A STABLE ISOTOPIC INVESTIGATION OF THE SMITH'S KNOLL SAMPLE

INVESTIGATING DIET AND REGIONAL ORIGINS IN THE SMITH'S KNOLL SKELETAL SAMPLE, STONEY CREEK, USING STABLE ISOTOPES.

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Abstract

This thesis uses stable isotopic analysis to identify diet, geographic origins and long-term residency in a sub-sample of the Smith's Knoll skeletal collection, soldiers who died during the June 6th 1813 Battle of Stoney Creek. The major objectives of this study have been to differentiate between two major modes of dietary consumption, one wheat-based, the other maize-based, in an attempt to decipher British colonial from American soldiers. These objectives were paired with stable oxygen and strontium isotopes, two isotopic elements presently used to identify migration and regional origins. Oxygen isotopic results from teeth suggest that, as children, 5 individuals may have originated in North America. Nine individuals have isotopic signatures indicative of both a North American or United Kingdom origins. The isotopic composition from bone collagen and phosphate suggest similar geographic origins, with diets composed of both wheat- and maize-based foods. Bone phosphate values indicate that 2 individuals possibly resided in North America. The remaining 20 individuals have bone values indicative of long-term residency in both geographic regions with a significant amount of dietary mixing. These results suggest that other military participants, soldiers from the King's 8th Regiment and Canadian militiamen, may also be represented in this study. Prior investigations have omitted this crucial information, focusing their historic research primarily on the British 49th Regiment. The data presented in this thesis offers a broader geographic, pan-nationalistic perspective on the possible infantrymen and militiamen who fought during the battle, including select Canadian militiamen from the Niagara region and the King's 8th Regiment from Britain.

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Chapter 1 Introduction

1.1 Bioarchaeology and Stable Isotopes

The biology of the human skeleton has been used to investigate health and disease, diet, geographic origins, trauma, and ancestry of both prehistoric and historic human populations. The human burial process is a complex event involving the beliefs, rites and rituals of the community, and material items that symbolize the living in death. In some cases the burial context and associated artifacts may help researchers identify the cultural affiliations of the deceased. However, environmental and human disturbance may displace materials, leading to comingled and disarticulated assemblages. This is particularly true for historic battlefield sites. It is not uncommon to find the remains of fallen soldiers disassociated from material belongings and artifacts that could aid in deciphering their identification and cultural affiliations.

The Smith's Knoll skeletal sample, consisting of soldiers who died during the June 6th, 1813, Battle of Stoney Creek, offers a unique opportunity to investigate the lives of 19th century British colonial and American soldiers using stable isotopic techniques in order to better understand the lives of these historic individuals. This thesis uses stable isotope analysis of carbon, nitrogen, oxygen, and strontium to reconstruct the regional origins, long-term residency and diet in a small sample of soldiers from the Stoney Creek skeletal collection.

Stable isotope analysis of archaeological remains seeks to achieve the following goals: 1) establish major dietary shifts over small and large temporal-spatial scales (e.g. Bentley et al. 2003; Borić et al. 2004); 2) integrate isotopic data with mechanical (tooth wear), biological (faunal remains), and other archaeological materials associated with diet (e.g. Knudson et al. 2009; Kusaka et al. 2009); 3) identify relationships between dietary consumption patterns, age, sex, social status, and health (e.g. Ambrose et al. 2003; Prowse et al. 2005, 2007) and 4) establish intra- and inter-sample relationships between dietary shifts and isotopically identified migrants, or non-local individuals in the context of goals 1 through 3 (e.g. Chenery et al. 2010; Eriksson 2004; Evans et al. 2006a/b; Giblin 2009; Grupe et al. 1999; Keenleyside et al. 2011; Schwarcz and Schoeninger 2011).

This thesis focuses on the main elements used to reconstruct dietary and migration patterns in ancient populations; these include carbon ($^{13}C/^{12}C$), nitrogen ($^{15}N/^{14}N$), oxygen ($^{18}O/^{16}O$) and strontium ($^{87}Sr/^{86}Sr$) stable isotopes, all of which have been extensively studied in bioarchaeology. The oxygen isotope results presented here will be compared with data from Blyth's (2003) Battle of Stoney Creek study, with strontium, carbon, and nitrogen isotopic results presented here adding further quantitative evidence to the investigation of the soldiers buried at Smith's Knoll. Blyth's (2003) study investigated the geographic origins of the Smith's Koll soldiers using oxygen isotopes from bone and tooth phosphate.

1.2 Research Objectives

Bones and teeth are the primary materials used to identify dietary change in ancient populations, and since these skeletal elements reflect developmental differences during the life-course, they are frequently used together to track dietary change throughout life. Carbon and nitrogen from bone collagen and tooth dentine mainly reflect the protein and carbohydrate source of food (Ambrose 1993). Alternatively, bone and tooth carbonate are believed to reflect the total diet of the consumer (Ambrose 1993). Since tooth mineralization is usually complete by the age of 15 (third permanent molar), the isotopic signature of the foods consumed throughout the initial stages of childhood becomes fixed in the tooth enamel. Bone, however, continuously remodels during life (approximately every 10 to 20 years), changing the isotopic values from childhood to adulthood, reflecting the dietary input of the individual during the last 10 to 20 years of life (Katzenberg 2008; Manolagos 2000). This isotopic variability within the skeleton allows bioarchaeologists to compare dietary shifts within a single individual (if the individual is represented by both bones and teeth), as well as intra- and inter-site comparisons.

Prior studies into the lives of British colonial and American soldiers have included crucial historical information concerning who was involved in battle. Schwarcz et al. (1991) were the first to apply stable oxygen isotopes techniques to a small bone sample recovered from Fort Erie. Since that time, the historical accounts documenting the events and soldiers involved at the Battle of Stoney Creek and other major War of 1812 battles have greatly improved over the past two decades. Elliott's (2009) documentation of the

Battle of Stoney Creek has raised a series of questions not addressed in earlier isotopic investigations (Schwarcz et al. 1991; Blyth 2003; Raynor and Kennett 2008) of the geographic origins of soldiers from 19th century Upper Canada, such as the potential diverse geographic origins of the War of 1812 participants. Interestingly, these preliminary isotopic studies have focused primarily on the American and British 49th Regiment participants. This thesis is a multi-isotopic analysis of the regional origins and long-term residency of the 1812 soldiers who died at Stoney Creek that considers the recent historical evidence for the participants involved in the War of 1812, namely recruits from the King's (8th) Regiment and Canadian-born militiamen (Elliott 2009; Turner 2000), participants who received considerably less attention in prior analyses (e.g. Blyth 2003; Schwarcz et al. 1991).

The goals of this thesis are threefold. First, to provide information concerning the dietary behaviours of these soldiers and identify whether these individuals were subsisting off a largely wheat-based diet (possibly indicating United Kingdom origins), or a diet composed mainly of maize and sugarcane (possibly indicating North American origins). Given that carbon, nitrogen, and strontium isotopes can be used to infer individual dietary habits, this research addresses broader questions concerning staple dietary consumption among the Smith's Knoll soldiers than Blyth's (2003) study using enamel and bone phosphates alone. The second aim is to investigate the regional origins and long-term residency of the soldiers in this sample using strontium and oxygen isotopes, through a comparison of these isotopic data to those obtained by Blyth (2003) and Schwarcz et al. (1991). The final goal is to integrate the isotopic results with prior

historical evidence and earlier isotopic investigations in order to better understand the lives of these 1812 soldiers according to the food and water they consumed during life.

1.3 Thesis Organization

Chapter 2 begins with an introduction to the War of 1812 to situate the objectives of this thesis within the larger historical narrative of military events preceding the Battle of Stoney Creek, and to highlight the life histories of these soldiers within that context. Chapter 3 describes the Smith's Knoll skeletal sample used in the present research, as well as the sample previously used by Blyth (2003). This chapter also includes a discussion of the Smith's Knoll archaeological context, along with a physical description of the remains. Chapter 4 provides a detailed review of stable isotope analysis – including applications and methodological limitations – from various archaeological contexts. Chapter 5 details the material preparation and methods used in this research and Chapter 6 presents the results obtained from isotope ratio mass spectrometry measurements. These results are then interpreted within a historical framework in Chapter 7, through a detailed analysis of dietary practices common to the early 19th century inhabitants of the United States, British Canada, and the United Kingdom. The aim is to distinguish local from non-local individuals (i.e. British, Canadian, or American) that fall within documented isotopic dietary ranges of both North America and the United Kingdom. Chapter 7 also compares the oxygen and strontium isotopic composition of bones and teeth to meteoric precipitation and water-catchment baseline maps, both of which document the geographic

variability in oxygen and strontium isotopes across North America and the United Kingdom. The remaining sections of Chapter 7 discuss the limitations in isotopic research, future academic considerations for the Smith's Knoll skeletal collection, followed by concluding remarks.

This study significantly contributes to prior isotopic research, first undertaken by Blyth (2003) on the Smith's Knoll sample, and adds to earlier pioneering studies conducted by Schwarcz et al. (1991), Katzenberg (1991), and Raynor and Kennet (2008) concerning the diet, ancestral and geographic identities of colonial soldiers during the 1812 war at Snake Hill cemetery, Fort Erie, Ontario. The sample used for this thesis is an additional step towards understanding geographic origins and diet in historic battlefield cemeteries in Ontario.

Chapter 2 Historical Background

2.1 A Note on the Beginning and End of the 1812 War

The War of 1812 was a military conflict between American and British forces that began on June 18th, 1812, and lasted until the Treaty of Ghent was signed on December 24th, 1814 (Turner 2000). Although the war formally ended with the signature of this document in Ghent (now modern day Belgium), word about the peace agreement took several weeks before reaching the United States. This delay allowed the Battle of New Orleans, Fort Phillips, and subsequent capture of Fort Bowyer on January 8th and 9th, and February 5th, 1815, respectively (Horsman 1969). The Treaty of Ghent was ratified by the United States Senate on February 16th, 1815, leading to an end in military confrontations between Britain and the United States, and forcing the withdrawal of British military forces stationed in the Gulf of Mexico back to naval bases located throughout the Caribbean (Caffrey 1977). Figure 2.1 depicts the major battlefield sites relevant to military events discussed in this chapter.

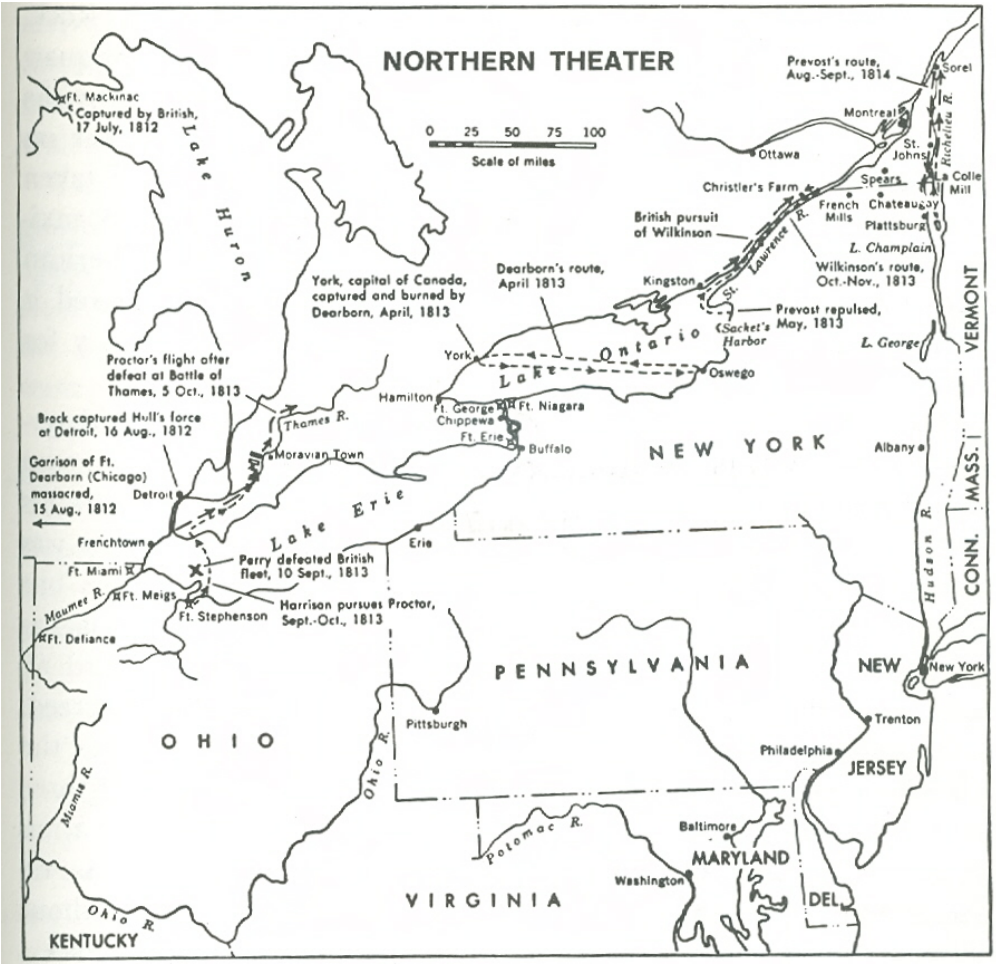


Figure 2.1: Map showing the major battlefield sites of the northern war theater in the United States and Canada (Jacobs 1969: 49).

2.2 The United States Declares War on Britain

The 1812 war grew out of sea-bearing hostilities between Britain and America over a period of 10 years prior to its declaration on June 18th, 1812 (Jacobs 1969). These military tensions arose from numerous land and sea regulations, imposed primarily by the British on domestic trade along the eastern seaboard of the United States, and foreign

commerce to European states across the Atlantic Ocean (Jacobs 1969). In 1803 Napoleonic France resumed its conflict with the British Empire leading to further trade restrictions and a mutual sea blockade. The result of these international trade sanctions led to a neutral United States whose primary goal was to capitalize by trading with both Britain and France (Bukovansky 1997). In turn, the British and French, aware of American financial interests in war profiteering, commandeered American merchant ships both in international waters and along the American eastern coastline (Hatzenbuehler and Ivie 1980). Restrictive policies imposed by the United States against Britain stretch back to the post-revolutionary era during the late 18th century, when America gained independence from Britain after the Treaty of Paris was signed in 1783 (Hickey 1981). These policies, particularly those enacted between 1793 and 1815, advocated domestic prosperity and growth, the protection of these national interests abroad, and foreign policies based on neutrality during times of war (Hickey 1989). Between 1806 and 1812, Jefferson and Madison's Republican Parties implemented trade restrictions on domestic and foreign goods, opposing war, on the grounds that these sanctions represented a peaceful means in dealing with European foreign trade relations between their imperial assets and colonial counterparts abroad (Brant 1966). These measures were to justify a way to undermine European domination, favouring American superiority in international trade (Coles 1969). Unfortunately, a small majority of Republican representatives saw these restrictions as a means to wage war (Hickey 1981). Nevertheless, Thomas Jefferson's Embargo Act of 1807 – formulated after the British ship *Leopard* opened fire on the American Frigate, the *Chesapeake*, killing 3 and wounding 18 men – and

Madison's Non-Intercourse Act of 1809 were emplaced. This legislation resulted in serious disapproval by American merchants and industrialists, all of whom sought profit from overseas trade along the North American eastern seaboard (Jacobs 1969; Hickey 1981; Shulman 1992).

