STABLE ISOTOPE ANALYSIS AND GEOGRAPHIC ORIGINS OF 19TH CENTURY PORT HOPE PIONEERS

A Thesis Submitted to the Committee of Graduate Studies
in Partial Fulfillment of the Requirements for the Degree of Master of Arts
in the Faculty of Arts and Science.

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ABSTRACT

Stable Isotope Analysis and Geographic Origins of 19th Century Port Hope Pioneers

Catherine A. Paterson

The aim of this research is to determine the geographic origins of 26 individuals, known as the Hawkins collection, who were buried in the Old Wesleyan Methodist Cemetery in Port Hope, Ontario between 1830 and the mid 1870s. This was done using stable oxygen isotope analysis of the carbonate component of bone and enamel. Analysis of nine First Nations individuals from burial sites near Campbellford and Lake Scugog provide the local isotopic signature of -9.5 to -12‰. The $\delta^{18}O_c$ values obtained from the analysis of the enamel of the Port Hope individuals range from 22.67 to 26.91‰ (-6.19 to -11.52‰ when converted to $\delta^{18}O_w$) indicating that they originated from Upper Canada, the Northeastern United States, and the British Isles. All seven children under the age of 15 were born in the Port Hope region. Twelve of the 16 adults of known age older than 15 are non-local and often relocated during their childhood.

Keywords: Port Hope, oxygen isotopes, bone and enamel carbonate, geographic origins and movement, 19th century Upper Canada.

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CHAPTER 1

INTRODUCTION

The town of Port Hope, advantageously located on Lake Ontario at the mouth of the Ganaraska River in Southern Ontario, Canada, was settled in the late 18th and early 19th century by American and European pioneers who developed the town into a thriving community and successful port. In the 1880s, when the population peaked at over 5500 people, Port Hope was home to various businesses, industries, schools, and churches. The history of the town and its people is well documented in census records, newspapers, photographs, and personal diaries and letters.

Additional information about 19th century Port Hope has been provided by the archaeological excavation of 64 individuals who were buried in the Old Wesleyan Methodist Cemetery between 1830 and 1870. Study of the skeletal remains of individuals who lived in 19th century Upper Canada supplements the historic record, as well as provides information about the lives of past populations that is not addressed in archival sources. To date, several 19th century Upper Canadian cemeteries, ranging from small, rural family plots to larger, urban cemeteries, have been excavated and the artifacts and skeletal remains studied.

In addition to overall osteological analysis, areas of research have included health and disease (Hawken 2006; Helmuth and Jamieson 2001; Keenleyside and Clark-Wilson 1991; Parish 2000; Pearce 1989; Pfeiffer et al. 1989), theoretical issues such as testing the representative nature of cemetery skeletal samples (Saunders et al. 1995), as well as artifacts such as coffin hardware (Kogon and Mayer 1995; Woodley 1992). In addition, analyses of trace elements and stable isotopes have been applied to 19th century cemetery samples from Upper Canada in order to address research questions regarding diet (Blackbourn 2006; Katzenberg 1991), weaning (Herring et al. 1998; Katzenberg and Pfeiffer 1995), and geographic origins (Pcholkina 2004).

The skeletal remains of the individuals buried in the Old Wesleyan Methodist Cemetery, referred to as the Hawkins collection, have been the focus of two previous studies. Blackbourn (2006) investigated diet and health through the assessment of dental pathology and the analysis of stable isotopes. As well, a paleopathological analysis of the skeletal remains has been carried out in order to investigate the patterns of health and disease within the population (Hawken 2006). The aim of this research is to reconstruct the geographic origin of a sample of the Hawkins individuals using stable oxygen isotope analysis.

The geographic origins of human populations have been investigated by anthropologists using isotopes such as lead, oxygen, neodymium, and strontium. While studies usually focus on isotopes of a single element, the principle of using each is similar. During a person's life, the isotopes in the food and water they consume are incorporated into their tissues in ratios reflective of certain geographic areas. These ratios can then be measured in enamel and bone samples to determine the geographic area(s) in which an individual lived during their life.

Oxygen isotopes are relevant to human migration studies because their distribution in meteoric precipitation, which is consumed as drinking water by humans, varies between geographical regions in predictable patterns depending on distance from bodies of water, humidity, latitude, elevation, and temperature (Dansgaard 1964; Dupras and Schwarcz 2001; Yurtsever and Gat 1981).

Oxygen isotopes consumed in drinking water are incorporated into human teeth during the process of mineralization of the tooth crowns between the ages of 5 fetal months and 15 years. Because enamel does not remodel (Hillson 2005), the oxygen isotopes incorporated during this time are permanently retained in the enamel. Therefore, no matter where an individual moves during his or her life, the isotopic composition of the tooth enamel will reflect the water sources of the region where the individual spent his or her childhood.

Bone tissue, on the other hand, mineralizes and remodels throughout an individual's life. As a result, the isotopic composition of bone will adjust to reflect the isotopic composition of the water in a new environment if an individual relocates. It is not known exactly how long it takes for this re-equilibration to occur. It is thought that the isotopic content of bone is a reflection of the average isotope intake over several years, and it is estimated that a complete turn-over takes at least ten years (Manolagas 2000:4).

Combining isotopic analysis of bone and enamel tissue therefore provides information about location of origin as well as patterns of migration throughout an individual's life. It is concluded that individuals with different isotopic values in their enamel and bone moved to a new environment during their lifetime, and those with similar isotopic values did not.

The aim of this research is to: (1) establish the local isotopic signature of Port Hope through isotopic analysis of local skeletal remains of First Nations individuals from the Myles and Scugog archaeological sites; (2) use oxygen isotope analysis to determine the region of origin of 26 individuals buried in the Old Wesleyan Methodist Cemetery; (3) determine, where possible, the timing of relocation of individuals who are not local to Port Hope through the analysis of enamel that mineralized during different periods during life; (4) investigate possible patterns of origin and movement within the sample through comparison of males and females, different age groups, and individuals buried in the same grave; and finally, (5) compare the results of the isotopic analysis to historical records of five individuals identified by coffin plaques.

Chapter Two provides an overview of the historical record of the immigration and settlement patterns of 19th century Port Hope. The theoretical basis of stable oxygen isotope analysis and its applications to studies of past human populations is reviewed in Chapter Three. Chapter Four outlines the samples selected for analysis from the Hawkins collection and from the Myles and Scugog First Nation burial sites. As well, the methods used to determine whether bone and enamel samples have been altered in the burial environment and those used to perform the oxygen isotope analysis are summarized. The results of the isotopic analysis are presented in Chapter Five and interpreted and discussed in Chapter Six. Chapter Seven summarizes the major findings and outlines areas of interest for future research.

Through this analysis of skeletal remains, new insight into the settlement of Port Hope is obtained that compliments and expands upon the historic record of the region. Results of this study will contribute to the ongoing research to better understand the lives of a group of people who lived in 19th century Port Hope.

CHAPTER 2

HISTORICAL BACKGROUND

2.1. American and European Settlement of Upper Canada

European presence in the Great Lakes region of what is now Ontario was established in the 17th century and consisted mainly of forts and trading posts of the French and British (Semple 1996:42). This was the pattern until the 1700s, when relations between the Americans and British in the Thirteen Colonies to the south began to deteriorate (Craig 1963:1,2). Americans fought for their freedom from British rule in the War of Independence (1775-1783), which was granted in 1783 with the signing of the Treaty of Paris (Craig 1963:3; White 1985:52). Not all residents of the Thirteen Colonies, however, supported such independence. An estimated ten (White 1985:55) to twenty five (Craig 1963:3) percent of the two million inhabitants of the Thirteen Colonies remained loyal to Britain, referring to themselves as Loyalists. During and after the war, Loyalists began to emigrate to the United Kingdom, the West Indies, Nova Scotia, Quebec, and what is now Ontario (Craig 1963:3; White 1985:56).

The first major wave of Loyalist immigrants to present-day Ontario arrived in the 1780s, the majority of whom were from New York, Pennsylvania, and the New England states (Canniff 1971:617; Craig 1963:6-7; White 1985:57). Loyalists also emigrated from Georgia, Maryland, New Jersey and Rhode Island (White 1985:57). Both Errington (1987:14) and White (1985:56) note that while Loyalists emigrated from the same area, they were of multiple origins, including Dutch, German, English, French, Native, and Scottish.

In 1791, the Quebec Act established Upper and Lower Canada as two separate legal entities (White 1985:63). By 1792, the first areas in Upper Canada had been settled by an estimated 3,625 Loyalists along the north shore of the St. Lawrence River and the lower Great Lakes (Errington 1987:14; Guillet 1933:321; White 1985:56). These settlements were isolated from each other and often did not extend more than several miles into the surrounding dense forest (Craig 1963:51). Upon their arrival, Loyalists were granted parcels of land by the newly formed government. The amount of land granted depended on the status of the immigrants and ranged from 50 acres for a single man, 100 - 200 acres depending on military rank, and 100 acres for heads of households with an additional 50 acres for each family member (Canniff 1971:165; Craig 1963:5-6). As a result of the promise of free land, the flow of immigration from the United States continued steadily into the 1800s (Craig 1963:44). By 1812, an estimated 75,000 people resided in Upper Canada (Craig 1963:51).

This pattern of immigration continued until 1815, after which the origin of the majority of immigrants was the British Isles (Brunger 1990:150). When the War of 1812 ended in 1815, the government of Upper Canada began to restrict immigration from the United States (White 1985:82). This coincided with the end of the Napoleonic Wars and the resulting emigration of members of the rural population from Great Britain (White 1985:82). While land was no longer granted for free, assistance was still available and was used by Irish and Scottish immigrants, and less frequently by English (Craig 1963:130; White 1985:83). During the 1820s, the government was interested in increasing the immigration of established professionals and others who were seeking opportunity to improve their lives (Craig 1963:130).

Immigration from the British Isles first peaked in the early 1830s, and in the late 1830s, the population of Upper Canada was recorded at just under 400,000, four times larger than it was in 1815 (White 1985:80). In the 15 years after the war, Upper Canada had greatly developed as a colony (Errington 1987:89; Guillet 1933:322). With the increase in population came a lessening of the isolation that had been encountered by the Loyalists, as roads, as well as coach and steamship services were established (Craig 1963:90). By the 1850s railways further opened the region (White 1985:108). The population of Upper Canada continued to increase throughout the 19th century, due to both the continued immigration of individuals from the British Isles, and the growth of the previous generations.

2.2. Settlement and History of Port Hope

Port Hope, one of the settlements established on the north shore of Lake Ontario during the first wave of immigration of Loyalists in the 18th century, is located at the mouth of the Ganaraska River, approximately 100 kilometers east of present-day Toronto. Because of its location, Port Hope became a port of entry to Upper Canada for newly arriving immigrants. Those who remained in Port Hope were involved in its development from a small settlement to a thriving industrial centre of 19th century Ontario.

2.2.1. Port Hope Settlement

Already established at the location of present-day Port Hope prior to Loyalist settlement was a First Nations Mississauga village and a trading post that was used by Peter Smith from 1778 to 1790 (Belden 1996; Leetooze 1997:4; Reeve 1967:18). The village was then known as Ganaraska, Penetascutiang, Cochingomink, or Smith's Creek (Leetooze 1997:4). The Township of Hope, named after Colonel Henry Hope, the Lieutenant Governor of Quebec from 1785-89, was established as part of Durham County, in 1792. According to specifications, the township was nine miles from east to west, twelve miles from north to south, and divided into 200 acre lots (Reeve 1963:9-10).

In 1792, Loyalist Elias Smith, who was seeking trading opportunities along Lake Ontario, arrived in Smith's Creek (Leetooze 1997:4). Based on the area's established trading and its potential for settlement, Smith, along with fellow Loyalists Abraham and Jonathan Walton, petitioned for land grants in return for bringing forty settlers to the township (Leetooze 1997:4; Reeve 1967:23). For their efforts, the men were granted Lots 5, 6, and 7 of Concession 1 (Figure 2.1.), the land that would become Port Hope, (Reeve 1963:40), in addition to the land they were entitled to as Loyalists (Cruickshank 1987:4). Twenty three members of the Ashford, Harris, Johnson, and Stevens families arrived in 1793 and were granted land in the township (Leetooze 1997:5; Reeve 1967:24-28). A census taken by Elias Smith in 1799 recorded a total of 167 people (41 heads of household, 23 wives and 103 children) living in Smith's Creek (Leetooze 1997:5; Reeve 1967:24-28). Census returns from 1803 indicate that the population had grown to 277 people (68 men, 47 women, 80 boys, and 82 girls under 16) (Leetooze 1997:13-14). No records indicate the number of Native inhabitants in the settlement.

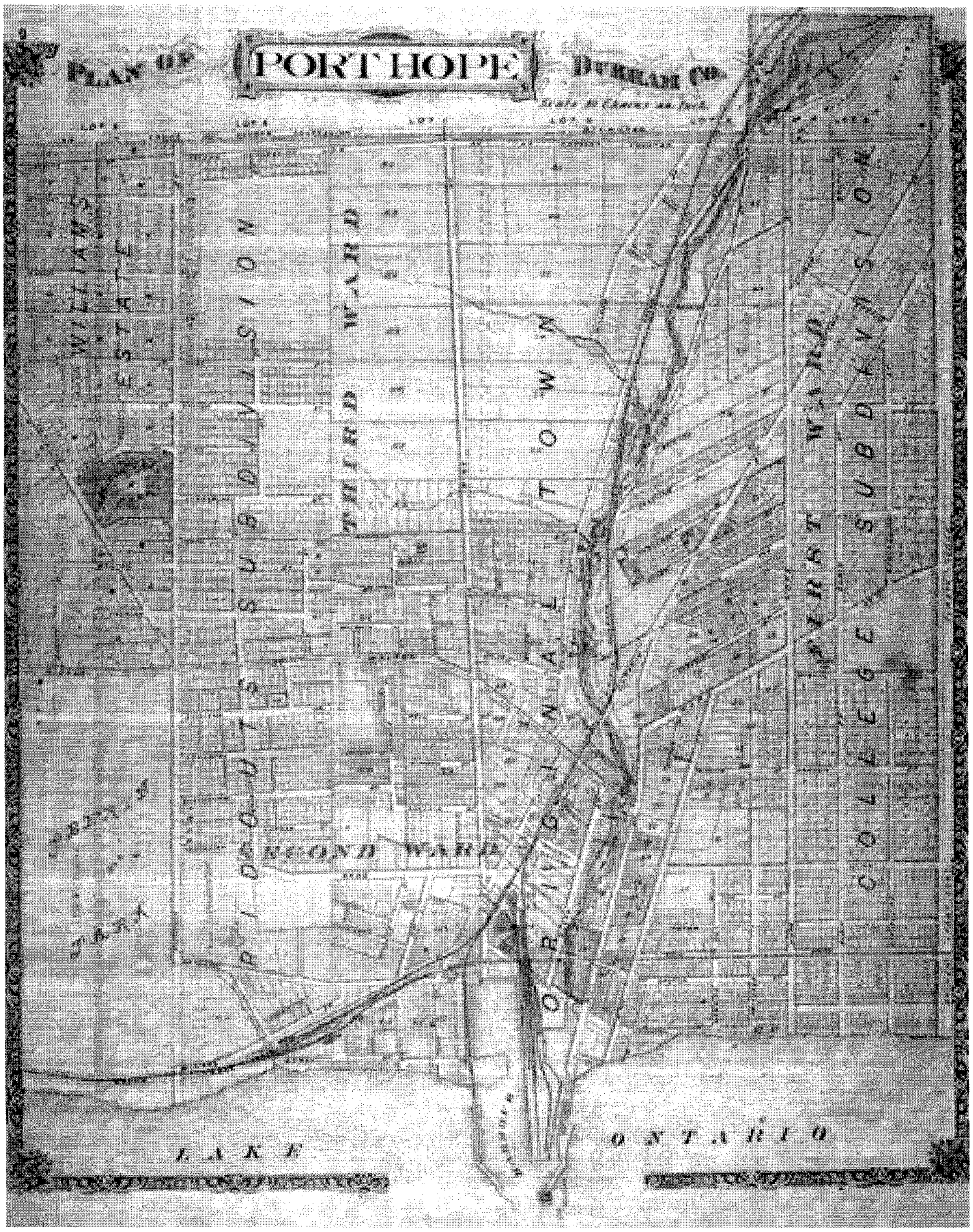


Figure 2.1. Map of Port Hope (Belden:1996)

The population of Port Hope continued to increase steadily over the years. Americans continued to arrive and settle in the area during the War of 1812 (Belden 1996), and the population of the township rose to 754 by 1820 (Reeve 1963:55). It was with the establishment of the post office in 1817 that the name Port Hope was officially adopted, replacing the name Toronto, which had been used for a brief time (Cruickshank 1987:4; Leetooze 1997:174; Pickford 1967:69).

The year 1820 marked a shift in the origin of immigrants to Port Hope, as the majority of settlers began arriving from the British Isles (Ennals 1975:184; Reeve 1963:55). In 1834, the year Port Hope was officially incorporated as a town, it was considered to be one of the larger settlements in Upper Canada (Cruickshank 1987:5). The population of Port Hope and Hope Township over the 19th century is shown in Table 2.1.

Year	**Port Hope Population**	**Hope Township Population**
1803	/	277
1810	/	391
1820	/	754
1830	/	1,741
1838	/	3,436
1851	2,476	5,299
1861	4,162	5,883
1871	5,114	5,075
1881	5,585	4,522
1891	5,042	3,887
1901	4,188	3,273

Table 2.1. Population trends in Hope Township and Port Hope 1803-1901 (from Leetooze 1997:24; Reeve 1963:53).

The Port Hope census return listed in the 1856-57 Port Hope Business Directory includes the country of origin for the 4,579 inhabitants, as shown in Table 2.2.

Country	**Number**
England	878
Scotland	223
Ireland	1,201
Canada	1,954
United States	279
Other Countries	44
Total	**4,579**

Table 2.2. Nativity of immigrants as recorded in the 1856 census of Port Hope (Port Hope Business Directory 1856)

The birthplace of residents of the town of Port Hope is also included in the 1871 and 1881 Census Reports of the Canadas, as shown in Table 2.3.

Birth Place	**Census Year**	
	1871	**1881**
England or Wales	828	772
Ireland	726	570
Scotland	166	112
Ontario	3090	3776
Quebec	95	163
United States	166	156
New Brunswick	5	3
Nova Scotia	6	7
P.E.I.	5	3
Newfoundland	0	2
The Territories (Canada)	0	1
Channel Islands	3	0
Other British Possessions	3	1
Germany	19	10
France	0	1
Italy	0	1
Sweden, Norway, Denmark	1	1
At Sea	1	0
Other Countries	0	3
Not Given	0	3
Total Population	**5114**	**5585**

Table 2.3. Place of birth for 1871 and 1881 Port Hope populations.

With its increase in population, Port Hope experienced municipal and industrial development that put it in competition with other major centres of the time. By 1825, Port Hope was considered to be one of the main towns on the shore of Lake Ontario, along with Belleville, Cobourg, and York (Guillet 1933:322). Port Hope's notable status in 19th century Ontario was maintained over the years, as in the 1880s it "would become one of the most important centres in Durham/Northumberland, and in the whole of Upper Canada" (Leetooze 1997:23).

2.2.2. Port Hope Industry

The first Loyalist settlers obtained flour from Kingston, and when they began producing their own crops, mills in Belleville and Napanee were utilized as it wasn't until 1798 that grist and saw mills were erected on the Ganaraska River (Leetooze 1997:5; Reeve 1963:40). The town developed slowly over the next twenty years (Belden 1996; Cruickshank 1987:4). As more settlers arrived, Port Hope expanded to the north (Cruickshank 1987:4). Local industry began to develop with the arrival of skilled tradesmen and professionals in the 1820s and 30s (Leetooze 1997:79). As Port Hope grew, so did the divide between the different classes of inhabitants. This was reflected in the different housing areas within the town, as noted by a visitor in the late 1800s: "Port Hope had stark contrasts between the lordly mansions of Dorset Street and the sordid hovels of North Cavan Street" (Cruickshank 1987:10).

During the 1820s and 30s, the downtown area, especially Walton, Queen, Mill, and John Streets, began to be developed to accommodate the growing number of professional establishments (Leetooze 1997:175). In 1846 Port Hope had one grist mill operating, with a second being built, an ashery, a foundry, a brewery, four tanneries, and five distilleries. The town was also home to eighteen stores, eleven tailors, ten shoemakers, seven blacksmiths, six taverns, four bakers, four saddlers, four wagon shops, four physicians, three lawyers, three tinsmiths, two banks, two ladies' seminaries, and one each of a surveyor, druggist, bookseller, livery stable, printer, watchmaker, and a school for boys (Leetooze 1997:178-9). By the 1860s the number of businesses doubled and industry flourished (Leetooze 1997:183).

The location of Port Hope at the mouth of the Ganaraska was not only key in establishing mills, but the harbour itself played a large role in the town's history. Port Hope was established as a port of entry in 1819 and in 1829, the Port Hope Harbour and Wharf Company was formed, with the goal of constructing a harbour by 1844 (Craick 1901). It was not until 1855, however, that development of the harbour began. It is important to note that even before the harbour was developed, the port was quite active as a point of entry for immigrants who would settle in the townships to the north, as well as an active point of export for various townships (Leetooze 1997:175). Reeve (1963:176-181) provides an inventory of imports and exports that shows a steady increase in harbour activity throughout the 1800s. Head (1975:88) notes that "particularly significant is the growth of exports at Port Hope and Toronto, at each of which the expansion from 1851 to 1867 was about three times that of the general provincial expansion in plank and board export."

