Glacial Lake Arkona – Whittlesey transition near Leamington, Ontario: geology, plant, and muskox fossils

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Proglacial subaquatic fans between Leamington and Colchester, Essex County, Ontario, were deposited in glacial Lake Maumee at the end of the Port Bruce Stade by ice retreating northward. Some fans were buried by till and glaciolacustrine materials. One fan surface, northwest of Leamington, was only modified by lake current that transgressed and regressed over it. An aggregate excavation (Bondi site) exists within the surface of this fan. We describe the sedimentology of the site that provides evidence for fan and overlying bar deposits.

Lake levels fell to the levels of lakes Arkona (216 m) and Ypsilanti (122 m) following the deposition of the fans. Large terrestrial areas supported plants and animals. Their presence is recorded at the Bondi site by a single bone and several organic mats recovered from the fan and bar sediment contact at two separate exposures. Radiocarbon dates on the bone of 13 410 ± 100 BP (TO-1803), organic material dates of 13 225 ± 200 BP (BGS-1404) and 13 150 ± 100 BP (WE-01-89), the altitude (209 m), and the sedimentological setting indicate deposition during the Lake Arkona (216 m) – Lake Whittlesey (226 m) transition period.

The pollen and plant macrofossil assemblages recovered from the organic material indicate a forest–tundra environment, with a mean July temperature of 14°C. This interpretation fits well with the bone identified as cf. *Euceratherium* sp., a shrub-ox. The discovery of cf. *Euceratherium* sp. is surprising, as its previous range was south and west of this site. The organic material was subsequently buried by the formation of a bar as water levels rose within the Lake Erie basin and transgressed the site.

Les éventails subaquatiques proglaciaires entre Leamington et Colchester, comté d'Essex, Ontario, furent déposés dans le lac glaciaire Maumee, à la fin du Stade de Port Bruce, par le glacier retraitant vers le nord. Certains éventails furent recouverts par du till et des matériaux glaciolacustres. Une surface d'éventail, au nord-ouest de Leamington, n'a été que légèrement modifiée par les courants dans les lacs qui transgressaient et régressaient au-dessus d'elle. Une excavation pour l'exploitation d'agrégats (site de Bondi) a été creusée à l'intérieur de la surface de cet éventail. Nous décrivons la sédimentologie de ce site qui fournit des enseignements sur les dépôts de l'éventail et de la barre sus-jacente.

Les niveaux des lacs se sont abaissés aux niveaux des lacs Arkona (216 m) et Ypsilanti (122 m) à la suite du dépôt des éventails. Des plantes et des animaux avaient colonisés de vastes aires terrestres. Cette occupation est documentée au site de Bondi par la découverte d'un os et de tapis organiques, au contact qui sépare les sédiments de l'éventail et de la barre et qui est exposé à deux endroits. L'os est daté au radiocarbone de 13 410 ± 100 Av.P. (TO-1803) et le matériel organique de 13 225 ± 200 Av.P. (BGS-1404) et de 13 150 ± 100 Av.P. (WE-01-89), l'altitude (209 m), et le contexte sédimentologique, indiquent que le dépôt s'est formé durant la période de transition lac Arkona (216 m) – lac Whittlesey (226 m).

Les pollens et les plantes macrofossiles recueillis dans le matériel organique indiquent un milieu de type forêt–toundra, et une température moyenne en juillet de 14°C. Cette interprétation est compatible avec l'os identifié comme le représentant de cf. *Euceratherium* sp., un boeuf armé de bois. La découverte de cf. *Euceratherium* sp. est surprenante, car cette espèce n'était connue qu'au sud et à l'ouest de ce site. Le matériel organique a été subséquemment enterré par les matériaux d'une barre lors de la montée des niveaux de l'eau dans le bassin du lac Érié et de leur transgression sur le site.

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Introduction

Sections through 14 m of Late Pleistocene sediments were exposed in 1989 in the Bondi aggregate excavation located 5 km northwest of Leamington (NTS 40J/2b; 42°05′17″N, 82°38′15″W; Fig. 1). Three excellent exposures within the excavation (western, eastern, and northern) are about 400, 300, and 350 m long and 14, 5.6, and 5.6 m high, respectively (Fig. 2).

The sediments record a glacial Lake Maumee proglacial subaquatic fan, a still-water deposit, a bar, and shoreface beach sands of the Arkona–Whittlesey transition. Within the western exposure a workman found a bone at a contact separating Lake Maumee from Lake Whittlesey sediments. Within the eastern exposure at about the same altitude, plant-rich organic horizons were found within still-water deposits.

We describe the site, its sedimentary facies, the fossil plants and bone, and the paleoenvironment based upon the relationships between the materials. Preliminary results were reported in Morris (1988, 1989*a*, 1989*b*, 1990, 1992).

Abbreviations

ANSP, Academy of Natural Sciences, Philadelphia; BGS, Brock University Geological Sciences, Radiocarbon Laboratory; GIN, Geological Institute of the Academy of Sciences

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of the U.S.S.R. (now Geological Institute of the Russian Academy of Sciences); NMC, Canadian Museum of Nature, Ottawa; TO, University of Toronto, Isotrace Laboratory; ROM, Royal Ontario Museum, Toronto; UCMP, University of California Museum of Paleontology, Berkeley; USNM, United States National Museum, Washington, D.C.; WE, University of Waterloo, Environmental Isotope Laboratory; ZIN, Zoological Institute of the Academy of Sciences of the U.S.S.R. (now Zoological Institute of the Russian Academy of Sciences).

Site description

The sediments exposed in the excavation are associated with sand deposits that occur from west of Leamington to Colchester. These deposits are fan shaped, with the apex of each fan orientated north. The apexes of several fans lie proximal to or beneath minor recessional moraines. The sand is commonly buried beneath glaciolacustrine silt and clay or clayey silt till. Locally, the sand is either enclosed within the till or lies on top of it.

The Bondi excavation is located within the easternmost fan, one of two fans that were not buried by till. Following deposition, the unprotected sand was reworked by a lake current. This reworking formed several eastward-orientated lunate-shaped bars. Vagners (1972*a*, 1972*b*) recognized three wave-cut benches and beaches related to bars that formed in glacial lakes Whittlesey, Warren, and Grassmere. Two additional glacial lake levels recognized by us are correlated with glacial lakes Wayne and Lundy. Sand, transported in an easterly direction from the bars, thinly covers the glaciolacustrine silts and clays north and northeast of Leamington, southeast of the site.

The excavation surface, bar, wave-cut bench, and beach surface altitudes were determined with a Wallace and Teirnan altimeter (precision to ±3 m) and a 1 : 25 000 scale map (NTS 40J/2b; contour interval 3 m). The surface at the site (217 m) lies to the east and is lower than a glacial Lake Whittlesey wave-cut bench (226 m). Farther to the east and lower than the site is a Glacial Lake Warren wave-cut bench (209 m).

Western exposure

This exposure is largely composed of sand (sections 1–3, Fig. 2) and comprises three units. The lowest unit, unit 1, displays a suite of bed forms that range from north to south: trough cross-beds, channel scours, and gently dipping planar beds. The trough cross-beds and planar beds have paleocurrent directions of 208° and 165°, respectively. There are a few clayey silt clasts (2–4 cm in diameter) within each of these bed forms. Unit 1 is capped by 30 cm of massive, medium-grained sand, which fines upwards to 52 cm of massive sandy silt.

A sharp contact separates the massive sandy silt from the second unit. At the northern end of the western exposure, the second unit consists of coarse sand with gravel that becomes finer grained towards the southern end. Structurally, the second unit consists of steeply dipping foreset beds at the northern end of the exposure, but the angle of these beds decreases southward.