Although trade restrictions were implemented on both sides of the Atlantic, American ships suffered most under the auspices of Imperial Britain and France. Both European powers were involved in enforcing measures against the United States, but unlike the French, the British seized valuable cargo, searched ships and forced American seamen to join the ranks of the Royal British Navy, a form of tyranny imposed by the British termed 'impressment' (Fabel 1980). Strum (1980) placed the number of impressed American seamen at over 6,000, captured from merchant trade ships operating along the American east coast. After several violations of trade restrictions, embargos and acts, the attack on the *Chesapeake*, and brief skirmishes between British and American ships, in May 1811 President Madison became convinced that war with Great Britain was inevitable (Jacobs 1969). By November 1811, American congress drafted war measures against Great Britain bringing to the House of Representatives in Washington 142 members of state. According to Horsman (1964), this included 106 Republican and 36 Federalist representatives. Republican support for further trade sanctions – an alternative still supported by President Madison – or war was divided, with Republican members from Virginia, Pennsylvania, Georgia, and South Carolina supporting economic measures over war, as did Republican members from towns close to the sea, such as Baltimore, New Orleans and New York (Wehtje 1970). The Federalists, however, had always

opposed war in favour of further trade restrictions (Hickey 1981; Strum 1980). War mongering Republican members, the War Hawks, advocated the invasion of Canada on the basis of national defense and sovereignty of the nascent Republic (Hatzenbuehler and Ivie 1980). The justification for war came not entirely from American ship restrictions and impressments, but to ensure that encroaching British power would not lead to yet another British colony in the Americas. A memorandum written by Peter Buell Porter, a Republican representative serving as chairmen of the House Select Committee on Foreign Relations, decreed that "The possession of Upper Canada, would give to the Unites States the control of savages; afford an easy conveyance by the waters that descend towards Montreal … and enable them to fall upon Lower Canada on the side of the United States and of Upper Canada at the same time, without leaving an enemy in the rear to disturb their operations or cut off a retreat" (Stagg 1999: 419-420). Interestingly, this is exactly the military trajectory taken by the American Army in late October, 1813, when Generals Hampton and Wilkinson attempted to sack Montréal via the Châteauguay River and St. Lawrence waterway at Chrysler's farm (Berton 1995).

The British further instigated conflict with the Americans by allying themselves with First Nations tribes along the American frontier. This resulted in harassment and small scale attacks by local warrior tribes, which the Americans deplored as another attempt by the British to undermine the sovereignty of the United States (Horsman 1957). Furthermore, solidarity between various First Nations tribes increased under the command of the Shawnee War Chief, Tecumseh, in response to American expansion into the North American western frontier (Goodman 1941). Conflict between the American

settlers and First Nations tribes over a period of several decades prior to the 1812 war resulted in the Treaty of Grenville, signed in August 1795, at Fallen Timbers close to Fort Miami (Dale 2001). Most historians, however, generally agree that the 1812 conflict arose out of the British imperial agenda to thwart American rights, both domestic and abroad while a significant fraction of the Republican constituency saw these instigations as a pretext for British annexation (Dale 2001; Horsman 1964; Turner 2000).

The most widely cited causes for a war against Great Britain began with President Madison's message – lobbied heavily by the War Hawks – to congress in support of a declaration of war on June 1st, 1812 (Gilpin 1958). In his congressional letter, President Madison stated four reasons in support of military action against England. The first and second causes were the impressments of American seamen into the British Royal Navy and the forced search of American vessels off the North American East coast (Fabel 1980). The third was the British blockade, which hindered American foreign trade. The last reason was the instigation of conflicts between First Nations tribes and American settlers by the British along America's western frontier (Turner 2000). War on Great Britain was officially declared when President Madison signed the measure into law on June 18th, 1812 (Gilpin 1958). The British suspended judgment regarding the conflict until January 1813, in hopes that the American administration would withdraw from a confrontation in North America (Turner 2000).

2.3 American and British Military Strength

Unlike the major naval battles being fought in Europe during this time, America had no intention of waging a sea-bound war with Great Britain. During the onset of war the American fleet consisted of 3 large frigates (*Constitution*, *President* and *United States*), 5 smaller frigates, 2 corvettes, 8 schooners, brigs and sloops (Jacobs 1969). In comparison, the Royal British Navy – the largest navy in the world during the 19th century – had over 800 battleships at its disposal (Jacobs 1969). In contrast, American ground forces greatly outnumbered British regular troops stationed in Upper and Lower Canada with a total civilian population roughly 10 times the size of British Canada combined (~ 6 million) (Barbuto 2000). So much so were the odds against the British and Canadian settlers that President Thomas Jefferson stated the takeover of British territories would be "a mere matter of marching" (Dale 2001: 17). British troops stationed throughout the colonies varied according to region. There were 4,300 regular soldiers stationed in Nova Scotia, Newfoundland, Prince Edward Island, and New Brunswick; 5,600 soldiers in Lower Canada and 1,600 regulars in Upper Canada (Turner 2000). Canadian militia estimates – what the British called Canadian 'Fencibles' – numbered upwards of 60,000. Barbuto (2000) placed this number much higher, with 71,000 militiamen in line to fight for the British colonies (maritime estimates were upwards of 15,000 militiamen). British command was reluctant to secure many of these individuals with active arms as a significant fraction of the colonial population were Loyalists, who defected during the War of Independence and thus posed a risk for treason (Horsman 1969). In fear of Upper Canadians taking arms against British regulars, General Isaac

Brock pushed for measures in the Upper Canadian legislature for militiamen to renounce allegiance to all foreign powers. Nevertheless, being far from well equipped and trained, General Prevost approved the arming of 2,000 men (on annual rotation) during the early months of war.

In contrast to British military figures, American regular ground forces numbered between 10,000 and 35,000 and were backed by approximately 326,011 to 471,622 militiamen by war's end (Barbuto 2000). Regardless of their numbers early battles of the 1812 campaign showed just how inadequate and ill-prepared American regular soldiers and generals were at mobilizing infantry to fight. Many American militiamen were poorly trained, ill disciplined, and sometimes refused to cross international boundaries on the basis of ex-patriotic partnerships and the constitutional right to reject warfare on foreign soil (Turner 2000). In other words, many newly settled Canadians in the British colonies had some form of familial history with the American military and feared a colonial civil war (Berton 1995).

2.4 The 1812 Campaign: America Invades Upper Canada

Faced with superior American troop numbers, the British relied heavily on unconventional military tactics and strategies aimed at persuading the American army of greater infantry numbers among British regiments. These tactics proved relatively successful along several frontiers in Upper Canada, particular during the capture of Detroit, the battles of Stoney Creek and Beaver Dams, and the defense of Montréal (Gilpin 1958). Adding to this strategic deception, communication between American

commanding officers was slow and inefficient, hindering American strategic and intelligence capabilities along different war frontiers (Jacobs 1969). This process was so slow that the American Lieutenant in command of Fort Michilimackinac, Porter Hanks, surrendered the fort without one shot being fired to a small contingent of British regulars, Ottawa, Ojibwa, Winnebago, and Sioux First Nations warriors on July 17th, 1812, unaware of the declaration of war without one shot being fired (Adams 1957). Similarly uninformed of the war effort against the British, American General William Hull prepared to invade Upper Canada via Sandwich (present day Windsor) and attack Fort Malden in Amherstburg (Berton 1980). After receiving word of the American invasion of Sandwich, General Brock, accompanied by 40 British regulars and 200 militiamen set off to Amherstburg by water. With 70 regular soldiers and 100 First Nations warriors under the direction of Tecumseh, British Captain Muir attacked a detachment of American infantrymen and a supply train at Brownstown (Dale 2001). This defensive act, along with a fear of First Nation aggression, led General Hull to retract his invasion force at Sandwich, returning back to Detroit on August 8th (Gilpin 1958).

Meanwhile on August 14th, Tecumseh and General Brock outlined a plan to attack Detroit. With an army of 300 regulars, 600 First Nations warriors, 400 militiamen, and 3 pieces of field artillery, against Hull's 2,500 poorly trained American regulars and 33 cannons, General Brock and Tecumseh proceeded with the attack on August 16th (Carter-Edwards 1987). Unknown to General Hull was General Brock's clever tactic to clothe local militiamen in old Red Coats gathered from the British 41st Regiment (Gilpin 1958). This led American infantrymen stationed behind the walls of Fort Detroit to believe they

faced not 300, but 700 British regular soldiers. First Nations warriors also participated in these bluff military tactics, and many of the warriors – staying outside of the American line of fire – peered in and out of view along the forest's edge of the fort, further convincing the American troops that they were surrounded by a great number of First Nations warriors (Benn 1998). Fearing a massacre, Hull eventually surrendered.

Brock's written messages to the American General further instilled fear in the American garrison, and in the end they allowed the British to take control of the fort, the town, and indeed the entire territory of Michigan (Dale 2001). However, General Brock understood that this brief victory would eventually open the frontier along the Niagara Peninsula. In haste, he returned to Fort George on August 24th. Tecumseh was later killed during the Battle of the Thames at Moraviantown on October 5th, 1813, retreating along the Thames River towards Brigadier-General John Vincent's army stationed at Burlington Bay (Smelser 1969; Turner 2000).

An armistice agreement that began in late August and ended on September 8th, 1812, allowed American forces to prepare, gather supplies, and station men along the Niagara frontier (Barbuto 2000). General Brock, well aware of American intentions to invade Upper Canada via the Niagara Peninsula, became increasingly infuriated as he watched troop presence at Lewiston increase, an American town located across the Niagara River from Queenston (Figure 2.2). His calls for an aggressive attack on the American presence were rejected by his contemporary, Commander George Prevost, and during the early hours of October 13th roughly 300 American regulars and over 250 militiamen under the command of Lieutenant-Colonel Christie and Colonel Solomon Van

Rensselaer embarked from Lewiston on the first boats headed for Canadian shores (Dale 2001).

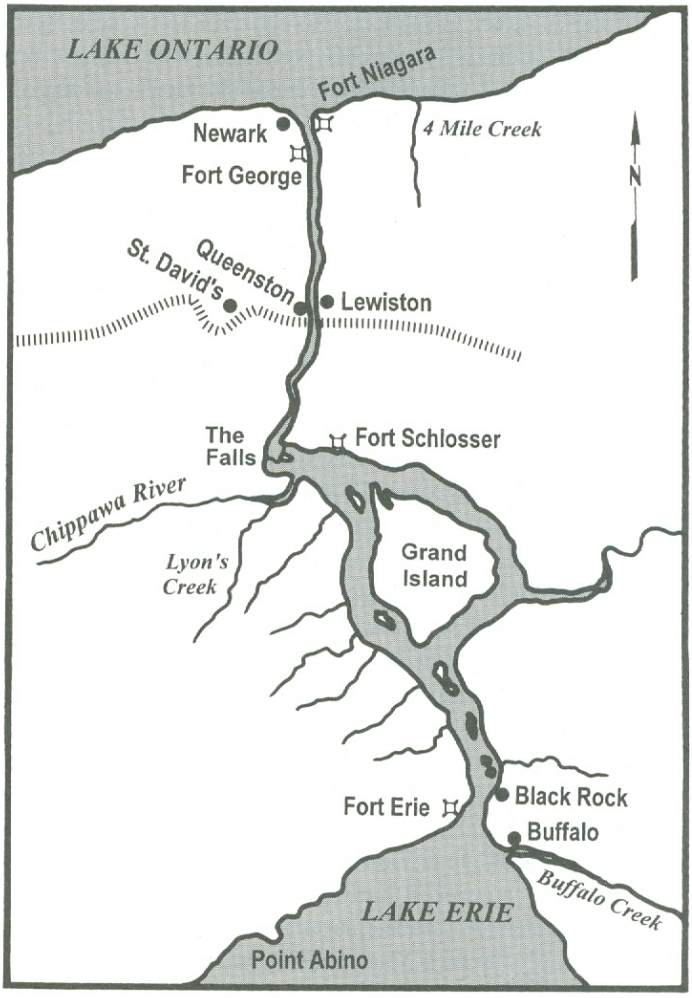


Figure 2.2: Niagara frontier showing the locations of Queenston, Lewiston, and Fort George (Barbuto 2000: 42).

American regulars landing at Queenston were eventually successful at securing the main gunners that sat atop the Heights, the Redan battery, which was sabotaged (spiked) by the British moments before they retreated down from high ground

(Malcomson 1995). General Brock, awakened by the sounds of war 8 kilometers away, arrived by horseback not long after the battle had started. Here, he gathered approximately 100 regulars and militiamen to retake the Redan battery, but his attempt was unsuccessful. As he climbed the Heights a musket ball fired less than a few meters away struck him in the chest, collapsing him to the ground (Cruikshank 1904). His successor, Lieutenant-Colonel John MacDonell, rallied the troops for yet another charge. However MacDonell's attempt also failed, narrowly escaping the fate befallen by General Brock moments earlier. General Brock was knighted Sir Isaac Brock three days before his death. Unfortunately word from Great Britain would not arrive about his honourary title until the end of October 1812 (Adams 1957).

By mid-morning the American invasion force in Queenston had increased, ushering in 1,300 more infantrymen and several pieces of field artillery. Confined to Vrooman's battery in the north end of the village, British and Canadian soldiers continued to lay siege against their American counterparts. In the interim, Fort Niagara and Fort George had been engaged in artillery and cannon bombardment for most of the morning (Coles 1969). British General Sheaffe, under previous orders given by General Brock before his death, ordered a significant portion of the garrison stationed at Fort George to reinforce Queenston, leaving only a few regular soldiers to operate the cannons and continue their assault on Fort Niagara (Cruikshank 1904). Roughly 100 Six Nations warriors under the command of John Norton – war chief of the Mohawk – also joined Sheaffe's British reinforcements (Adams 1957). Although American infantrymen greatly outnumbered British regulars, militiamen and Native warriors, continuous musket fire

kept American lines pinned down. Between British musket volleys followed by bayonet charges and warrior guerilla tactics at American flanks, American commander Winfield Scott had no choice but to offer a cease-fire. In total, 500 Americans were killed or wounded, 436 regular soldiers and 489 militiamen had been captured, and of the total strength of American ground forces available at Lewiston, estimated at 6,000, only 1,600 crossed the Niagara River to fight (Malcomson 1994). On the British side, 77 men were wounded, and 21 were captured. Casualties were also comparatively low, with 11 regulars, 2 militia, and 5 Six Nations warriors dead by battles end (Malcomson 1994). Victory at Queenston Heights acted as a catalyst for the war effort against the Americans, particularly for Canadian militiamen reluctant to fight for the British (Dale 2001). Yet as the war progressed throughout the early spring of 1813, American efforts at defeating the British only increased.