At the same time that the harbour was being developed, the potential of railways to open Port Hope to the backcountry and other towns along Lake Ontario was recognized. Situated 11 kilometers to the east, Cobourg was Port Hope's greatest competition to succeed at establishing railways to increase trade opportunities and offer personal transportation to its inhabitants (Cruickshank 1987:8; Ennals 1975:188). The Port Hope section of the Grand Trunk railway, running from Montreal to Toronto was completed in 1856. The Midland Railway, running to Lindsay, was completed in 1858, and later extended to Peterborough (Leetooze 1997:185; Reeve 1963:173). Port Hope did not complete its rail systems before Cobourg, but it was able to dominate trade (Ennals 1975:189). Leetooze (1997:183) estimates that the building of the harbour and railways employed hundreds of men.

The population of Port Hope began to decline at the end of the 19th century as the town fell behind in competition with Toronto, and further development ceased around 1885 (Cruickshank 1987:12). The downtown core still remains, and is considered one of the best preserved from 19th century Ontario.

2.3. History of the Methodist Church in Port Hope

The Wesleyan Methodist Church was established in England in 1739 by John and Charles Wesley, and George Whitefield as a "counter-reformation within the established Anglican Church" (Semple 1996:14). Wesleyan Methodism was introduced in America in 1765 and was brought to Upper Canada by ministers of the British Army (Canniff 1983:285; Wesleyan Church 2004). According to Canniff (1983:292), "although the Lutheran, Presbyterian, and English churchmen had preceded the Methodists into Canada, neither seemed to obtain that hold upon the hearts of the plain U. E. Loyalists, that the Methodists did." Ministers were assigned a circuit which they traveled on horseback, preaching in available homes until churches were built.

Early in its development in Upper Canada, the Methodist Church relied on financial contributions from its parishioners, a concept that took time to catch on as the settlers at the time were "generally ill served, impoverished, and unfamiliar with the rather novel notion that members should pay for church services" (Semple 1996:27). By the late 1800s, as towns began to prosper, the Methodist Church came to be formed by mainly middle-class members and larger, more impressive churches were built to reflect their wealth and status (Semple 1996:339).

The first records of the Wesleyan Methodist Church in Port Hope are shown in Table 2.4. The records until 1825 are listed under Smith's Creek, which was included in the Prince Edward District and Belleville County Circuit, which included the road from the Trent River to the boundary of the Yonge Street Circuit (Cornish 1881:299). Records commencing in 1840 are listed for Port Hope, which was included in the Cobourg Circuit (Cornish 1881:284).

According to the census of 1856, Methodism was the third most popular religion, as shown in Table 2.5.

Year	Minister	No. of Members
1805	Thomas Madden	?
1806	Luther Bishop	76
1808	Elias Pattie	105
1810	John Reynolds	125
1820	Philander Smith	203
1825	David Breakenridge, John Black	472
1841	Asahel Hurlburt	178
1850	George Goodson	350
1860	John Hunt and Alex T. Green	525
1870	Isaac B. Howard	240

Table 2.4. Selected Ministers and number of members of the Wesleyan Methodist Church in the Belleville – Whitby circuit (1805-1825) and the Cobourg circuit (1841+). (from Cornish 1881:191, 284, 299-300).

Religion	No. of Members
Episcopal	1,563
Roman Catholic	944
Methodist	829
Presbyterian	816
Baptist	182
Bible Christian	181
Other	64
Total	**4,579**

Table 2.5. Breakdown of 1856 population by religion (Port Hope Directory for 1856-57)

2.3.1. History of the Old Wesleyan Methodist Cemetery

Cemeteries in Port Hope were originally established by different religious denominations and were located on church property within the town limits (Craick 1966:106). In the early 1830s the Methodist Church opened a cemetery on the South side of Bedford Street in Port Hope. No cemetery records are known to exist except for a map showing names and plot numbers, as shown in Figure 2.2. It has been estimated that the

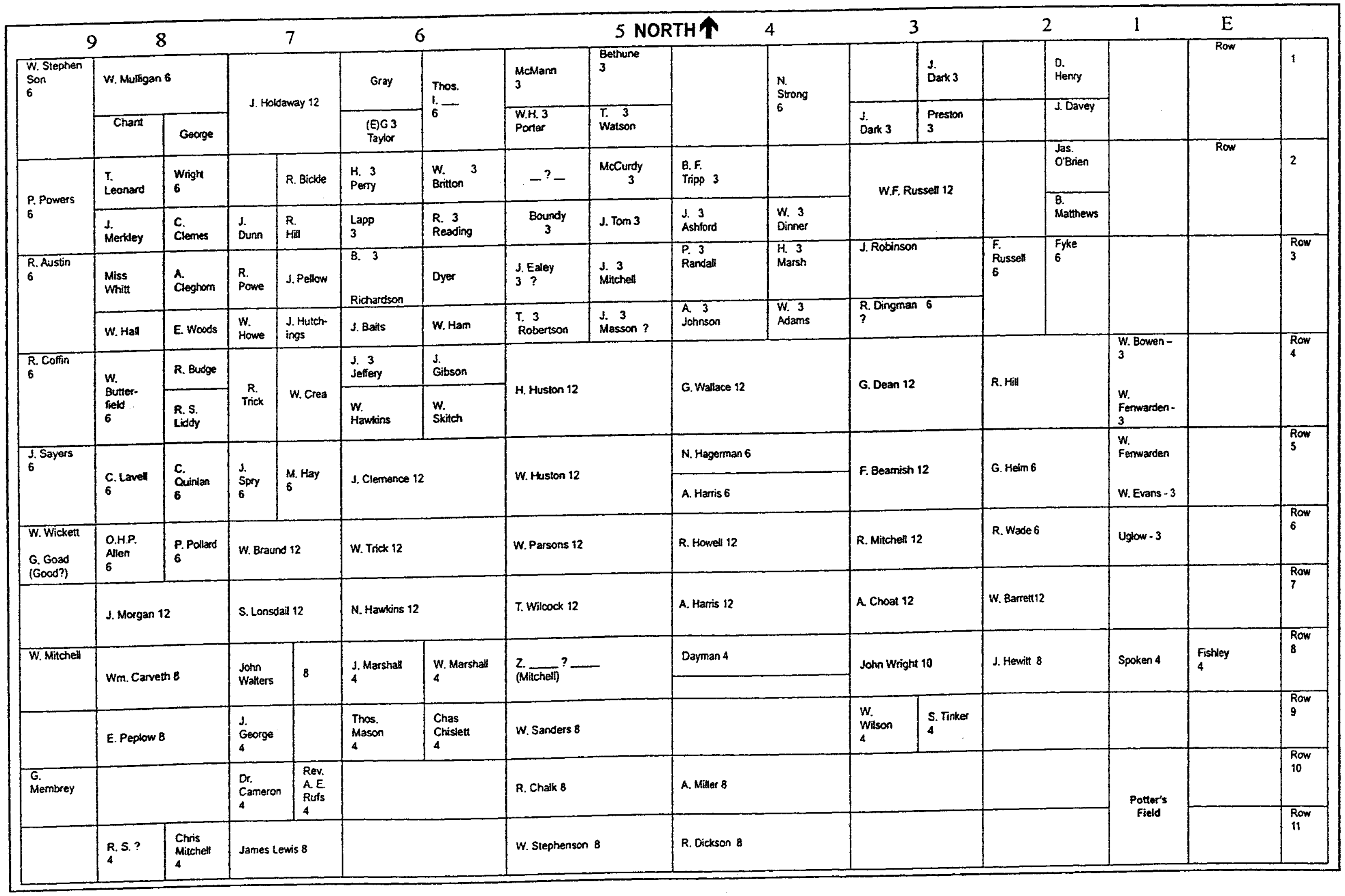


Figure 2.2. Map outlining plots of the Old Wesleyan Methodist Cemetery.

cemetery had a capacity of 750 burials and at the time of its closure, approximately 200 individuals were buried in the cemetery (Bolton 2006).

The trend of in-town churchyard burials continued into the 1870s, until the Union Cemetery Company, established in April of 1873, purchased land outside of town on Toronto Road with the purpose of creating a cemetery to be used by all denominations (Craick 1966:107). Plots in the Union Cemetery began to be sold on August 25, 1874, and as of September 1, 1874, the Union cemetery was open and burials within town limits were no longer permitted (Craick 1966:107).

After the closure of the Methodist cemetery, some individuals were reinterred in the Union or Welcome cemeteries. The Methodist cemetery became run-down and vandalized, as described in a newspaper article:

> "The[re] are comparatively few graves remaining in the old Methodist cemetery, and … [t]he stones and monuments remaining are getting badly disfigured, and fresh damage has been recently done" (Port Hope Weekly Guide, 16 November 1906).

In 1887, the Hawkins High School opened on the corner of Bedford Street and Pine Street to the east of the Old Wesleyan Methodist cemetery. The school board purchased the land containing the cemetery, and in 1931 all burials were supposedly cleared so the land could be used as a schoolyard. In 2001, the land was sold to be developed into a subdivision. During construction, human remains were uncovered and local archaeologists were hired to locate and remove all remaining burials. The site, as seen in Figure 2.3, was excavated over the summers of 2002 and 2003 by Donna

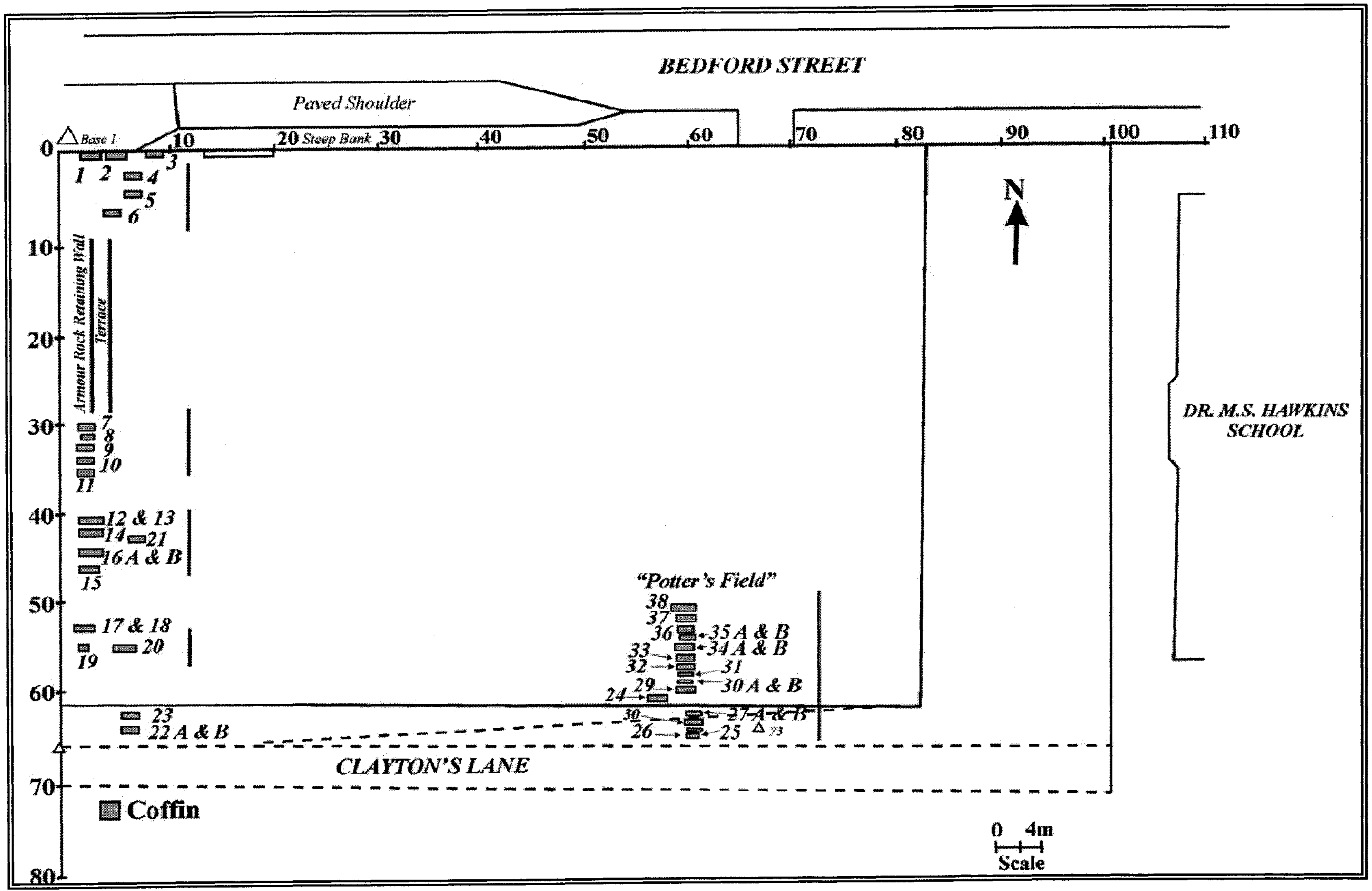


Figure 2.3 Site map of excavation of Old Wesleyan Methodist Cemetery by Advance Archaeology.

Morrison and Advance Archaeology. All remains were transported to Trent University for analysis and were reburied in the fall of 2004.

2.3.2. Identification of Individuals Buried in the Old Wesleyan Methodist Cemetery

While no records of interment are known to exist for the Old Wesleyan Methodist cemetery, the identity of some individuals was recorded at the time of reinterment. When possible, individuals were identified by tombstones or coffin plaques during both the 1931 clearing of the cemetery, and the 2002-03 excavation. A list of these individuals, including age-at-death, date of death, and information obtained from census records is shown in Table 2.6. At least 45 other burials were moved without identification.

2.4. 19th Century Sources of Drinking Water in Port Hope

As is discussed in Chapter 3, consumption of drinking water is the basis of stable oxygen isotope analysis. The sources of the drinking water consumed by the individuals buried in the Old Wesleyan Methodist Cemetery are not known. Potential sources of drinking water that were consumed, however, can be outlined. Prior to arrival in Port Hope, individuals emigrating from Europe would have consumed water stored on their sailing vessel. The water was stored in tanks that held up to 300 gallons and was passed out daily (Guillet 1937:75). This water originated from "the river in which they happened to be anchored" (Guillet 1937:75). As a result, the water was often not of good quality, and even when it was, the amount provided to passengers often varied.

Name	Age at Death (Yrs)	Year of Death	Occupation	Birthplace
Allcott child	?	?	?	?
B. Allcott	33	?	?	?
R. Ashton	37	?	?	?
Flossy Bayley	5	?	?	?
? Beamish	?	?	?	?
Edna E. Black	11 mos, 28 days	?	?	?
John Braund	45	1869	Sailor	England
Margaret Budge	31	1851	?	?
Robert Budge	?	?	Merchant Tailor	England
Baby Gott and Mrs. Conroy	?	?	?	?
Cunning infant	?	?	?	?
Hannah Cunning	21	1871	?	Quebec
John Fish	87	?	?	England
Thomas Gott	40	?	Labourer	Ireland
Jane Hagerman & a child	23	1852	?	?
Jennie Hall	?	?	?	?
James Handyside	24	?	?	?
Allan Harris	58	?	?	Upper Canada
Phoebe (Gowen) Harris	32	1854	?	?
Isabella Haw	40	?	?	?
Helen E. Hayden	2	1867	?	?
Mr. Hayward & a child	31	1845	?	?
Sarah Jane Hill	25	1857	?	?
Mr. Howell	?	1850	?	?
? Howell	?	?	?	?
S. Johnston	?	1871	?	?

Table 2.6. Individuals buried in the Old Wesleyan Methodist cemetery and later reinterred in the Union Cemetery.

Name	Age at Death (Yrs)	Year of Death	Occupation	Birthplace
Mary F. Lapp	1	1873	?	?
Mother Lapp	?	?	?	?
W.E. Lapp	18	?	?	?
Mary Libby	5	?	?	?
Stephen Lonsdale	59	1861	Carpenter	England
Cynthia McGaffey	27	1864	?	U.S.A.
Mr. Milligan	?	?	?	?
Charles Jacob Mitchell	child	1867	?	Upper Canada
Francis Chester Mitchell	6	1867	?	Upper Canada
Martha J. Mitchell	9	1867	?	Upper Canada
Mary Priscilla Mitchell	infant	1867	?	Upper Canada
Sarah Murkly	?	?	?	?
Elizabeth Ogley	13	1873	?	Upper Canada
John Pigeon	23	1870	?	?
June Quibble	19	?	?	England
A. Raymond	82	1861	?	?
Sarah A. Rosevere	33	1871	?	?
Caroline M. Russell	20	1864	?	Ireland
C.J. Ryan	17	1865	?	?
J.? Saga(r)?	8	?	?	?
Babs & Gertrude Sanders	?	?	?	?
John Thomas Skitch	?	?	?	?
Margaret Turk	78	1857	?	?
Mrs. Julia Wade	56	1852	?	?
Ralph Wade	70	?	?	?
Mary Whitt	21	1859	?	?
Martha Alice Williams	4 months	1868	?	?
? Woodhouse	?	?	?	?

Table 2.6. continued. Individuals buried in the Old Wesleyan Methodist cemetery and later reinterred in the Union Cemetery.

Legislation passed in 1842 required three quarts of water to be provided to each adult passenger, but prior to that time, some ships were supplying only 5 pints per day due to poor quality and quantity. If the water quality was poor enough, passengers often added vinegar, or resorted to salt water (Guillet 1937:76).

The location of Port Hope was ideal in terms of its proximity to both the Ganaraska River and Lake Ontario. There were also several streams and creeks within the town that could be exploited for drinking water. An article in the local newspaper outlines the concern of the townspeople for a waterworks department to be established, mainly to be able protect the town from fire, as well as to provide a sewer system. The editor notes, however, that "water for family use can at present be procured by every resident of this town, without very great inconvenience. A few domiciled on Cavan street may not be so favorably located in this respect." (Port Hope Evening Guide [PHEG], 18 August 1856).

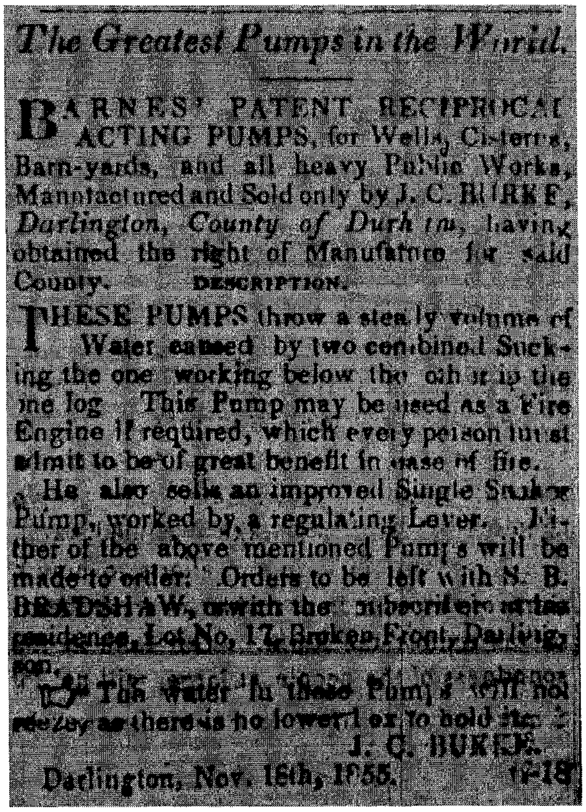
The article includes a report by George Stewart, a civil engineer, who was contracted to plan the development of a water system for town use. The proposed source of the water were the springs north of the Old Wesleyan Methodist Cemetery, to the west of Pine Street. Mr. Stewart states that the spring water was of excellent quality and of sufficient supply to provide 40 gallons of water per day for 3,000 of the (then) 4, 000 people living in Port Hope.

Archival references to the use of wells in Port Hope exist as well. John Skitch, aged 8, from Port Hope died on August 18, 1855 "while engaged with his father cleaning a well upon their own premises by relaxing his hold on the bucket when nearly raised to the surface by his father, consequently precipitating him to the depth of about sixty feet, inflicting such internal injuries as caused instant death" (Court Records of the United Counties of Northumberland and Durham 1855).

An additional newspaper article contains information about an outbreak of dysentery in the town. The author notes:

> "The endemic [sic] in Port Hope this season, appears to have broken out amongst a number of small cottages which are crowded together upon a level surface and nearly surrounded by trees particularly upon the South side where the delightful Lake breeze is cut off by this dense bush, the soil is a light sand very porous, and readily allowing any fluids thrown upon it to percolate thro' from the surface. Not even an excuse for drainage is attempted. The pits for the water-closets are seldom more than two or three feet deep , in many cases in very close proximity to the wells and in nearly every case emitting a most horrible effluvia. As an effect of the want of drainage and the readiness with which all liquid matters are absorbed by the soil, the slops containing all sorts of animal and vegetable refuse are thrown without thought carelessly around the dwellings, thus the surface becomes contaminated, and the sun's rays falling upon it with all the force of our Tropical summer, gives rise to emanations which are the very seeds of disease" (PHEG 22 August 1857).

Finally, advertisements for pumps were placed in the local newspaper, as seen in Figure 2.4.



The Greatest Pumps in the World.

BARNES' PATENT RECIPROCAL ACTING PUMPS, for Wells, Cisterns, Barn-yards, and all heavy Public Works, Manufactured and Sold only by J. C. BURKE, *Darlington, County of Durham,* having obtained the right of Manufacture for said County.

DESCRIPTION.

THESE PUMPS throw a steady volume of Water caused by two combined Sucking the one working below the other in the one log. This Pump may be used as a Fire Engine if required, which every person must admit to be of great benefit in case of fire.

He also sells an improved Single Stroke Pump, worked by a regulating Lever. Either of the above mentioned Pumps will be made to order. Orders to be left with S. B. BRADSHAW, or with the subscriber at his residence, Lot No. 17, Broken Front, Darlington.

☞ The Water in these Pumps will not freeze, as there is no lower box to hold it.

J. C. BURKE.

Darlington, Nov. 16th, 1855. 17-18

Figure 2.4. Port Hope pump advertisement from 1856 (PHEG 5 April 1856).

Based on the archival records of water use in Port Hope, it is likely that during the 19th century, individuals obtained drinking water from the local river, lake, and stream sources, and/or from wells dug on their property.

