Charcoal in Crawford Lake, Ontario, sediment shows that prehistoric Iroquoians burned their fields rather than the forest

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Abstract
Sediment dating ca AD 1268-1520 contains fossil dung pellets of Canada goose. Concentrated in the pellets are pollen and seeds of cultigens (Zea, Cucurbita, Phaseolus, Helianthus) and weeds (Poaceae, Portulaca, Solanum) together with herb charcoal, particularly from Poaceae. This shows that geese foraged on nearby Iroquoian fields, which had been burned, and inadvertently consumed herb charcoal before flying to the lake where they cast charcoal-laden dung pellets that were fossilized. We reject an earlier report, which attributed the charcoal to be wind-blown from forest fires deliberately set by Iroquoians.

Introduction
Crawford Lake (latitude 43.468624°N, longitude 79.948857°W) is sedimenting microfossil-laden annual pairs of laminas (varves) of organic matter and calcium carbonate, which since AD 1300 are well preserved (Byrne and McAndrews 1975, Boyko-Diakonow 1979, Dickman 1979, McAndrews and Boyko-Diakanow 1989, Yu 2003, Ekdahl et al. 2004, McAndrews and Turton 2007). Varve preservation stems from lake meromixis whereby stagnant and toxic bottom water excludes bioturbating detritivores. AMS carbon dating shows that varve preservation began shortly before 1300 and continued almost regularly to the present. Zea and other cultigen and weed pollen that document prehistoric human disturbance (Fig. 1) led to the discovery and excavation of the nearby Crawford village site and seven other Iroquoian sites within 3 km of the lake (Finlayson 1998). The Iroquoian Zone dating 1300-1500 had thick varves, containing pellets that DNA analyses showed were dung of Canada geese (McAndrews and Turton 2007).

Charcoal in Crawford Lake sediment has been used to infer prehistoric forest fires over the past two millennia. Clark and Royall (1995) imbedded sediment with resin, ground thin sections and then counted charcoal particles. Charcoal was found in every one of the ca. 65 levels sampled. In addition to a general charcoal abundance in the Canadian Zone, there were several peaks in the Iroquoian Zone from which they inferred that the Iroquoians burned the forest. During and after the inferred forest fires, the tree pollen indicated succession from beech-maple to oak and then pine forest. Campbell and McAndrews (1995) disagreed with their interpretation because these charcoal peaks
were too slight to be from forest fires and they explained the forest succession as driven by climatic change.

Byrne and Finlayson (1998) also found multiple charcoal peaks during the Iroquoian Zone, which they interpret as eight phases of forest clearance by Iroquoians. However, unlike Clark and Royall (1995) they distinguished conifer-dicot charcoal, which could be from either woody or herbaceous plants, and monocot charcoal of herbs, most likely from Poaceae. We believe that they recorded charcoal largely from goose dung pellets. To test the goose dung hypothesis, we analyzed both the goose dung pellets and the sediment matrix beside, above and below the pellets.

**Methods**

From a frozen core, we collected 35 dated samples, then dispersed and centrifuged each of them in a graduated centrifuge tube where the sediment volume was recorded. Tablets containing 13,900 *Lycopodium* spores were added to each sample followed by treatment with dilute HCl and KOH and mounting in glycerin: no sieving was involved. Charred (black) plant particles were counted and measured on a video screen and recorded together with 10 introduced *Lycopodium* spores, thus permitting calculation of particle density per mL. Charcoal pieces were tallied in six size classes; we chose to present our results as number of particles >10 μm long.

**Results and discussion**

Charcoal density per mL ranged from a low of $7 \times 10^4$ in a matrix sample to a high of $7 \times 10^6$ in a pellet sample (Fig. 2). Of the 27 matrix samples, the eight paired with pellet samples in the Iroquoian Zone had lower charcoal values. Only one other matrix sample, this from the Canadian Zone, compared with the charcoal density in the pellets.

In general, we confirm Clark and Royall’s (1995) observation that charcoal particles peak in the Iroquoian and Canadian Zones when there was forest clearance for agriculture. However, the herb charcoal observed by Byrne and Finlayson (1998) also indicates field maintenance by burning. To this we add that the charcoal in the Iroquoian Zone is concentrated in goose dung pellets and the adjacent matrix charcoal is probably from pellets that have disintegrated. The same cannot be said for the other zones where pellets are absent and wind transport is more likely. Prehistoric human-set forest fire is not supported.

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Fig. 1. Pollen diagram for the second millennium AD at Crawford Lake showing the main tree and herb pollen types: percentages are based on 200 tree pollen (McAndrews and Turton 2007). Prehistoric forest succession was driven by climate change whereas in the Canadian Zone, Betula and Ulmus pollen reflect post logging succession. Herb pollen in the Canadian and Iroquoian Zones are defined by weed (Poaceae) and Zea together with Ustilago (maize smut) spores.
Fig. 2. Charcoal diagram for the second millennium AD at Crawford Lake. Note that matrix and dung pellet samples are paired in the Iroquoian Zone. Pellets were absent from the other zones.