2.5 The 1813 Campaign: The Attack on York

Naval superiority had always been a key factor in British victories at sea. Throughout the late months of 1812 the British controlled most major waterways along Upper Canada's southeast coast including Lake Erie and Ontario, despite losing several skirmishes against the young American Navy (Coles 1969). Communication and arms shipments were thus disseminated with relative ease throughout the various regions of British Canada, particularly to Lower Canada via the St. Lawrence River. However, American efforts to thwart British domination over the Great Lakes increased over the final months of 1812, and Captain Isaac Chauncey – United States Naval Commodore of Lake Ontario and Erie – converted numerous civilian schooners into warships (Jacobs

1969). During this time he oversaw the building of a 24-gun corvette, *Madison*, stationed in Sackets Harbour. By the end of November 1812, the *Madison* was launched. The Americans considered this a formidable undertaking specifically because the largest naval warship patrolling the Great Lakes belonged to the British, the *Royal George* (Benn 1984). As the war entered a new year, new changes were also being made within the American administration. John Armstrong, the new American Secretary of War (now called Secretary of Defense), profoundly impacted the 1813 campaign. He was significantly more aggressive, calling for an invasion of the Niagara Peninsula and Montréal, the capture of Kingston, and destruction of the shipyard at York, present day Toronto and historic capital of Upper Canada (Barbuto 2000). So lightly guarded was the capital that the Americans were almost certain of victory by a sea-bound invasion via Lake Ontario.

Military personnel stationed at York were few; they included a few hundred regular soldiers of the King's (8th) Regiment and Royal Newfoundland Regiment, accompanied by Light Infantry Fencibles and York militiamen (Benn 1984). When the Americans attacked on April 27th, 1813, the garrison at York was overwhelmed. British General Sheaffe, with only 700 men to defend his British settlement, faced an American force – commanded by Brigadier Zebulon Pike – of over 1,700 men and 15 armed vessels (Horsman 1969). Opposed by little resistance, the American force was able to successfully land troops and bombard York with cannon fire from the lake. British forces took severe casualties during the opening hours of battle, numbering over 100 killed or wounded (Benn 1984). Outnumbered and outflanked, the British garrison abandoned

York, retreating through a ravine near the back gate of the fort. The Americans continued their advance, seizing valuables, private property, British artillery, while setting aflame several government buildings before returning to their ships (Dale 2001). Although an American victory over York was inevitable given the lack of British and Canadian troops and firepower, the British, before retreating, lit a fuse connected to large amounts of gunpowder stored in Fort York's powder magazine. The explosion of the stored gunpowder was extremely powerful, killing 38 and wounding 222 American infantrymen (Turner 2000). By the end of the day, however, the British had paid a heavy cost, losing York to an American assault while further arming American ambition to formalize another attack on the Niagara Peninsula, this time by capturing Fort George.

On May 25th, 1813, with similar strategy and effectiveness as the victory over York, the American fleet commanded by Isaac Chauncey launched an aggressive assault on Fort George (see Figure 2.3) (Caffrey 1977). American reinforcements returning from the western shores of Lake Ontario increased troop presence at Fort Niagara to over 8,000 men (Dale 2001). Comparatively, British Brigadier-General John Vincent had roughly 1,050 British regulars, 300 militiamen, 28 men from the 'Coloured Corps' (a division composed of individuals of African descent), and over 50 Six Nations warriors stretched along an 18-kilometer frontier (Auchinleck 1855). As with previous encounters, the British were ill equipped to take on such a large invasion force. The Americans bombarded Fort George and the British troops were forced to retreat to Queenston. Once again, the British, in their last attempts to inflict greater casualties among the Americans, lit fuses connected to various powder magazines throughout the fort, just as they had done

before retreating from Fort York (Turner 2000). Unfortunately this time the explosion had minimal effect on American advancement.

Over the ensuing weeks the Americans would advance only as far as Stoney Creek before retreating once more to the eastern corner of the Niagara Peninsula. The Battle of Stoney Creek and Beaver Dams, taking place on June 6th and 24th, respectively, overturned the idea that Upper Canada would eventually capitulate to superior numbers of an American army. The Americans would never again reach as far into Canadian territory for the rest of the war.

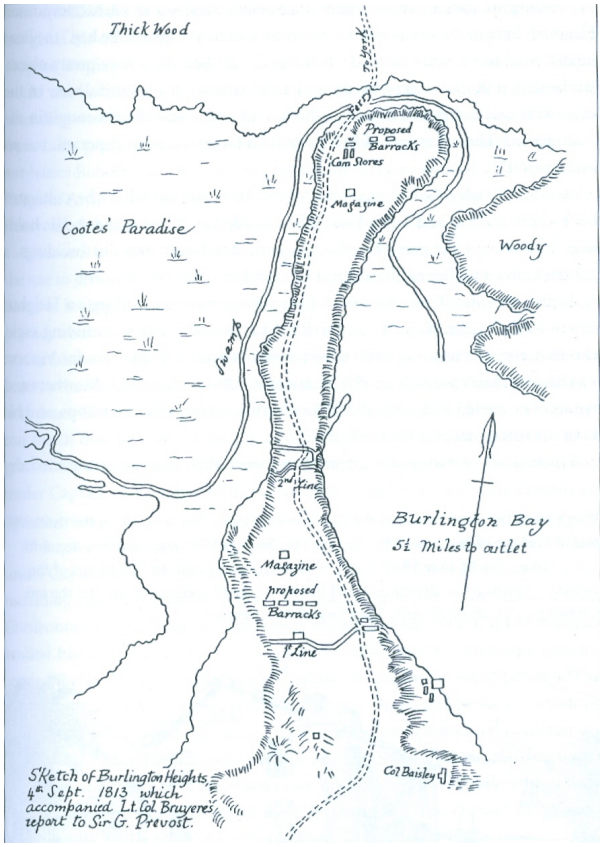


Figure 2.3: Burlington Heights showing position of British encampment (Elliott 2009: 53).

2.6 The Battle of Stoney Creek: May 28th – June 4th

As the American high command quarreled over the whereabouts of the British after the attack on Fort George, the British garrison had already begun to regroup at Queenston, resting briefly before marching southwest towards Beaver Dams atop the Niagara escarpment (Elliott 2009). Here the British were able to evaluate their strategic position relative to American detachments that, by this time, occupied Fort George and most of the surrounding land of the northeastern Niagara peninsula. Worried that the Americans might eventually catch up with the retreating regiments, General Vincent commanded his troops to march towards Burlington Heights, an area of high ground between Burlington Bay and swamp known as Cootes' Paradise (Figure 2.4). British detachments of the 8th, 9th, 41st and 49th Regiments had all but abandoned their positions along the Niagara frontier, and were forced to retreat to the southwest corner of Lake Ontario to make a final stand against the advancing American army (Fryer 1986).

With nearly a full day behind the British retreat, on May 28th 1813, American commanding Generals Henry Dearborn and Morgan Lewis set out to intercept what was thought to be a fleeing, scattered, and demoralized British army (Marquis 1920). Fortunately for the British, the Americans followed a southerly path to Queenston, allowing the retreat unabated access to Queenston road running West along the lakeshore to Burlington Heights. By May 29th, British infantry and artillerymen reached Forty Mile Creek (present day Grimsby). With bad weather and high winds keeping the American fleet from outflanking Vincent's army along Lake Ontario's western shoreline, Vincent's men also avoided Lewis' uncoordinated attempt to capture his retreating companies by

water (Jacobs 1969). General Vincent, initially acknowledging Mohawk War Chief John Norton's aims to stay and defend Forty Mile Creek, decided to push further West to the Head of the Lake, an area today comprised of the heights, bay, and beach of Burlington (Elliott 2009). This brief lapse in conflict allowed Vincent to gather supplies and mobilize his large battalion, which now numbered upwards of 1,600 men, to construct a defensive position with a significant number of regular soldiers and field artillery (Elliott 2009; Jacobs 1969). From the heights, Vincent's army would await further orders from General Prevost concerning the deployment of reinforcements to Kingston, which was generally understood to be the final destination. The militia, however, would remain stationed West of Fort George, Queenston, Chippawa, and Fort Erie, which was firmly under control of American forces (Hickey 1989).

By May 31st the British Regiments had marched towards the homestead of Richard Beasley, a merchant Indian trader and politician whose property stretched the ancient glacial lakeshore of Burlington Heights. This 5 kilometer long peninsula, rising 30 meters above the Lake Ontario shoreline, was an advantageous military vantage point. This position gave the Royal Army a clear view of the Lake Ontario shoreline running East of the heights (Elliott 2009). By the eve of May 31st, the British army had reached the West end of Burlington Bay (present day Hamilton Harbour). Upon arrival they immediately evicted the Beasley family and the house quickly became living quarters for Vincent and other high-ranking military commanders, and their barn transformed into a military barracks (Elliott 2009). The stretch of the heights morphed almost overnight into a defensive base, with trenches dug for gun positions and *abatis* (crude defensive

blockades) constructed out of sharpened tree stumps and branches to thwart an American frontal assault. The retreat was over. Vincent's men were now firmly entrenched on the heights and awaited either further orders or an attack.

By June 1st, American Brigadier General William Henry Winder's troops had arrived at Fifteen Mile Creek, including three companies of the 2nd Artillery. The bulk of the infantry, however, remained at Twelve Mile Creek (Figure 2.4), where they joined forces with the 13th Infantry (Elliott 2009). The march from Twelve Mile Creek onwards was treacherous and slow, with several bridges and fallen trees removed from creeks and rivers by the retreating British in hopes of stalling the advancing American brigade.

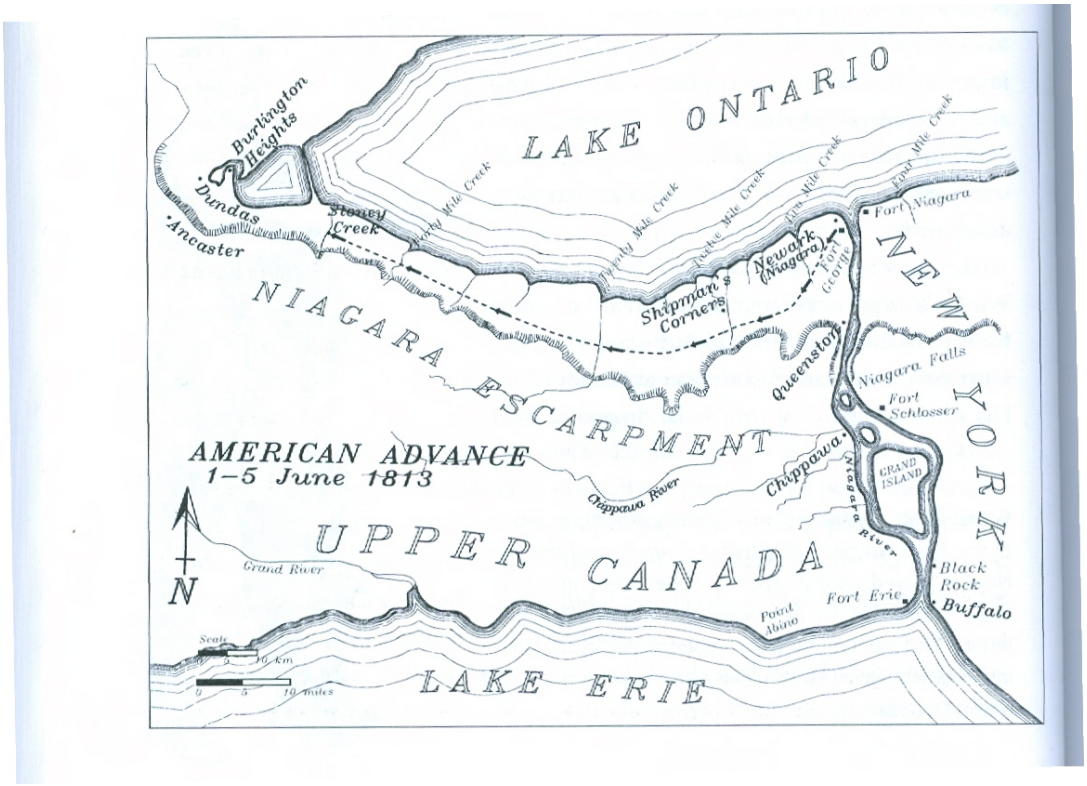


Figure 2.4: The American advance into the Niagara Peninsula June 1st-5th, 1813, showing the location of Twelve and Fifteen Mile Creeks (Elliott 2009: 64).

The British received little support from local militia and Native warriors during the days leading up to battle (Benn 1998). The only support General Prevost afforded was a small naval convoy headed by Captain Sir James Yeo, who set sail from Kingston carrying approximately 220 troops of the King's Regiment, plus supplies (Horsman 1969). Indeed, clothing and ammunition ran dangerously low. General Vincent became increasingly agitated over the lack of supplies and external support, knowing that he could rely on but a few indigenous fighters, including John Norton and his cousin from the Cherokee tribe, a small number of Chippawas, one Mohawk and Cayuga, and possibly three warriors from the Delaware tribe (Elliott 2009). The militia was also largely absent from fighting at Stoney Creek. Although staffed with a few dragoons, artificers (military servicemen trained in mechanics), artillery drivers, and a small number of selected militiamen, the rest had retired back to their farms and homes (Elliott 2009). Nevertheless, by June 4th, John Norton and a dozen of his Native warriors set out to Forty Mile Creek to harass Winder's brigade who, like their British counterparts, awaited Brigadier General John Chandler's reinforcement of troops and supplies from Sackets Harbour (Dale 2001). Ambushing a small scouting party of light dragoons not far from the American settlement, Norton and his fighters fired several shots at the soldiers, killing one and mortally wounding another. This had a profound effect on the psychological dispositions of American infantrymen, most of whom held the belief that the British had enlisted "all the Indians in Canada" for allied support (Elliott 2009: 73). The length of this victory was short, however, and Vincent himself knew that his brigade would eventually face an overwhelming display of American firepower. Troop numbers after the

rendezvous with Brigadier General Chandler increased Winder's forces to approximately 3,750, with some estimates citing over 4,000 infantrymen (Hickey 1989; Horsman 1969; Elliott 2009). The ranks of the American brigade included three artillery companies, two companies of riflemen, ten regiments of regular soldiers, one light horse squadron, and three light artillery companies with nine field cannons (Elliott 2009). This military procession, according Elliott (2009), took roughly a half-hour to pass at any point along Queenston road. After leaving Forty Mile Creek (Figure 2.4), Chandler planned to take the heights by deploying along Burlington Beach, which, if properly executed, would cut the British off from retreating east towards York. A direct assault on the heights, as calculated by the two generals in charge, was avoided.

The British light company of the 49th Regiment marched east on June 5th, 1813 towards the village of Stoney Creek, a small hamlet with less than 700 inhabitants. The American regiments were also in the vicinity at this time, to the east of the Gage farm (Figure 2.5). The first skirmishes that day took place outside Edward Brady's tavern, an establishment on Queenston road where a small number of the British light company was stationed (Biggar 1873).