CHAPTER 3

DETERMINATION OF GEOGRAPHIC ORIGINS USING STABLE OXYGEN ISOTOPE ANALYSIS

3.1.Oxygen Isotopes

Isotopes are atoms of the same element that contain the same number of protons, but a different number of neutrons. As the number of neutrons varies, so does the mass of an isotope. While isotopes of the same element react similarly in chemical reactions, they can exhibit differences in chemical and physical properties (Hoefs 1997:4). For example, when isotopes of the same element are involved in biological processes, such as evaporation or photosynthesis, they react at different rates due to their difference in mass. This process is called fractionation, and it acts to discriminate against heavier isotopes, which react more slowly during chemical reactions, in favour of the lighter isotopes (Hoefs 1997:11).

Isotopes are either radioactive or stable. Radioactive isotopes break down to form other elements, while stable isotopes do not. There are three, naturally occurring, stable isotopes of oxygen: ^{16}O, ^{17}O, and ^{18}O with natural abundances of 99.763%, 0.0375%, and 0.1995% respectively (Hoefs 1997:47). Two isotopes of oxygen are used in this type of study, ^{16}O and ^{18}O, due to their greater natural abundances and greater mass difference between them (Dansgaard 1964:437; Hoefs 1997:22). The absolute abundances of these isotopes present in bone and enamel tissues are not measured. Instead, the relative difference in isotope abundance between the bone or enamel sample and a reference standard is measured to obtain $^{18}O/^{16}O$, also referred to as $\delta^{18}O$, as shown in equation 1:

$$(1)\ \delta^{18}O = \frac{^{18}O/^{16}O_{(sample)} - {}^{18}O/^{16}O_{(standard)}}{^{18}O/^{16}O_{(standard)}} \text{ x } 1000$$

The reference standard commonly used to determine $\delta^{18}O$ is Vienna Standard Mean Ocean Water (VSMOW) and results are reported in parts per mil (‰). When a sample has a $\delta^{18}O$ of 1.5‰ it has 1.5‰ more of the heavier isotope (^{18}O) than the reference standard. Conversely, a sample that has a $\delta^{18}O$ of -1.5‰ has 1.5‰ less ^{18}O than the reference standard (Gat 1996:3).

3.2.Oxygen Isotopes in the Environment

Oxygen is Earth's most abundant element, and its isotopes are present in the physical environment in minerals, liquids, and gases. It is the oxygen isotopes contained in water, consumed as drinking water by humans, that are relevant to this type of study. The source of drinking water is usually meteoric water, which is defined as water that has been involved in the meteorological cycle. Surface waters such as lakes, rivers, and glaciers, but not oceans are considered to be meteoric water (Hoefs 1997:103-4). As the water goes through the various processes of evaporation, condensation and precipitation, and changes between liquid and gaseous states, its isotopic composition is altered due to fractionation.

The majority of the Earth's water vapor originates in the tropics, where there is extensive evaporation of ocean water. This process favours water molecules carrying ^{16}O and results in the water vapor being isotopically lighter than the ocean water. The vapor then travels to higher latitudes during which time the water vapor condenses as rain. This process favours water molecules carrying ^{18}O and the rain is isotopically heavier than the vapor. The higher the latitude, the isotopically lighter the vapor, and therefore the rainwater, becomes, with the isotopically lightest precipitation falling at the poles (Dansgaard 1964:439; Yurtsever and Gat 1981:113). This trend can be seen in Figure 3.1.

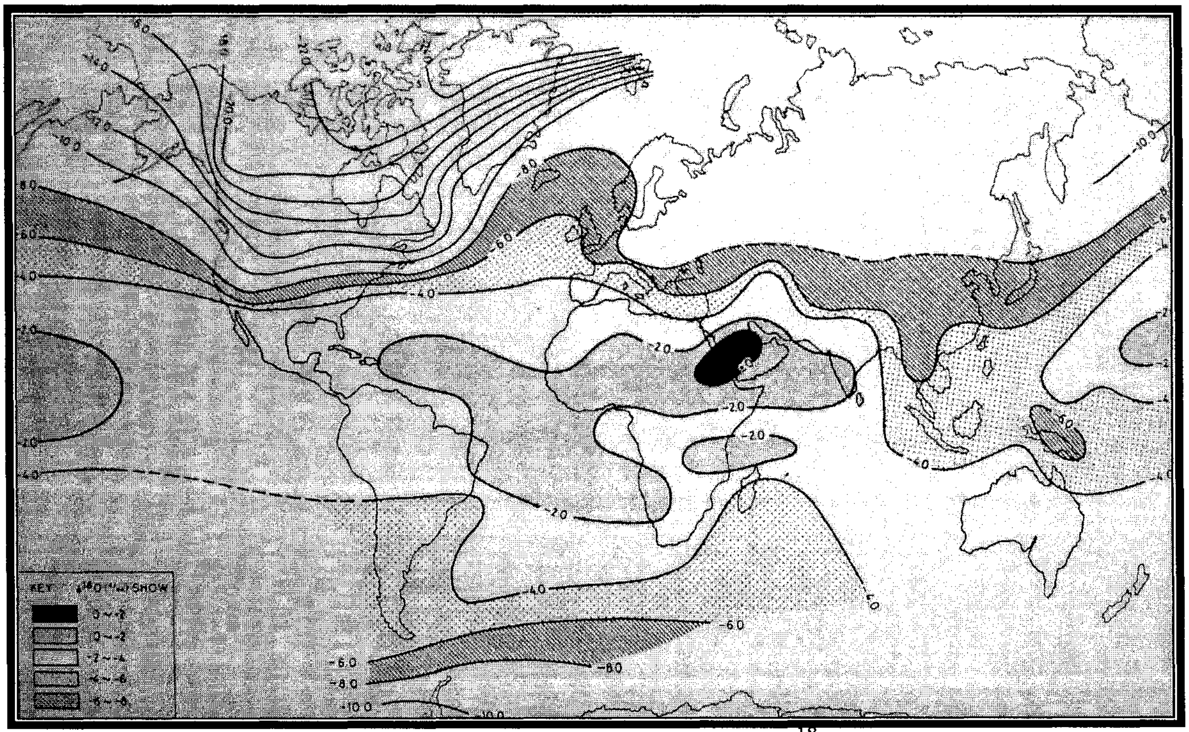


Figure 3.1. General distribution of worldwide mean $\delta^{18}O$ of precipitation (from Yurtsever and Gat 1981:112)

Other factors of geography and climate have been found to influence the isotopic content of water. Yurtsever and Gat (1981:113) found that the further inland a location is, the lower the $\delta^{18}O$ of meteoric water, as shown in Figure 3.2. $\delta^{18}O$ of meteoric water ($\delta^{18}O_w$) also increases as altitude increases, and decreases as temperature decreases (Yurtsever and Gat 1981:113, 117). Evaporation caused by low humidity acts to increase $\delta^{18}O_w$ due to the loss of ^{16}O during the process (Dupras and Schwarcz 2001:1202).

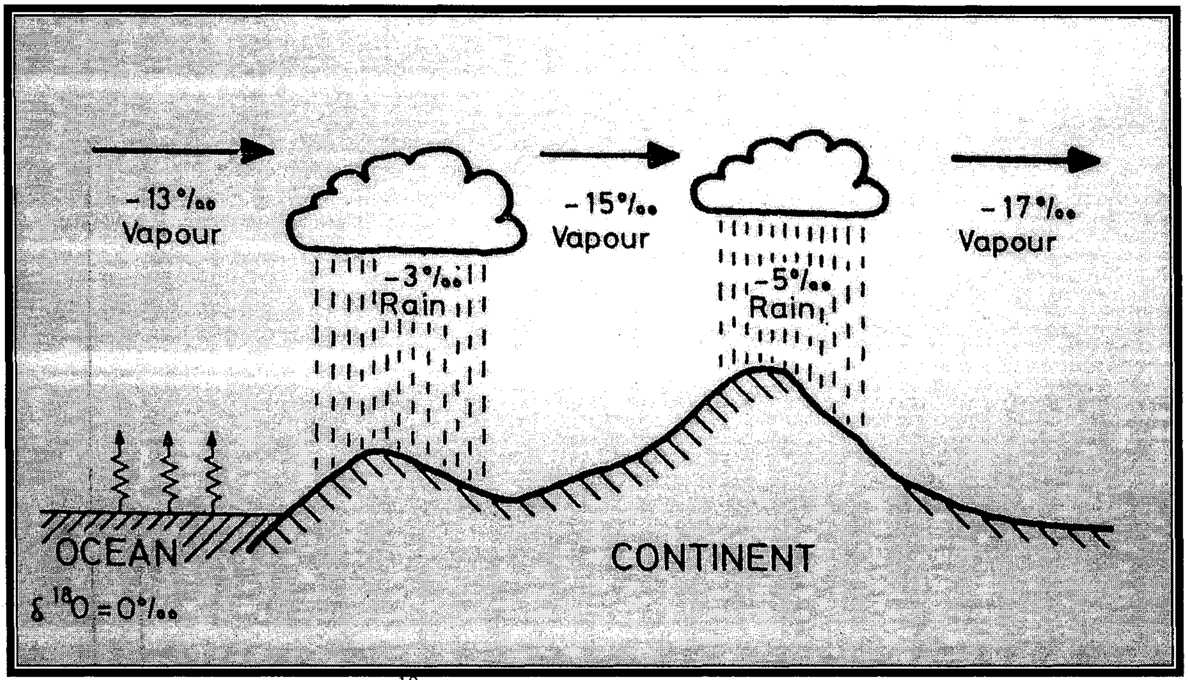


Figure 3.2. General trend in $\delta^{18}O$ of meteoric water with increasing distance from a body of water (from Hoefs 1997:104).

3.3. Oxygen Isotopes in Human Bone and Enamel

3.3.1. Human Bone

Human bone is a dynamic tissue that gains its properties from both its organic and mineral components. Thirty to forty percent of the weight of mature bone is made up of organic components, known as the osteoid matrix, 90% of which is made up of collagen fibres (Boivin and Meunier 2003: S20; Grollman 1978:63). The fibres are arranged in bundles and act as a framework for the inorganic components and provide the flexibility and tensile strength needed by bone to prevent damage from twisting and stretching forces (Marieb 2001:180; Su et al. 2003:158). The additional 10% of organic components include proteoglycans and glycoproteins, that along with collagen forms the osteoid matrix, as well as cells such as osteoblasts, osteoclasts, and osteocytes that are involved in bone formation and destruction (Marieb 2001:180).

The remaining 60-70% weight of mature bone is composed of inorganic mineral salts, mainly containing ions of calcium and phosphate, that are referred to as apatites (Grollman 1978:65). The general formula for apatite is $Ca_{10}(PO_4)_2(?)_2$, where (?) can be several different ions. The most common form in human bone (and teeth) is hydroxyapatite $[Ca_{10}(PO_4)_2(OH)_2]$, but fluorapatite $[Ca_{10}(PO_4)_2(F)_2]$ is also found (Hillson 2005:146). The apatites found in bone serve several biomechanical and metabolic functions. The apatite minerals are present in the form of tightly packed crystals that bond to the collagen fibres (Grollman 1978:65; Marieb 2001:180). Each crystal is approximately 50-100 nm in length (Su et al. 2003:150), and the structure and arrangement of crystals are responsible for the hardness of bone that allows the skeleton to resist damage due to mechanical forces, as well as protect vital organs (Glimcher 1992:285).

Bone also acts as a reservoir for the many ions needed for the body to function. For example, 99% of the body's calcium, 35% of the body's sodium, 80% of the body's carbonate, and 60% of the body's magnesium is contained within the bones in a human body (Boivin and Meunier 2003: S20; Glimcher 1992:285). The apatite crystals are in contact with the extra-cellular fluid where these ions are located, and the crystals interact with the ions to transport them as they are needed in various physiological functions (Glimcher 1992:285).

Macroscopically, bone is organized into cortical and cancellous bone. The difference between these types of bone is in their organization, as they have the same histological elements. Cortical bone is more dense than cancellous bone, which appears as spongy, lattice-like outgrowths. (Grollman 1978:67).

Human bone begins to form *in utero* and undergoes mineralization. This is a complex process that involves the interaction of calcium and phosphate to form plate-like crystals of hydroxyapatite which then proliferate in the osteoid matrix (Scheuer and Black 2000:22-23). Once formed, bone undergoes growth and modeling in order to develop into the adult skeleton. Growth involves increasing the length and width of bone, while the process of modeling sculpts the overall structure of the developing bone by forming bone (osteoblast action) in some locations and removing bone (osteoclast action) in others (Scheuer and Black 2000:30; Robling and Stout 2000:187). When an individual reaches skeletal maturity, growth and modeling cease.

The process of remodeling occurs throughout the entire life of an individual (Dempster 1992:370), and involves the removal of sections of bone in packets referred to as bone structural units (BSUs) that are then replaced with newly formed bone (Robling and Stout 2000:190). As such, existing bone is replaced without affecting the size and shape of the bone. It is thought that remodeling functions to repair microstructural damage (Scheuer and Black 2000:30) and to facilitate the movement of ions stored within the bone (Dempster 1992:355).

Bone remodeling occurs more frequently in children's skeletons than in adult skeletons (Dempster 1992:370; Mulhern 2000:525). As well, the bone of older individuals is more porous and less mineralized than the bone of younger individuals (Mulhern 2000:526). According to Dempster (1992:373), adult cortical bone turns over at a rate of 2-3% per year and cancellous bone turns over at a rate of 25% per year. Manolagas (2000:4), however, estimates that the complete turnover of the human skeleton takes ten years. Human bone at the time of death therefore contains apatite crystals that were recently incorporated during the process of remodeling, as well as apatite crystals that were incorporated at many different stages over the last several years of the individual's life (Grynpas 1993:S58).

3.3.2. Human Enamel

Human dentition develops in two stages. Deciduous (baby) teeth develop *in utero* and erupt during the first two years of life (Hillson 2005:8), and include 8 incisors, 4 canines, and 8 molars. These teeth are then replaced by the permanent teeth that follow a pattern of development and eruption that spans from *in utero* to approximately 20 of age, and include 8 incisors, 4 canines, 8 premolars, and 12 molars. As seen in Figure 3.3., all teeth are composed of a root, embedded in the mandible or maxilla, and a crown, that is exposed in the mouth. The crown and root surround a layer of dentine, that in turn surrounds the pulp chamber that contains the blood vessels and nerves that supply the tooth (Hillson 2005:8).

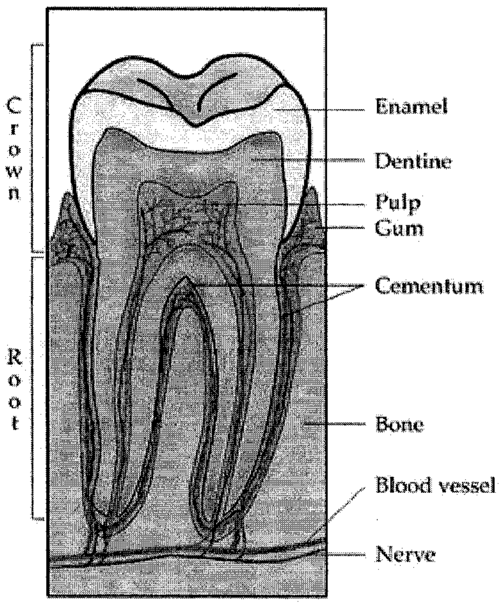


Figure 3.3. Structure of human teeth.

The enamel that encloses the crown is made of both organic and inorganic components. By dry weight, enamel is approximately 96% inorganic material and less than 1% organic material, with the remainder as water (Hillson 2005:155). As found in bone, the inorganic phase of enamel is composed of tightly packed hydroxyapatite crystals, although the crystals found in enamel are longer (at least 1600 nm) (Hillson 2005:155).

Both sets of human teeth develop in crypts within the bone of the jaws. During development, ameloblast cells are responsible for the production of enamel (Hillson 2005:155; Scheuer and Black 2000:154). Ameloblasts first deposit an organic matrix embedded with undeveloped apatite crystals that is one third apatite, one third protein, and one third water. Enamel is first laid down at the occlusal (chewing) surface of the crown and is then deposited in increments towards the root. Mineralization involves the removal of most of the protein and water along with the growth of the mineral crystals

(Hillson 2005:155-6). Once the crown has developed, there is no turnover or remodeling of the enamel (Hillson 2005:152). The remainder of the tooth develops from other types of cells, and once complete, it erupts from the bone. The pattern and timing of the development and eruption of both sets of human dentition has been established, and are outlined by Brown (1985), Moorrees et al. (1963), Ubelaker (1978).

3.3.3. Deposition of Oxygen Isotopes in Bone and Enamel

Due to the nature of the apatite crystals in human bone and enamel, it is possible to substitute ions of elements without the general structure of hydroxyapatite [$Ca_{10}(PO_4)_2(OH)_2$] being negatively affected (Grollman 1978:65). In addition to the exchange of (OH^-) and (F^-) discussed above, it is possible for sodium (Na^+) or strontium (Sr^+) to replace calcium, orthophosphate ($HPO^{2-}{}_4$), carbonate ($CO^{2-}{}_3$), or hydrogen carbonate ($HCO^-{}_3$) to replace phosphate, or chloride (Cl^-) or carbonate to replace hydroxyl; it is also possible for any of these ions to bond to the surface of the existing crystals (Hillson 2005:147).

When analyzing the oxygen isotope content of human bone and enamel in studies of geographic origins, it is possible to determine the $\delta^{18}O$ of the oxygen in either the phosphate ($PO^{3-}{}_4$) or carbonate ($CO^{2-}{}_3$) molecules within the hydroxyapatite. The focus of this study is carbonate. The principle behind analysis is that, as discussed above, the ratio of oxygen isotopes in the precipitation at a given location is determined by geographic factors such as latitude, altitude, and temperature. When this water is consumed by humans, the isotopes are incorporated into bone and enamel tissue in ratios that are reflective of the environment of the water source.

$\delta^{18}O$ of human bone and enamel carbonate ($\delta^{18}O_c$) is in equilibrium with, and therefore determined by, the $\delta^{18}O$ of the body water ($\delta^{18}O_{bw}$) at a constant temperature of 37°C (Bryant et al. 1996:5145). $\delta^{18}O_{bw}$ itself is determined by the total flux of oxygen through the body (Luz and Kolodny 1985:29; Luz et al. 1984:1690), which comes mainly from drinking water ($\delta^{18}O_w$), but oxygen from ingested foods and from the atmosphere also contribute (Luz et al. 1984:1690). Oxygen is lost from the body in carbon dioxide, urine, and sweat (Luz et al. 1984:1691).

When the oxygen in the carbonate component of human tissues is incorporated from meteoric water by way of body water, fractionation occurs. The fractionation factor between $\delta^{18}O_c$ and $\delta^{18}O_w$ has not been experimentally determined for humans (Bryant et al. 1996:5145). It can, however, be theoretically determined because the fractionation factor between phosphate ($\delta^{18}O_p$) and $\delta^{18}O_w$ is known (Luz et al. 1984:1690), as is the relationship between $\delta^{18}O_p$ and $\delta^{18}O_c$ in mammalian bone tissue (Iacumin et al. 1996:4).

When $\delta^{18}O_p$ and $\delta^{18}O_w$ of human teeth obtained by Luz et al. (1984) are plotted, the regression line is:

$$\delta^{18}O_p = 0.78\ \delta^{18}O_w + 22.7 \qquad (1)$$

Iacumin et al. (1996) measured $\delta^{18}O_p$ and $\delta^{18}O_c$ in mammalian bone and when plotted, found the following relationship:

$$\delta^{18}O_p = 0.98\ \delta^{18}O_c - 8.5 \qquad (2)$$

with an average $\delta^{18}O_c - \delta^{18}O_p$ of 9.1‰. Combining equations (1) and (2) after Dupras and Schwarcz (2001:1205), it is seen that:

$$0.98\delta^{18}O_c = 0.78\ \delta^{18}O_w + 31.2 \qquad (3)$$

Using equation 3 it is then possible to analyze geographic origins using $\delta^{18}O_c$.

3.3.4. Bioarchaeological Applications

The nature of how and when isotopes are incorporated into human bone and enamel allows for interpretations to be made about the origin and movement of individuals who lived in the past. It has been shown that the $\delta^{18}O$ of human skeletal tissue reflects the $\delta^{18}O$ values of water consumed, which are in turn a reflection of the environment of the water source. As enamel is formed at known, predictable times during development and does not remodel, its isotopic content will always reflect the geographic region occupied during the mineralization of that tooth. The isotopic content of human bone, however, is modified over time due to the process of remodeling, and the $\delta^{18}O$ of bone will gradually re-equilibrate to reflect the $\delta^{18}O$ of water in a new geographic region.

Comparison of bone and enamel $\delta^{18}O_c$ values can provide information about an individual's origin and relocation during his or her lifetime. For example, similar $\delta^{18}O_c$ values of enamel and bone indicate that the individual spent the majority of his or her life in the same geographic location. Different $\delta^{18}O_c$ values of enamel and bone, however, indicate that the individual relocated to a new geographic location during his or her lifetime. When possible, the comparison of $\delta^{18}O_c$ of enamel from teeth that form at different stages (e.g. M1 and M3) can provide information about timing of relocation during childhood. When $\delta^{18}O_c$ values are converted to $\delta^{18}O_w$ values, it is then possible to determine the actual geographic locations using maps of $\delta^{18}O_w$ distribution (Figure 3.2).

3.4. Previous Research

The first study that applied stable oxygen isotope analysis to investigating human geographic origins was completed by Schwarcz et al. (1991) on a sample of unknown soldiers who were killed during the war of 1812. Since then, the method has been used to study past human populations from several different regions of the world, including Mesoamerica (Spence et al. 2004; Stuart-Williams et al. 1996; White et al. 1998, 2002, 2004), Egypt (Dupras and Schwarcz 2001), England (Evans et al. 2006), and North America (Blyth 2003; Keenleyside et al. 1996; Pcholkina 2004; Schwarcz et al. 1991).