A bone found at the contact between units 1 and 2 at an altitude of 209 m in section 2 yielded an accelerator mass spectrometry (AMS) radiocarbon date of 13 410 ± 100 BP (TO-1803; Table 1).

The top of unit 2 is marked by a sharp contact with unit 3,

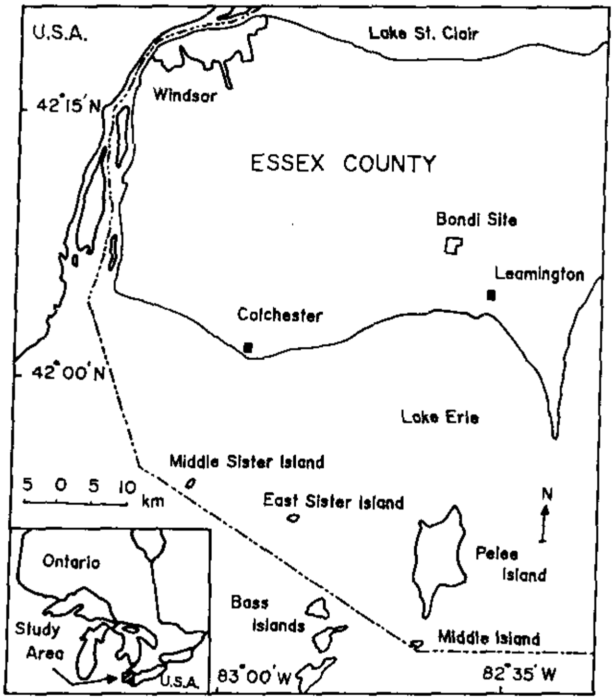

FIG. 1. Location of the Bondi site northwest of Leamington, southwestern Ontario.

which consists of medium sand with minor gravel. The medium sand is 5.8–7.4 m thick and displays multidirectional ripple cross-laminations. The upper 1.6 m of unit 3 has more gravel, and its structure has been destroyed by weathering.

Eastern exposure

The eastern face exposes clayey silt till, sand, and laminated glaciolacustrine silt and clay (sections 4 and 5, Fig. 2). There are four units. The first and lowermost consists of over 1.6 m of compacted, massive sand with diamict stringers that extend laterally south at 190°. Water escape structures occur at the top of this unit.

The second unit is a clayey silt till, which thins southward. The lower part of the till, observed only in the north part of the exposure, is massive. The upper part of the till consists of southward-orientated flows. Separating the upper and lower part of the till is a weakly developed stone pavement. The long axis orientation of stones within the pavement is 178°.

A sharp, wavy contact separates the till from overlying unit 3. At the southern end of the eastern exposure (section 4, Fig. 2), the till is overlain by 35 cm of laminated silt and clay that coarsens upwards into a medium-grained sand. This sand is planar bedded except for low-angle ripples in the middle. Shells and slivers of wood are present. The gently dipping planar beds have a strong paleocurrent direction of 164°.

At the northern end of the exposure, the third unit thickens and the structure becomes more complex where gently dipping planar beds of the medium-grained sand are disturbed by flame dewatering structures (section 5, Fig. 2). About 60 cm of massive sand overlies the disturbed beds. Overlying the massive sand is 35 cm of dark-grey laminated silt and clay with shells. Organic layers between the laminations were dated at 13 225 ± 200 BP (BGS-1404; Table 1). The surface of this unit is marked by a clear, smooth contact at 209 m.

A shell-rich, 50 cm thick massive sand overlies the laminated silt and clay. This massive sand is overlain by a second,

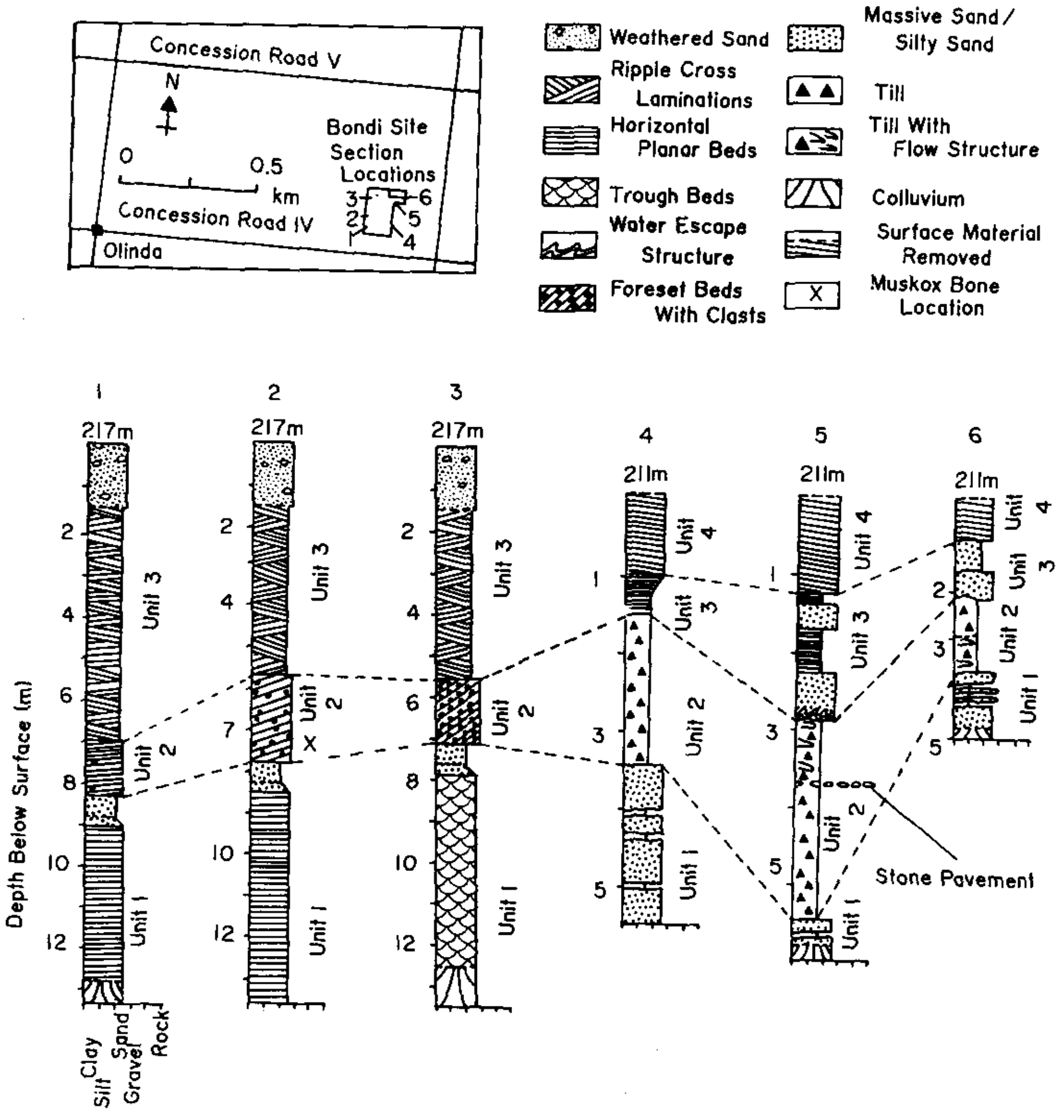

FIG. 2. Sedimentary facies of the western, northern, and eastern exposures of the Bondi site (with inset map). Surface altitude of sites 1, 2, and 3 is 217 m, while surface altitude of sites 4, 5, and 6 is 211 m.

