* do not co-occur with *Dicrostonyx* today. Therefore, the occurrence of *D. hudsonius* in the Caverne de la Mine deposit does not definitely imply that tundra conditions prevailed in the area 7 200 years ago. However, the incorporation of such a northern species in the fossil fauna, along with other taxa having boreal affinities, is indicative of significant faunal change, and that cool boreal-like environmental conditions prevailed locally during early portions of the Holocene. Handley (1971) described how the Appalachian mountain range offered cool environments suitable for sustaining boreal and even arctic mammals at low latitudes during warming cycles of the Holocene until further warming forced some species to migrate northward. Furthermore, *Dicrostonyx* and other northerly occurring taxa may well have lingered south of their present range long after deglaciation (R. Graham, personal communication, 1999). Consequently, it is possible that the migration of *D. hudsonius* towards its current territory may be relatively recent. The occurrence of the lemming in STRATUM IV of the Caverne de la Mine lower deposit suggests that the species may well have inhabited the area, as recently as circa 7 200 years B.P.

Elsewhere in Canada, fossil assemblages which include *D. hudsonius* (Caverne St-Elzéar and Trou Otis) also suggest cooler environmental conditions than those of today. Along with *D. hudsonius*, these sites contained northerly occurring species such as the arctic shrew and arctic hare [Caverne St-Elzéar (Lasalle 1984)] and even the grizzly bear (*Ursus arctos*) [Trou Otis (Harington 1980)]. Some of these species may have migrated together into north eastern Canada as the Wisconsin ice sheet retreated (C. R. Harington, personal communication, 2000).

While the occurrence of *D. hudsonius* adds an explicit boreal aspect to the older portion of the lower infill, the presence of *M. pinetorum* within the three superior strata gives southern affinities to the fossil assemblage of this part of the infill. The woodland vole is closely associated with the deciduous forest, as its name suggests. It is often used as an indicator species of the Carolinian life zone as its distribution generally mimics the biotic province's geographic disposition. Churcher and Karrow (1963) have shown how the Hamilton Bay record of

M. pinetorum emphasised the fauna's southern affinities. The Hamilton Bay deposit is believed to be contemporaneous with the Scarborough Bluffs fossil deposit dated at 5 550 ±70 years B.P., which also exhibits southern affinities (Churcher and Karrow 1963). Together, these fossil faunas point to altered environmental conditions characterised by increased temperate conditions during mid-Holocene times.

The peculiar occurrence of *M. pinetorum* in the Caverne de la Mine deposit between 5 000 and 6 000 years B.P. may likewise reflect warm conditions. A northward displacement of the vegetation zones initiated by a warmer and drier climate during the middle Holocene (McAndrews 1980; Liu 1990; Anderson 1995) may have prompted the vole to also expand its range northward well into the region. Such a range adjustment is not an isolated case. Other Holocene fossil faunas have also shown that the range of some small mammals have likewise fluctuated, the evidence being most apparent near the margins of the actual ecotones and especially within the Mississippi Valley (Handley 1971; Semken 1983).

While *M. pinetorum* appeared within the local fauna about 6 000 years ago, it did not displace other taxa sharing the same territory. By integrating itself into the existing local vole community, the arrival of the pine vole created a biotic association with no modern analogues. While *M. pinetorum* is sympatric with most species recovered from STRATUM I, STRATUM II and STRATUM III, it is generally not found alongside *M. chrotorrhinus* and *C. gapperi*, two voles with boreal affinities. It is not impossible that the diversified flora growing on the Eardley Escarpment (Brunton and Lafontaine 1974; Gagnon and Bouchard 1981) could have supported the coexistence of these species. At that time, *M. pinetorum* may well have inhabited the south-facing flanks of the Escarpment where hardwood taxa, such as maple, oak and beech, are found while *M. chrotorrhinus* and *C. gapperi* inhabited the higher plateaux and summits, today characterised by a cooler micro-climate and a vegetation with northern affinities. The upper infill failed to yield any remains of *M. pinetorum* therefore it is expected that by 5 000 years B.P., the vole's range had already receded southward towards its present position in response to climate

cooling. The occurrence of *M. pinetorum* in the upper portions of the lower infill suggests ameliorated environmental conditions between 5 000 and 6 000 years B.P.