Extensive research has been carried out using oxygen isotope analysis in ancient Mesoamerica (Spence et al. 2004; Stuart-Williams et al. 1996; White et al. 1998, 2002, 2004). Much of this research focuses on the relationship of Teotihuacán with other Mesoamerican regions such as the Valley of Oaxaca, Kaminaljuyu, Guatemala, and Altun Ha, Belize. Not only is the geographic origin of individuals from these regions determined, but the results are applied to broader research questions regarding social and political relationships between and within local and non-local groups.

An early study by White et al. (1998) used stable oxygen isotope analysis to investigate the presence of different ethnic groups buried at sites in Teotihuacán. During Teotihuacán's period of growth between 100 B.C. to 200 A.D., people from various distant regions, such as the Valley of Oaxaca, settled there, often retaining their ethnic identity and burying their dead in selected areas. The authors analyzed the remains of 64 individuals excavated from five archaeological contexts in Teotihuacán and from Monte Alban in the Valley of Oaxaca. Individuals from the two regions were found to have distinct isotopic signatures with very little overlap. It was determined that individuals from Teotihuacán had bone $\delta^{18}O$ values between 14 and 17‰ and those from Oaxaca had values between 12 and 14‰.

The extent and pattern of immigration of individuals from the Valley of Oaxaca to Teotihuacán was further studied by White et al. (1998). This was done through the analysis of 11 individuals who were known to have immigrated from the Valley of Oaxaca to the site of Tlailotlacan near Teotihuacán in AD 200. While it is known that these individuals originated from Oaxaca, the authors were interested in the pattern and duration of immigration. The bone $\delta^{18}O$ values of the 11 Tlailotlacan individuals are compared to the values of 11 individuals from the Teotihuacán residential site of Tlajinga 33, and 16 individuals from Monte Alban, who are used to represent the isotopic baselines for the Basin of Mexico and the Valley of Oaxaca respectively.

The $\delta^{18}O$ values of Tlajinga 33 (mean = 14.75‰ ± 0.28) and Monte Alban (mean = 13.01‰ ± 0.63) are very uniform, indicating very stable populations with little to no immigration. In contrast, the $\delta^{18}O$ values of the Tlailotlacan sample (mean = 15.21‰ ± 0.79) are quite variable and are closer to the Tlajinga 33 $\delta^{18}O$ values. While there is a significant difference in the $\delta^{18}O$ values of adults and children, the sample is too small to statistically analyze the difference between adult males and females and between primary and secondary burial contexts. The authors suggest that the difference between age groups is related to breastfeeding and weaning practices and that the difference between the sexes in the sample is related to female-based endogamy. In terms of the pattern of immigration, it is suggested that there was an initial immigration event from the Valley of Oaxaca followed by limited contact. Archaeological evidence supports this, as the form and decoration of ceramics produced at Tlailotlacan did not change over time, whereas they did in Oaxaca, indicating that there was no contact between the two regions.

The site of Tlajinga 33, Teotihuacán was the focus of additional research by White et al. (2004) who were interested in determining the heterogeneity of childhood residence of craft producers from the residential compound. It was not known whether craft producers received immigrants to augment or maintain their productivity. The original sample analyzed in their previous study (White et al. 1998) was expanded to 25 individuals of different sex, status groups and burial contexts. In addition to increasing the sample size, White et al. (2004) include the analysis of the oxygen isotopic composition of enamel in order to determine childhood residence. The mean $\delta^{18}O$ values of bone are reported as 15.1‰ ± 1.3, slightly higher than the results of the previous study. Results indicate that 29% of the individuals in the sample immigrated to Tlajinga 33. While some of these non-local individuals were excavated from burial contexts of low status, such as middens, others were recovered from burial contexts of higher status, such as tombs, indicating a high social status of non-locals. Isotopic analysis was also carried out to examine the dietary patterns of these individuals, and the lack of difference between the locals and non-locals is suggested to be evidence of assimilation (White et al. 2004).

Stable oxygen isotope analysis was performed on a sample of sacrificial victims including soldiers, women, and individuals interred in the central interior at the site of

Feathered Serpent Pyramid, Teotihuacán (White et al. 2002). Stable oxygen isotope analysis of the soldiers was carried out with the aim of determining the degree of heterogeneity, in terms of place of origin, of the soldiers in order to gain information about Teotihuacán's political and military structure. Samples of enamel and bone from 41 soldiers were analyzed and it was concluded that some soldiers were natives of Teotihuacán and others were being recruited from four regions within Mesoamerica and had lived at Teotihuacán for several years prior to their death. It is suggested, based on age-at-death and isotope turnover time, that individuals were recruited in early adolescence. The difference in $\delta^{18}O$ values of the enamel and bone samples of the females in the group also indicates heterogeneous origins. It is suggested that the choice of these individuals for sacrifice was meant by Teotihuacán as a display of power to the rest of Mesoamerica.

A later study by Spence et al. (2004) investigated the geographic origin of the 36 human maxillae worn as trophies by four of the Feathered Serpent Pyramid soldiers. $\delta^{18}O$ values of teeth from 15 of the trophy pendants indicate that the victims originated from various regions, including Teotihuacán and the soldiers' own homelands. The presence of multiple pendants with various $\delta^{18}O$ values being worn by single individuals indicates that the military was active in several campaigns in different regions.

Research on migration patterns in the Dakhleh Oasis in Egypt was also successfully carried out using stable isotope analysis (Dupras and Schwarcz 2001). Previous archaeological research indicates that the Oasis was involved in the trade of goods such as olives and dates, and that migrant farmers were encouraged to settle there. The analysis was conducted on a sample of 109 individuals from the Kellis 2 cemetery which has a ^{14}C date of 250 to 450 A.D. In order to maximize the amount of information obtained about the effects of trade and immigration on the population structure, the authors combined the use of stable oxygen isotope analysis with stable nitrogen isotope analysis, which has been shown to be useful in reconstructing past diet. Dupras and Schwarcz (2001) suggest that nitrogen isotope analysis has potential application for migration studies because individuals from very arid regions have elevated nitrogen values. The results of their analysis indicate that in general, adult males were migrating to the area, possibly due to their involvement in trade with the Nile. Analysis of the oxygen isotopic composition of teeth from this sample is underway in order to investigate the origins of these individuals.

Several studies of human geographic origin using stable oxygen isotope analysis have been conducted that include individuals who were determined to originate from Upper Canada and Europe. The results of these studies are useful for comparison with the current study, and are summarized in Table 3.1.

Schwarcz et al. (1991) investigated the origins of six of 28 soldiers who fought in the War of 1812 and were buried in the Snake Hill cemetery outside of Fort Erie, Ontario. Based on the differences in enamel and bone δ^{18}O values, it was concluded that none of the soldiers were local to the Fort Erie region. After the δ^{18}O values of the enamel samples were compared to the values of individuals who were known to originate from southwestern Ontario and Maryland, U.S.A., it was concluded that all six soldiers grew up in the northeastern United States. The δ^{18}O values of their bone samples were very uniform, suggesting that the soldiers had been living in the same environment together for several years prior to their deaths.

Author(s)	**Sample**	**Sample Size**	**$\delta^{18}O_p$ (VSMOW)**
Schwarcz et al. (1996)	Soldiers killed in War of 1812	6 bone	12.14 - 12.89
	Reference sample: SW Ontario	2 bone	12.15, 12.17
	Reference sample: Maryland	1 bone	13.18
Blythe (2004)	Soldiers killed in Battle of Stoney Creek	5 bone 34 enamel	13.3 - 14.82 15.25 - 17.9
	Soldiers killed at Fort William Henry	9 bone 18 enamel	14.24 - 15.88 15.7 - 17.98
Keenleyside et al. (1996)	Members of Franklin Expedition	2 enamel	18.96, 19.0
Evans et al. (2006)	Individuals local to the Hampshire area of southern England	7 enamel	17.0 - 18.5
Pcholkina (2004)	Individuals buried in Peterborough Armoury	9 bone 7 enamel	13.27 - 15.72 16.46 - 20.08
	Quackenbush individuals	7 bone	13.67 - 15.91

Table 3.1. Summary of results of previous relevant stable oxygen isotope analyses.

With the aim of determining the geographic origins of soldiers who were killed during the French and Indian War (1756 to 1763) and the War of 1812, Blyth (2003) used stable oxygen isotope analysis of bone and enamel samples of individuals who died at Fort William Henry and at the Battle of Stoney Creek. It was concluded that the soldiers who died during both wars were born in America, some of whom spent several years prior to their deaths in the northern United States as well as some time in eastern Ontario or in Quebec.

Keenleyside et al. (1997) present the results of their analysis of the fragmentary remains of a minimum of 11 men recovered on King William Island in the Canadian Arctic. The remains were thought to be of individuals who were part of the Franklin expedition who perished in the Northwest Territories in approximately 1848. In addition to osteological and pathological analysis, the stable oxygen isotope analysis of molars from two individuals was carried out in order to determine their geographic origin. The enamel $\delta^{18}O$ values obtained were compared with $\delta^{18}O$ values of modern precipitation for several regions in Europe and North America and were found to be closer to known European $\delta^{18}O$ values. These results supported the conclusion that the remains belonged to crew members of the Franklin expedition.

A recent study combines the methods of oxygen and strontium isotope analysis to investigate the origins of a group of individuals buried in a 4th century Romano-British cemetery in the south of England (Evans et al. 2006). These individuals were thought to be non-local, likely from the Danube region of central Europe, due to the difference in the type and amount of grave goods associated with each group. In order to establish the local isotopic signature, enamel samples from nine individuals thought to be local were included in analysis. It was determined based on comparison with modern precipitation $\delta^{18}O$ values that seven of these individuals were local, with $\delta^{18}O_p$ values ranging from 17.0 to 18.5‰. The results of analysis of those thought to be non-local indicate that they immigrated from several different regions.

Research has also been undertaken to investigate the origins of individuals excavated from the Peterborough Burial Ground (Pcholkina 2004). As part of a Master's thesis at Trent University, the origin of nine individuals from this European burial ground was investigated using stable oxygen isotope analysis of bone and tooth enamel. This study also analyzed human remains from the Quackenbush First Nations skeletal collection, with the assumption that this population had been living in the Peterborough region for all of their lives and could therefore be used as a local isotopic reference sample to which unknown individuals could be compared (Pcholinka 2004).

It was found that the $\delta^{18}O$ values of bone and enamel of the Peterborough Burial Ground individuals were different, indicating a change in residence. In contrast, the $\delta^{18}O$ values of bone of the Peterborough Burial Ground and Quackenbush individuals were not significantly different, indicating that the former individuals had been living in the Peterborough area for several years prior to their death. Comparison of enamel $\delta^{18}O$ values with modern $\delta^{18}O$ values of precipitation indicates that the individuals originated from Ireland, which coincides with the results of archival research. Pcholkina (2004) was also able to conclude that these individuals were the first settlers to the Peterborough region, based on the enamel $\delta^{18}O$ values and the known dates of use of the cemetery.

3.5. Factors Affecting Analysis

3.5.1. Breastfeeding and Weaning Practices

The practices of breastfeeding and weaning have been found to influence $\delta^{18}O$ due to the difference between the oxygen isotope ratios of drinking water and breastmilk. Wright and Schwarcz (1998) determined that breast milk is enriched with ^{18}O relative to water, and as a result, children that are being breastfed have higher $\delta^{18}O$ values of enamel and bone compared to individuals not consuming breastmilk. The difference in $\delta^{18}O$ between teeth that develop at different times is indicative of the ages at which solid foods are introduced and when they gradually replace breastmilk.

Wright and Schwarcz measured these differences in an archaeological sample from Kaminaljuyu, Guatemala, and an increase of 0.7‰ (the weaning offset) was detected in teeth that form while a child was being breastfed (permanent first molars) compared to teeth that form once breastfeeding has ceased (permanent third molars). Similarly, an increase of 0.5‰ was observed in teeth that form during the consumption of breastmilk and solid foods during the process of weaning (permanent premolars) and teeth that form once breastfeeding has ceased (permanent third molars). Based on the ages at which these teeth develop, it was concluded that the children in this population began consuming solid food by two years of age while continuing to consume breastmilk until the age of 5 or 6 (Wright and Schwarcz 1998:15).

While these findings can be used to gain information about breastfeeding and weaning practices in past populations, they must be taken into consideration in studies of oxygen isotope analysis of geographic origins. White et al. (2004:177-178) adjusted the results of oxygen isotope analysis to compensate for the trophic shift resulting from breastmilk consumption by lowering the $\delta^{18}O$ of bone and enamel tissue that was formed during breastfeeding by 0.7‰, and lowering the $\delta^{18}O$ of tissue formed during weaning by 0.35‰. The breastfeeding and weaning practices of the individuals buried in the Old Wesleyan Methodist Cemetery have not yet been determined and the weaning offset values are not known. Studies of two contemporary samples have been performed, however, and can shed light on the issue.

Katzenberg and Pfeiffer (1995) investigated the process of weaning in a sample of individuals buried in Prospect Hill Methodist Cemetery in Newmarket, Ontario. Based on carbon and nitrogen isotopic analysis of collagen, it was concluded that consumption of breastmilk ceased by the age of 12 months. Herring et al. (1998) investigated the weaning process of individuals buried in St. Thomas' Anglican Church in Belleville, Ontario using a combination of archival records and stable nitrogen isotope analysis. It was found that solid foods were introduced around 5 months of age and the consumption of breast milk ceased around the age of 14 months.

It can be inferred that for individuals living in Upper Canada during the second half of the 19th century, the enamel tissue that developed prior to the approximate age of 5 months is enriched in $\delta^{18}O$ due to the consumption of breastmilk. Enamel tissue that developed between the ages of 5 and 14 months should also be enriched, but to a lesser degree, due to the consumption of both breastmilk and solid foods. The $\delta^{18}O$ of these tissues can then be adjusted assuming the trophic difference seen in the Hawkins sample is 0.7‰ as determined by Wright and Schwarcz (1998).

The breastfeeding and weaning practices of the individuals buried at the Myles and Scugog archaeological sites are not known. The practices of the Huron, Menominee, Potawatomi, and Southwest Chippewa First Nations groups from Northeastern North America have been recorded and can be used to establish a very general trend. Southwestern Chippewa infants were weaned at the age of two or later (Ritzenthaler 1978:750). Similarly, ethnographic accounts of the Huron state that infants were nursed for two to three years while also consuming meat that had been well-chewed by their mother. When the mother's breastmilk was not available, the child was fed the water remaining from the boiling of corn (Tooker 1967:123). According to Spindler (1978:718), Menominee infants were breast fed "for as long as [they] would reach for the breast, and weaning was not sudden." As well, Potawatomi infants were weaned after several years, or when their mother became pregnant again (Clifton 1978:735). Based on these accounts, the ages at which weaning began and ended are not clear, but it can be inferred that infants were consuming both breastmilk and solid foods at least until the age of three. The enamel tissue that developed prior to the age of three should therefore be enriched compared to the enamel of an individual not consuming breastmilk and depleted compared to the enamel of an individual consuming only breastmilk.

3.5.2. Diagenesis

Diagenesis is defined as postmortem alteration of the chemical composition of bone that occurs when a skeleton is deposited in soil (Sanford and Weaver 2000:334). This process of alteration is due to the dynamic nature of bone responsible for ion substitution in living bone, as discussed above. This chemical interaction continues when bone enters the soil environment and, as a result, diagenesis can either incorporate or remove components of skeletal elements (Sanford and Weaver 2000:334).

Von Endt and Ortner (1984:248) state that the process of diagenesis involves both intrinsic and extrinsic factors. Extrinsic factors relate to the burial environment, which has been determined to be the primary factor in determining the preservation of human bone (White and Hannus 1983). They include features such as soil pH, temperature, microorganisms, groundwater, precipitation, and soil texture, hydrology, mineralogy, and organic content. Intrinsic factors are related to the structure of bone itself and include features such as the size, histology, porosity, and biochemistry of bone (Sanford and Weaver 2000:335).

In terms of the carbonate component of bone, diagenesis can cause alteration of the isotopic composition that was present in living bone by incorporation of carbonates from the sediment into spaces between existing apatite crystals or onto the crystal surfaces (Koch et al. 1997:418). Apatite crystals can also be removed by groundwater present in the burial environment (Hillson 2005:147).

Substances with low density and crystalinity, such as bone, are easily altered by diagenesis due to their porous nature. The process of diagenesis is complex, but several patterns have been established. In general, the more porous the bone, such as that of juveniles and cancellous bone compared to cortical bone, the greater the effects of diagenesis. Enamel, however, is much less susceptible to diagenesis due to its high mineral content (Koch et al. 1997:418; Kohn et al. 1999:2745).

It has been determined that mechanical cleaning of samples prior to analysis (Price et al. 1992) and treating bone and enamel with dilute acid (Koch et al. 1997) are effective methods of removing contaminants resulting from diagenesis. As well, methods to test for diagenesis have been established. Based on the fact that diagenesis alters the mineral component of bone and enamel, Fourier transform infra-red (FTIR) can be used to quantitatively measure crystalinity. As outlined by Wright and Schwarcz (1998), using the spectra of bone or enamel, the crystalinity index (CI), or the degree of recrystalization of bone of tissue, can be measured. A CI of 2.8-3.0 is normal for modern bone samples, and CI values ranging from 3.44 to 4.02 (Wright and Schwarcz 1996) and 3.5 to 4.8 (Stuart-Williams et al. 1996) have been found. Samples with a CI greater than 4.25 are considered highly recrystalized and have been found to exhibit depleted $\delta^{18}O$ values (Wright and Schwarcz 1996:939).

CHAPTER 4

MATERIALS AND METHODS

4.1. Samples

This research involves the analysis of individuals from one historic and two First Nation burial sites in Port Hope, near Campbellford and near Lake Scugog respectively (Figure 4.1.). Bone and enamel samples from skeletons from the Hawkins, Myles, and Scugog sites were selected based on availability. Bone analyzed included samples of rib, mandible, and maxilla. It is possible to compare the isotope values of different bones as samples of multiple skeletal elements from the same individual have been found to have similar $\delta^{18}O$ values (Dupras and Schwarcz 2001:1203).

When possible, multiple teeth from a single individual were analyzed in order to obtain oxygen isotope results from different stages of their life. Teeth analyzed included samples of enamel from: (1) the permanent upper first incisor, which mineralizes between the ages of three months and four years; (2) the permanent upper canines, which mineralize between birth and the age of five; (3) the lower first premolars, which mineralize between the ages of one and six; (4) the lower second premolars, which mineralize between the ages of two and eight; (5) the permanent upper and lower first molars, which mineralize between birth and the age of three; (6) the permanent upper and lower second molars, which mineralize between the ages of three and eight; and (7) the upper and lower third molars, which mineralize between the ages of eight and fifteen (Moorrees et al. 1963; Ubelaker 1978).

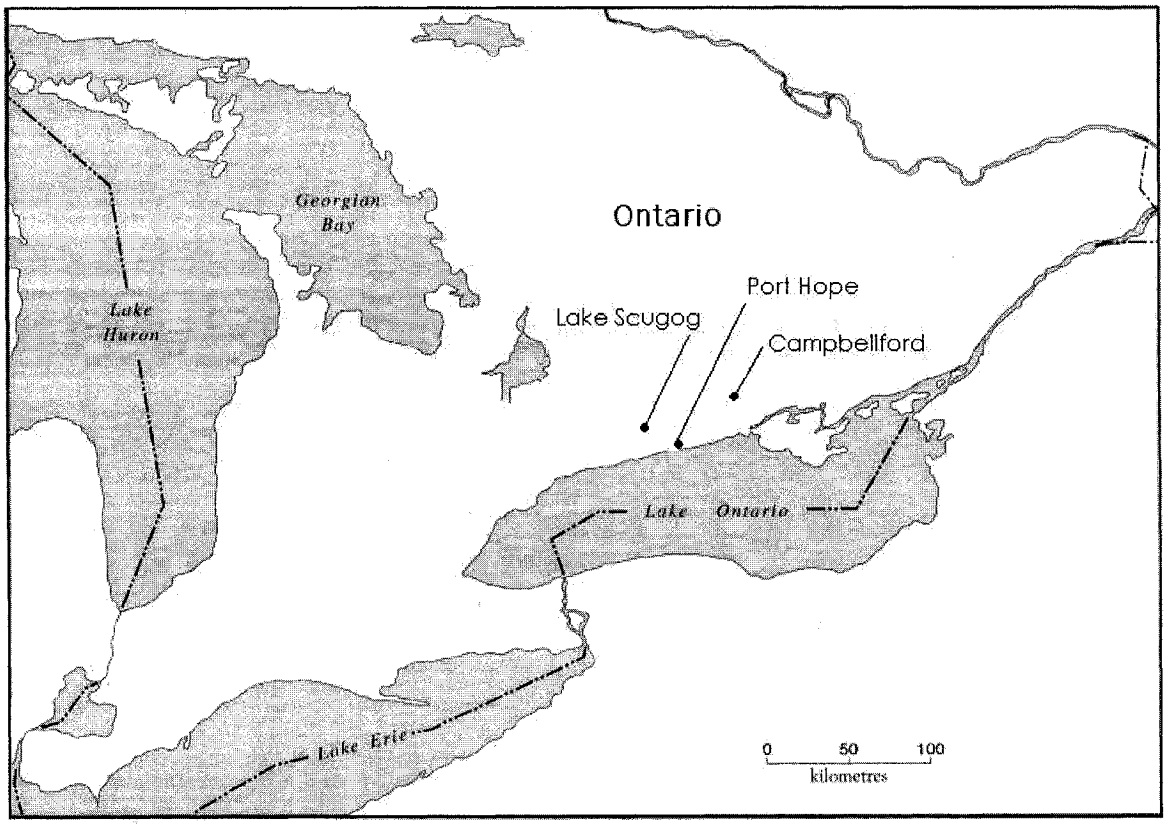


Figure 4.1. Map indicating the location of the three archaeological sites included in this study.