25 cm thick laminated silt and clay bed. This second silt and clay deposit also contains organic layers that yielded wood that was dated at 13 150 ± 100 BP (WE-01-89; Table 1). Gently dipping planar-bedded sand overlies the second silt and clay deposit. The planar beds have a paleocurrent direction of 126°. The surface altitude of the eastern exposure is at 211 m but an unknown thickness of material has been removed.

Northern exposure

This exposure consists of clayey silt till and sand (section 6, Fig. 2). Four units are preserved within the exposure. The first and lowermost unit consists of about 1 m of alternating beds of massive, medium-grained sand and clayey silt diamict; these beds are orientated at 185°. The first unit is separated from the second by a sharp contact. The second unit is a clayey silt till about 1.5 m thick. The lower part of this unit contains southward-orientated flow structures, which grade upwards into a massive till.

The second unit is separated from the third by a sharp, wavy contact. The third unit is a massive medium-grained sand about 1.2 m thick, which fines upward. The third unit is separated from the fourth by a sharp contact at 209 m. The fourth unit consists of low angle plane bedded sand. An unknown thickness of material has been removed from the surface by excavation.

Paleoecology of section 5

A 110 cm thick monolith was collected from unit 3, section 5, (see Fig. 2) and sampled in the laboratory for loss on ignition and fossil pollen and seed analysis. Loss on ignition was performed on dry samples at 550°C to determine the amount of organic matter and at 1000°C for $CaCO_3$ (Dean 1974). In the clay horizons, organic matter was low, ranging up to 6%, except at 7 cm where it was 18%. $CaCO_3$ was 15−24%, except in the upper clay where there was a peak of about 33%, suggesting marl precipitation rather than limestone clasts.

Pollen analysis was done on 15 samples of 0.9 mL each. A spike of 13 500 *Lycopodium clavatum* spores was added to the sample to estimate pollen density. The samples were then treated with 10% HCl to dissolve carbonate and sieved to obtain the 10−150 μm pollen fraction (Cwynar et al. 1979). Silicates

TABLE 1. Summary of radiocarbon-dated material

Material	Age (years BP)	Laboratory No.	Site
Shrub-ox (ROM 41960) bone collagen	13 140 ± 100	TO-1803	Bondi site, west exposure, 363700m.E. 4660600m.N.
Muskox (ROM 1194) bone collagen	11 580 ± 70	TO-3652	See McDonald and Ray (1989)
Bison (ROM 20891) bone collagen	290 ± 50	TO-3651	See Churcher and Karrow (1977)
Wood	13 225 ± 200	BGS 1404	Bondi site, east exposure, 364000m.E. 4660700m.N.
Wood	13 150 ± 100	WE-01-89	Bondi site, east exposure, 364000m.E. 4660700m.N.

NOTES: See text for laboratory abbreviations.

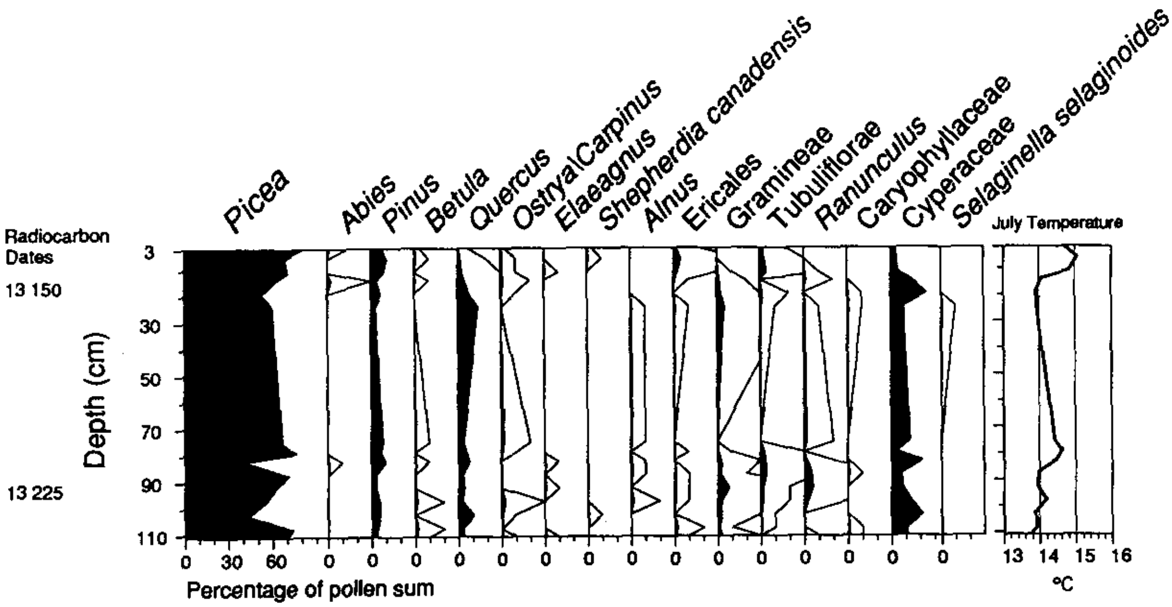

FIG. 3. Pollen diagram for section 5. The line is 10× exaggeration. Not shown are recycled pre-Quaternary spores, which exceed 30% at each level, and occasional pollen grains of *Larix, Populus, Salix, Acer, Tsuga, Celtus, Ulmus, Carya, Thalictrum, Liguliflorae, Ambrosia, Chenopodiineae, Sparganium* type, *Dryopteris* type, and *Lycopodium*.

were dissolved with HF, and acetolysis was used to remove organic matter. The residue was stained with safranine and mounted in silicone oil. One hundred pollen grains of upland plants were identified in each sample together with introduced *Lycopodium* spores. Identifications follow McAndrews et al. (1973).

Pollen grains were well preserved. Fossil pollen density was variable, ranging from 900 to 34 000 per mL, with sand having less than silt. The pollen spectra (Fig. 3) are dominated by *Picea* (spruce) and Cyperaceae (sedge family) and show no stratigraphic trend. The few temperate tree pollen grains of *Pinus* (pine), *Quercus* (Oak), and *Ostrya–Carpinus* (ironwood – hop hornbeam) are anomalous in this otherwise arctic assemblage and are probably recycled or, less likely, blown in from the south. The pollen of *Elaeagnus* (silver berry), *Shepherdia canadensis* (rabbit-berry), *Alnus* (alder), and *Ericales* (heaths) together with the herbs Gramineae (grass), Tubuliflorae (aster group), Caryophyllaceae (pinks), *Selaginella selaginoides* (spikemoss), and Cyperaceae (sedge family) indicate open ground. When the pollen–climate function B of Bartlein and Webb (1985) was applied to the assemblage, a July mean temperature of 14°C was estimated, which is consistent with forest–tundra.