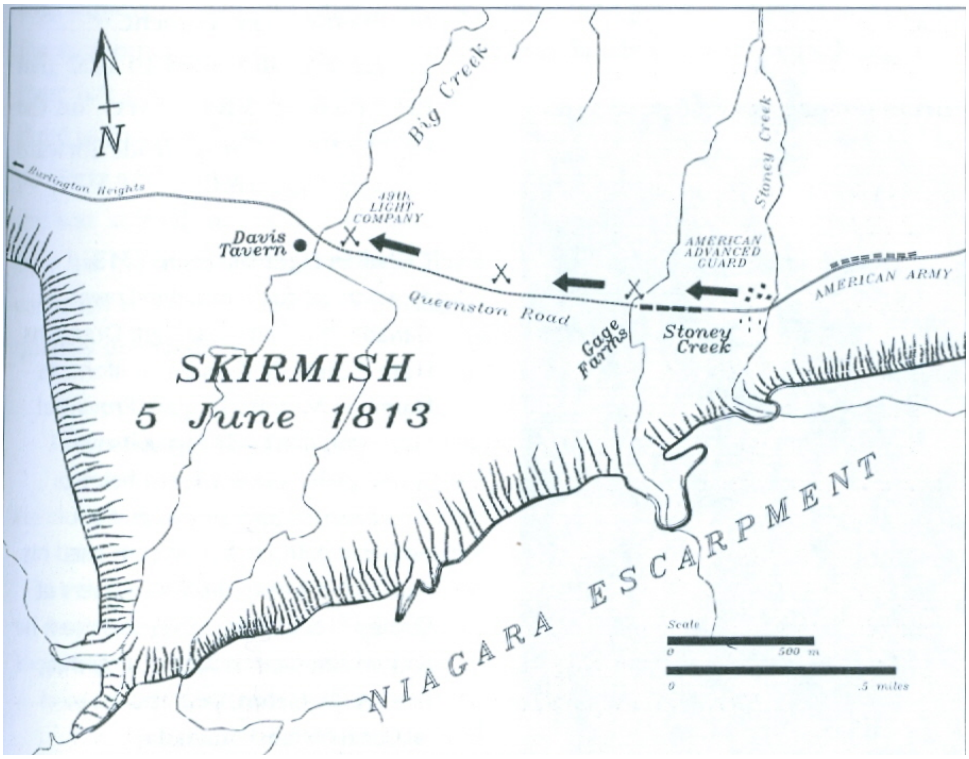


Figure 2.5: Map showing the location of the first skirmish between American and British forces near Davis' tavern. The location of the American army is east of Stoney Creek (Elliott 2009: 83).

The British light company was outmatched with only 70 regulars against 400 American troops and light dragoons. After firing several two-man file volleys, the 49th light company retreated into the woods. More fighting ensued as the British took refuge in William Davis' barn (Figure 2.5). Faced with superior American firepower and numbers, the redcoats retreated once more. Exact casualty figures are unknown, but likely totaled less than 15 (Elliott 2009). Again, with the persistent belief that Native warriors supported the British, retreating to the woods no doubt brought to the mind images and thoughts of massacre and scalping to the Americans. Disorder characterized the structure

of the American encampments (Biggar 1873). Lieutenant Colonel Harvey observed this chaotic disorder firsthand. As he descended the heights to rendezvous with the 49th light company, he was able to scout within reasonable distance the basic layout of the American camp's advance guard. Unable to get the full view, however, Harvey sent a dispatch to inspect the rest of the encampment. What he discovered would be the basis for the ensuing battle; that "…the camp was not secure, unit positions were haphazard and the guns poorly protected. In short the American camp was vulnerable" (Elliott 2009: 89). This intelligence led several commanding officers to suggest a night attack. Although the artillery commanders unanimously rejected the proposed night raid, strategy gave way and a surprise attack was accepted as the best solution to thwart American efforts to take the heights. American commanders Major John Smith and Assistant Defense Commander, Lieutenant Donald Fraser, possibly anticipated a night attack based on the relocation of the 25th Infantry to higher ground. However, it is more likely that Smith and Fraser were merely securing the front lines in the unlikely event of an indigenous assault rather than anticipating a preemptive strike by the British.

2.7 An Attack by Night: June 6th, 1813

Lieutenant Colonel John Harvey's night expedition comprised several of England's mature battalions, specifically the King's (8th) Regiment of Foot and the 49th Regiment (Marquis 1920). Officers of these two military bodies saw combat during earlier battles of the 1812 war, such as the Battle of Queenston Heights, or had been commissioned from overseas while fighting the French. Harvey's lines were also composed of other battle-hardened regiments and companies, including Cameron's

Provincial Incorporated Artillery Company, the Niagara Provincial Light Dragoons, York, Oxford and Lincoln Regiment, the Incorporated Militia of Upper Canada, and a dozen of Norton's Native warriors (Elliott 2009). Between 1:30 and 2:00 on the morning of June 6th, Harvey's battalion of approximately 700-800 men had reached Davis's tavern, where the brief skirmish between the 49th light company division and American light dragoons had taken place the previous day (Caffrey 1977; Elliott 2009). Stealth and silence accompanied the men as they progressed through the darkness towards the scattered American camps.

Stationed around the American camp were several pickets and guards, whose jobs were to secure and negotiate the perimeter around the settlement. Entering within American lines would have been a difficult task, yet the British managed to secure these positions without alarming the main body of the American infantry as they approached. It was during this stage of the operation that the local legend of a young scout, Billy Green, was born (see Elliott 1994). Another account claims that Harvey – or some other British officer – detained the first American sentry at bayonet point. After exchanging the password for the young private's life, Harvey approached the second sentry with this password (Elliott 2009). Still, it is entirely possible that the British captured or killed the sentries by bayonet without a sound being emitted. Notwithstanding British means to subvert and gain entry into American lines, they were subsequently able to do so without one musket shot being fired and thus retained the element of stealth and surprise, advancing within 300 yards to the advanced American line before firing their muskets.

The first shot was fired at 2:20 in the morning on June 6th by an American sentry just a few hundred yards from the American main guard (Elliott 2009). Not long after, the British companies, excited to renounce their concealment began yelling and whooping as they made their way through the dark (Caffrey 1977). The element of surprise was lost. Lieutenant James FitzGibbon stated that: "The moment I heard the shouts spread amongst the men, I considered our situation very critical. For I was aware that it would be almost impossible to make the men silent again, and that consequently orders could not be heard or obeyed" (Elliott 2009: 119). The 49th and King's Regiment advanced on the main guard North and South of Queenston road, respectively. The King's Regiment, advancing south of Queenston road, contended with three times its numerical strength against the 5th, 16th, and 23rd Regiments of the American army. Against these odds, the element of surprise and darkness allowed the King's companies to inflict severe casualties on these American soldiers, who, incidentally, had the advantage of firing from higher ground (Elliott 2009).

Much confusion ensued as the British 49th light companies, faces now lit by the numerous campfires, haphazardly opened fire (Fryer 1986). No ordered volleys were to be completed as many men had yet to secure flints within their muskets (Turner 2000). Yet apart from much confusion, the American artillery divisions were the first to commence a battery assault, aimed specifically against Captain Jacob Hindman's forces on William Gage's farm lane. With surprising inaccuracy, Towson's artillery point (Figure 2.6) fired upon the lane that comprised both British and American troops and several American infantrymen fell under their own ballistics (Turner 2000). The entire

advance was described as ‘a continuous sheet of fire’, intertwined with random bayonet charges as regular soldiers struggled to sort friend from foe (Elliott 2009). Under the cover of night, the British Regiments were unable to penetrate the American advance without suffering a barrage of musket and cannonade fire. At battle’s midpoint many British soldiers who had been so confident in their initial approach, fled to the safety and darkness of the forest.

Approximately 20 to 30 minutes after the opening attack, the odds of gaining ground had turned in favour of the Americans; yet a crucial strategic mistake profoundly affected the outcome of the battle. In normal combat, artillery positions require infantry support. Towson’s artillery position was completely undefended; its men also without small arms to defend themselves in close quarter combat. Chandler, noticing that his artillery position was vulnerable to British charge, sent Winder a message to relocate the 23rd Infantry to take the advance position and provide cover for the battery. These orders, however, were never received. No lines were formed to protect Towson’s artillery barrage and, in a failed attempt to enforce the orders himself, Chandler’s horse, either shot or stumbling over uneven ground, fell knocking the general unconscious for several minutes (Horsman 1969; Marquis 1920).

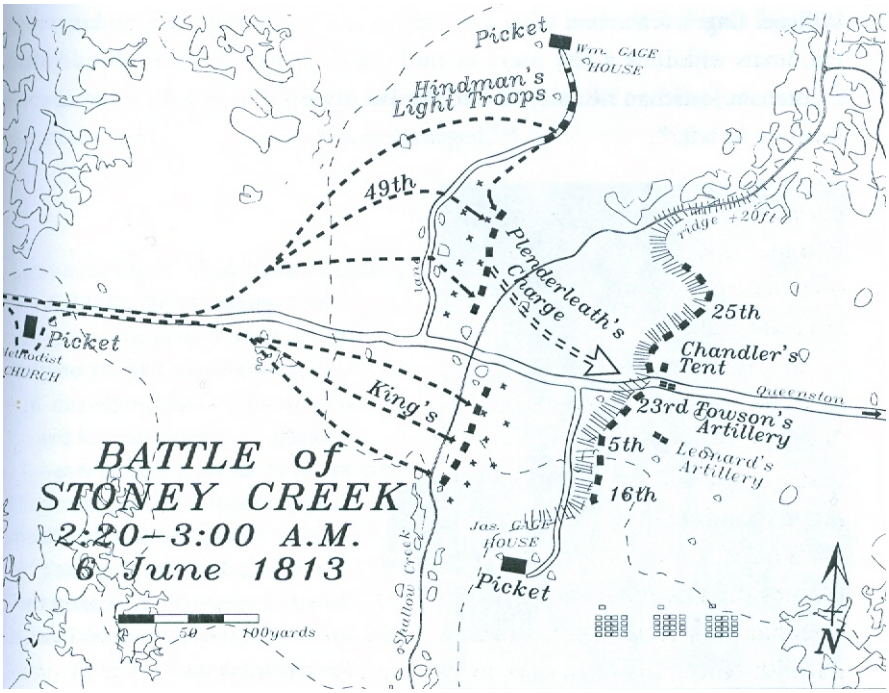


Figure 2.6: The Battle of Stoney Creek showing the location of the American camp and artillery on top of the knoll (Elliott 2009: 121).

On the opposite side, British Major Charles Plenderleath observed the position of the American infantry by the powerful ignition of musket and artillery fire. From this he was able to secure the exact whereabouts of Towson's battery position, which was located much closer to combat lines than British officers had previously recognized. The British 49th grouped into a small party of roughly 20 strong for a bayonet charge against the battery atop the knoll (Figure 2.6).

Regular soldiers of the 49th regiment charged while American artillery troops were rearming and loading the cannons; this brief lapse in fire gave them a chance to confront their enemies with 17-inch steel blades (Fryer 1986). Following Assistant Sergeant

Alexander Fraser, the British stormed Towson's position effectively "stabbing every horse and man they met", and continued to charge the 23rd Infantry before they retreated towards the rearguard (Elliott 2009: 137). Confused and disordered, the two Brigadier Generals Winder and Chandler fell to the British while trying to reestablish the position of the American frontline. They were captured and relocated to Burlington Heights (Coles 1969). Command rights were subsequently given to cavalry Colonel James Burn, who was not aware of his newly appointed position until several hours after the confrontation (Fryer 1986). In the end, and with nearly a quarter of the American army dispersed throughout the woods, the British had successfully acquired two pieces of artillery, taken 75 prisoners, several war horses, two captains, one major, and two generals (Elliott 2009). With American command in disarray and effectively absent, the British had narrowly escaped with victory.

Casualty figures for both sides are uncertain. American sources claim roughly 17 deaths and 38 wounded (Horsman 1969). However, Lieutenant FitzGibbon, upon close inspection of the battlefield and adjacent paths, purported to have counted at least 31 dead (Ibid). Officially, the tally of dead, wounded, or missing American soldiers was approximately 150-155 (Elliott 2009; Hickey 1989). Official British casualties were upwards of 213 soldiers dead, wounded, or missing (Elliott 2009). It is possible however that this figure was slightly higher – around 220 – if militia casualties are included in the official British account.

2.8 The Invasion of Montréal

Following the retreat of the Niagara region, plans had been drafted to attack Montréal by mid-autumn, 1813, via the St. Lawrence River. The battle was to take place on October 26th, 1813, with the defense of Upper and Lower Canada falling primarily on the French Canadian militia, a small contingent of British regulars, and a few Caughnawaga warriors. On the Canadian side Lieutenant-Colonel Charles Michel d'Irumberry de Salaberry was hastily organizing a defense of the hitherto unknown American invasion ahead. Sounded by the advancement of Purdy's battalion across the river, Red George MacDonell sent two companies of soldiers to defend the eastern ford of the river. As Purdy's advance guard of approximately 100 men waded through dense pine and undergrowth they approached MacDonell's battalion, immediately opening fire on each other (Marquis 1920). Confusion on both sides ensued, and some of Purdy's men, fearing the forest to be full of enemies, shot at their own troops while retreating. In the meantime, de Salaberry waited for the American approach on the opposite side of the river. Prior to battle General Hampton dispatched an officer to deliver a message to the Canadians enclosed behind their *abattis* (barrier) constructed out of fallen trees and bush, he said "Brave Canadians, surrender yourselves; we wish you no harm!" (Berton 1995). de Salaberry replied by shooting the young officer off his horse.

Canadian, British, and First Nations infantrymen were greatly outnumbered, so as with previous encounters, de Salaberry relied on strategic deception, convincing the Americans that they were now engaged in a much larger battle than initially anticipated (Suthren 1986). As the battle progressed, General Hampton's forces fell into disarray.

Canadian militia and indigenous warriors wildly ran in and out of sight of American battle lines, and across the river, Purdy's men were under assault by a small group of French Canadian militiamen firing from the opposite shoreline. General Hampton capitulated after several hours of fighting, believing his forces were vastly outnumbered.

His judgments were flawed; instead a Canadian force of 400 had successfully resisted an American force of over 4,000 (Hickey 1989). Similar events unfolded the following month. On November 11th, 1813, American forces led by General Wilkinson staged an attack on the British at Crysler's Farm, a small stretch of flat land near present day Upper Canada Village (Coles 1969). Wilkinson had approximately 8,000 troops while British commanders William Mulcaster and Joseph Waton Morrison had only 900 regular soldiers and militiamen to defend the St. Lawrence Waterway (Marquis 1920). Against all odds, the British again successfully resisted American invasion. Both conflicts resulted in few casualties on the Canadian and British side, with 5 and 22 killed during the battles of Châteauguay and Crysler's Farm, respectively (Berton 1995). Casualties on the American side were heavier, with approximately 50 killed along the Châteauguay and 102 reported lying dead at Crysler's Farm (Suthren 1986). By the end of the 1813 campaign Montréal, Kingston, and the Niagara Peninsula was securely in possession of the British, yet the Americans still occupied a small stretch of land in southern Ontario, at Amherstburg. The summer of 1814 would see a more professional American Army and firmly establish British respect for the Americans, but with Britain's war with France coming to an end in Western Europe, thousands of troops and military equipment would be sent to North America to reinforce the British colonies.