The information gathered from the Caverne de la Mine faunal assemblages suggests a gradual transformation of the local fauna between the early and mid-Holocene from a predominantly boreal association to an admixture of boreal and southern resembling the modern local fauna. While the local vegetation cover was undergoing significant transformations since the deglaciation, the local mammal community structure was changing as well. Based mostly on taxonomic presence/absence, the following chronological faunal sequence was established from the entire fossil deposit:

a) boreal taxa (i.e. *T. hudsonius*, *G. sabrinus*, *C. gapperi*, *D. hudsonius*, *M. pennsylvanicus* and *M. chrotorrhinus*) were first to be incorporated in the deposit as they migrated from their ice age refuge to the south into an open white birch – jack pine dominated boreal type forest, sometime between about 7 280 and 8 230 years ago;

b) between circa 5 020 and 7 280 years B.P., the boreal type forest was transformed into a mixed conifer-deciduous forest dominated by the white pine and several hardwood taxa at which time temperate taxa (i.e. *B. brevicauda*, *T. striatus*, *M. pinetorum*) integrated themselves into the local fauna. By that time, *D. hudsonius* had likely abandoned the region;

c) as hardwood vegetation became predominant on the south-facing Escarpment after about 5 000 years ago, the local fauna took on a modern form with southern taxa becoming increasingly dominant by the addition of more taxa living in the deciduous forest environments (i.e. *S. carolinensis*, O. *virginianus*) while several boreal taxa (i.e. *C. gapperi* and *M. chrotorrhinus*) disappeared from the region and *M. pinetorum* migrated southward toward its current range, presumably in response to a cooling climate.

As the above faunal sequence suggests, early Holocene faunal change is largely associated with evolving vegetation cover in the area. As the forest cover evolved from a white birch – jack pine dominated boreal forest about 8 230 years ago to a closed canopy mixed conifer-deciduous woodland by circa 5 000 years B.P., the local fauna similarly evolved from a predominately boreal assemblage to a deciduous woodland type assemblage. Additionally, the effects of a mid-Holocene warming may have also played an important role in the distribution of certain species, notably *M. pinetorum*.

In comparison to the St-Elzéar fossil deposit, Caverne de la Mine shares many similarities. In fact, both are early Holocene cave deposits which produced eclectic fossil assemblages made up predominantly of small mammals. Furthermore, the two sites are found within Dice's Canadian Life Zone have comparable Quaternary histories. Both acted as natural traps and therefore have similar taphonomic pathways.

The St-Elzéar cave deposit and that of the Caverne de la Mine lower infill have produced faunal assemblages which apparently predate their respective modern fauna as they contain taxa that do not occur in the vicinity of the fossil sites today. Mostly manifested by the inclusion of taxa with affinities to boreal and tundra environments, both fossil assemblages are indicative of cool environmental conditions during the early Holocene. This is particularly apparent in the case of the St-Elzéar deposit as all six extirpated taxa encountered generally occur north of the cave deposit today. While some are found close to the fossil site, particularly the boreal taxa (i.e. *Sorex arcticus*, *Phenacomys intermedius*, *Mustela nivalis*), others are mostly confined to tundra environments, some distance away from the deposit (i.e. *Lepus arcticus*, *Dicrostonyx hudsonius*, *Microtus xanthognathus*).