Plant macrofossils were concentrated from a measured volume of sediment by water sieving with a 500 μm sieve. Identifications were made using a seed and leaf herbarium. The assemblage (Fig. 4) is dominated by seeds of aquatic plants and open ground herbs and shrubs; angiosperm subshrub twigs are abundant. The submerged pondweed *Potamogeton vaginatus* indicates a deep, cold, pond on which floated *Ranunculus* sect *Batrachium* (water crowfoot); along the pond margins were emergent *Carex* (sedge). Along the sandy beach was the perennial herb *Potentilla anserina* (silver weed). The dry upland was dominated by herbs such as *Carex* (sedge), *Dryas integrifolia* (arctic avens), *Linum* (flax), and *Arenaria* (sandwort), as well as the subshrubs *Artostaphylos* (bearberry) and *Empetrum* (crow-berry). Among the larger shrubs, the sparse pollen of wind-pollinated *Alnus* (alder) and *Betula* (birch) indicate they were rare or absent, but the occasional pollen of insect-pollinated *Shepherdia canadensis* (rabbit-berry)

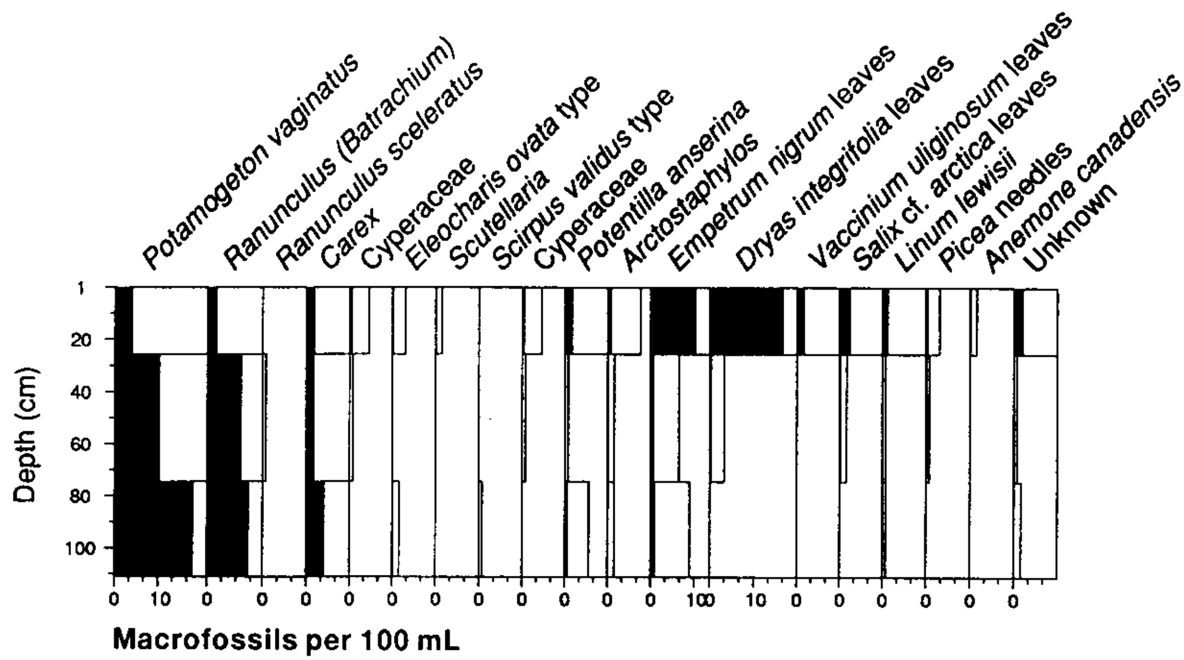

FIG. 4. Plant macrofossil diagram showing densities of seeds and leaves per 100 mL. The line shows density per litre.

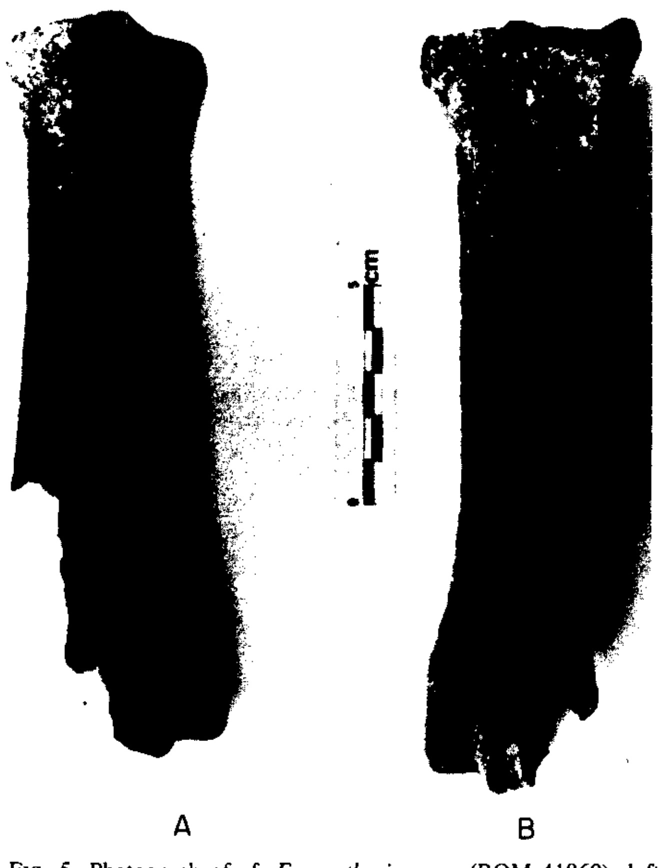

FIG. 5. Photograph of cf. *Euceratherium* sp. (ROM 41960), left metacarpal from Leamington, Ontario: (A) anterior view, (B) posterior view. The photograph was taken before the small portion used for the AMS date was extracted from the lateral side of the mid-shaft region (illustrated as absent in Fig. 9A).

in the immediate area and *Elaeagnus* (silver-berry) indicate that these nitrogen fixers were present. The only indication of trees is a few sparse spruce needles.

Other relevant forest–tundra macrofossil sites

A similar assemblage of forest–tundra macrofossils was found at the contemporary Vanderven site, 180 km to the east (Warner and Barnett 1986). Like the Bondi site, it is part of a proglacial delta deposit dating to the Mackinaw Interstadial (about 13 600 BP). It was interpreted as at least partly redeposited because of a 25 000 BP date on water-rounded wood and because several habitats are represented by the macrofossils. In contrast, the well-preserved Bondi site macrofossils consistently represent forest–tundra and, therefore, are unlikely to be redeposited.

The Nichols Brook site near Buffalo, New York, 350 km to the east (Calkin and McAndrews 1980; Fritz et al. 1987), spans the age of the Mackinaw Interstadial (about 13 600 – 13 000 BP). Unlike the Ontario sites it is a still-water, mollusc-rich pond marl rather than a delta deposit and thus is unlikely to have recycled macrofossils. The pollen assemblage is similar to the Bondi site, but unlike the Ontario macrofossil assemblages it is dominated by *Picea* needles and lacks the tundra indicator *Dryas*. The beetle fauna indicates southern boreal forest.

Bone identification (section 2)

ROM 41960 (Fig. 5) is a weathered left metacarpal III and IV (the fused cannon bone typical of artiodactyls) lacking part of the shaft and all of the distal trochlea on the medial side (Figs. 6–8). The specimen's shape and proportions suggest a bovid (Family: Bovidae). Several features identify it as a muskox (Tribe: Ovibovini): in outline, the shaft is subparallel proximally and diverges distally; the transverse width of the distal end is wider than the transverse width of the proximal end; the dorsal longitudinal groove is reduced to a faint mesial deepening near the proximal end; and the dorsal surface of the shaft is flattened (De Giuli and Masini 1983).