2.9 The 1814 Campaign: The Niagara Frontier and War's End

For the third time since 1812, American forces again attacked Upper Canada via the Niagara Peninsula, anticipating that this time they would capture Fort Erie, Fort George, recapture Fort Niagara – which at the time was firmly in the hands of 700 British troops – destroy the regiment stationed at Burlington Heights, sack York for the second time, capture Kingston, and occupy Montréal (Barbuto 2000). They would, however, only be initially successful at this attempt. Crossing the Niagara River from Black Rock and Buffalo, New York, an American force of 4,000 troops besieged Fort Erie capturing the settlement on July 3rd, 1814 (Coles 1969). Fearing a quick advancement on Queenston, Fort George and Niagara, British forces harassed the American advance at the crossing of every major creek before the Chippawa River (Dale 2001). A ferocious battle ensued once the Americans reached this river, killing over 100 British, Canadian, and Native warriors. The Americans suffered half these casualties, with just over 50 killed during battle (Dale 2001).

By July 24th, the Americans were again on the offensive, warring with British battle and artillery lines at Lundy's Lane (Geary 1912). The conflict ended in a stalemate, both sides reporting heavy casualties. The Americans then returned to Fort Erie to strengthen their fortifications in preparations for a British recapture of the fort. After the initial attack on August 15th, 1814, and several days of cannon and artillery bombardment, the fort fell back to British occupation (Turner 2000). In subsequent weeks the British would march on to Washington, burning several government buildings including the White House, on August 24th, in retaliation for the destruction of York in

April 1813. Although subsequent battles were fought in January 1815, the war effectively ended December 24th, 1814, when British and American diplomats signed the Treaty of Ghent in Belgium (Barbuto 2000).

The United States and Great Britain neither lost nor gained significant ground throughout the conflict. Provisions of the Treaty of Ghent mandated that all previously held territory would be returned to their governing powers prior to the declaration of war (Turner 2000). This included the exchange of Fort Niagara for the return of Amherstburg in southern Upper Canada. Yet in the end, the individuals who would suffer most under the stresses and destructive forces of war would be the inhabitants of villages once enveloped by musket, cannonade, and artillery fire, particularly Lewiston, Niagara, Fort Erie, and Youngstown, and the Native Americans of the western frontier who would eventually be dispossessed by American expansionism (Dale 2001). The 1812 war arguably marked the beginning of a Canadian identity, specifically as a result of resisting American expansion. For the Americans, the War of 1812 was their first attempt to extend their young, independent state, based on national interest and sovereignty. This process would continue throughout the 19th, 20th, and 21st centuries, further justifying American imperial aims throughout much of the world.

Chapter 3 The Bioarchaeology of Smith's Knoll and Skeletal Sample

3.1 Smith's Knoll Site Description and Excavations

The 12-acre stretch of land that surrounds Smith's Knoll was formerly property of the Crown and was granted to William Gage and his family in 1802. The name, Smith's Knoll, derives from the married name taken by Gage's great granddaughter, Louisa, and her husband, Herim Smith (Elliott 2009) (see Appendices A, B and Figure 3.1 for site location). Initial discovery of human remains were first made sometime in the 1880s by Allen Smith, the son of Louisa and Herim while ploughing the surrounding land. Eyewitness reports claimed that human remains were also interred in unmarked burials in the graveyard of a nearby Methodist Church (McCulloch 1932). In 1888, the Hamilton mortician, Charles Blachford, uncovered what he believed to be the remains of soldiers who died during the Battle of Stoney Creek in the church graveyard. Elliott (2009) has suggested that these two discoveries occured around roughly the same time. There is no evidence to suggest what Allan Smith or Charles Blachford did with the remains if they were exhumed.

Figure 3.1: Map showing the location of the Smith's Knoll (borden # AhGw-132) archaeological site and Battlefield Park, Stoney Creek (Google Earth Images).

Another account claims that the local millwright and historian, Peter Van Wagner, had dug up several bodies buried within the knoll (Elliott 2009). When the Wentworth Pioneer and Historical Society held its first Stoney Creek gathering in 1889, they were informed by Van Wagner that "a long trench in which forty friends and foe lie sleeping and waiting the last bugle call" and raised concern over the possibility of subsequent

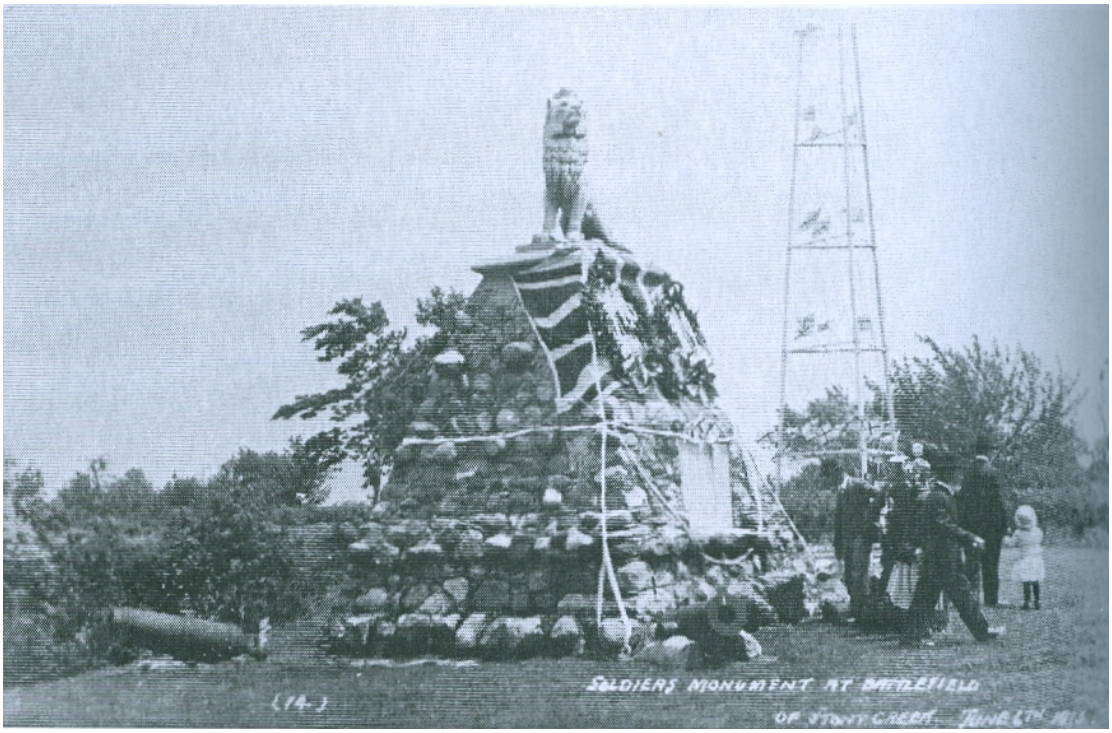


Figure 3.2: Photograph taken on June 6th, 1913, showing stone cairn and lion at Battlefield Park, Stoney Creek (Elliott 2009: 220).

public disturbance (Elliott 2009: 218). Ten years later Van Wagner told the President of the Wentworth Historical Society that 40 bodies had been exhumed from the knoll, 22 of which he had excavated for phrenological analysis (an early attempt to investigate the relationship between the contours of the skull, personality, and intelligence) (Mills 1899). By 1894 the Smith family bestowed property rights of the knoll to the Wentworth Historical Society to erect a stone monument and fence around the plot to commemorate the soldiers in return for a small payment of 50 dollars. The return, however, was much higher, and the family eventually received 400 dollars 14 years after the initial agreement to consecrate the land as a cemetery (Blyth 2003; Elliott 2009). A stone lion was placed

atop the stone cairn by 1910, in possession of the County of Wentworth Veterans' Association, which was then ceded to the municipality of Stoney Creek in 1995 (Figure 3.2) (Elliott 2009).

Archaeological excavations of the Smith's Knoll site (borden #AhGw-132) was carried out in 1998 and 1999 by RGS Archaeological Services and headed by Project Archaeologist and field director Rita Griffin-Short, revealing much more disturbance than anticipated. Archaeologists discovered several comingled assemblages of disarticulated human remains, refuse, and animal bones, rather than a proper cemetery, distributed around the Smith's Knoll historic monument. During her two field seasons Griffin-Short was able to exhume the partial remains of 24 individuals (Griffin-Short 2001). In 1998, the remains were sent to graduate student Claire McVeigh at McMaster University and in 1999, to Dr. Maria Liston (University of Waterloo) who analyzed the material from both field seasons to determine the age, sex, stature, and health of these soldiers. Their preliminary analyses suggested that these male soldiers were in relatively good health at death; an observation Dr. Liston claimed to be indicative of British rather than American origins, based on historical documentation supporting a well-nourished and well-prepared British army (Liston 2000; Griffin-Short 2001). Predictably, some of the remains displayed traumatic injury consistent with early 19th century warfare, specifically sharp force and projectile trauma resulting from bayonet, musket, and/or buckshot impact wounds (Liston 2000).

The primary goal of the RGS team in 1998 was to uncover and delineate the boundaries of the features that bisected the knoll. The remains were uncovered in sub-

soil, suggesting that there had been considerable disturbance between the initial discovery by Allen Smith and the first archaeological excavation in 1998. They discovered no intact, well-preserved burial features. Griffin-Short (2001) remarked that the trench, if extended further east, might uncover more remains on the adjacent property occupied by Rosa's Spa. Albeit unclear at this point, it is impossible to say with certainty that all human remains have been recovered from the land occupied by Rosa's Spa.

While the RGS team obtained the majority of artifacts during the initial 14 weeks of excavations, the trench was covered with plastic and backfilled until the following field season. The combined 1998 and 1999 excavations revealed several artifacts indicating continuous settlement from early 19th century to present. This included ceramics, clay pipes, civilian and military buttons, butchered animal remains, glass, nails, hardware, and other metallic objects, Onondaga chert flakes and point tip, as well as other miscellaneous objects, amounting to a total of 4,126 artifacts (Griffin-Short 2001). Appendix C depicts the plan of excavation undertaken at Smith's Knoll during the 1998 and 1999 field seasons.

According to the Smith's Knoll site report, the majority of recovered ceramics were British, representing the vast monopoly of early to mid-19th century production, export and import of goods between Great Britain and its Canadian colonies (Griffin-Short 2001). This is shown by ceramic style and decoration, namely cream and pearl-wares and blue and white transfer print tea-wares that were popular in Britain at this time. As manufactured types shifted post-1850, imports consisted of ironstone plates and pots, as well as blue and white flow-ware, which are further supported by 22 clay pipes dating

to the late 19th century (Griffin-Short 2001). Other seriated transitions were also discovered, specifically the shift in glass types from oil lamps to light bulbs, a technological transition and replacement that occurred at the beginning of the 20th century. However, the majority of recovered glass was identified as fragments of lamp chimneys and shades, with miscellaneous fragments belonging to windows, tables, canning, medicinal and liquor jars. Metallic objects comprise the highest number of recurrent artifacts, with a combined frequency of 46% (Griffin-Short 2001).

Recovered military buttons provided significant foundation to the historical data, mainly by confirming the presence of both British and American regiments involved in the battle. Griffin-Short (2001) identified 4 buttons attributed to the British 49th Regiment and 1 artillery button, along with 10 American 2nd Artillery Regiment and 7 standard issue pewter buttons of varying sizes. An unmarked British badge was also discovered whose regimental affiliation is unknown. The statistical frequency for all recovered archaeological materials is shown in Appendix D.

3.2 The Bioarchaeology of Smith' Knoll

Dr. Claire McVeigh, then a PhD candidate at McMaster University, analyzed the human remains unearthed in 1998. Her task was to determine the sex, age at death, stature, and pathology of the 8 individuals in her sample (bone fragments, $n = 434$). Estimation of sex was determined using the pelvis and mandible, whose morphology suggested that all individuals in this sample were male (McVeigh 1998). Age at death was determined through the analysis of tooth wear in 34 teeth, with subsequent

identification of 3 age categories based on these teeth: 18-30 (*n* = 21), 30-45 (*n* = 3), and >45 (*n* = 9). Dental remains provided the bulk of identifiable pathology including 3 teeth showing carious lesions together with calculus and alveolar resorption as a result of poor oral hygiene (McVeigh 1998).

Following McVeigh's (1998) preliminary study, Dr. Maria Liston was contacted to investigate the combined 1998 and 1999 skeletal assemblage. A minimum number of individual (MNI) count was established at 24 (Liston 2000). Age at death was determined using the auricular surface of the ilium instead of the dentition. This provided a rather broad age range for the entire sample, ranging between 25 and 49 years (*n* = 24). Stature estimates were obtained using 6 complete femora and 11 incomplete, reconstructed femora. Complete femora yielded a mean stature estimate of 174.16 cm (5'6"), while the mean value for the reconstructed femora was 172.7 cm (5'7"). Palaeopathological analysis revealed similar results to McVeigh's (1998) dental assessment, namely the presence of carious lesions and calculus, all symptoms of poor dental health (Liston 2000).

Trauma was also very prevalent within the Smith' Knoll sample, as might be anticipated by the hostile context from which these individuals were derived. Liston's (2000) initial description provided preliminary evidence concerning the types of injuries sustained by these soldiers during battle. Injuries included musket ball impact wounds on several cranial fragments, particularly evident on one occipital bone fragment (Liston 2000). Other identified injuries bear marks of musket ball and bayonet entry wounds, such as cut marks on the ribs, fibulae, and the right clavicle of one individual (Griffin-

Short 2001). Further palaeopathological and trauma analysis of the Smith's Knoll skeletal sample is underway, currently conducted by Dr. Megan Brickley and her MA student, Laura Lockau, at McMaster University.

In 2003 Lisa Blyth, a Master's student at the University of Western Ontario, conducted stable isotope analysis on a subset of the Smith Knoll sample, consisting of 34 teeth and 5 fragments of bone (Blyth 2003). Her primary objectives were to investigate the regional origins of these soldiers using oxygen ($^{18}O/^{16}O$) isotopes from bone and tooth phosphate. Her oxygen isotope results suggested that these individuals likely spent a significant amount of time in either North American or the United Kingdom, which did not help to differentiate British from American soldiers buried in the knoll.

3.3 2012 Smith's Knoll Sample Description

The sample used for this research is composed of 14 2nd molars, 21 left femora, and 1 mandibular fragment (Table 3.1). Second molars were chosen for analysis due to the availability of teeth in the sample, and to obtain dietary information during post-weaned, childhood. Approximately 80 teeth, 34 of which were selected by Blyth for isotopic analysis in 2003, represents the Smith's Knoll tooth collection. From this, nine 2nd molars from Blyth's sample were isotopically reanalyzed to obtain the oxygen and carbon ($^{13}C/^{12}C$) results from enamel carbonate (CO_3), as well as to obtain strontium ($^{87}Sr/^{86}Sr$) isotopic values for these samples. This reanalysis permits a comparison between the oxygen isotope results obtained for this research and those obtained by Blyth (2003), adding second regional indicator of origins by analyzing the strontium

composition of these 9 teeth. A further five 2nd molars that had not been previously analyzed were also selected from the Smith's Knoll tooth collection.