4.1.1. Hawkins Collection

The Hawkins skeletal collection is comprised of 64 individuals who were buried in the Old Wesleyan Methodist Pioneer Cemetery in Port Hope during the 19th century. In the summers of 2002 and 2003 a total of 46 coffin burials, and a group burial consisting of the commingled remains of at least 18 individuals were excavated. The skeletal remains were transported to Trent University, where skeletal inventories and biological profiles were completed by Karen Blackbourn (2006), Christianne Hawken

(2006), and Anna Pcholkina. Prior to reburial in the Union Cemetery in Port Hope in 2004, rib and tooth samples from some individuals were selected and retained in order to conduct future research.

This project involves the analysis of 23 bone and 31 tooth samples from 23 of the 46 individuals interred in the coffin burials, as shown in Table 4.1. The remaining 23 burials are not included because samples were not available for analysis. An additional three individuals are represented by three upper right first molars selected from the commingled remains. Age and sex of the individuals were determined by Christianne Hawken (2006) and Karen Blackbourn (2006) following the methods outlined in Buikstra and Ubelaker (1994), and their assessments are used in this study.

4.1.2. Myles Site

Skeletal remains were excavated from the Myles site (BbGk – 11.1), approximately 10km Southeast of Campbellford, Ontario in 2002. The remains of 4-5 individuals were found in dry, sandy soil in what is now the basement of a cottage. The skeletal remains of two of these individuals, identified as Burial A and Burial B, were very well preserved and nearly complete. The commingled remains of the 2-3 other individuals were not as well preserved or complete. During further excavation in 2003 the fragmented remains of a minimum of six adults and four subadults were discovered. Radiocarbon dates of 1110 ± 40 AD and 1170± 40 AD were established for two samples of charred wood that were in contact with Burial A. All skeletal remains from the Myles site were taken to the Department of Anthropology at Trent University where they were

Burial Number	Sex	Age (Years)	Enamel Sample	Bone Sample
1	Male	20-35	URM1 ULM3	rib
2	Indeterminate	15-20	URM1 LRM3	rib
2A	Female	35-50	URM1	rib
2B	Indeterminate	20-35	LRP1	rib
2C	Indeterminate	birth - 5	LRM1	rib
3B	Indeterminate	5-10	LRM1	rib
5	Male	50+	LRP1	rib
7	Indeterminate	5-10	LLM1	rib
13	Female	20-35	LRM3	rib
14	Indeterminate	15-20	ULI1	rib
15	Male	35-50	LLM1	rib
16A	Indeterminate	10-15	URC LRM2	rib
16B	Female	35-50	LLP2	rib
21	Male	50+	LLM2 LLM3	rib
23	Indeterminate	5-10	URP1	rib
24	Male	35-50	URM1 LRM3	rib
27B	Indeterminate	5-10	LLM1	rib
29	Indeterminate	15-20	LRC LLM2	rib
30A	Male	35-50	URM1 LLM3	rib
31	Female	50+	LLM1	rib
33	Indeterminate	15-20	ULM1 ULM2 URM3	rib
35A	Indeterminate	birth - 5	LRM1	rib
36	Female	20-35	URC ULM3	rib
Isolated 1	Indeterminate		URM1	none
Isolated 2			URM1	
Isolated 3			URM1	

Table 4.1. Bone and enamel samples from the Hawkins site included in analysis (ULI1 = upper left first incisor, URC = upper right canine, LRP1/LLP2 = lower right first premolar/lower left second premolar, URM1/ULM1/LRM1/LLM1/ = upper right first molar/upper left first molar/lower right first molar/lower left first molar, ULM2/LRM2/LLM2 = upper left second molar/lower right second molar/lower left second molar, ULM3/LRM3/LLM3 = upper left third molar/lower right third molar/lower left third molar).

inventoried and analyzed (Helmuth 2002).

While the fragmentary nature of the remains did not allow for many conclusions to be made about the individuals, for some fragments it was possible to determine sex, age, and ancestry, and to assess pathology. A more thorough analysis of burials A and B was possible due to their complete nature. The remains were determined to be of First Nation ancestry based on cranial morphology and metrics, as well as long bone morphology (Helmuth 2002).

The samples selected from the burials at the Myles site include bone and tooth samples from individual B. Individual A was not included because sufficient enamel was not available due to the extreme attrition of her dentition. As the rest of the remains are commingled, the issue of obtaining bone and enamel samples from the same individual was addressed by selecting teeth that were still embedded in bone. One molar embedded in a fragment of maxilla (MC) and another embedded in a mandibular fragment (MD) were selected. The samples are known to be from two different individuals due to the different stages of dental eruption (>15 and 9-10 years old respectively) exhibited in the mandible and maxilla. Samples selected include a total of three bone and three enamel samples from three individuals as shown in Table 4.2.

Burial I.D.	**Sex**	**Age (Years)**	**Enamel Sample**	**Bone Sample**
MB	Male	50-60	LRM1	rib
MC	Indeterminate	9-10	URM1	maxilla
MD		>15	LLM1	mandible

Table 4.2. Bone and enamel samples from the Myles site included in analysis

4.1.3. Scugog Site

Commingled fragmentary skeletal remains were excavated by Chief Kris Nahrgang from shallow mounds from the Lake Scugog area in 2003. Radiocarbon dating of two femoral bones, one immature and one mature, has provided dates of 405 A.D. to 535 A.D. and 1145 A.D. to 1275 A.D. respectively. A minimum of seven individuals were buried at this site, although the absolute number of individuals is likely higher (Morgan 2006). As the remains are commingled, bone and enamel samples were obtained from the same individual by selecting teeth still embedded in bone when possible. For individuals SA and SB, the maxillary bone and a molar that was still embedded in it were sampled. An additional loose molar was included in the analysis, as was a random selection of three rib fragments. A total of three enamel and five bone samples were obtained from a minimum of three individuals for analysis, as shown in table 4.3.

Burial I.D.	Sex	Age (Years)	Enamel Sample	Bone Sample
SA	Indeterminate		ULM1	maxilla
SB			ULM1	maxilla
SC			ULM1	none
S1			none	rib
S2				rib
S3				rib

Table 4.3. Bone and enamel samples from the Scugog site included in the analysis.

4.2. Sample Preparation

4.2.1. Bone Preparation

A sample of bone from each individual was fragmented and washed in a beaker of tap water in an ultrasonic cleaner until the water decanted off the sample was clear. The samples were then placed in an ultrasonic cleaner in beakers of MilliQ water and washed for 15 minutes three times. Once dry, the bone was crushed to form 100mg of powder using a mortar and pestle. In order to remove organic contaminants from the bone, 4mL of 2.5% sodium hypochlorite (Javex™ Bleach) was added to each sample for 72 hours with occasional agitation. Using a centrifuge and pipette, the bleach solution was removed and the bone powder was rinsed five times with MilliQ water. The bone was then soaked in 4mL of acetic acid buffered with calcium acetate for 24 hours with occasional agitation in order to remove diagenetic carbonates. The buffered acid solution was then removed using a centrifuge and pipette, and the bone powder was rinsed four times with MilliQ water. Once dry, the powder was weighed to determine the amount of sample lost during preparation.

Samples were then transferred to the Stable Isotope Biogeochemistry Laboratory at McMaster University. Approximately 2mg of bone powder was reacted with 100% phosphoric acid at 90° in an Isocarb analyzer. The CO_2 gas produced was then analyzed with a VG Optima mass spectrometer to determine the oxygen isotope composition of the samples.

4.2.2. Enamel Preparation

Teeth were cleaned ultrasonically in beakers of tap water, and then in beakers of MilliQ water. Using a Dremal Tool with a diamond burr attachment, the external surface of enamel was removed in order to remove possible adhering contaminants. Approximately 10mg of enamel was then removed from the surface of the tooth and soaked in 0.4mL of 2.5% sodium hypochlorite (Javex™ Bleach) solution and left for 24 hours with occasional agitation. Using a centrifuge and pipette, the bleach solution was removed and the enamel powder was rinsed five times with MilliQ water. The enamel powder was then soaked in 0.4mL of acetic acid buffered with calcium acetate for 24 hours with occasional agitation in order to remove diagenetic carbonates. The buffered acid solution was then removed using a centrifuge and pipette and the enamel powder was rinsed four times with MilliQ water. Once dry, the enamel powder was weighed to determine the amount of sample lost during preparation.

Samples were then transferred to the Stable Isotope Biogeochemistry Laboratory at McMaster University. Approximately 2mg of enamel powder was reacted with 100% phosphoric acid at 90° in an Isocarb analyzer. The CO_2 gas produced was then analyzed with a VG Optima mass spectrometer.

The error of the procedure, obtained through combining the precision and accuracy of analysis, is ±0.2‰. Bone and enamel results are presented in the standard δ notation in per mil (‰) where x = sample and std = standard:

$$\delta^{18}O_x = \{ [(^{18}O/^{16}O)_x / (^{18}O/^{16}O)_{std}] - 1\} \times 1000$$

4.2.3. FTIR Analysis

In order to assess the degree of diagenesis, samples of powder that had been prepared with the bleach and buffered acetic acid solutions were passed through a #200 mesh sieve. Two mg of this powder was combined with 200mg of potassium bromide and compressed at 15,000 psi using a Carver Lab Press to form 12mm diameter pellets. The pellets were then analyzed using a Varian 1000 Scimitan Series FT-IR using the empty chamber as the background reference. Absorbance spectra for each sample were obtained from 400 to 2000 cm^{-1} at a resolution of 8 cm^{-1}. Once the baseline was corrected, peak absorbance was measured at 565 and 605 cm^{-1}, as was the absorbance at the valley between them, at 595 cm^{-1}. The crystalinity index (CI) was then calculated by adding the absorbance values at 565 and 605 cm^{-1} and dividing by the absorbance value at 595 cm^{-1}.

CHAPTER 5

RESULTS

5.1. FTIR Analysis

The results of the FTIR analysis are shown in Table 5.1. The CIs obtained for bone samples from the Hawkins individuals range from 2.63 to 3.76 with an average CI of 3.38 (n=23). While the results of the Myles and Scugog individuals represent two distinct sites, the results of the FTIR analysis are combined in order to allow statistical analysis not permitted when the results are separated due to small sample sizes. For the Myles and Scugog individuals, the CIs of bone samples range from 2.56 to 3.6 with an average CI of 3.19 (n=7). All of these values fall within the range of CIs obtained for archaeological bone by Stuart-Williams et al. (1996) indicating low diagenetic alteration.

The expected crystalinity index of archaeological enamel has not been determined, but is expected to be higher than the CI of bone due to the highly crystallized nature of enamel that exists prior to burial (Schwarcz pers. comm 2006). The CIs of enamel samples of the Hawkins individuals range from 3.86 to 4.48 with an average CI of 4.18 (n=20). The CIs of the enamel samples of the Myles and Scugog individuals range from 4.25 to 4.68 with an average CI of 4.44 (n=5).

Samples altered by diagenesis are expected to demonstrate a correlation between CI and $\delta^{18}O_c$ values. In order to explore this relationship statistically, the distribution of all results were tested for normalcy using the Kolmogorov-Smirnov test and the linearity of the relationship was tested using an ANOVA test. All results were found to be normally distributed. For results determined to be linear, the relationship between CI and $\delta^{18}O_c$ values was explored using the Pearson Correlation. For results determined to be non-linear, data was transformed into rank variables and the relationship between CI and $\delta^{18}O_c$ values was explored using the Spearman's Rho.

No correlation between CI and $\delta^{18}O_c$ values was observed for the Hawkins bone (Spearman's $r = -0.143$, $p = .508$) or enamel samples (Pearson's $r = -0.015$, $p = .95$), as seen in Figures 5.1 and 5.2. These results indicate that the bone and enamel of the Hawkins individuals is well preserved. This is further supported by the results of tests of collagen preservation by Blackbourn (2006). Both the C:N ratio and the % collagen yield were determined for rib samples of 16 individuals, all of whom are included in this study. The C:N ratios range from 3.0 to 3.4, with an average of 3.2, values that indicate good preservation (Blackbourn 2006:96). The collagen yields range from 2.4% to 16.6%, with an average of 10.6%, again indicating good sample preservation (Blackbourn 2006:95).

When the relationship between the CI and $\delta^{18}O_c$ values of the Myles and Scugog bone samples are compared (Figure 5.3), a significant correlation is observed (Spearman's $r = 0.893$, $p = .007$). A significant correlation is also found when the CI and $\delta^{18}O_c$ values of the Myles and Scugog enamel samples are compared (Spearman's $r = 0.900$, $p = 0.37$) (Figure 5.4). This indicates that the Myles and Scugog bone and enamel samples are not as well preserved as the Hawkins tissues.

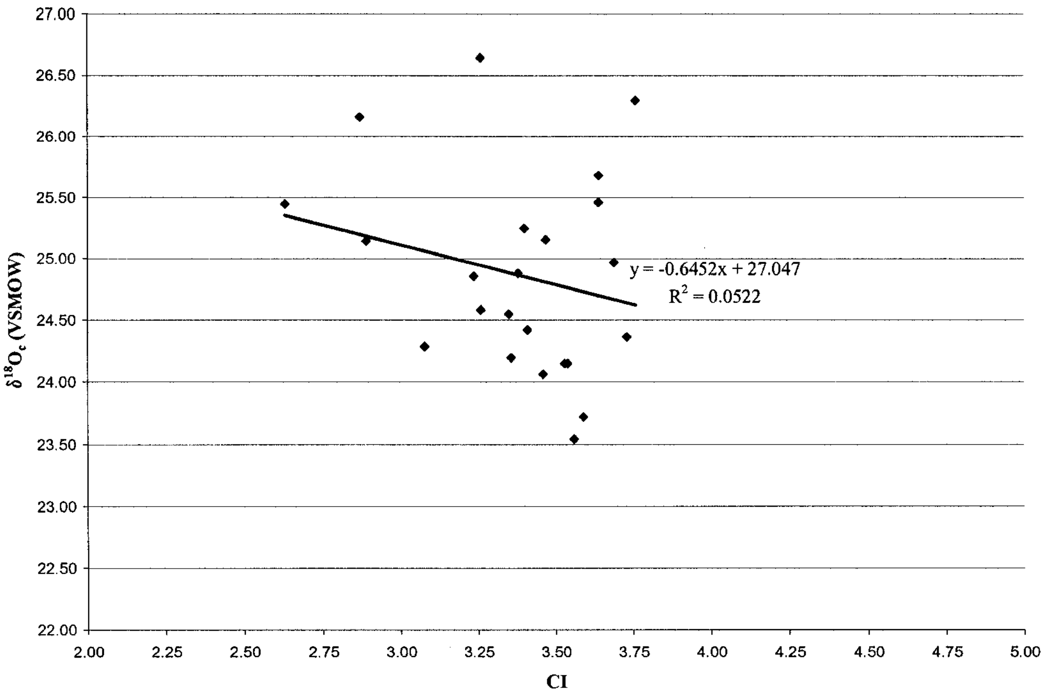


Figure 5.1. Relationship between crystalinity index (CI) and $\delta^{18}O_c$ values of bone samples from the Hawkins individuals.

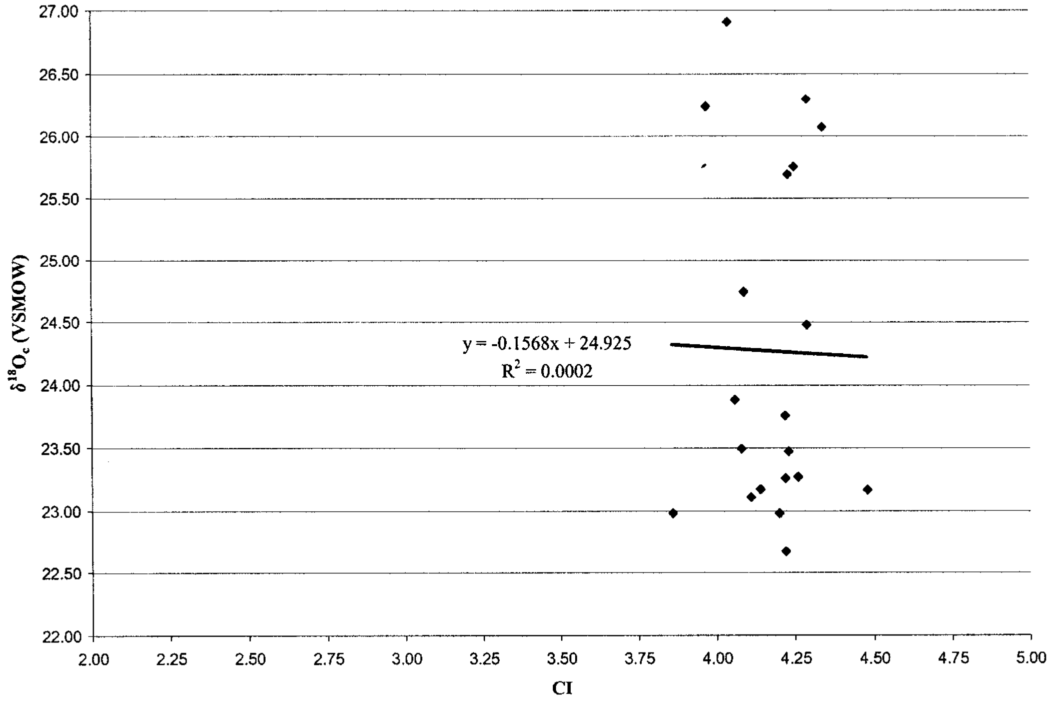


Figure 5.2. Relationship between crystalinity index (CI) and $\delta^{18}O_c$ values of enamel samples from the Hawkins individuals.

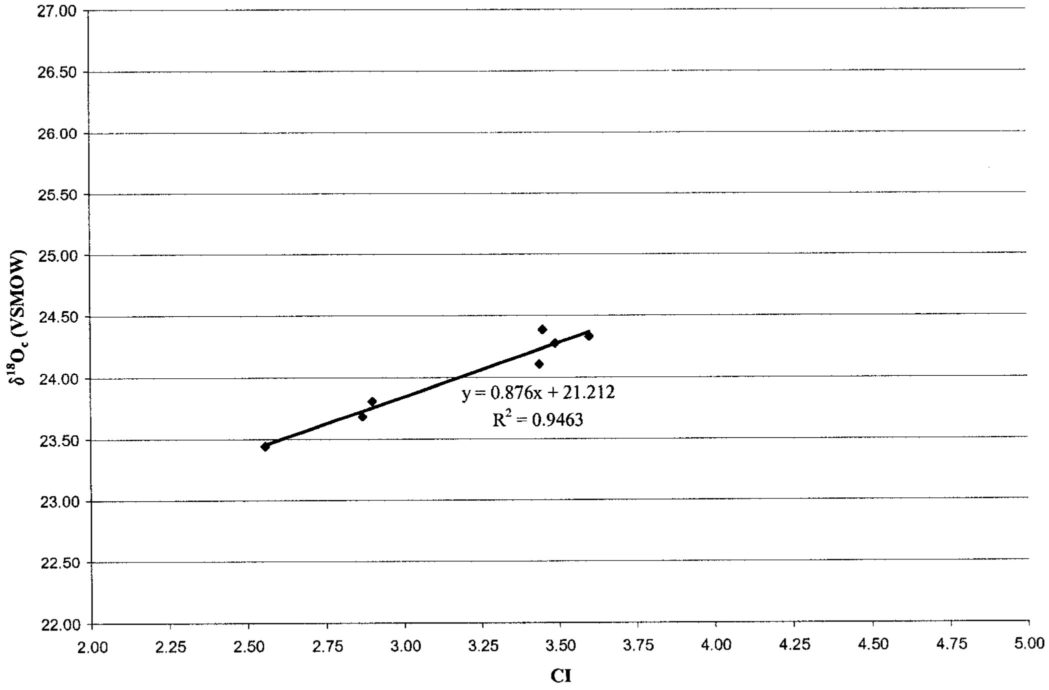


Figure 5.3. Relationship between crystalinity index (CI) and $\delta^{18}O_c$ values of bone samples from the Myles and Scugog individuals.

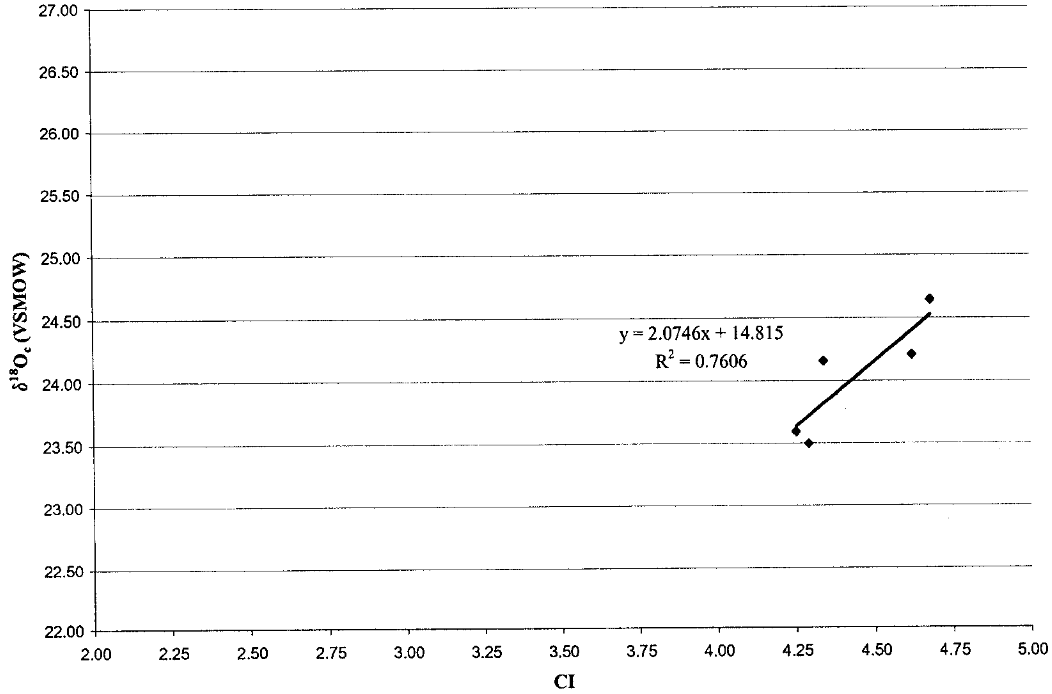


Figure 5.4. Relationship between crystalinity index (CI) and $\delta^{18}O_c$ values of enamel samples from the Myles and Scugog individuals.