Additionally, even though the distal end is incomplete, the intertrochlear space, especially on the posterior face, is wide, typical of ovibovines (De Giuli and Masini 1983). Other fea-

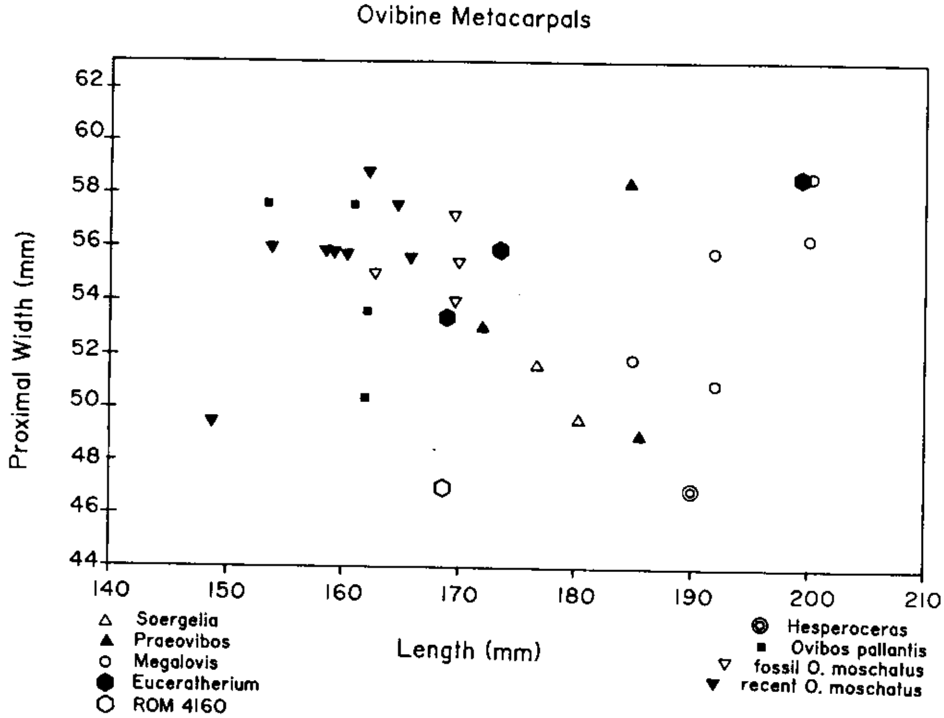

FIG. 6. Plot of length vs. proximal width of ovibovine metacarpals. Raw data are presented in Table 1.

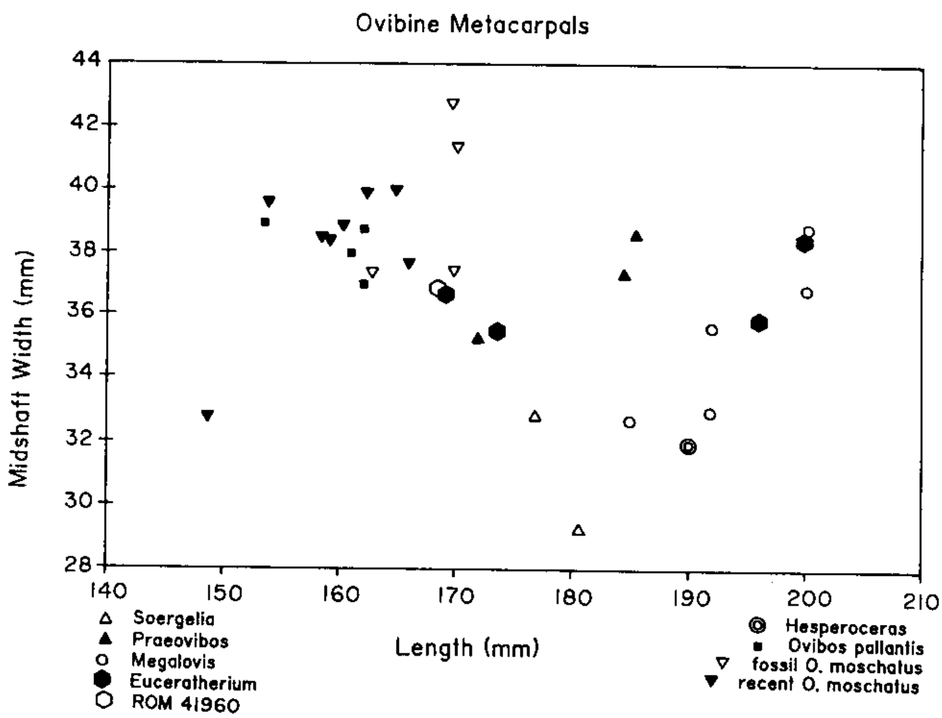

FIG. 7. Plot of length vs. midshaft width of ovibovine metacarpals. Raw data are presented in Table 1.

tures of this bone that separate ovibovines from bovids (*Bison*, *Bos*, *Ovis*, and *Capra*) include the lack of an intermetacarpal foramen on the proximal end; the lack of a medial groove on the anterior face of the bone (except as noted above); and the round shape of the intermetacarpal foramen distally on the anterior face of the bone. More than one half the distal width remains, and it is useful to estimate this measurement. Other typically ovibovine features of the metacarpal described by De Giuli and Masini (1983) are not preserved, and thus identification to the generic level is difficult. When compared with recent specimens, however, ROM 41960 is not seriously damaged. The measurements presented here are not likely to be more than 2 mm less than they were originally.

Published illustrations of *Hesperoceras*, *Megalovis*, *Praeovibos*, *Euceratherium*, and *Ovibos pallantis* (Table 2) suggest that the metacarpal of these animals are similar to ROM 41960

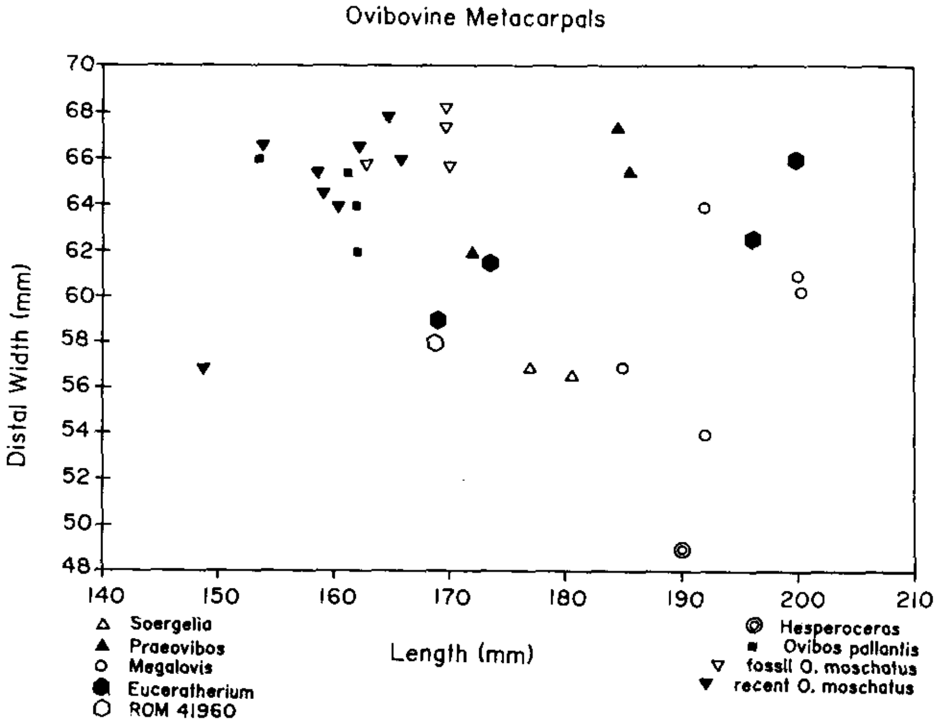

FIG. 8. Plot of length vs. distal width of ovibovine metacarpals. Raw data are presented in Table 1.

except for their overall proportions. Therefore bivariate graphs of proximal width, midshaft width, and distal width were plotted against length (Figs. 6–8).

Bootherium is known to have been more sexually dimorphic than the living *Ovibos moschatus* (McDonald and Ray 1989). Unfortunately, this dimorphism has not been assessed using postcranial material and no smaller (presumably female) *Bootherium* metacarpals were available for study. The *Bootherium* specimens at hand (presumably male) are much larger than ROM 41960, as well as all other genera considered here (Fig. 9); for this reason measurements for these specimens have not been plotted in Figs. 6–8. We therefore consider it unlikely that ROM 41960 represents a small female *Bootherium* although this remains to be substantiated in the future.