Mineralization of the 2nd molar begins at approximately 2.5 years and terminates between the ages of 7 and 8, providing information regarding the water and food sources consumed during this early stage in life (Sheuer and Black 2000). Unfortunately, given the disarticulated nature of the skeletal assemblage, the isotopic results represented by the teeth of these soldiers only provides cross-sectional information on childhood residency and diet, with bone representing a separate sample of individuals, apart from the teeth. The sample SK 110 – represented by the 2nd molar imbedded in a fragment of mandible – yields the only comparative example used to assess dietary change from childhood to adulthood at the individual level.

Unlike teeth, bone continuously remodels throughout life. This remodeling process, taking approximately 10 to 20 years to complete, provides dietary information regarding water and food consumed approximately 10 to 20 years prior to death (Manolagos 2000). Carbon and oxygen isotopic results from bone carbonate were analyzed to provide general insight into the total dietary breadth and long-term residency of these soldiers. Carbon and nitrogen ($^{15}N/^{14}N$) isotopes were also analyzed in bone collagen in order to acquire information regarding staple dietary items in the diet, differentiating C_3 (wheat and barley) and C_4 (maize) consumers from Great Britain and North America (Katzenberg 1991).

Table 3.1: Smith's Knoll skeletal sample, 2012. SC and SK denote Stoney Creek and Smith's Knoll, respectively.

N	Sample ID for Left Femora and Mandible*	Sample ID for M2s (* indicates reanalyzed samples
1	SK 001	*SC 29
2	SK 002	*SC 40
3	SK 034	*SC 41
4	SK 037	*SC 45
5	SK 040	*SC 47
6	SK 042	SK 110
7	SK 045	SK 283
8	SK 054	SK 286
9	SK 088	SK 288
10	SK 089	SK 294
11	SK 098	*SC 339
12	SK 099	*SC 344
13	SK 101	*SC 346
14	SK 103	*SC 393
21	SK 104	
15	SK 105	
16	SK 107	
17	*SK 110	
18	SK 111	
19	SK 116	
20	SK 119	
22	SK 122	

3.4 Identifying the Age and Sex of the Smith's Knoll Sample

Sex of the Smith's Knoll skeletal collection was determined using the pelvis and mandible by McVeigh (1998). McVeigh's (1998) analysis showed that the pelvic and mandibular morphology of these individuals indicated that these soldiers were indeed male. In addition to sex, preliminary identification of age was estimated using tooth wear (McVeigh 1998) and the auricular surface of the ilium (Liston 2000). While determining

age in this investigation relied solely on left femora, fusion of the femoral epiphyses suggested that the male soldiers represented in this thesis were either young adults (<20 years of age) or adult (>20 years of age). Two individuals, SC 40 and SC 45, in the Smith's Knoll sample were identified as possible young adults.

Chapter 4 Stable Isotopes and the Reconstruction of Diet and Geographic Origins

4.1 Stable Isotopes: An Introduction

The fields of chemistry and physics advanced rapidly at the beginning of the 20th century, particularly in the new branch of elementary physics called quantum mechanics. From the earliest attempts to define the structural components of nature, modern scientific techniques had verified the existence and behaviour of both atoms and their sub-atomic constituents (e.g. protons, neutrons, electrons, and quarks). Further attempts to define the properties of these particles uncovered interesting sub-atomic peculiarities regarding the radioactive processes of various elements in the periodic table (Attendorn and Bowen 1997). Experiments devised during the late 19th and early 20th centuries identified radiogenic atoms by collecting the energy emitted (radioactive decay) by these elements over time. Stable isotopic experiments that measured mass balance differences between atoms occupying the same elemental category in the periodic table were discovered not long thereafter. Unlike radiogenic elements, (e.g. ^{14}C, ^{40}Ar, ^{235}U, and ^{232}Th), stable isotopes are the product of stellar and supernova nucleosynthesis or isotopic decay, and are therefore fixed (Attendorn and Bowen 1997). Subsequent studies on the isotopic composition of various vertebrate tissues revealed that these biological components reflected the isotopic composition of food and water consumed during life (DeNiro and Epstein 1978, 1981). These investigations were then expanded to test the carbon and

nitrogen isotope composition in prehistoric human remains (Chisholm et al. 1982; Vogel and van der Merwe 1977), including the variability of other stable isotopes, such as oxygen (Schwarcz et al. 1991) and strontium (Ericson 1985). Testing environmental and biological materials from bioarchaeological (and modern) contexts has since provided substantial information regarding diet and human migration throughout antiquity. This chapter is an introduction to the basic principles of stable isotope analysis in bioarchaeological research, and describes the inherent problems (diagenesis) in bioarchaeological research when environmental contamination in human remains is high.

4.2 Stable Isotopes in Nature

An isotope is an element comprised of the same number of protons but different numbers of neutrons. This asymmetry within the atom increases the mass of the element but has no effect on atomic charge (Pollard et al. 2007). Many of the naturally occurring isotopes are incorporated in both biological and non-biological components of organic and inorganic systems. In order to explain the distribution and mass abundances of various stable isotopes in nature, particularly as they exist on earth, a brief summary of stellar formation and nucleosynthesis is reviewed.

The solar system formed at least 5 billion years ago beginning with the birth of our sun. According to astronomers our sun was the result of a dense hydrogen rich cloud that collapsed under extreme gravitational forces, in equilibrium with the pressure produced by nuclear reactions at its core (Beatty et al. 1999). The remaining matter that orbited our proto-sun then accreted to form the planets of our solar system. All of the

matter of the surrounding disk was comprised of elements formed either by the Big Bang or prior nucleosynthesis in a past, dead star. More likely, the stable isotopes of carbon (^{12}C and ^{13}C), nitrogen (^{14}N and ^{15}N), and oxygen (^{16}O, ^{17}O, and ^{18}O) were produced in a previous star at least 1.1 times more massive than our sun, hot enough to ignite a nuclear chain reaction called the carbon-nitrogen-oxygen (CNO) cycle (Seeds 2005). This nuclear reaction continuously fuses hydrogen into helium using carbon, nitrogen, and oxygen as a reactionary template (Figure 4.1). Other stable isotopes, such as strontium (^{86}Sr and ^{87}Sr), originated either from the decay of rubidium (^{87}Rb) or slow neutron capture (S-process), a fusion process that takes place during the red giant phase of a dying star (Richter et al. 1992).

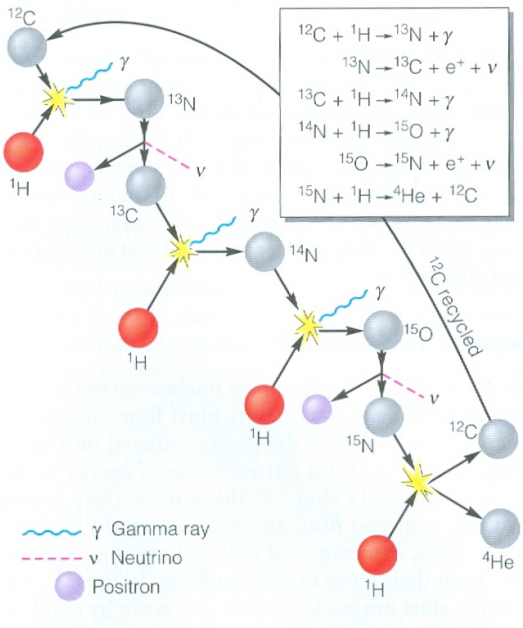


Figure 4.1: The CNO cycle depicting ^{12}C as the catalyst for hydrogen-helium nuclear fusion. High temperature fusion results in the stable isotopes of C, N, and O (Seeds 2005: 223).

Of the light elements, the stable isotopes of C, N, O and Sr are the most frequently used in bioarchaeological research. In terms of prevalence, the lightest isotope (e.g. ^{12}C) is generally more abundant in nature, with the others present in trace amounts (e.g. ^{13}C) (Brown and Brown 2011). Table 4.1 lists the atomic stable isotopes relevant to bioarchaeological investigation.

Element	Isotope Mass Numbers	Proportion in Nature	Stability
Carbon	12	98.93%	Stable
	13	1.07%	Stable
	14	one part per trillion	Half-life of 5730 ± 40 years
Nitrogen	14	99.64%	Stable
	15	0.36%	Stable
Oxygen	16	99.76%	Stable
	17	0.04%	Stable
	18	0.20%	Stable
Strontium	84	0.56%	Stable
	86	9.86%	Stable
	87	7.00%	Stable
	88	82.58%	Stable

Table 4.1: Properties of the stable isotopes most frequently used in bioarchaeology (Brown and Brown 2011: 80).

Stable isotopes are subject to a variety of environmental and physiological factors that influence their distribution and composition in different types of materials. This chemical differentiation is called fractionation, a process whereby a measurable mass difference in the heavier isotope is observed between the substrate (e.g. water and food) and product (e.g. consumer) (Pollard et al. 2007). Substrate and product fractionation reactions, rates, and differences are generally well understood. The first, or kinetic isotope

fractionation, is defined as the reaction resulting from the addition of a chemical property (Schoeninger 1995). For example, different types of plants incorporate ^{13}C in their tissues in different proportions. The amount of ^{13}C in plants is controlled by chemical reactions that convert sunlight and CO_2 into organic compounds (i.e. photosynthesis), such as sugars to produce cellulose (Pollard and Heron 2008). The second fractionation effect, called equilibrium fractionation, is defined as a reaction resulting from a physical property (Schoeninger 1995). Temperature and evaporation, for example, are two main physical factors that control the global distribution of ^{18}O (Gat 2005; Hoefs 2004). Some isotopes, such as ^{87}Sr, undergo no fractionation process in nature. Instead, strontium from the bedrock (or weathered from adjacent outcrops geologically composed of rocks deposited from by retreating glaciers) will be incorporated into the tissues of plants and subsequently passed on unaltered to consumers (Kusaka et al. 2009; Schwarcz, personal communication, 2012). In other words, the strontium value for these tissues will be the same as the strontium of the regional soil, provided that the organism subsisted off plants and animals local to that area, and that the soil was deposited from local geological sources (outcrops and hilly terrain) into local valley regions (see Chapter 7, section 7.5, for a detailed discussion on future considerations in strontium isotope research). The stability of ^{87}Sr in geological and biological systems is therefore a useful tool to provenience an organism's geographic origins or track migration, particularly in tissues that form early in life, such as tooth enamel.

Isotope geochemists have adopted the delta (δ) notation to magnify the small traces of the heavier isotope against the more abundant lighter isotope, relative to an

international standard (Gourcy et al. 2005). Carbon ($^{13}C/^{12}C$), nitrogen ($^{15}N/^{14}N$) and oxygen ($^{18}O/^{16}O$) ratios are expressed as δ values in parts per mil (‰, or parts per thousand), and is defined by the following equation (Hoefs 2004):

$$\delta = \left(\frac{R(sample) - R(standard}{R\ (standard)}\right) \times 1000$$

Carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$) and oxygen ($\delta^{18}O$) values from organic (bone collagen) and mineral apatite are either enriched or depleted relative to the recognized standard. For carbon, the international measure is the Vienna Peedee Belemnite (VPDB) standard, which was set by the International Atomic Energy Agency (IAEA) after all CO_2 stocks from the Cretaceous belemnite outcrop (the source for the original PDB standard) in South Carolina was exhausted (Pollard et al. 2007). Nitrogen values are standardized against atmospheric N_2, or the AIR standard, and oxygen, relative to the Vienna Standard Mean Ocean Water (VSMOW) and VPDB standard (Pollard and Heron 2008; Gourcy et al. 2005). Oxygen phosphate values ($\delta^{18}O_p$) from hydroxyapatite are measured against VSMOW, while carbonate oxygen values ($\delta^{18}O_c$) against VPDB. There is no internationally recognized standard for $^{87}Sr/^{86}Sr$ values; these are set by internal laboratory standards (e.g. NBS 987) (Dickin 2005).

4.3 Carbon and Nitrogen Fixation

Carbon isotopes are fractionated twice before being incorporated into human tissue. The first kinetic effect is produced during plant photosynthesis, when atmospheric CO_2 ($\delta^{13}C$ = -7‰) is taken in through the stomata of plant leaves and H_2O taken up by the

root (Pollard et al. 2007). There are three types of plants whose metabolic pathways incorporate ^{13}C in different proportions; these are termed C_3, C_4 and CAM (crassulacean acid metabolism) plants (Larsen et al. 1992; White and Armelagos 1997). C_3 plants discriminate against ^{13}C more than C_4 plants, so organisms maintaining a consistent C_3 diet have collagen $\delta^{13}C$ values between -19‰ and -26.5‰. C_3 plants include wheat, rye, barley, rice, trees, shrubs, temperate grasses and sedges, aquatic plants, and algae (Pollard and Heron 2008). Alternatively, C_4 plants discriminate less against ^{13}C leading to less negative, or enriched, $\delta^{13}C$ values. Individuals maintaining a C_4 diet have collagen $\delta^{13}C$ values between -12‰ and -16‰ (Ibid). Important C_4 cultigens for humans include maize, sorghum, sugar cane, and millet. The third metabolic pathway, or CAM pathway, is characteristic of plants growing in arid, dry, aquatic and tropical biomes (Pollard and Heron 2008; van der Merwe 1989). CAM plants yield a wide range of $\delta^{13}C$ values, from -14 to -33‰, and include succulent plants, cacti, bromeliads, orchids, and aquatic angiosperms (Ambrose 1993; Eriksson 2004; Schwarcz and Schoeninger 2011).

Carbon isotopes undergo fractionation a second time once incorporated into the body. This metabolic fractionation varies between different organisms and is largely controlled by routing factors that influence isotope mass balance differences in different body tissues. Controlled dietary studies revealed that the fractionation offset between diet and collagen is +5‰ for herbivores and plants, and roughly +7‰ between carnivores and herbivores (Krueger and Sullivan 1984; van der Merwe 1989). Figure 4.2 is a generalized diagram showing the stepwise fractionation of atmospheric, C_3, C_4, and collagen $\delta^{13}C$ values through the food chain.