With the exception of *D. hudsonius*, the Caverne de la Mine deposit did not produce taxa now occurring exclusively north of the site. In this respect, it is different from the St-Elzéar cave deposit. To some, this may appear quite peculiar as they would have expected to encounter other north-occurring taxa along with *Dicrostonyx*. It is in fact somewhat surprising that Caverne

de la Mine failed to yield the remains of nearby occurring taxa such as *P. intermedius*, *S. arcticus*, *S. borealis*, yet produced *D. hudsonius*, which today is found exclusively within the northern reaches of eastern Canada. This may be attributed to several factors, such as a low sample size (the St-Elzéar deposit having produced significantly more remains than Caverne de la Mine), low fossil count in the oldest section of the infill, species distributions and possibly species-specific responses to environmental change.

Quaternary research over the past 20 years, especially the FAUNMAP project, has shown how individual species adjusted their ranges differently in response to environmental fluctuations in accordance to their own tolerance limits (i.e. in different directions, for different distances at different times) rather than as community units (Graham 1985a, 1985b; Graham and Mead 1987; FAUNMAP Working Group, 1996). It is possible that in this case, *Dicrostonyx* lingered south of its present range well into the Holocene in adequate refuges, whereas other northerly occurring species were well established within their present range early after deglaciation, which prevented them from being incorporated into the deposit. Environmental changes would have later obliged *Dicrostonyx* to abandon the niche and retreat northward toward its present range. This scenario is in general accordance with American records which have repeatedly shown how faunal equilibrium was reached early in the Holocene while mammal species have shown individualistic readjustments in their distributions throughout the past 10 000 years (Handley 1971; Semken 1983; Graham 1985b). The inclusion of *M. pinetorum* in the Caverne de la Mine lower infill offers yet another example of individualistic response. In fact, its presence indicates that the Carolinian species periodically shifted its range northward, sometime between circa 5 020 and 7 280 years B.P. While ameliorated environmental conditions may have favoured the expansion of this species' range at the time, it did not, however, lead to a displacement of the Carolinian life zone onto the Canadian life zone. In fact, the fossil fauna from the superior strata of the lower infill maintained its general composition, with typical Canadian life zone species (e.g. *C. cristata*, *C. gapperi* and *M. chrotorrhinus*) occurring alongside *M. pinetorum*.

Similarly, other scattered Holocene fossil sites — notably those situated on the peripheries of ecotones — simultaneously exhibit comparable occurrences.

Species have been shown to respond individually to environmental changes. Consequently, explicit pre-modern communities or faunal assemblages are virtually improbable and not apt to be specifically predicted. Past community structures are understandably derived from generalized and localized episodic environmental phenomena for which reason there are often no modern analogues of these communities. The absence of certain taxa thought to have been included in the Caverne de la Mine lower deposit therefore makes sense. Furthermore, since species did not respond to environmental change in community units but rather individually, differences within the taxonomic assemblages of separate fossil sites are foreseeable and should not be considered unusual.

Analysis of the lower infill of the Caverne de la Mine fossil deposit has shown that a terrestrial mammalian community was established locally early after deglaciation. While producing a fossil fauna similar from today's local fauna, the lower infill revealed a fauna which clearly predates its modern form. The taxonomic assemblage of this pre-modern fauna is characterized by a predominance of boreal taxa in the oldest section of the deposit (circa 7 280 years B.P.) which becomes more modern looking in the younger section (circa 5 020 - 7 280 years B.P.) as proportions of southern taxa increase and those of boreal taxa remain constant. The faunal assemblage of the lower infill therefore represents, to some degree, an episode of faunal change. These changes echo local environmental transformations which occurred during the early Holocene as the regional and local floral records have clearly displayed. Finally, faunal transformations appear to have diminished circa 5 000 years ago, as evidenced by the fact that the fossil assemblage produced from the upper infill is virtually undistinguishable from the modern local fauna.

7. CONCLUSIONS

The primary objective of this study was to investigate an early Holocene fossil fauna and to indicate differences between the mammalian composition of the fossil fauna and the modern local fauna of the lower St. Lawrence - Ottawa valley region. To resolve the question, the hypothesis that postglacial environmental changes and faunal colonisation affected early Holocene local fauna was put forth. The hypothesis was tested by analysing the Caverne de la Mine lower infill fossil assemblage.