The metacarpals of the Old World genera *Hesperoceras* and *Megalovis* also appear to have been too long and slender to represent ROM 41960 (Figs. 6–8; Pl. 1-1 and Pl. 1-2 to 1-6, respectively, in De Giuli and Masini 1983). On the other hand, ROM 41960 appears too long and slender to represent fossil or Recent *Ovibos moschatus* (Fig. 9) or fossils of the Old World species *Ovibos pallantis* (Figs. 6–8; Pl. 1-14 in De Giuli and Masini 1983). Rather, it has the intermediate proportions represented by *Soergelia* (Fig. 9; Pl. 1-15 in De Giuli and Masini 1983), *Praeovibos* (Pl. 1-11 to 1-13 in De Giuli and Masini 1983), and *Euceratherium* (Fig. 9; Pl. 20, fig. 2 in Sinclair 1905; Pl. 14, fig. 10 in Schultz and Howard 1935; Fig. 15.16 in Kurtén and Anderson 1980).

Soergelia is known from at least four North American sites (located in Texas, Kansas, Nebraska, and the Yukon) all considered middle Pleistocene in age (Harington 1989). Only one metacarpal from North America has thus far been referred to this genus, NMC 20757 (Fig. 9). *Praeovibos* is known in North America only from the Alaska–Yukon area and is not known to have survived into the Late Pleistocene (McDonald et al. 1991). It is probable that this genus represents the direct ancestor of *Ovibos* (McDonald et al. 1991). No metacarpals have been reported among the North American material of this genus, and it is uncertain whether among the Eurasian material considered to be *Praeovibos*, any metacarpal is associated with diagnostic cranial material (see Kahlke 1964). Because of this, material reported by Kahlke (1963) as *Ovibos moschatus süssenbornensis* may represent *Praeovibos*, as suggested by De Giuli and Masini (1983). Since the AMS date on ROM 41960 (13 410 ± 100 BP) is latest Pleistocene, it is unlikely to represent either *Soergelia* or *Praeovibos*.

Unequivocal finds of Late Pleistocene *Euceratherium* occur in western North America, primarily California (Sinclair 1905; Furlong 1905; Stock and Furlong 1927), New Mexico (Schultz and Howard 1935; Simpson 1963), Oklahoma (Stovall 1937), and Kansas and are mainly Wisconsinan in age (Kurtén and Anderson 1980). Specimens described under the name *Aftonius calvini* from Iowa (Hay 1914) were considered to be *Euceratherium* by Frick (1937) and Kurtén and Anderson (1980). *Aftonius calvini* came from middle Pleistocene gravels of Aftonian age, the interglacial before the Kansan glaciation, when Harington (1989) considered the radiation of *Soergelia* to have occurred in North America. Consequently, both *Aftonius* and *Soergelia* in North America date from the middle Pleistocene, while *Euceratherium* fossils are Late Pleistocene. However, the specimens of *Aftonius calvini* need to be reevaluated; both Harington (1989) and Churcher (1990) have noted that *Aftonius* looks like *Soergelia*, while Churcher (1990) pointed out the possibility that both *Aftonius* and a recently recognized small North American Pleistocene shrub-ox similar to the Spanish *Soergelia minor* may be congeneric with the living takin *Budorcas taxicolor*. No metacarpals of *Aftonius* are known and none of an adult living takin were available for study, although Wu (1989) noted that the metapodials of shrub-oxen and of the living takin are similar. Teeth from the middle Pleistocene Cumberland Cave, Maryland locality, and

TABLE 2. Measurements of ovibovine metacarpals

Taxon	Category No.[a]	Source[b]	Length	PW	MSW	DW
Megalovis		1	185	52	32.7	57
Megalovis		1	192	51	33.0	54
Megalovis		1	192	56	35.7	64
Megalovis		1	200	56.5	36.9	61
Megalovis		1	200.2	58.7	38.9	60.3
Hesperoceras		1	190	47	32	49
Soergelia		1	180.6	49.8	29.3	56.6
Soergelia	NMC 20757		177	51.8	32.9	57
Praeovibos	GIN 835-29/19	2	172	53	35.3	62
Praeovibos	GIN 835-136/21	2	185.5	49	38.7	65.5
Praeovibos	GIN 836-95/47	2	184.5	58.5	37.4	67.4
Ovibos pallantis	ZIN 367/100	2	153.6	57.7	39	66
Ovibos pallantis	ZIN 367/100	2	161	57.7	38	65.4
Ovibos pallantis	ZIN 965/176-6	2	162	50.4	38.8	64
Ovibos pallantis	ZIN 965/271-5	2	162	53.6	37	62
Fossil *Ovibos moschatus*	NMC 29186	3	162.8	55.1	37.4	65.8
Fossil *Ovibos moschatus*	NMC 6758	3	169.6	57.3	42.8	67.4
Fossil *Ovibos moschatus*	NMC 13592	3	169.8	54.1	37.5	68.2
Fossil *Ovibos moschatus*	NMC 23579	3	170	55.6	41.4	65.7
Recent *Ovibos moschatus*	ROM R1125		148.8	49.5	32.8	56.9
Recent *Ovibos moschatus*	USNM 288025		153.8	56.0	39.6	66.6
Recent *Ovibos moschatus*	ROM R1137		158.5	55.9	38.5	65.4
Recent *Ovibos moschatus*	ROM R1136		159	55.9	38.4	64.5
Recent *Ovibos moschatus*	ROM R1146		160.2	55.8	38.9	63.9
Recent *Ovibos moschatus*	ROM R1145		162.2	58.8	39.9	66.5
Recent *Ovibos moschatus*	ROM R1125		164.7	57.6	40.0	67.8
Recent *Ovibos moschatus*	ROM R1124		165.8	55.6	37.7	66
Euceratherium	UCMP 9352		169	53.4	36.7	59
Euceratherium	UCMP 8289		173.6	55.9	35.5	61.5
Euceratherium	UCMP 35715		196	—	35.9	62.6
Euceratherium	ANSP 13950	4	199.8	58.7	38.5	66
ct. *Euceratherium*	ROM 41960		168.7	47.0	36.9	58

NOTES: PW, proximal width; MSW, midshaft width; DW, distal width.
[a]For explanation of abbreviations see text.
[b]1, De Giuli and Masini (1983); 2, Sher (1974); 3, Harington (1977); 4, measurements taken off illustration in Schultz and Howard (1935). Specimens with no source codes were measured by the author, except UCMP specimens measured by J. Theodor and USNM specimen measured by J.N. McDonald.

a tooth from Kimmswick, Missouri, also were questionably referred to *Euceratherium* by Frick (1937). In short, while there are no good skulls or skeletons of *Euceratherium* from eastern North America, there are enigmatic remains of at least one other ovibine besides *Ovibos* and *Bootherium*. Churcher (1990) suggested additional enigmatic may represent a species of *Soergelia* (or *Budorcas*), therefore possibly extending the North American age range of this genus into the Late Pleistocene.

We do not have any comparative material for *Praeovibos* and have only NMC 20757 (Fig. 9) for *Soergelia* and UCMP 9352 (Fig. 9) for *Euceratherium*. If *Praeovibos* can be eliminated on temporal grounds, then this bone should be referred to either *Soergelia* or *Euceratherium*. With the material at hand we cannot separate the metacarpals of *Soergelia* and *Euceratherium* using any apparently useful morphological features except overall proportions.