5.2. Oxygen Isotope Analysis of Hawkins Individuals

5.2.1. Oxygen Isotope Analysis of Enamel

The $\delta^{18}O_c$ (VSMOW) values obtained from the analysis of enamel from the Hawkins samples have an average of 24.47‰ and range from 22.67‰ to 26.91‰ (Table 5.1.), a difference of 4.24‰. In order to compensate for the weaning effect, following White et al. (2004), results for the enamel of teeth that were being mineralized while an individual was being breastfed (first molars) have been lowered by 0.23‰. This value was obtained by dividing the weaning offset (0.7‰) by three because breastmilk was consumed for approximately one of the three years during mineralization of the first molars. Results for the enamel of teeth that were being mineralized while an individual was being weaned (canines and incisors) have been lowered by 0.14 (0.7‰/5) and 0.18‰ (07‰/4) respectively. These values were used because breastmilk was consumed for approximately one of the five years and one of the four years during mineralization of the canines and incisors respectively. These adjustments will not likely affect interpretation of the results, as the values that are used to lower $\delta^{18}O_c$ are very close to or within the error of the analysis (0.2‰).

When converted to $\delta^{18}O_w$ (VSMOW) using the equation established by Dupras and Schwarcz (2001):

(1) $0.98\delta^{18}O(CO_3\text{-apatite}) = 0.78\delta^{18}O(\text{water}) + 31.2$

the values range from -6.19‰ to -11.52‰ (Table 5.1.), a difference of 5.33‰.

	Enamel					Bone			
Sample #	Sample	$\delta^{18}O$ PDB	$\delta^{18}O_c$ VSMOW	$\delta^{18}O_w$ VSMOW	CI	$\delta^{18}O$ PDB	$\delta^{18}O_c$ VSMOW	$\delta^{18}O_w$ VSMOW	CI
H ISO-01	URM1	*-7.37*	23.27	-10.77	4.26	n/a			
H ISO-02	URM1	*-7.38*	23.26	-10.78	4.22				
H ISO-03	URM1	*-7.64*	22.98	-11.13	4.20				
H1	URM1	*-7.69*	22.94	-11.18	n/a	-6.30	24.36	-9.39	3.73
	ULM3	-7.46	23.17	-10.89	4.14				
H2	URM1	*-7.75*	22.88	-11.26	n/a	-6.60	24.06	-9.77	3.46
	LRM3	-7.15	23.49	-10.48	4.08				
H2A	URM1	*-4.50*	26.22	-7.05	no sample	-4.43	26.29	-6.96	3.76
H2B	LRP1	-4.93	25.78	-7.61		-4.56	26.16	-7.13	2.87
H2C	LRM1	*-7.52*	23.11	-10.97	4.11	-6.38	24.29	-9.49	3.08
H3B	LRM1	*-7.24*	23.40	-10.60	no sample	-6.47	24.19	-9.60	3.36
H5	LRP1	-3.83	26.91	-6.19	4.04	-4.10	26.64	-6.53	3.26
H7	LLM1	*-6.69*	23.97	-9.89	no sample	-6.93	23.72	-10.20	3.59
H13	LRM3	-7.95	22.67	-11.52	4.22	-6.51	24.15	-9.66	3.54
H14	ULI1	*-4.49*	26.24	-7.03	3.97	-5.54	25.15	-8.40	3.47
H15	LLM1	*-5.42*	25.28	-8.24	no sample	-5.80	24.88	-8.74	3.38
H16A	URC	*-7.65*	22.98	-11.13	3.86	-7.10	23.54	-10.42	3.56
	LRM2	-7.49	23.14	-10.93	n/a				
H16B	LLP2	-4.65	26.07	-7.24	4.34	-6.52	24.15	-9.66	3.53

Table 5.1. Results of oxygen isotope analysis and FTIR analysis of bone and enamel samples from Hawkins individuals. $\delta^{18}O$ PDB values in italics have been adjusted to correct for the weaning effect. (ULI1 = upper left first incisor, URC = upper right canine, LRP1/LLP2 = lower right first premolar/lower left second premolar, URM1/ULM1/LRM1/LLM1 = upper right first molar/upper left first molar/lower right first molar/lower left first molar, ULM2/LRM2/LLM2 =upper left second molar/lower right second molar/lower left second molar, ULM3/LRM3/LLM3 = upper left third molar/lower right third molar/lower left third molar).

Sample #	Enamel					Bone			
	Sample	**$\delta^{18}O$ PDB**	**$\delta^{18}O_c$ VSMOW**	**$\delta^{18}O_w$ VSMOW**	**CI**	**$\delta^{18}O$ PDB**	**$\delta^{18}O_c$ VSMOW**	**$\delta_{18}O_w$ VSMOW**	**CI**
H21	LLP2	-4.95	25.76	-7.64	4.25	-5.26	25.45	-8.03	2.63
	LLM3	-5.36	25.34	-8.16	n/a				
H23	URP1	-7.17	23.47	-10.51	4.23	-6.09	24.58	-9.12	3.26
H24	URM1	*-3.86*	26.89	-6.22	n/a	-6.13	24.55	-8.36	3.35
	LRM3	-5.02	25.69	-7.72	4.23				
H27B	LLM1	*-6.77*	23.88	-9.99	4.06	-5.03	25.68	-6.93	3.64
H29	LRC	*-5.93*	24.75	-8.91	4.09	-5.45	25.24	-7.48	3.40
	LLM2	-6.26	24.41	-9.33	n/a				
H30A	URM1	*-4.96*	25.75	-7.64	n/a	-5.72	24.97	-7.83	3.69
	LLM3	-6.20	24.48	-9.25	4.29				
H31	LLM1	*-4.74*	25.98	-7.36	no sample	-6.25	24.42	-8.52	3.41
H33	ULM1	*-4.43*	26.30	-6.96	4.29	-5.24	25.46	-7.21	3.64
	ULM2	-4.79	25.92	-7.43					
	URM3	-6.86	23.79	-10.11					
H35A	LRM1	*-7.47*	23.17	-10.89	4.48	-5.83	24.86	-7.97	3.24
H36	URC	*-6.89*	23.76	-10.15	4.22	-5.55	25.14	-7.61	2.89
	ULM3	-6.84	23.81	-10.09					
Minimum		**-7.95**	**22.67**	**-11.52**	**3.86**	**-7.10**	**23.54**	**-10.42**	**2.63**
Maximum		**-3.83**	**26.91**	**-6.19**	**4.48**	**-4.10**	**26.64**	**-6.53**	**3.76**
Mean		**-6.20**	**24.47**	**-9.26**	**4.18**	**-5.82**	**24.87**	**-8.48**	**3.38**
S.D.		**1.31**	**1.35**	**1.70**	**0.14**	**0.79**	**0.82**	**1.15**	**0.29**

Table 5.1., continued. Results of oxygen isotope analysis and FTIR analysis of bone and enamel samples from Hawkins individuals.

For the nine individuals represented by multiple tooth samples, both increases and decreases in $\delta^{18}O_c$ values are seen between the first and second tooth to mineralize. Using the formula provided by Wright and Schwarcz (1998:8), the $\delta^{18}O_c$ value of the later forming tooth was subtracted from the $\delta^{18}O_c$ value of the earlier forming tooth (Table 5.2). The difference in $\delta^{18}O_c$ values between the different teeth ranges from -0.61‰ (H21) to 2.51‰ (H33).

Individual	**$\Delta O = \delta^{18}O_{early} - \delta^{18}O_{late}$**
H1	-0.23
H2	-0.61
H16A	-0.16
H21	0.42
H24	1.2
H29	0.34
H30A	1.27
H33	2.51
H36	-0.05

Table 5.2. Difference in $\delta^{18}O_c$ between multiple teeth sampled for one individual.

When organized by age at death (Figure 5.5.), the $\delta^{18}O_c$ values of enamel of the younger individuals (less than 15 years) and the three individuals of unknown age from the commingled feature are grouped around 23‰ (mean = 23.34‰) while the values of the older individuals (35-50+ years) are grouped around 26‰ (mean = 26.11‰). A range between both of these values is seen for the individuals between the ages of 15 and 35 years. There is a significant difference between individuals older and younger than 15 (Mann Whitney U = 90, p =.023). No difference is observed between $\delta^{18}O_c$ values of the enamel of males and females (Mann Whitney U = 17, p =.715) in the sample.

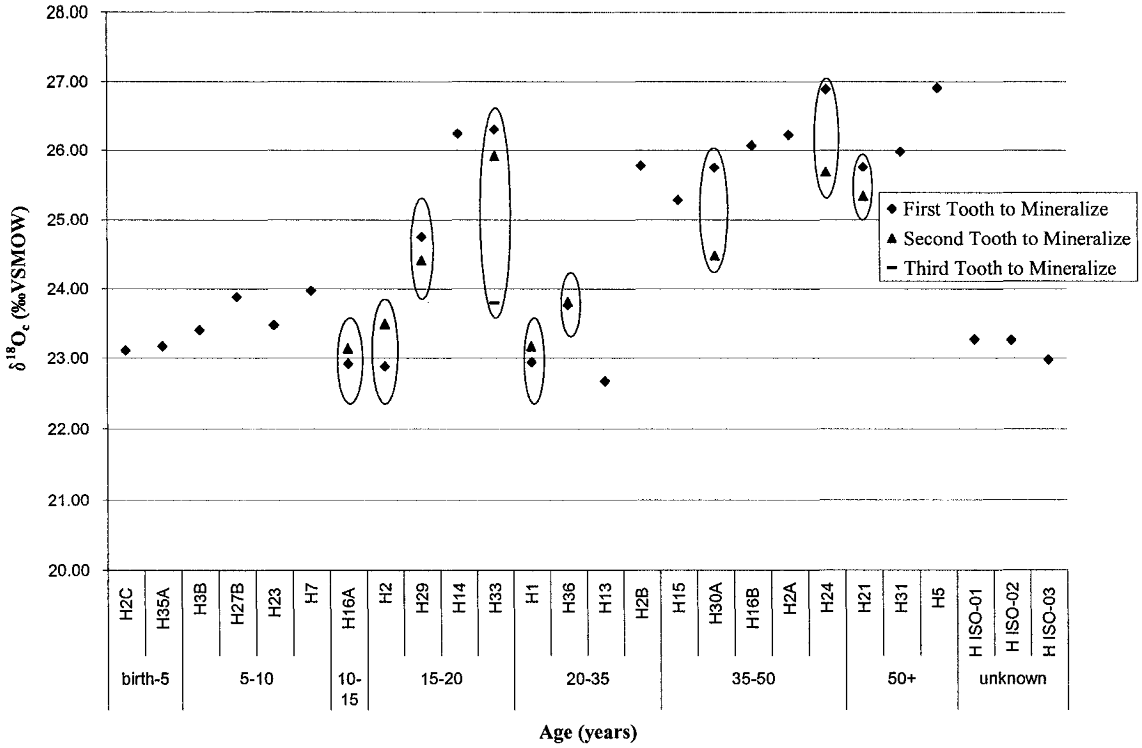


Figure 5.5. $\delta^{18}O_c$ values of Hawkins enamel samples by age. Results of multiple enamel samples from one individual are circled.

5.2.2. Oxygen Isotope Analysis of Bone

The $\delta^{18}O_c$ values obtained from the analysis of bone from the Hawkins samples range from 23.54‰ to 26.64‰ (Table 5.1.), a difference of 3.10‰. When converted to $\delta^{18}O_w$ values using equation (1), the values range from -6.53‰ to -10.42‰ (Table 5.1.), a difference of 3.89‰.

5.3. Oxygen Isotope Analysis of Myles and Scugog Individuals

5.3.1. Oxygen Isotope Analysis of Enamel

The $\delta^{18}O_c$ values obtained from the analysis of enamel from the Myles sample range from 23.49‰ to 24.16‰ (Table 5.3.), a difference of 0.67‰. For the Scugog samples, $\delta^{18}O_c$ values range from 24.21‰ to 24.83‰ (Table 5.3.), a difference of 0.62‰. When converted to $\delta^{18}O_w$, the Myles values range from -9.65‰ to -10.48‰, a difference of 0.83‰. For the Scugog samples, the $\delta^{18}O_w$ values range from -8.81‰ to -9.59‰, a difference of 0.78‰. In order to compensate for the weaning effect, following White et al. (2004), the results of analysis of the first molars have been lowered by 0.35‰ as they were mineralized while an individual was consuming breastmilk and solid foods. As discussed in section 3.5.1., however, the weaning practices of these individuals is not known, and therefore it cannot be determined if this value is appropriate.

5.3.2. Oxygen Isotope Analysis of Bone

The $\delta^{18}O_c$ values obtained from the analysis of bone from the Myles samples range from 23.44‰ to 24.33‰ (Table 5.3.), a difference of 0.89‰. The values of the Scugog samples range from 23.68‰ to 24.56‰, a difference of 0.88‰. When converted to $\delta^{18}O_w$ using equation (1) the Myles bone values range from -9.43‰ to -10.02‰, a difference of 0.59‰. The Scugog bone values range from -9.14‰ to -10.25‰, a difference of 1.11‰. No statistical difference was found between bone and enamel

	Enamel					**Bone**				
Sample	**Sample**	**$\delta^{18}O$ PDB**	**$\delta^{18}O_c$ VSMOW**	**$\delta^{18}O_w$ VSMOW**	**CI**	**Sample**	**$\delta^{18}O$ PDB**	**$\delta^{18}O_c$ VSMOW**	**$\delta^{18}O_w$ VSMOW**	**CI**
MB	LRM1	*-6.51*	24.16	-9.65	4.34	rib	-6.34	24.33	-9.43	3.60
MC	URM1	*-7.15*	23.49	-10.48	4.29	maxilla	-6.85	23.80	-10.09	2.90
MD	LLM1	*-7.05*	23.59	-10.36	4.25	mandible	-7.20	23.44	-10.55	2.56
Min		**-7.15**	**23.49**	**-10.48**	**4.25**		**-7.20**	**23.44**	**-10.55**	**2.56**
Max		**-6.51**	**24.16**	**-9.65**	**4.34**		**-6.34**	**24.33**	**-9.43**	**3.60**
Mean		**-6.90**	**23.75**	**-10.16**	**4.29**		**-6.79**	**23.86**	**-10.02**	**3.02**
S.D.		**0.35**	**0.36**	**0.45**	**0.05**		**0.43**	**0.45**	**0.56**	**0.53**
SA	ULM1	*-6.04*	24.64	-9.04	4.68	maxilla	-6.97	23.68	-10.25	2.87
SB	ULM1	*-6.46*	24.21	-9.59	4.62	maxilla	-6.39	24.27	-9.50	3.49
SC	ULM1	*-5.86*	24.83	-8.81	no sample	n/a				
S1	n/a					rib	-6.29	24.38	-9.36	3.45
S2						rib	-6.56	24.10	-9.71	3.44
S3						rib	-6.11	24.56	-9.14	no sample
Min		**-6.46**	**24.21**	**-9.59**	**4.62**		**-6.97**	**23.68**	**-10.25**	**2.87**
Max		**-5.86**	**24.83**	**-8.81**	**4.68**		**-6.11**	**24.56**	**-9.14**	**3.49**
Mean		**-6.12**	**24.56**	**-9.15**	**4.65**		**-6.46**	**24.20**	**-9.59**	**3.31**
S.D.		**0.31**	**0.32**	**0.40**	**0.04**		**0.32**	**0.33**	**0.42**	**0.30**

Table 5.3. Results of oxygen isotope analysis and FTIR analysis of bone and enamel samples from Myles and Scugog individuals. $\delta^{18}O$ PDB values in italics have been adjusted to correct for the weaning effect. (URM1/ULM1/LRM1 = upper right first molar/upper left first molar/lower right first molar).

results of the Myles (Mann Whitney U = 5, p = .827) or Scugog (Mann Whitney U = 12, p =.179) individuals.

5.4. Hawkins, Myles, and Scugog Results

The results of the analysis of the Hawkins enamel samples (n=36) and the Myles (n=3) and Scugog (n=3) enamel samples have average $\delta^{18}O_c$ values of 24.47‰, 23.75‰ and 24.56‰ respectively. The mean $\delta^{18}O_c$ value of bone for the Hawkins collection(n=23) is 24.87‰ compared to 23.86‰ for the Myles (n=3) and 24.20‰ for the Scugog (n=5) bone samples (Figure 5.7). When compared, there is no statistical difference between the enamel results of the Myles and Scugog individuals (Mann Whitney U = 9, p = .049) or the bone results of the Myles and Scugog individuals (Mann Whitney U = 11, p = 0.297). It is of interest to note the much smaller ranges of values obtained for the bone and enamel samples from the Myles and Scugog individuals compared to those of the Hawkins individuals (Figure 5.6.).

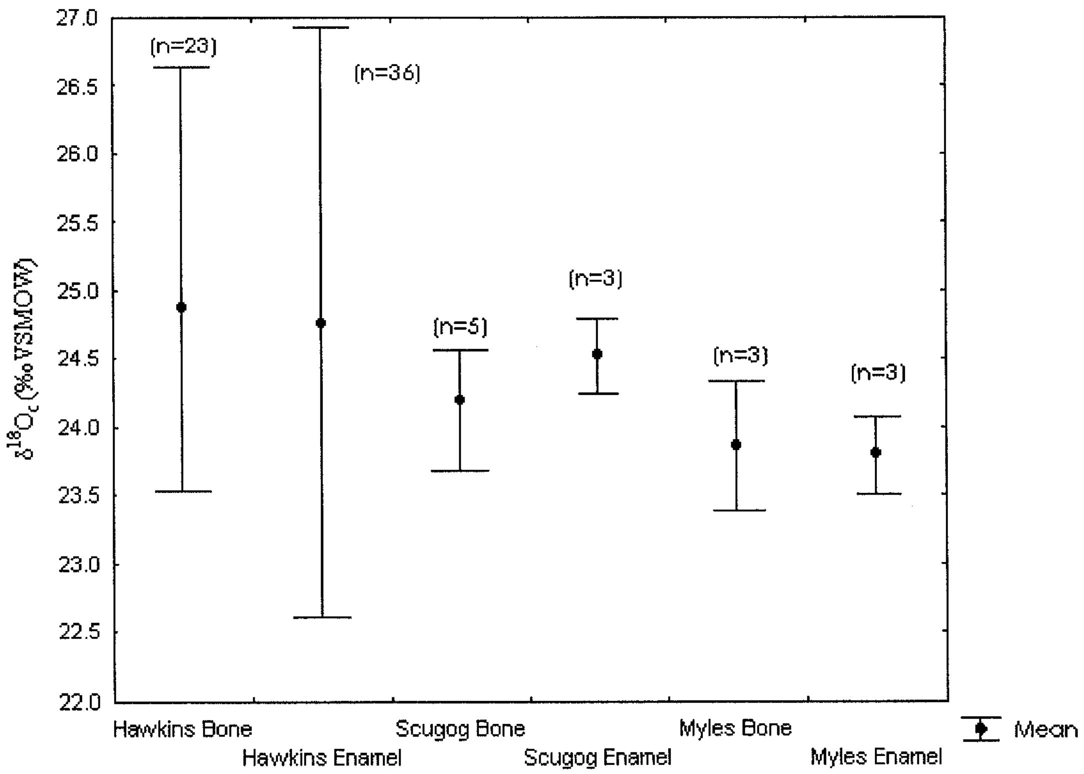


Figure 5.6. Ranges of $\delta^{18}O_c$ (VSMOW) for Hawkins, Myles, and Scugog enamel and bone samples.

CHAPTER 6

DISCUSSION

6.1. Interpretation of Results

Based on historic records, the majority of the people living in 19th century Port Hope were born in Upper Canada, the British Isles, or the northeastern United States. Other locations of origin within Canada and Europe, as well as more distant regions including Cape of Good Hope, South Africa, India, and Italy, are possible according to the 1861 Port Hope census return. The geographic origins and movements of 26 individuals buried in the Old Wesleyan Methodist Cemetery can now be constructed based on the isotopic content of their bone and enamel tissue. This is done by consulting maps of oxygen isotope distribution measured in modern precipitation and comparison with results from similar analysis of individuals from the Myles and Scugog sites as well as results from other studies of archaeological samples. Once potential geographic origins are determined, broad patterns of the structure and movement of the group of individuals buried in Port Hope can be discussed.

6.1.1. Local Isotopic Signature

Prior to determining the origin of the individuals buried in the Old Wesleyan Methodist Cemetery, the local isotopic signature of the Port Hope area must be established in order to recognize locals and non-locals. Maps illustrating the global distribution of oxygen isotopes are available from the Global Network of Isotopes in Precipitation (GNIP). As seen in the GNIP map of North America (Figure 6.1.), Port Hope falls into the $\delta^{18}O_w$ range of -10 to -12‰. It is important to note that this range extends to the East to include parts of the Northeastern United States including New York, Massachusetts, New Hampshire, Vermont, and Maine, as seen in Figure 6.1.