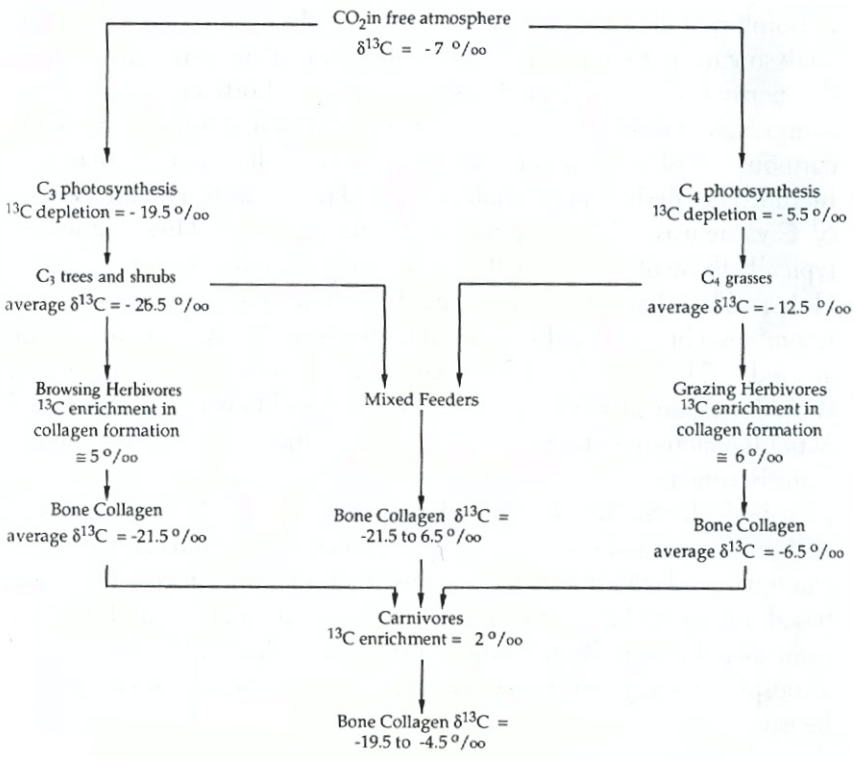


Figure 4.2: Diagram showing the fractionation steps of $\delta^{13}C$ throughout a C_3 and C_4 food webs (van der Merwe 1989: 110).

Controlled dietary studies by DeNiro and Epstein (1978), Tieszen and Fagre (1993), and Ambrose and Norr (1993), showed varying $\delta^{13}C$ values for different tissues of the body were predominantly a function of dietary routing (Figure 4.3). It is generally accepted that bone collagen $\delta^{13}C$ reflects dietary protein, with carbon atoms from protein preferentially routed to collagen, while bone carbonate $\delta^{13}C$ is believed to represent total dietary intake (i.e. carbohydrates, protein and fats) (Lee-Thorp and van der Merwe 1987). Krueger and Sullivan (1984) established the systematic difference between isotope composition and dietary routing when they discovered a constant offset between apatite

and collagen $\delta^{13}C$ values (denoted as $\Delta_{ap\text{-}col}$) between 4‰ and 7‰. Subsequently, Lee-Thorp et al. (1989) showed that this offset varied depending on an organism's trophic level status. This study found that herbivores had a larger offset ($\Delta_{ap\text{-}col} = 7 \pm 1$‰) than carnivores, omnivores, and birds ($\Delta_{ap\text{-}col} = 4 \pm 1.5$‰), suggesting that dietary components like carbohydrates and proteins from C_3 and C_4 sources vary depending on the amount of these items in the diet (Ambrose 1993). In other words, in cases where ^{13}C is enriched relative to the whole diet, producing a $\Delta_{ap\text{-}col}$ offset of less than 4.4‰, likely indicates a dietary intake composed of C_3 carbohydrates and marine protein. Alternatively, a $\Delta_{ap\text{-}col}$ difference greater than 4.4‰ would indicate a diet composed of C_4 carbohydrates and C_3 protein, confirmed by lower $\delta^{13}C$ values. This pattern was identified in individuals from prehistoric southern Ontario, when maize was introduced into a predominantly C_3 biome (Harrison and Katzenberg 2003).

Nitrogen isotopic ratios ($^{15}N/^{14}N$) are often used in dietary studies to identify trophic level and differentiate between diets composed of terrestrial and marine foods. DeNiro and Epstein (1981) showed that nitrogen isotopes in vertebrate tissues reflect dietary protein. Schoeninger and DeNiro (1984) subsequently discovered that $\delta^{15}N$ values increased with each subsequent step in the food chain, what has become known as the 'trophic level effect' (TLE). Nitrogen isotopic signatures ($\delta^{15}N$) are frequently plotted against $\delta^{13}C$ values in order to differentiate between C_3 and C_4 consumption and identify the trophic level of organisms subsisting off these plants (Figure 4.4).

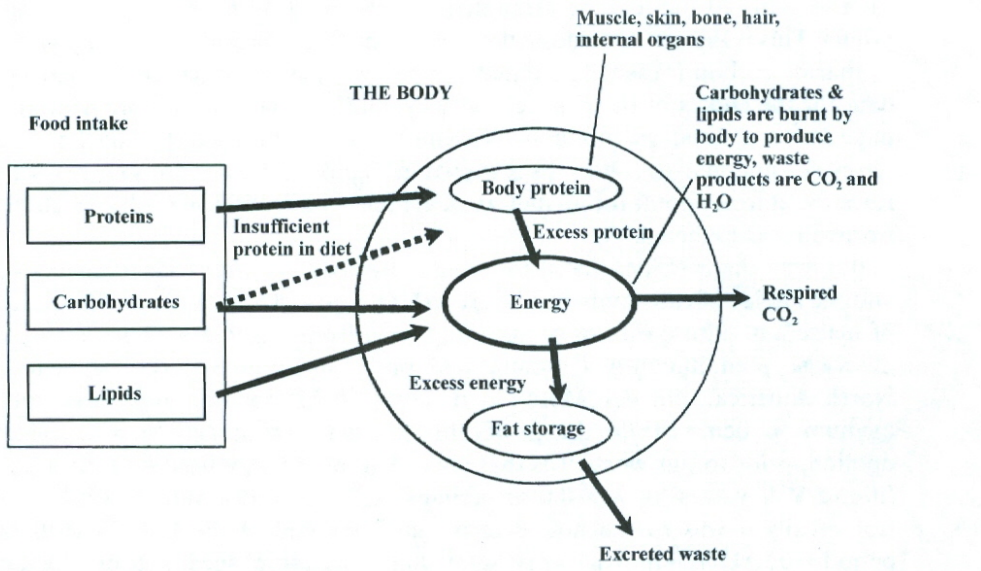


Figure 4.3: Diagram showing protein, carbohydrate, and lipid intake into the body (Pollard and Heron 2008: 355).

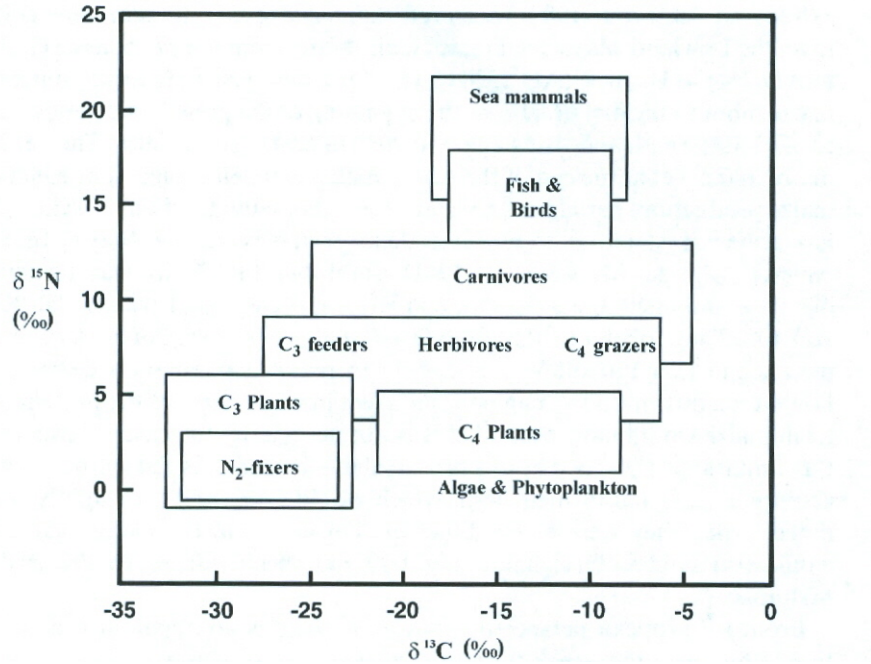


Figure 4.4: Carbon and nitrogen trophic level diagram showing marine and terrestrial food webs (Pollard and Heron 2008: 357).

Fractionation of ^{15}N begins in nitrogen-fixing (legumes) and non-fixing plants; nitrogen-fixing plants have the lowest $\delta^{15}N$ values. Subsequent stepwise enrichment of ^{15}N in the food chain has been measured between +3‰ and +5‰; however, a general enrichment of approximately +3‰ is commonly cited for human remains (White and Armelagos 1997; Hedges and Reynard 2007). A measurable trophic level effect of approximately 1‰ has also been detected in $\delta^{13}C$ and $\delta^{18}O$ values obtained from infant skeletons (Schwarcz and Schoeninger 2011; Wright and Schwarcz 1998, 1999). It has also been demonstrated that during breastfeeding infants are isotopically enriched in ^{15}N relative to their mothers, so they have higher $\delta^{15}N$ values (Fogel et al. 1989; Fuller et al. 2006). The isotopic signature approaches the mean adult isotopic levels following weaning as external foods are introduced into the diet (Ambrose 1993; Fogel et al. 1989; Katzenberg and Pfeiffer 1995; Schwarcz and Schoeninger 2011).

Since aquatic ecosystems have more trophic levels than terrestrial systems, it is possible to identify individuals relying heavily on marine resources versus those with predominantly terrestrial diets. Individuals consuming terrestrial foods have $\delta^{15}N$ values between 6‰ and 12‰, while those consuming a diet consisting of marine resources are significantly higher, with $\delta^{15}N$ values between 17‰ and 20‰ (Pollard and Heron 2008). An admixture of terrestrial and marine consumption produces intermediary $\delta^{15}N$ values, ranging between 12‰ and 17‰.

4.4 Stable Oxygen and Strontium Isotopes

Stable oxygen isotopes from human bones and teeth reflect the ^{18}O composition of meteoric water ($\delta^{18}O_w$) (White et al. 2000). This isotopic signal is preserved in both the phosphate (PO_4) and carbonate (CO_3) mineral phase of hydroxyapatite (Schwarcz et al. 2010). Oxygen isotope values from body tissues are in equilibrium with the total oxygen pool of body water. A balance between dietary and physiological inputs, namely water, food, and atmospheric O_2, and excretion, or exhaled CO_2, urine, and sweat, largely determines the $^{18}O/^{16}O$ composition of the body (Dupras and Schwarcz 2001). Since oxygen isotopes in environmental water vary with the regional distribution of local meteoric precipitation, they can be used to trace migration and identify regional origins. Killingley (1980) and Killingley and Lutcavage (1983) were the first to use oxygen isotopes to document migratory patterns in California grey whale and Loggerhead turtle populations. The first application of oxygen isotope analysis to human remains was by Schwarcz et al. (1991), who attempted to distinguish British from American soldiers recovered from the Snake Hill Cemetery, Fort Erie, Ontario. To date, oxygen has been extensively used to provenience human remains in a wide range of modern historic, forensic and prehistoric contexts (e.g. Bowen et al. 2009; Eckardt et al. 2009; Knudson 2009; Prowse et al. 2007; Turner et al. 2009; White et al. 2004).

The $^{18}O/^{16}O$ composition of meteoric water is determined by equilibrium and kinetic fractionation factors, these include: evaporation, evapotranspiration, latitude, distance from the coast, altitude, and temperature – collectively known as 'Dansgaard effects' (see Dansgaard 1964; Gat 2005; Sharp 2007; Schwarcz et al. 2010). Most notable

is the clear relationship that exists between air temperature and weighted mean meteoric $\delta^{18}O_w$ values (Figure 4.5). A second important fractionation factor influencing $\delta^{18}O$ values in teeth and bones is distance from the coast (Knudson et al. 2009). As rainclouds progress inland they become depleted in ^{18}O (Figure 4.6) (Sharp 2007). This fractionation effect means that individuals consuming water from inland regions will have more negative $\delta^{18}O$ values. On the other hand, individuals consuming water from coastal areas will show more positive $\delta^{18}O$ values. Another important factor to consider in bone and tooth apatite is the offset between oxygen phosphate and carbonate. Iacumin et al. (1996) showed this linear offset to be approximately 9.2‰, suggesting that both oxygen phosphate and carbonate reach equilibrium within the total oxygen pool in the body in linear proportions.

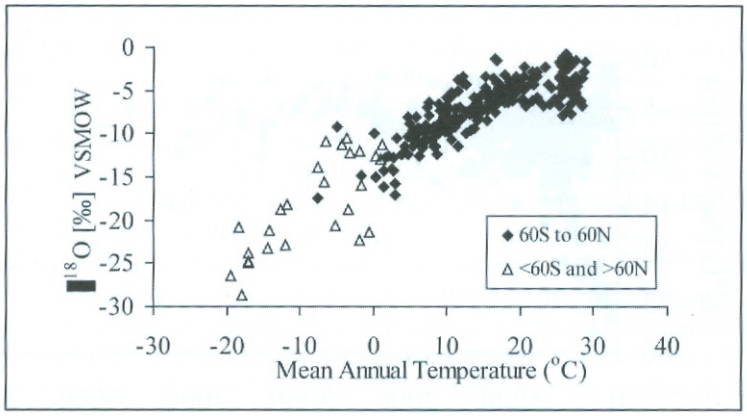


Figure 4.5: Relationship between temperature and weighted means of $\delta^{18}O_w$ for 325 Global Network Isotope Precipitation (GNIP) stations (Gourcy et al. 2005: 47).

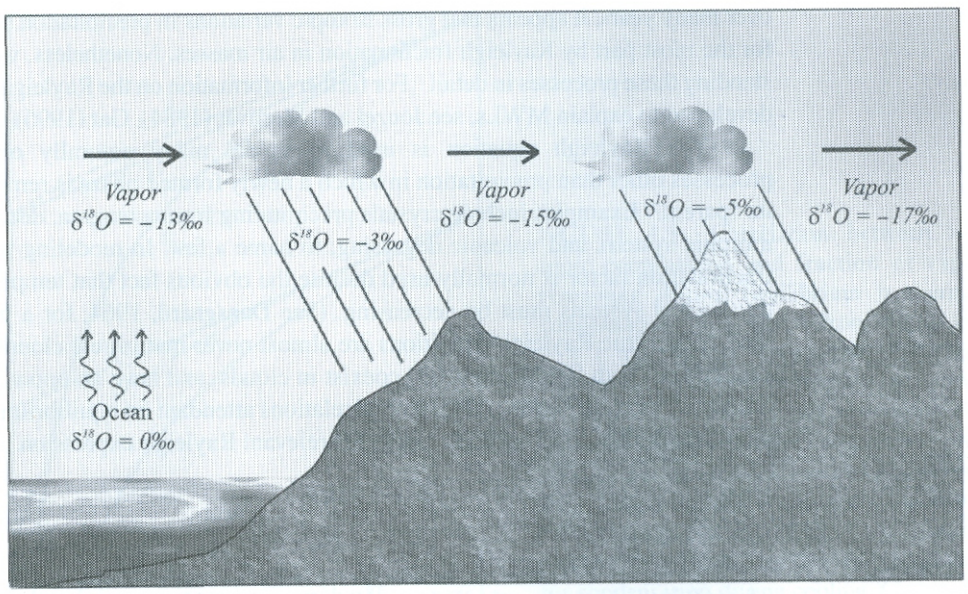


Figure 4.6: Diagram showing the large kinetic fractionation effect as rainclouds progressively move inland from the coast (Sharp 2007: 80).