Figure 6 demonstrates that the proportions of ROM 41960 are approximately those of *Soergelia*, although smaller; the measurements for *Euceratherium* are more widely scattered but indicate either a larger or relatively wider proximal width for this genus. Figure 7 plots ROM 41960 closest to *Euceratherium*, but also near a fossil of *Ovibos moschatus*, NMC 13592. The proximal and distal widths compared with the length of NMC 13592 (Fig. 9), however, demonstrate that ROM 41960 cannot represent *Ovibos moschatus*. Figure 8 places the estimated measurement for the distal width of ROM 41960 closest to two *Euceratherium* specimens, although not near two others. ROM 41960 is also similar to *Praeovibos* using this measurement.

With the status of the genus *Aftonius* in question and with no *Praeovibos* metacarpals on hand, ROM 41960 should only be tentatively identified as cf. *Euceratherium* sp. However, given the variability of *Euceratherium*, as plotted in Figs. 6–8, and the relatively narrow proximal width of ROM 41960, as plotted in Fig. 6, cf. *Soergelia* sp. could also be a reasonable conclusion at this time.

On zoogeographic grounds, the two Late Pleistocene muskox genera most likely to occur in Ontario would be *Ovibos* and *Bootherium*. ROM 41960 is clearly not *Bootherium*, as at least male *bootherium* was a much larger animal with a relatively more elongate metacarpal (Fig. 9). A *Bootherium* metacarpal from Indiana measured 268.5 mm in length (Richards and McDonald 1991) and one from Saltville, Virginia, measured 269.5 mm (USNM 24885).

Without examination of the proportions of the specimen, the overall small size of ROM 41960 should indicate *Ovibos*. However, all proportions fall outside the range of *Ovibos*

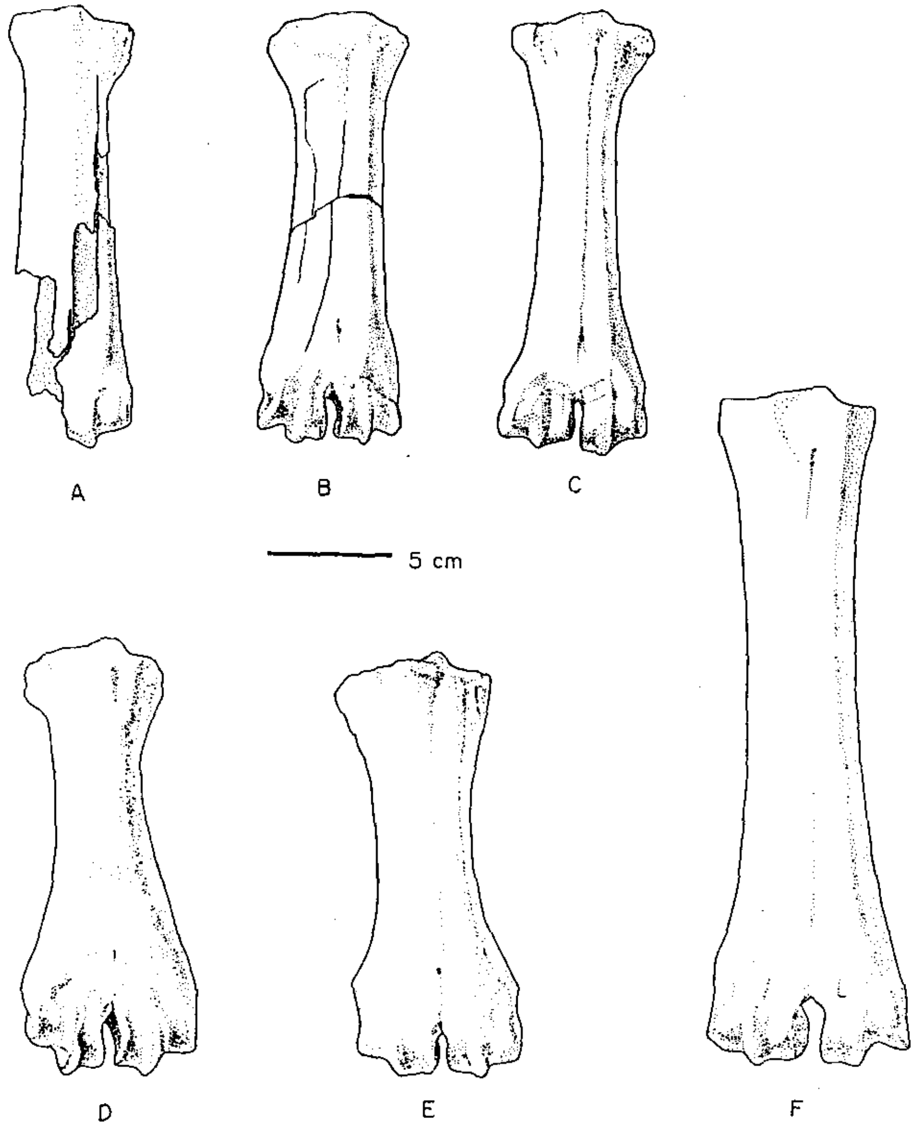

FIG. 9. Anterior views of cast of the left metacarpals of (A) cf. *Euceratherium* sp., ROM 41960, from Leamington, Ontario; (B) *Euceratherium coolinum*, UCMP 9352, from Samwell Cave, Shasta Co., California; (C) *Soergelia* cf. *S. elisabethae*, NMC20757, from Old Crow locality 29, Yukon Territory; (D) *Ovibos moschatus*, NMC 13592, from Old Crow locality 11A, Yukon Territory; (E) Recent *Ovibos moschatus*, ROM R1145, from near Eureka, Northwest Territories; (F) *Bootherium bombifrons*, USNM 24885, from near Saltville, Virginia. Bar is 5 cm.

specimens at hand, with the exception of the midshaft width relative to the length of NMC 13592 (Figs. 7 and 9), a fossil from Old Crow locality 11A, Yukon. But how can we be sure that ROM 41960 bone is not just a very slim *Ovibos*? ROM 41960 evidently represents at least a 2½ year old subadult animal because of its completely fused proximal and distal epiphyses, using *Bos* for comparison (Schmid 1972). The smallest, and possibly subadult, *Ovibos* specimen on hand (ROM R1125), although shorter than ROM 41960 and slightly slimmer than the other *Ovibos* metacarpals, still plots within the proportions of the other *Ovibos* specimens (Figs. 6–8). We can be fairly certain then that even when small, living *Ovibos* metacarpals are characteristically broad for their length. The *Ovibos moschatus* bone mentioned, NMC 13592, is unusually slim for its size; however, its proximal and distal widths are relatively greater than ROM 41960, revealing its true identity. ROM 41960 lacks these proportions and hence cannot now be referred to as *Ovibos moschatus*.

Other fossil muskox records from Ontario

This is the third report of Quaternary muskox remains from Ontario and is the only record with stratigraphic context. The first was a partial skull, ROM 1194 (Figs. 45, 48, and 51 in McDonald and Ray 1989), recovered from a Toronto aggregate operation. This skull was recently AMS dated at 11 580 ± 70 BP (TO-3652). Bensley described a new species (*Ovibos proximus*) on this specimen, but this species is now considered to be conspecific with, and a junior synonym of, *Ovibos moschatus* (Harington 1970; McDonald and Ray 1989).

The second specimen was recovered from the Scarborough Bluffs east of Toronto (Churcher and Karrow 1977) and consists of a heavily eroded right metatarsal (not metacarpal, as originally stated). This bone, ROM 20891, has been considered "problematic" (Harington 1990), as it is too long and slim to represent a bone from an ovibovine.