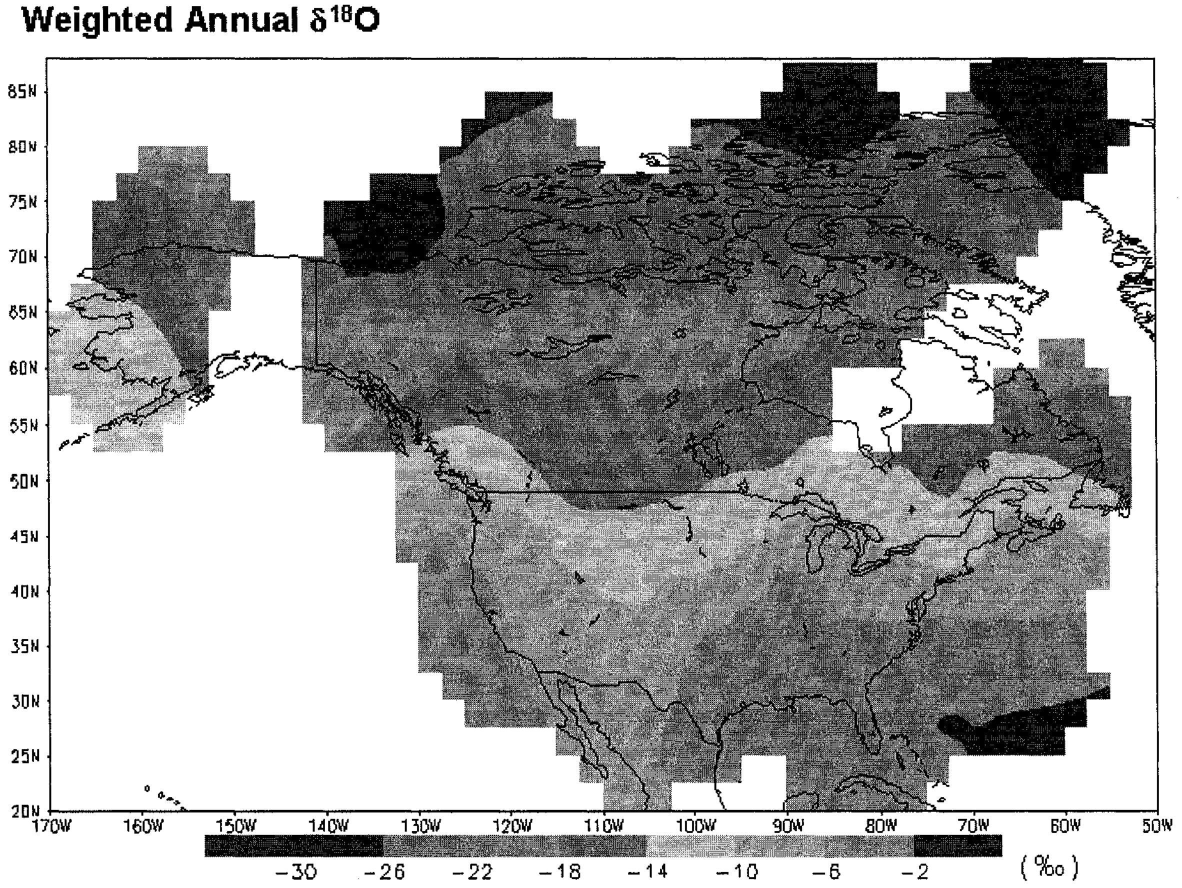


Figure 6.1. Distribution of oxygen isotopes in modern precipitation for North America (IAEA 2001).

Isotopic studies of geographic origins often include analysis of individuals of known origin as reference samples in order to establish the expected local isotopic signature of a region (see Evans et al. 2006; Pcholkina 2004; Schwarcz et al. 1991; White

1998). In these cases, the $\delta^{18}O_c$ values of enamel and bone tissue should be similar, reflecting long-term occupation of the same geographic region. As well, the corresponding $\delta^{18}O_w$ values should fall within the expected range predicted by maps of oxygen isotope distribution (e.g. GNIP). In this study, samples from the Myles and Scugog sites were included in order to obtain values characteristic of individuals who consumed water sources local to Southern Ontario.

Individuals from the Myles site have very similar bone and enamel $\delta^{18}O_c$ values. There is a difference of 0.17‰ between the enamel and bone $\delta^{18}O_c$ values of individual MB, and differences of 0.31 and 0.15‰ between the enamel and bone $\delta^{18}O_c$ values of individuals MC and MD respectively. While this sample is small (n=3), the differences in values are very close to, or fall within, the expected error of the method (0.2‰), indicating that all three individuals lived the majority of their lives in the same region where they spent their childhood.

Bone and enamel samples of individuals from the Scugog site have slightly higher $\delta^{18}O_c$ values than the three Myles individuals. However, due to the commingled nature of the latter burials, corresponding bone and enamel samples from the same individual were only available in two cases. For individual SB, there is a difference of 0.06‰ between the enamel and bone $\delta^{18}O_c$ values, which indicates no relocation during his or her lifetime. In contrast, a difference of 0.96‰ exists between these values of individual SA, which is indicative of someone who did relocate to an area different from where their childhood was spent, as the difference is greater than the expected error.

According to the GNIP map of North America (Figure 6.1.), the Campbellford area and Lake Scugog, which are approximately 50km apart, both fall into the -10 to

-12‰ range expected for Port Hope. When converted to $\delta^{18}O_w$, the average bone and enamel values of the Myles individuals (-10.16 and -10.02‰, respectively) fall into this range. Individual MB does have slightly less negative bone and enamel $\delta^{18}O_w$ values which do not fall within the expected range of the Campbellford area. Thus, it is possible that individual MB is non-local, and that based on the similarity between the bone values, which reflect the isotopic composition of water consumed between the ages of approximately 40-60 years, and enamel values, reflecting the isotopic composition of water consumed between birth and the age of three (a difference of 0.07‰), he died shortly after arriving in Southern Ontario.

When the average enamel and bone $\delta^{18}O_c$ values obtained for the Scugog individuals are converted to $\delta^{18}O_w$, average enamel values of -9.15‰ and bone values of -8.96‰ are obtained. The $\delta^{18}O_w$ of the enamel of individual SA is -9.04‰, which corresponds to $\delta^{18}O_w$ of precipitation in New York, Pennsylvania, New Jersey, and Ohio. The $\delta^{18}O_w$ of the bone of individual SA is -10.25‰, which corresponds to $\delta^{18}O_w$ of precipitation in Central Ontario. It is therefore likely that this individual was born in the United States but spent at least the last ten years of his or her life in Southern Ontario. The $\delta^{18}O_w$ of the enamel of individual SC is -8.81‰ is also indicative of being born in the United States. Lack of a corresponding bone sample for this individual prevents further interpretation. The bone and enamel $\delta^{18}O_w$ values of individual SB (-9.59 and -9.50‰ respectively) are closer to the expected Port Hope range.

While the small sample size and unknown ages at death make interpretation difficult, it is also possible that the Scugog individuals are local to the region and have higher $\delta^{18}O$ values due to the consumption of different water sources than the individuals living in 19th century Port Hope. The lack of difference between enamel and bone values of individual SB suggests long-term occupation of the region. It is also possible, however, that this person died not long after arriving in the area.

An important factor to take into account is the nature of the site. The radiocarbon dates of 405 A.D. to 535 A.D. and 1145 A.D. to 1275 A.D. obtained from femur fragments of two individuals buried at the Lake Scugog site indicate long-term sacred use of the locale. It is therefore possible that individuals SA, SB and SC were local to the area and have different $\delta^{18}O$ values than expected based on modern precipitation due to differences in water sources utilized over the extended period of time the site was inhabited. It is also possible, however, that the individuals were no longer living in the area, but returned to the burial site for ceremonial purposes.

This long-term use of sacred areas for burial purposes has been previously suggested by Johnston (1979:93), based on evidence at the Serpent Mounds site on the North shore of Rice Lake (approximately 20km north of Port Hope). In addition to the Late Woodland ossuaries at the site, it contained a shell midden, a habitation area, nine mounds, and burials identified as Middle Woodland (Spence et al. 1990:160). Radiocarbon dates of 185 B.C. to 580 A.D. and 225 A.D. to 565 A.D. were obtained from the mound burials, which were both primary and secondary in nature (Spence et al. 1990:127).

Three Late Woodland ossuary pits containing the incomplete, fragmentary remains of 15, 29, and 25 individuals were found at Serpent Mounds. Two of these were radiocarbon dated to 1045 A.D. and 1290 A.D. Johnston (1979:93) argues that the different dates obtained for each ossuary reflect the long-term use of the site, even after it had been otherwise abandoned, in order to continue burial rites that had been established centuries earlier.

One other study to date has examined the oxygen isotopic content of the skeletal tissue of First Nations individuals (Pcholkina 2004). In order to determine the expected local isotopic signature of Peterborough, Ontario, located 20km north of Port Hope, the $\delta^{18}O_c$ of bone samples were obtained from individuals from the Quakenbush site, who are thought to be local to the area. The $\delta^{18}O_w$ values of bone samples from seven Quakenbush individuals were found to range from -11.56 to -8.71‰ with an average of -10.28. Pcholkina's results are not significantly different from the Myles or Scugog bone or enamel results and are similar to the expected range for the region. It is therefore likely that the local isotopic range of the Port Hope area should be adjusted to -9.5 to -12‰, using the average $\delta^{18}O_w$ values of the enamel from the Myles and Scugog samples as the upper limit.

6.1.2. Expected Locations of Origin

Expected locations of origin for the individuals in this study who are not local to Port Hope are the British Isles and the former Thirteen Colonies of the United States, mainly New York, Pennsylvania and the New England States (Canniff 1971:617; Craig 1963:6-7; White 1985:57). Based on the GNIP map for Europe, the expected $\delta^{18}O_w$ of the British Isles is -5 to -8‰ (Figure 6.2.). The variation of $\delta^{18}O_w$ distribution within the British Isles has been investigated by Darling et al. (2003), as shown in Figure 6.3. The

GNIP map of North America (Figure 6.1.) shows the expected $\delta^{18}O_w$ values for the northeastern United States to be -8 to -12‰.

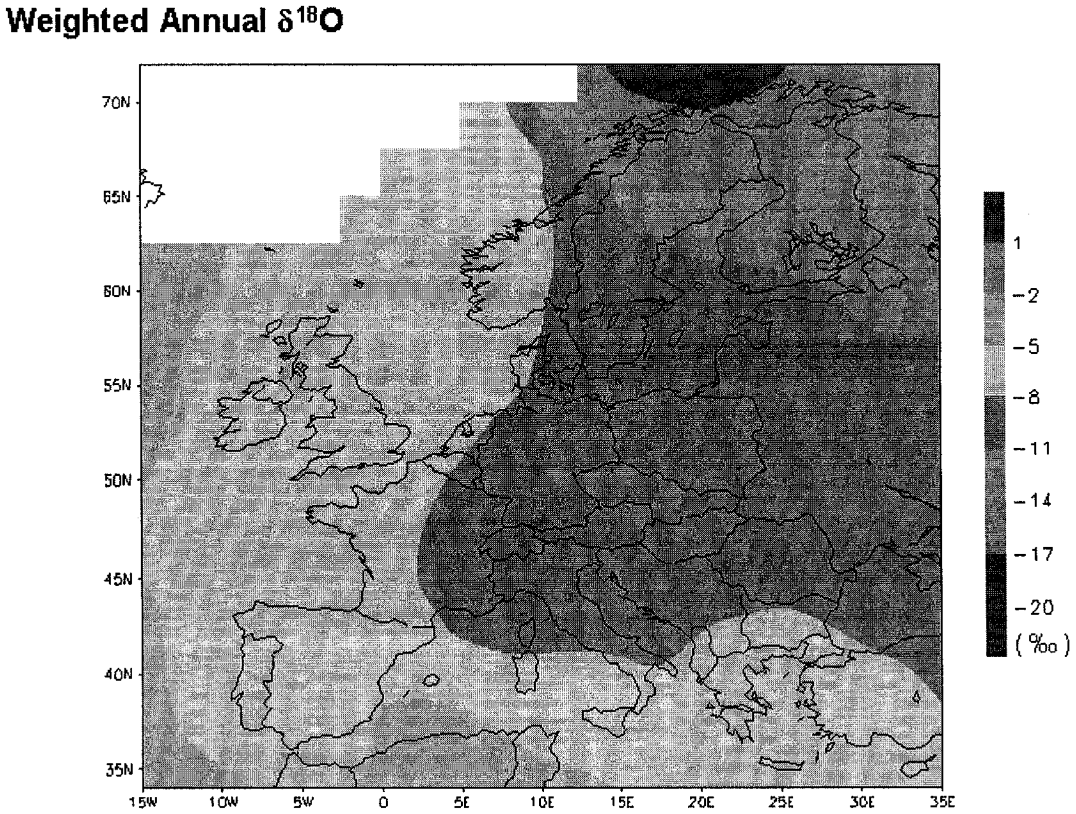


Figure 6.2. Distribution of oxygen isotopes in modern precipitation for Europe (IAEA 2001).

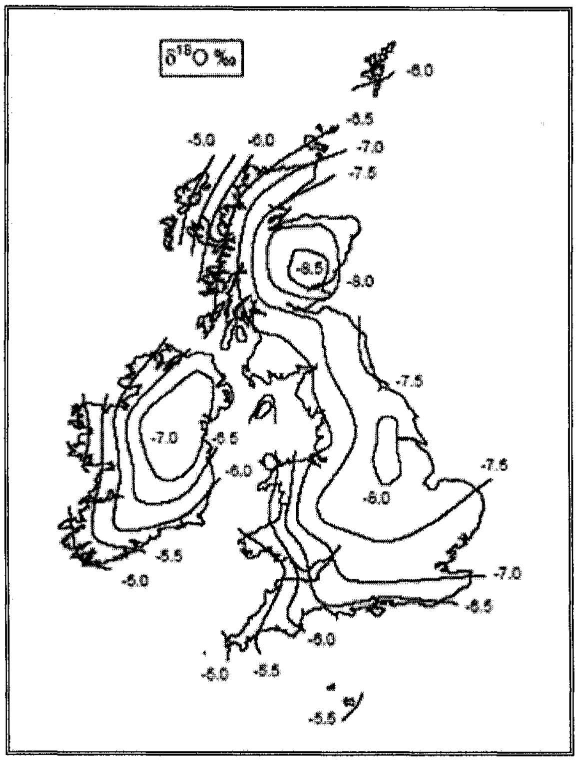


Figure 6.3. Distribution of oxygen isotopes in the British Isles (From Darling et al. 2003).

Several studies using oxygen isotope analysis have investigated the geographic origins of individuals thought to be from the British Isles. Based on the historic records, individuals from the Peterborough Burial Ground collection analyzed by Pcholkina (2004) were thought to originate from Ireland. Results of oxygen isotope analysis support this, as the $\delta^{18}O_w$ values of 7 enamel samples were found to range from -3.36 to -8.00‰ (mean= -5.97‰). With the exception of the individual with a $\delta^{18}O_w$ value of -3.36‰, the results fall within the -5 to -8‰ range of the British Isles as illustrated on the GNIP map of Europe.

In another study, oxygen isotope analysis was carried out to investigate the origins of human remains found in the Canadian Arctic. Based on artifacts located on the King William Island site, the remains were thought to be members of the Franklin

Expedition. Results of isotopic analysis of two enamel samples indicate that drinking water of -5.6‰ was consumed during childhood, and it was concluded that the individuals originated from western Europe (Keenleyside et al. 1992:40).

The first study to use stable oxygen isotope analysis investigated the origins of six of 28 soldiers who fought in the War of 1812 and were buried in the Snake Hill cemetery outside of Fort Erie, Ontario. While the $\delta^{18}O$ values of their bone samples were very uniform, suggesting that the soldiers had been living in the same environment together for several years prior to their deaths, the average $\delta^{18}O_w$ value of bone was found to be -13‰, which is lower than expected for individuals who spent part of their lives in the United States. Schwarcz (1991:265) suggests that this may be due to error in method of calculation of $\delta^{18}O_{w.}$

In another study, analysis of two groups of soldiers who fought in the War of 1812 and who are thought to be from the northeastern United States has provided results of enamel analysis ranging from -11.20 to -6.86‰ (Blyth 2003:105, 111). It was concluded that the individuals originated from Pennsylvania, New York, Connecticut, Rhode Island, Massachusetts, Maine, Vermont, New Hampshire, and as far west as Ohio and as far south as Virginia.

6.2. Location of Origin of Hawkins Individuals

The results of oxygen isotope analysis of the 26 individuals buried in the Old Wesleyan Methodist Cemetery indicate multiple locations of origin. Fifty four percent of the individuals (n=14) fall within the expected $\delta^{18}O_w$ range of -9.5 to -12‰ for Port

Hope. Eight percent (n=2) of the remaining individuals have enamel $\delta^{18}O_w$ values (-8.24 to -8.91‰) that correspond to precipitation in New York, Pennsylvania, Massachusetts, Connecticut, and Rhode Island. The remaining 38% of the individuals (n=10) have $\delta^{18}O_w$ values of enamel that range from -6.19 to -7.64‰ which correspond to precipitation in eastern Ireland or western England and Scotland. Due to overlap in the oxygen isotope distribution in precipitation, it is also possible that these non-locals originated from the Virginia area of the United States.

6.2.1. Time Since Relocation

Because the human dentition mineralizes at known ages and enamel does not remodel, it is possible to obtain isotopic information for individuals at multiple ages during their lives. For eight individuals in this sample it was possible to obtain two enamel samples, one that mineralized during early childhood, and a second that mineralized later in life. For a ninth individual it was possible to analyze three enamel samples, the isotopic content of which are reflective of three different time periods in his or her life. Bone values can also be used to determine time since location, as the isotopic composition of bone re-equilibrates to reflect new geographic areas as the tissue remodels.

Of these nine individuals, four have $\delta^{18}O_w$ values reflective of Port Hope precipitation for both their early and later forming teeth, indicating that they were born and spent their lives in the Port Hope region. Of these four individuals, two (H2 and H16A) have bone $\delta^{18}O_w$ values that are reflective of the $\delta^{18}O_w$ of Port Hope drinking water. The bone $\delta^{18}O_w$ value for H1 (-9.39‰) is within the 0.2‰ error range to the upper end of the expected range. The remaining individual (H36), has a bone $\delta^{18}O_w$ value of -7.61‰, indicative of a non-local water source.

The $\delta^{18}O_w$ values of the enamel samples from individual H29 (LRC = -8.91‰, LLM2 = -9.33‰) indicate that this individual was born in the northeastern United States. The difference between the canine and second molar values suggests that a different source of water was being consumed while these two teeth were mineralizing. The difference between the two teeth is not very large (0.42‰), and the $\delta^{18}O_w$ value of the later forming tooth does not quite fall within the Port Hope range, possibly indicating that this individual moved while the second molar was mineralizing between the ages of three and eight, and therefore incorporated oxygen isotopes from two different geographic regions. The bone $\delta^{18}O_w$ value (-7.48‰) does not fall in the expected Port Hope range, and is in fact less negative than either of the enamel values.

Individuals H21, H24, and H30A all have a similar pattern of $\delta^{18}O_w$ values in their enamel samples. All three individuals have $\delta^{18}O_w$ values of the first tooth to mineralize that correspond to $\delta^{18}O_w$ values of precipitation in eastern Ireland, western Scotland, or the south and west regions of England. Due to overlap in the isotopic gradients between Europe and North America, it is also possible that these individuals came from the northeastern United States. All three $\delta^{18}O_w$ values of the second tooth to mineralize are closer to, but not within the expected range for Port Hope, again suggesting that movement occurred between the ages of eight and approximately fifteen (the approximate age when the third molar is finished mineralizing). The bone results from these three individuals are not as similar. The bone $\delta^{18}O_w$ value for individual H24 suggests re-equilibration was occurring at the time of death. The bone $\delta^{18}O_w$ values for individuals H21 and H30A, however, are lighter than expected for individuals living in Port Hope.

Finally, three enamel samples from individual 33 indicate that this individual was born and spent his or her childhood in eastern Ireland, western Scotland, the south or west regions of England, or the northeastern United States. During the mineralization of the third molar (between the approximate ages of eight and fifteen), however, this individual was living in the Port Hope region. Due to the difference between the age of relocation and the age at death (at least seven years), the oxygen isotope content of bone for this individual should be reflective of Port Hope. The bone $\delta^{18}O_w$ value, however, is indicative of drinking water in the birthplace region.

For the remaining seventeen individuals in the Hawkins sample, only one enamel sample was available. Of these, three do not have a corresponding bone sample. For the fourteen that do, interpretations can be made based on the comparison of bone and enamel results. For four individuals (H2C, H3B, H7, and H16A), both bone and enamel results indicate that they were born and spent their lives in Port Hope. For two individuals (H2A and H2B), the bone and enamel results are similar and both reflect water sources from the British Isles or the Northeastern United States. This suggests that they died soon after arriving in Upper Canada, before their bone tissue began to re-equilibrate to reflect the new environment. Both individuals therefore immigrated as adults, as individual H2A was 35-50 years old at the time of her death and individual H2B was 20-35 years old at the time of his or her death.

The enamel results of five individuals (H5, H14, H15, H16B, and H31) indicate that they were born outside of Port Hope. The corresponding bone $\delta^{18}O_w$ values of each individual are lighter than expected for their region(s) of birth, but are not as light as values indicative of Port Hope. This suggests that their bone tissue had begun to incorporate oxygen isotopes from their new environment but the individuals died before complete turn-over occurred. It can be concluded, therefore, that these five individuals arrived in Port Hope as adults, as their ages at death range from 15-20 years to older than 50 years of age.

An interesting trend is seen in the results of the remaining four individuals (H23, H27B, H35A, and H36). The $\delta^{18}O_w$ values of their enamel tissues indicate that they were born in the Port Hope region, but the $\delta^{18}O_w$ values of their bone tissue are heavier than expected for individuals consuming water in the region (similar to the results for individuals H21, H29, H30A, and H26, as discussed above). It is very likely that this trend is a reflection of the mobility of the inhabitants of 19th century Port Hope, which has been described as "a permanent characteristic of the resident Upper Canadian population after mid-century…" (Dudar et al. 2003:241). As discussed in Chapter 2, by the mid-1800s, travel by ship and rail was available to the individuals of Port Hope for travel within the region.