The results clearly indicated changes in the early Holocene local faunal composition. While many species of the local fauna established themselves in the area early in the Holocene, some differences exist between the fossil fauna dated between 5 020 ± 70 and 8 230 ± 60 years B.P. and the modern local fauna. These differences mostly appear as a shift in the community structure. The older sections of the lower deposit in particular produced taxa with affinities to boreal forest environments while the younger sections exhibited a progressive augmentation of southern species. Fossils recovered from STRATUM I, STRATUM II and STRATUM III are most characteristic of the actual mammal community structure of the Ottawa valley. The faunal gradient becomes quite clear when we include *Dicrostonyx hudsonius* and *Microtus pinetorum*, two habitat specific taxa which do not occur locally today. *D. hudsonius* is now restricted to cold environments north of the fossil site and *M. pinetorum* lives south of the site today and is closely related to environments of the deciduous forest. Remains of the first taxa were recovered from STRATUM IV dated at 7 280 ± 60 years B.P., whereas those of the latter were found in the three youngest strata (circa 5 020 to <7 280 years B.P.) of the lower infill. Changes within the local faunal community structure occur in tandem with transformations within the local vegetation

cover. During the corresponding period of the early Holocene, the local vegetation passed from a jack pine-dominated boreal forest to a mixed conifer-deciduous forest. Postglacial climatic changes and vegetation succession prompted significant modifications of the landscape. The dependant fauna adjusted itself accordingly.

The faunal response to these changes was not uniform. Different species responded individually to environmental change in accordance with their own biological tolerance. An example is the presence of *D. hudsonius* in the Caverne de la Mine lower infill whereas other nearby northerly occurring taxa are absent from the fossil fauna. The discrepancy suggests that the latter taxa were well established within their present range soon after the deglaciation while *D. hudsonius* lingered south of its present range until a later date. Similarly, improved environmental conditions during the mid-Holocene (5 000 - 7 000 years B.P.) favoured the northward expansion of some species into the area which included *M. pinetorum*, while others, such as *Sciurus carolinensis*, arrived much later (<5 000 years B.P.). Since species adjusted their ranges at varying rates, at different times and in divergent directions, the Caverne de la Mine local fauna was not a distinctive entity, but a dynamic assemblage of species which was in constant reorganisation from the early Holocene through modern times. Altogether, the local fauna appears to have acquired its modern appearance around 5 000 years B.P.

In summary, the Caverne de la Mine fossil deposit is a window on the postglacial history of the vertebrate terrestrial fauna of the lower Ottawa river valley region. The analysis of its fossil mammalian fauna has shown that several taxa of the local fauna were present in the area by circa 7 000 years ago. It also demonstrated some degree of contrast between the early Holocene local fauna and the local modern fauna. Postglacial environmental change coupled with faunal colonisation of the newly opened landscapes were important contributing factors of the faunal gradient. Species migration rates and their response to evolving landscapes were individualistic. Together they show an evolution of the community structure of the local fauna, from one with essentially boreal forest environment affinities, to one mostly associated to deciduous forest environments comparable to today's local fauna. On the whole, the analysis of the Caverne de la

Mine lower infill fossil fauna yields evidence of a modernisation of the local fauna, which is more apparent when the fossil fauna of both upper and lower infills are considered. The analyses of both sections of the deposit suggest that the local fauna attained a modern aspect about 5 000 years ago.

The excavations of the Caverne de la Mine have produced a fossil assemblage considered unique in the region with respect to its age, abundance and diversity. More importantly, the fossil deposit yielded two previously unrecorded taxa. Further excavations could provide a better understanding of the terrestrial fauna from the Champlain Sea episode. Unfortunately, while the deposit is clearly older than 8 230 years B.P., a poor fossil count in the lowermost section of the infill offers a less than promising prospect. A better research avenue could perhaps be found in the exploration and analysis of other regional fossil deposits, where data from this study would prove useful for analyses and comparisons.

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