The three features that Churcher and Karrow (1977) cite as being particularly ovibovine (an almost flat posterior face, a long wide groove between the fused metatarsals extending between the proximal and distal intermetatarsal foramina on the anterior surface, and the bridged proximal posterior intermetatarsal foramen) are in fact good *Bison* or *Bos* characters and were not present in any of the *Ovibos* metatarsals examined (ROM R1109, ROM R1110, NMC 33549, NMC 69312, NMC 69315). Also the distal intermetatarsal foramen pierces through the bone in ROM 20891, as it does in *bison* and *bos*. This feature was not present in any of the *Ovibos* metatarsals examined. Of the features that Balkwill and Cumbaa (1992) used to differentiate *Bison* and *Bos* metatarsals, only two of these are preserved on ROM 20891; the groove running between the proximal and distal intermetatarsal foramina on the anterior surface and the swelling above the distal condyles (their characters No 4 and No. 5, respectively). Both of these features suggest that ROM 20891 represents *Bos*. The aforementioned groove is narrow and runs the full length of the bone (as in *Bos*), whereas in *bison* this groove is much shallower and wider and rarely runs the full length of the bone (Balkwill and Cumbaa 1992). According to Balkwill and Cumbaa (1992), if this bone were to be identified as *Bos* solely due to this feature, it would have only a 3 in 24 chance of being misidentified. Although the bone is very water worn, most of the abrasion has occurred on either end of the bone, whereas the shaft is relatively unabraided. There is no evidence that the swelling above the distal condyles existed on ROM 20891; 24 of 27 *Bison* metatarsals examined had this feature and 10 of 14 *Bos* did not (Balkwill and Cumbaa 1992).

For many *Bison* and *Bos* bones, no single character exists which absolutely separates these two genera (Balkwill and Cumbaa 1992). Overall, however, ROM 20891 closely matches the morphology of *Bos*. Considering its questionable stratigraphic origin and a recent AMS date of 290 ± 50 (TO-3651), this bone should be best identified as subrecent *Bos taurus* and certainly not an ovibovine.

Therefore there are only two valid records from Ontario: the skull described by Bensley (1923), which is considered to represent *Ovibos moschatus*, and the new specimen reported here, which is tentatively identified as cf. *Euceratherium* sp. We do not consider a more definite identification to be possible at this time. Even if ROM 41960 is later referred to some other shrub-ox genus, it is relatively certain at this time that it is not *Bootherium* or *Ovibos*. This is, therefore, the first record of a fossil shrub-ox from Ontario.

Discussion

The exposed and buried sand deposits between Leamington and Colchester were originally deposited as proglacial subaquatic fans. The northern and eastern exposures have massive sand that indicates open channel turbulent flow, which is common where glacial meltwater from a confined channel at the base of the ice sheet enters a standing body of water (Ashley et al. 1985). In addition, the clayey silt clasts and stringers within sand plus the till lying directly over massive sand at the eastern exposure indicates the close proximity of the ice to the fans.

The fans are subaquatic for two reasons. Firstly, the stratigraphic relationship between the fans and the clayey silt till indicates that the fans were deposited from ice that had deposited the clayey silt till as the margin retreated northward. The clayey silt Tavistock Till was deposited during the Port Bruce Stade. Near the end of the Port Bruce Stade about 14 500 BP (Calkin and Feenstra 1985) when the fans were deposited glacial Lake Maumee abutted the ice margin. The lowest altitude of Lake Maumee is at 232 m (Calkin and Feenstra 1985). All the fan surfaces are well below this altitude at 195 m, although one fan surface east of the Bondi site occurs at 227 m. Therefore the fans must have been deposited below the Lake Maumee water plain.

Secondly, the sand structure and sedimentology observed within all three exposures are similar to those of subaquatic fans because they display massive sand, trough cross-breeding and planar bedding (Ashley et al. 1985; Rust 1977; Rust and Romanelli 1975), and channel scour (Postma et al. 1983).

Following the deposition of the fans, lake levels regressed from the area during the Mackinaw Interstade 13 600 ± 500 BP (Calkin and Feenstra 1985). During this regression, Lake Arkona (216 m) and Lake Ypsilanti (122 m) formed. These lakes were relatively small, and large areas of terrain were exposed for occupation by plants and animals. Their presence is recorded by the muskox bone recovered from the western exposure and the pollen and seed assemblage recovered from the eastern exposure. The radiocarbon ages of the bone (13 410 ± 100 BP) and the flora (13 225 ± 200 BP; 13 150 ± 100 BP) fall within the estimated Arkona–Whittlesey transition (about 13 600 BP; Calkin and Feenstra 1985).

At 13 410 ± 100 BP, the area around Leamington had therefore only recently been deglaciated and the vegetation was forest–tundra. A shrub-ox, cf. *Euceratherium* sp., inhabited the area at this time. This shrub-ox presumably differed from the other Late Pleistocene muskoxen in its ecological preferences, as it has been found farther south and west than most Pleistocene finds of *Ovibos* and *Bootherium*.

Fossils of *Ovibos* and *Bootherium* have been found in a number of states and provinces bordering Ontario (see map in McDonald and Davis 1989; McDonald and Ray 1989; Harington 1978). *Bootherium* has not yet been found in Ontario, although it has been found in Canada in Saskatchewan, Alberta, and British Columbia (Skwara and Walker 1989; Harington 1975; Khan 1970).

Ovibos moschatus, the present-day muskox, is currently restricted to arctic tundra, and fossil North American *Obivos moschatus* is usually associated with tundra (Harington 1977). Soergel (1939) and Crégut-Bonnoure (1984), however, have pointed out that some *Ovibos* fossils are associated with other "temperate" fauna or steppe conditions. The extinct *Bootherium bombifrons*, a North American endemic, is thought to be a woodland form living in pine- or spruce-dominated forests (Semken et al. 1964), and it is usually interpreted as having populated areas shortly after deglaciation (McDonald and Davis 1989). Harington (1977) argued that the evidence concerning the habitat preferences of this species was equivocal and could support other interpretations.

The bond recovered at the Bondi site indicates that another ovibone existed in the area during the Arkona–Whittlesey transition time period (Mackinaw Interstadial) but unfortunately does not allow paleoecological interpretation.

Following this period of low water in the Lake Erie basin, water rose to glacial Lake Whittlesey levels (226 m) covering the Bondi site. This occurred at the beginning of the Port Huron Stadial around 13 000 BP (Calkin and Feenstra 1985). This transgression buried the muskox bone within steeply dipping foreset beds of a bar and multidirectional trough crossbeds of a beach shoreface. This transgression is similarly marked by the disrupted still water sedimentation, as recorded by the massive, medium-grained sand between the laminated silts and clays. The overlying eastward orientated, low angle, planar beds are an extension of shoreface sands. These shoreface sands are also represented by the upper unit.

An eastward-flowing current within glacial Lake Whittlesey and subsequent lakes is recorded by (1) eastward dipping shoreface sands observed in the eastern and northern exposures; (2) the eastward orientation of the bars; and (3) the thin sand veneer located north and northeast of Leamington.

Summary

1. In 1989, an excavation exposed three important sections through 14 m of Late Pleistocene sediments. The excavation is in the easternmost fan of a series between Leamington and Colchester.

2. The lower sands within the western, eastern, and southern exposures were deposited in glacial Lake Maumee during the latter part of the Port Bruce Stade (14 500 BP).

3. Water levels regressed to the levels of lakes Arkona and Ypsilanti during the Mackinaw Interstade.

4. This regression permitted migration of flora and fauna into the area.

5. Pollen and plant macrofossil assemblages at this time (13 225 ± 200 BP and 13 150 ± 100 BP) indicate a forest–tundra with a 10–14°C mean July temperature.

6. The bond indicates that a muskox, cf. *Euceratherium* sp. lived in the area at this time, 13 410 ± 100 BP.

7. Transgression of water in the basin to glacial Lake Whittlesey levels reworked the exposed surface of the fan burying the muskox bone and plant fossils with bar and beach shoreface sand.

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