It is also possible that individuals returned to their country of birth. Such an instance is outlined in Langton's (1950:iv) description of the life of Anne Langton, who was born in England and emigrated to Upper Canada in 1837, and who:

> "after the deaths of her mother and aunt in 1846 … returned to England for a series of long visits to her brother and other relations …, but in spite of inducements held out by William to remain as a permanent member of his household she decided that her

real home must be … in Canada. So, except for occasional journeys to England to see her brother and his sons and daughters there, she remained in Canada from 1850 …"

The effect on bone $\delta^{18}O_w$ values from traveling overseas or to the Northeastern United States from Port Hope would be an increase, and this is what is observed in the above-mentioned cases. Both local-born and non-local-born individuals exhibit this trend, suggesting travel was common among both groups.

6.3. Patterns of Movement

Now that the origins of the individuals buried in the Old Wesleyan Methodist Cemetery have been established, patterns observed can be discussed. These include differences in location of origin between males and females and between different age groups, as well as differences between individuals buried together.

6.3.1. Origins and Age and Sex

As seen in Figure 5.6., all of the children under the age of 15 years at death are local to Port Hope compared to the 25% (4/16) of adults that are local. The lack of non-local children could be a reflection of two possibilities. The first is that few young children were immigrating to Port Hope. Alternatively, it is possible that young children were immigrating to Port Hope but were not included in this sample either because they survived to adulthood more often than local children, or they did not survive but were not found during excavation in 2002-2003.

Of the 11 individuals of known sex in this sample, five are female and six are male. There is no statistically significant difference between the $\delta^{18}O_w$ values of men and women and no pattern is apparent, as four of the six women and four of the five males have $\delta^{18}O_w$ values indicative of being non-local. This indicates that immigration was not a predominantly male or female activity in this sample. No historical records were found that indicate there was a difference in the immigration patterns of men and women.

6.3.2. Burials of Multiple Individuals

Several individuals in this sample were found together in graves during excavation. Two such examples are included in this study. Burial 2 included 4 individuals: a child between the age of birth and 5 years (burial 2C), a 15-20 year old (burial 2), a 20-35 year old of unknown sex (burial 2B), and a 35-50 year old female (burial 2A). The isotopic results indicate that the younger individuals in burials 2 and 2C were born in Port Hope, with enamel $\delta^{18}O_w$ values of -11.26/-10.48 and -10.97‰ respectively. The older individuals in burials 2A and 2B, however, have enamel $\delta^{18}O_w$ values of -7.05 and -7.61‰ respectively, indicating they originated from Eastern Scotland or England, central Ireland, or possibly New York, Pennsylvania, Massachusetts, Connecticut, or Rhode Island.

Two individuals were excavated in burial 16, a 10-15 year old and a 35-50 year old female. The enamel $\delta^{18}O_w$ values of the younger individual (-11.20/-10.93‰) are similar to precipitation $\delta^{18}O_w$ values in Port Hope, indicating this individual was born there. The enamel $\delta^{18}O_w$ value of the older individual (-7.24‰) indicates this individual was born elsewhere, possibly Eastern Scotland or England, central Ireland, or possibly New York, Pennsylvania, Massachusetts, Connecticut, or Rhode Island.

The pattern of grave use is not known for the Old Wesleyan Methodist Cemetery. It is possible that the graves were re-used, either by members of the same family or by new plot owners. It is also possible that individuals were buried together at the same time. For example, excavation of burial 30 revealed a 35-50 year old male (burial 30A) with an infant (30B, not included in analysis) in the crook of his elbow.

6.4. Identification of Hawkins Individuals

The results of the oxygen isotope analysis can now be compared to the historic record of known Port Hope pioneers. Of the 26 individuals included in this study, seven were identified during excavation by coffin plaques found in association with the skeletal remains. The coffin plaque found with burial 27B reads "Flossy Bayley/Aged 5 years." The coffin plaque found with burial 33 reads "C.J. Ryan/Aged 17 years/1865." No archival records referring to these two individuals were located. Information including location of origin was found for the remaining five individuals, J. Sagar (burial 7), Elizabeth Ogley (burial 16A), Martha Mitchell (burial 23), B. Allcott (burial 30A), and Cynthia McGaffey (burial 36).

Sources consulted include census records of Port Hope and Hope Township, local obituaries, and local business directories. Census records for Port Hope that are relevant to this study exist for 1861 and 1871. There is no 1851 census available for Port Hope, but there is an Assessment of the Town of Port Hope that was conducted in 1847. Census records also exist for the Township of Hope, and relevant records exist for 1803-1841 and 1848-1861. All variations of the spelling of names encountered in the historic records are included here uncorrected.

6.4.1. J. Sagar

The coffin plaque found in association with burial 7 reads "J(?) Saga(r)/ aged 8 years." Blackbourn (2006) and Hawken (2006) determined the skeletal remains in burial 7 to be of a child between the ages of 5 and 10 of undetermined sex. The $\delta^{18}O_w$ value of enamel of the individual in burial 7 (-9.89‰) is within the expected range for an individual born in Port Hope using the combined mean of the Myles and Scugog individuals (-9.5‰). The $\delta^{18}O_w$ value of bone is -10.20‰, which also falls into the expected Port Hope range.

The 1861 Port Hope census includes John W. Sagar, aged 59, who was born in Upper Canada and was a member of the Church of England. Sagar's occupation is listed in the census as saloon keeper, and the Port Hope Business Directory for 1856-1857 lists John W. Sager as the saloon keeper at Canada House on the corner of Madison and King Streets. Also listed in the 1861 census are C. Sagar and N.A. Sagar, aged 46 and 12 respectively, both of whom were born in Upper Canada. No other Sagars are listed in any of the Port Hope or Hope Township Census returns.

It is possible that J. Sagar was a son or daughter of John and C. Sagar and a sibling to N.A. who passed away prior to the 1861 census. It is not known whether J. Sagar would have been included in the 1851 census or if he/she had died prior to this, but it is also possible, as the individual located in burial 7 was 8 years old at death, that he/she was born and had died in the ten years between the 1851, 1861, and 1871 censuses, and was therefore never recorded. If the J. Sagar of burial 7 was in fact the child of John and C. Sagar, it is most likely that he/she was born in Upper Canada.

Results of the isotopic analysis and the historic record support each other in this case. The $\delta^{18}O_w$ value of the enamel of this individual suggests that using the mean $\delta^{18}O_w$ of enamel obtained for the Myles and Scugog individuals (-9.5‰) is appropriate as the lower limit of the expected local Port Hope $\delta^{18}O_w$ range instead of -10‰.

6.4.2. Elizabeth Ogley

The coffin plaque found in association with burial 16A reads "Elizabeth Ogley/Aged/13 Years/1873." Blackbourn (2006) and Hawken (2006) determined the skeletal remains in burial 16A to be of a 10 – 15 year old of undetermined sex. $\delta^{18}O_w$ values were obtained for two enamel samples from the individual in burial 16A. Both the $\delta^{18}O_w$ of the URC (-11.20‰) and the LRM2 (-10.93‰) fall within the expected range of Port Hope, as does the $\delta^{18}O_w$ value of bone (-10.42‰).

The Ogley family first appears in the 1851 Hope Township census with John Ogley, a 20 year old farmer. Also listed are two Elizabeth Ogleys, one a 56 year old widow and one a 17 year old. Also listed are Mary Ogely, aged 23, and Ann Ogley, aged 13. All five were born in England and belonged to the Methodist Church. In the 1861 Hope Township census John Ogley is recorded at age 28, along with his wife Delila B. A. Ogely, aged 26, who was born in the United States and who was also a Methodist. Their two children, Louis and Isabella Ogely, are both recorded as being 2 years old and born in Canada.

In the 1871 Hope Township census, Elizabeth Ogley is recorded as being 11 years old, born in Ontario, of English origin, and attending school. She is included as a member of the Halleran household of Thomas (27 years old), Dina (30 years old), Eva L. (5 months), and Francis (64) with a notation of having "no other home." It is not known what became of her parents and brother, but her grandmother Elizabeth is recorded in the 1871 Port Hope census as a 75 year old English Methodist who was a widow and knitter. Mary Oglay is listed in the 1871 Port Hope census as having died at the age of 42. No further records were found for Elizabeth's aunts Elizabeth and Ann. As two people were found in burial 16, (see 6.3.2.), it is possible that Elizabeth was buried with her mother. According to census records, Delila B. A. Ogely was born in the USA, which is supported by the isotopic results of the enamel of the individual in burial 16B (-7.24‰).

It appears likely that the Elizabeth Ogley buried in the Old Wesleyan Methodist Cemetery is the same Elizabeth recorded in the 1861 and 1871 census returns (as both Isabella and Elizabeth). It is known from these records that Elizabeth was born in Ontario. As her father is recorded in the 1851 census and again in the 1861 census with his wife, it is likely that Elizabeth, who was born in 1860, was born in Port Hope, a conclusion supported by the isotopic results.

6.4.3. Martha Mitchell

The coffin plaque found in association with burial 23 reads "Martha J. Mitchell/Aged/9 years/1867." Blackbourn (2006) and Hawken (2006) determined the skeletal remains in burial 23 to be a child between 5 and 10 years old of unknown sex. The $\delta^{18}O_w$ value of enamel of the individual in burial 23 (-10.51‰) is within the expected local range of Port Hope. The $\delta^{18}O_w$ value of bone, however, does not fall within the expected range.

The Mitchell family is recorded in the 1861 Port Hope census and includes Christopher (35 years old), Hannah (25 years old), Margaret (2 years old), and Frances (1 year old). All members of the Mitchell family are listed as Wesleyan Methodist and as having been born in Upper Canada. The 1861 census and the 1856-57 Port Hope Business Directory list Christopher Mitchell as being a carpenter, with a business located on Mill Street and a two storey frame house on Walton Street.

The only existing cemetery plan (Figure 2.2.) shows a four grave lot under the name of Chris. Mitchell in the southwest corner of the cemetery in the area where burial 23 was located. Also in this area were the graves of Mary Priscilla Mitchell and Frances Mitchell, who were identified by coffin plaques associated with burials 22A and 22B. The November 1867 edition of the Evening Guide includes an obituary that reads as follows: DIED – At Port Hope, Monday 25th inst., Francis Chester, son of Mr. Christopher Mitchell./ At Port Hope, on Tuesday, 20th instant, Charles Jacob, son of Christopher Mitchell./ At Port Hope, on Friday, 29th instant, Mary Priscilla, daughter of Mr. Christopher Mitchell.

It is likely that the Martha Mitchell in burial 23 is actually the Margaret Mitchell (incorrectly) recorded in the 1861 census. The age and date of death recorded on the coffin plaque of Martha correspond to the age of Margaret in the 1861 census. As well, Francis Mitchell, recorded in the 1861 census as the brother of Margaret (at the age of one), was found buried beside Martha. We know from his obituary that he died in 1867 which would have made him seven years old at the age of death. Analysis of the dentition of the child in burial 22B by Blackbourn (2006) and Hawken (2006) support this age at death, and further support the conclusion that Martha and Francis were the children of Christopher and Hannah Mitchell.

It is therefore most likely that the Martha Mitchell found in burial 23 was born in Port Hope, a conclusion supported by the results of isotopic analysis of enamel. It is of interest to note that the country of origin recorded for Christopher Mitchell varied between each census year he was recorded. He is listed as being born in Upper Canada in the 1861 census, England in the 1871 census, and Scotland in the 1881 census.

6.4.4. B. Alcott

The coffin plaque found in association with burial 30A reads "B. Allcott/Aged 33 years." Blackbourn (2006) and Hawken (2006) determined the skeletal remains in burial 30A to be those of a 35–50 year old male. It is of interest to note that during excavation, an infant (burial 30B, not included in this study) was found in the crook of the adult male's arm. The $\delta^{18}O_w$ of the URM1 (-7.64‰) falls within the expected range of eastern Ireland, western Scotland, the south and west regions of England or the northeastern

United States. The $\delta^{18}O_w$ of the LLM3 (-9.25‰) is less negative than expected for the Port Hope region, and may be the result of moving during the mineralization of the third molar, which would act to average the oxygen isotope ratios of two different regions. The $\delta^{18}O_w$ of the bone sample (-7.83‰), however, does not correspond to an individual that relocated during their early teens.

The 1861 Port Hope census includes a Benjamin Olcott, a 31 year old, single barkeeper. Olcott is listed as a Wesleyan Methodist and as being born in Upper Canada. There are no records of any Allcotts or Olcotts in the 1871 or 1881 census returns. The results of the isotopic analysis and archival research do not correspond in this case. It is possible that Benjamin Olcott is not the B. Alcott buried in the Old Wesleyan Methodist Cemetery. It is also possible that Benjamin Olcott's location of birth (and last name) were recorded incorrectly by a census taker, as seen in the case of Christopher Mitchell.

6.4.5. Cynthia McGaffey

The coffin plaque found in association with burial 36 reads "Cynthia McGaffey/Aged/27 Years/1864." Blackbourn (2006) and Hawken (2006) determined the skeletal remains in burial 36 to be of a 20-35 year old female. The $\delta^{18}O_w$ values of the URC and URM3 samples (-10.15 and -10.09‰ respectively) fall within expected range of Port Hope. The $\delta^{18}O_w$ of the bone sample (-7.83‰) again does not correspond to results of analysis of enamel tissue.

Census records from 1861 list the McGaffee family as Catherine (widow, aged 45 years), Cynthia (teacher, 24 years old), George (16 years old), Edgar (6 years old), and

Ernest (4 years old). All are listed as Wesleyan Methodist. Catherine, Cynthia, and George are listed as being born in the United States, and Edgar and Ernest were born in Upper Canada. Using the ages of Cynthia and George it appears that the family moved to Upper Canada after 1837 (when Cynthia was born in the U.S.) and before 1845 (when George was born in Upper Canada). This move would have therefore occurred when Cynthia was between birth and the age of eight.

While the isotopic results and census records appear to disagree, it is quite possible that Cynthia was born in an area of the northeastern United States that has the same expected $\delta^{18}O_w$ range as Port Hope (Figure 6.1.). This area includes New York, Massachusetts, New Hampshire, Vermont, and Maine. No archival records indicating where in the United States Cynthia was born were located.

6.5. Previous Research on Hawkins Sample

Using results obtained from previous studies, further analysis of the health and diet of the Hawkins individuals is possible. Hawken (2005) has investigated the patterns of health and disease within the population through paleopathological analysis and concluded that the individuals in the Hawkins collection lived with various health problems associated with their diet, occupation, and living conditions, including cribra orbitalia, porotic hyperostosis, infection, trauma, and osteoarthritis.

Of the individuals of known age, all of those under the age of 15 (n = 7) included in the present study were found to be from Port Hope. As a result, discussion will focus on the results of analysis by Hawken (2005) of individuals older than 15, 16 of which (4 local and 12 non local) are included in the present study. Skeletal evidence of disease appears to be spread between both local and non-local individuals. Two interesting cases were found, however.

The three individuals (H5, H15, and H24) who were determined to show evidence of joint disease other than osteoarthritis, specifically diffuse idiopathic skeletal hyperostosis and ankylosing spondylitis, were not local to Port Hope. Secondly, trauma was observed on the hands and feet of 13 adults. Eleven of these individuals were included in the present study and results indicate that two were local and the remaining nine were non-local. As Hawken (2006) makes inferences about the occupation of these individuals as being labour-related based on the types of injuries observed, these results suggest that a high number of non-local individuals held these types of jobs.

All of the 16 individuals analyzed by Blackbourn (2006) using carbon and nitrogen isotopes to investigate diet are included in the present study, of whom four were determined to be local to Port Hope and 12 were determined to be non-local. The results of nitrogen isotope analysis of the two groups are not significantly different (p=0.054) when compared using a Mann Whitney U test, indicating that the individuals were consuming similar sources of protein, argued by Blackbourn (2006:131) to be obtained mainly from herbivore meat as opposed to legumes and fish. When the $\delta^{13}C$ values of locals and non-locals are compared, the means are not statistically significant (p=0.029). This indicates that both groups were consuming the same sources of herbivore meat as well as grains such as wheat, barley, oats, and rye, and both avoided consumption of sugar cane and maize.

An additional component of Blackbourn's research was the analysis of dental pathology. It is of interest to comment on the presence of fillings in the Hawkins sample. Blackbourn (2006) observed gold and amalgam fillings in the teeth of two individuals excavated from coffin burials (16B and 36) as well as in four of the teeth in the commingled remains. According to Blackbourn (2006:104), individuals with fillings were considered well-off due to the expense of dental work in the 19th century. Both individuals in burials 16B and 36 were born outside of Port Hope. The individual in burial 36 has been identified as Cynthia McGaffey, who was born in the USA, and the isotope values of enamel of the individual in burial 16B indicate a location of origin of Eastern Scotland or England, central Ireland, or possibly New York, Pennsylvania, Massachusetts, Connecticut, or Rhode Island. While oxygen isotope analysis was not performed on the teeth from the commingled feature, it is of interest to note that individuals who were able to afford dental work were not found in coffin burials.

Combining the results of the three studies of the Hawkins individuals to date allows a more thorough investigation into the lives of this group of 19th century inhabitants of Port Hope. While the results of analysis of bone in this study are questioned and the sample is small, information about the origins of Port Hope pioneers has been gained through enamel analysis. The individuals buried in the Old Wesleyan Methodist Cemetery originated from a variety of locations. As the burial ground was established at the start of the period of great population growth in Port Hope, and its use extended for almost fifty years, it is fitting that such a range of locations of origin is observed.

CHAPTER 7

CONCLUSIONS

Oxygen isotope analysis of the Hawkins sample indicates that the people living in Port Hope between the 1830s and 1870s originated from various geographical regions, including Upper Canada, the Northeastern United States, and the British Isles. No difference in immigration was observed between male and female individuals in the sample, but a tendency for children to be local and older individuals to be non-local was observed. While a review of historical records of known individuals identified two cases of incorrect interpretation of region of origin, in total, thirteen individuals were determined to have been born in Port Hope, and the remaining half relocated from the Northeastern United States and the British Isles, often during their childhood.

The local isotopic signature of Port Hope was established through the analysis of First Nations individuals who were buried in sites near Campbellford and Lake Scugog. Radiocarbon dating and isotope results support the long-term use of the sites, as concluded by Johnston (1979). It was initially thought the individuals were local to the regions where they were buried, but isotopic evidence suggests that this may not be the case for the individuals from the Scugog site. This also supports Johnston's (1979) conclusion that certain areas were returned to for burial purposes.

The use of the carbonate component of enamel tissue was found to be a valid technique, as previously reported by Pcholkina (2004), Dupras and Schwarcz (2001), and Iacumin et al. (1996a and 1996b). The use of bone carbonate was also successful for the

Hawkins individuals. The results of FTIR analysis, however, indicate that the $\delta^{18}O_c$ of bone from the Myles and Scugog sites did not provide results that were as reliable as from the Hawkins site.

The limitations of oxygen isotope analysis encountered in this study include the following: (1) similar bone and enamel $\delta^{18}O_c$ values may reflect an individual who was not local, but died shortly after relocation (prior to bone remodeling) instead of an individual who occupied the Port Hope region for a long period of time; and (2), as seen in the case of Cynthia McGaffey, oxygen isotope analysis failed to recognize a non-local individual because the location of origin fell within the same expected oxygen isotope range as Port Hope. In order to address these issues, it would be of interest to combine the results of this study with the analysis of strontium isotopes.

Similar to oxygen isotopes, the strontium isotope content of rocks and minerals in a geographical region is incorporated into the local soil and groundwater and eventually the food chain (Knudson et al. 2004; Price et al. 2002). Because of their chemical similarity, strontium can substitute for calcium in the hydroxyapatite molecule (Knudson et al. 2004; Montgomery et al. 2000; Price et al. 2000). The principle of stable strontium isotope analysis is the same as stable oxygen isotope analysis in that the strontium ratios of the food and water consumed by humans are incorporated into their skeletal tissue and are a reflection of the isotopic composition of their environment. In contrast to oxygen isotopes, however, the distribution of Sr isotopes in the environment does not follow a predictable pattern, but must be determined for each potential region of origin.

An additional area of potential research is the analysis of other tissues from the Hawkins collection, such as dental calculus, which was found on the teeth of thirteen of the 32 individuals analyzed by Blackbourn (2006:90). Dental calculus is mineralized bacterial plaque that has an inorganic component of hydroxyapatite that is similar to that found in enamel and bone tissue (Lieverse 1999:220). While it has been stated that the presence of food particles in calculus allows for study of diet (Buikstra and Ubelaker 1994:56), no study to date has utilized dental calculus in an isotopic study reconstructing geographic origins. It is expected that the $\delta^{18}O_c$ values obtained from calculus would be similar to those of bone, although the timing of deposition would be a factor. Diagenesis is expected to be a factor, but the potential of the technique should be explored in order to be able to obtain the maximum amount of information in cases when isolated teeth are recovered in other sites.

In addition to further research investigating geographic origins, a study of the breastfeeding and weaning practices of the Hawkins individuals could be performed. Results would contribute to the existing base of knowledge about infant feeding patterns in 19th century Upper Canada established by Herring et al. (1998) and Katzenberg and Pfeiffer (1995). It would be unique because comparison of the practices of locals and non-locals is possible using the present data.

The results of this study provide information on the patterns of immigration to Port Hope including similarities and differences in location of origin between individuals of different age, sex, health, and status. When combined with the results of analysis by Blackbourn (2006) and Hawken (2006), interpretations and comparisons can be made about the patterns of health and diet of individuals born in Port Hope and those born elsewhere. This, and possible future analysis, contributes to what is known about the lives of the people buried in the Old Wesleyan Methodist Cemetery and can be incorporated into broader research on the history of Upper Canada.

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