Unlike the standard delta notation used for the lighter isotopic elements, strontium is represented as a ratio only. Some authors have used oceanic strontium ($^{87}Sr/^{86}Sr$ = 0.70918) as a universal standard (e.g. Chamberlain et al. 1997), however its standard use is uncommon in bioarchaeological literature. The amount of bioavailable ^{87}Sr is primarily a function of the amount of radiogenic ^{87}Rb in the local geology, which, in turn, reflects the age of the geological substrate (Faure and Powell 1972). Thus, $^{87}Sr/^{86}Sr$ values will be much higher in older rocks, as most of the ^{87}Rb in the rock will have decayed to ^{87}Sr. Alternatively, rocks of much younger age yield lower $^{87}Sr/^{86}Sr$ ratios due to the higher amounts of ^{87}Rb in the substrate. This ratio is subsequently taken up by plants and passed on unaltered to consumers throughout the food chain (Bentley et al. 2003, 2004; Giblin

2009; Sealy et al. 1991; Shaw et al. 2009). Ericson (1985) was the first to propose strontium isotope ratios as a tool to track prehistoric geographic mobility and regional origins. As a chemical element, strontium is very similar to calcium (Ca) and barium (Ba), and all three elements are readily incorporated in bone, teeth, and shell during the mineral formation of these tissues. Ba/Ca and Sr/Ca ratios have been used to identify trophic level effects in terrestrial and marine ecosystems, with particular emphasis on differentiating plant versus meat consumption (e.g. Arnay-de-la-Rosa 2009; Burton et al. 1999, 2003, 2008; Elias 1980). In addition, Knudson et al. (2010) documented trophic level effects in the food chain through strontium fractionation ($\delta^{88/86}Sr$). Although relatively new, this method is now suggested as a viable palaeodietary reconstruction tool.

The bioavailability and rock composition of $^{87}Sr/^{86}Sr$ has been mapped by bioarchaeologists and geochemists (e.g. Bataille and Bowen 2012; Evans et al 2010) and is required in order to match and provenience $^{87}Sr/^{86}Sr$ ratios from human remains. A large breadth of literature has contributed to the widespread use of strontium isotopes currently employed in forensic and archaeological investigations throughout the world (e.g. Beard and Johnson 2000; Bentley 2006, 2009; Hodell et al. 2004; Juarez et al. 2008; Juarez 2011; Meier-Augenstein 2010; Schwarcz and Walker 2005).

4.5 Skeletal Biochemistry

Bone is a highly dynamic structural tissue composed of organic collagen and inorganic hydroxyapatite. By dry weight, bone is composed of 30% collagen and 70% minerals (Brown and Brown 2011). The structural composition of bone and tooth mineral

is similar to the mineral dhallite, with the basic apatite structure, $Ca_{10}(PO_4)_6(OH)_2$, modified by the substitution of CO_3 (carbonate) or HCO_3- (bicarbonate) in the mineral lattice (Dupras and Schwarcz 2001; Hoppe et al. 2003; Kohn and Cerling 2002; Sponheimer and Lee-Thorp 1999). The development of bones and teeth are largely controlled by genetics, although bones require constant nutritional and biochemical maintenance in order to produce healthy organic and inorganic tissues throughout life. The isotopic signature from remodeled bone predominantly reflects the staple dietary items and water consumed roughly 10 to 20 years prior to death. Precise bone remodeling rates are currently unknown, however it is generally accepted that bone completely remodels approximately every 10 to 20 years (Hill 1998; Manolagas 2000).

Tooth development is controlled by genetics, so dental development and eruption stages are largely unaffected by environmental influences (White and Folkens 2000). Teeth begin to develop *in utero* and continue to grow postnatally until early adulthood, terminating between the ages of 18 and 20. During the first year of life, anterior teeth and the first permanent molar begin to mineralize. Between the ages of 2 and 4 the second permanent molar and premolars initiate mineralization, terminating between 6 and 8 years (Hillson 1996). The third molar forms last, initiating between the ages of 6 and 12 (Scheuer and Black 2000). Tooth enamel does not remodel, thus after initial mineralization the isotopic composition of enamel is fixed, and reflects the isotopic composition of the water and food ingested during this period of development (Katzenberg 2008).

4.6 Identifying Diet, Regional Origins, and Long-Term Residency Patterns in North American and Great Britain

Stable isotopes have been used to identify human migration and diet in a number of different geographic regions of the world, these include Central and South America (e.g. Buzon et al. 2011; Gil et al. 2011; Knudson and Torres-Roufe 2009; Slovak et al. 2009), North America (Craig et al. 2009; Ezzo et al. 1997; Katzenberg et al. 1995), south-east Asia (Bentley et al. 2009; Krigbaum 2003), Asia (Haverkort et al. 2008; Kusaka 2009), Oceania (Shaw et al. 2009), Africa (Buzon and Bowen 2010; Sealy 2006), and Europe (Bentley et al. 2003, 2005; Budd et al. 2003, 2004; Nehlich et al. 2009).

One of the most important questions in North American bioarchaeology, and Great Lakes archaeology in particular, concerns the spread, distribution, and wide-scale adoption of maize. Prior isotopic research established that maize was introduced in the lower Great Lakes region by A.D. 500 (van der Merwe et al. 2003; van der Merwe and Vogel 1978). Vogel and van der Merwe (1977) were the first to establish the temporal transition from wild resources to domestic maize in New York by measuring the carbon isotope composition of collagen from human remains recovered from 4 archaeological sites. Subsequent analysis discovered that by approximately A.D. 1000 maize comprised approximately 50% of the diet, reaching a peak dietary intake by A.D. 1350 (Harrison and Katzenberg 2003; Schwarcz et al. 1985; van der Merwe et al. 2003). With the adoption of maize (a C_4 cultigen), isotopic data obtained from post-A.D. 1000 skeletons showed higher $\delta^{13}C$ values compared to those of individuals exhumed from earlier sites, and whose isotopic signatures reflected a predominantly C_3 diet (i.e. more negative $\delta^{13}C$

values) (see Katzenberg 1984; Katzenberg et al. 1995). Maize remained a staple dietary item for individuals residing in North America from European contact onward, and was widely traded, adopted, and consumed by American, Canadian, and British settlers thereafter. In contrast, it was shown that $\delta^{13}C$ and $\delta^{15}N$ values for individuals of British origin remained relatively uniform over a 1500 year period, with $\delta^{13}C$ signatures reflecting C_3 dietary input, although $\delta^{15}N$ values were found to be higher during the medieval period due to fluctuating patterns in marine consumption (Müldner and Richards 2007).

Colonization of the Americas introduced new C_3 items into local diets in the form of wheat and rice. Katzenberg's (1991) preliminary study on bone collagen obtained from 1812 soldiers buried at Snake Hill cemetery confirmed that these soldiers had highly variable, mixed diets that may have included both C_3 and C_4 foods. These results were then compared to mean $\delta^{13}C$ results from European born and Native Americans from the North American northeast (Table 4.2). The mean $\delta^{13}C$ value of -15.8‰ (S.D. = 1.3‰) for the Snake Hill sample indicated that, although subsisting off C_3 foods such as wheat may have been relatively common for these soldiers, the majority of dietary protein had likely derived from maize (Katzenberg 1991).

Site	Mean	(‰)	s.d.	Ref.
Varden	8	-19.4	0.2	1
Mary Rose	9	-19.1	0.2	2
Saint-Pier	35	-19.0	0.3	2
Gray	50	-17.5	0.3	3
Red Bay	23	-17.2	0.4	2
Miller	5	-13.9	0.9	1
Ball	5	-12.6	1.0	4
Snake Hill	29	-15.8	1.3	5

Table 4.2: Mean $\delta^{13}C$ values from selected European (Mary Rose) and North American sites (Katzenberg 1991: 255).

The $\delta^{15}N$ values (range = 9.6 -11.8‰) for this sample were characteristic of a diet that included the consumption of terrestrial herbivores (or their byproducts), although 2 burials had $\delta^{15}N$ values of 13.0‰ and 12.9‰, suggesting either a diet high in terrestrial meat and fish, or a combination of both (Katzenberg 1991). Another important study by Katzenberg et al. (2000) concentrated on the isotopic differences between raw and cooked foods, and the impact that cooking had on bones exhumed from St. Thomas' Anglican Church cemetery, located in Belleville, Ontario. Although the authors showed that cooking food did in fact alter the original isotopic composition of dietary collagen, they concluded that males (mean $\delta^{13}C$ = -19.4‰; $\delta^{15}N$ = 10.2‰) and females (mean $\delta^{13}C$ = -19.7‰; $\delta^{15}N$ = 10.6‰) over the age of 18 were subsisting off a mix of C_3 and C_4 dietary items (Katzenberg et al. 2000). Historical research of the Upper Canadian diet during the 19th century confirmed that the diet included beef, mutton and pork, bread and cornbread,

and vegetables (Katzenberg et al. 2000). The authors also concluded that sugarcane (a C_4 cultigen) in the form of molasses was used to make cornbread and porridge, which likely added to the $\delta^{13}C$ variation in the sample (Katzenberg et al. 2000). These isotopic results were similar to those found in an earlier 19th century study by Katzenberg and Pfeiffer (1995), where bone collagen from individuals exhumed from a Methodist Church cemetery (Prospect Hill) in New Market, Ontario, yielded a mean $\delta^{13}C$ value of -19.5‰.

As mentioned above, determining place of origin and human migration by measuring the oxygen isotope composition of the human skeleton has become widespread in bioarchaeological research. Schwarcz et al. (1991) were the first to employ this method by measuring $^{18}O/^{16}O$ ratios in a small 1812 sample (n = 6) exhumed from a military cemetery at Fort Erie, Ontario. Preliminary analysis of skeletal oxygen-phosphate from this investigation revealed little variability in $\delta^{18}O_p$ values ($\delta^{18}O_p$ range = 12.14-12.89‰), suggesting that these soldiers originated from the northeastern United States, and were slightly more enriched than individuals from Ontario (Schwarcz et al. 1991). The $\delta^{18}O_p$ results for the Smith's Knoll sample analyzed by Blyth (2003) will be discussed with the $\delta^{18}O_c$ results obtained in this study in the following chapter. Unfortunately, there has been no study documenting the $^{87}Sr/^{86}Sr$ composition of human remains from historic 19th century archaeological sites.

4.7 Skeletal Preservation and Diagenesis

It is well established that teeth are less susceptible to post-mortem alteration. Unlike bone mineral, which has a smaller crystal structure, enamel hydroxyapatite is composed of larger crystals, making the mineral structure less porous and more robust than bone (Koch et al. 1997; Price 1989). There are several environmental and human factors that contribute the amount of organic and inorganic material left for recovery. Diagenetic and post-interment factors are the main determinants responsible for the loss of information in archaeological contexts, such modifications include soil chemistry, human and nonhuman animal removal or displacement, graviturbation resulting in the comingling of *in situ* material and erosion, along with other large scale ecological changes like wind, desiccation from the sun, and the effects of displacement from meandering river systems (White and Folkens 2000). Bone is much more likely to be modified by the surrounding geology, and microbial activity in particular (Brown and Brown 2011). The identification of diagenetic alteration in skeletal material is important because results yielded from poorly preserved remains may skew the original biogenic signature from the skeleton. In order to quantify the degree of diagenetic change in skeletal material a number of techniques have been used to assess collagen preservation (C:N-molar ratio in collagen, collagen % yield, C% and N%) as well as biogenic apatite recrystallization (Fourier transform infrared spectroscopy and X-ray diffraction) (Harbeck and Grupe 2009; Hare et al. 1991; Koch et al. 1997; Sponheimer and Lee-Thorp 1999).

In soluble environments fragments of collagen degrade through a process called hydrolysis, which breaks down collagen polypeptides into shorter fragments over time

(Harbeck and Grupe 2009; Pollard et al. 2007). The rate of collagen degradation is normally a function of soil pH. Highly acidic soil (pH = 1) increases this breakdown process 10-fold, whereas alkaline soils (pH = 12) can degrade collagen up to 100 times faster (Brown and Brown 2011). Other post-depositional factors affecting skeletal remains include microbes and fungi. These organisms aid in protein degradation by excreting enzymes that cleave peptide bonds into fragments that are then digested by the microorganism. It has been shown that this microbial alteration further depletes $\delta^{13}C$ values while enriching $\delta^{15}N$ values by an entire trophic level (Harbeck and Grupe 2009).

The standard method to assess collagen degradation in isotopic research has relied on the C:N-molar ratio to quantify bone collagen quality, a technique first introduced by DeNiro (1985), who concluded that C:N-molar yields between 2.9 and 3.6 indicated good collagen preservation. However, subsequent studies by Ambrose (1993) and van Klinken (1999) suggested that DeNiro's (1985) range was too broad, and that a more accurate variation of 3.29 ± 0.27 should be adopted. Ambrose (1993) and van Klinken (1999) also proposed % collagen yield by weight, as well as %C and %N as good indicators of collagen preservation. A minimum of 5% collagen was shown to produce well-preserved biogenic signatures, along with collagen samples whose percentage C and N values equal 3% and 1%, respectively (Schwarcz and Schoeninger 2011; van Klinken 1999).

Although teeth are more resistant to diagenetic processes, FTIR and X-ray diffraction techniques are frequently applied to evaluate diagenesis in inorganic samples from bones and teeth in archaeological contexts (Nelson et al. 1986). Mineral replacement requires favourable conditions in order for dissolution and eventual replacement between

organic and inorganic components to take place. Since the mineral matrix in bone is composed of elements that share certain chemical properties of the elements in regional soil, replacement of these atoms during the initial phases of fossilization are relatively fast, particularly in bone, altering the original bone δ value during mineral reprecipitation (recrystallization) (Price et al. 1992). In order to quantify the degree of mineral recrystallization, isotopic geochemist and bioarchaeologist frequently employ FTIR analysis to quantify the degree of recrystallization in bone and tooth apatite. This spectrographic technique measures diagenesis by splitting the phosphate absorption bands in the hydroxyapatite spectrum then quantifies the difference between the two FTIR peaks (Figure 4.7) (Schwarcz and Schoeninger 2011). Apatite alteration is proportional to the increase in the crystallinity index value, so the higher the value, the more mineral apatite has been recrystallized (Lebon et al. 2010). The separation value between the two FTIR peaks is measured using the crystallinity index (CI index), and is defined by the following equation:

$$CI = (A_{565} + A_{605})/A_{595}$$

Where A_x equals the absorbance at frequency x, biogenic bone mineral with a CI index < 3.8 is considered to be unmodified apatite (Shemesh 1990). Since bone apatite $\delta^{13}C$ and $\delta^{18}O$ are frequently measured to obtain dietary information, FTIR and X-ray diffraction techniques enable researchers to detect diagenetic alteration of the original biogenic signal. For example, Wright and Schwarcz (1996) showed that bone derived from Dos Pila, Guatemala, had been altered by decomposed vegetation and groundwater. They hypothesized that lighter and heavier $\delta^{13}C$ values from archaeological bone changed as a

result of decomposed organic matter, bone dissolution and subsequent reprecipitation, incorporating varying amounts of ^{13}C from the surrounding soil (Wright and Schwarcz 1996). Lighter $\delta^{18}O$ values were suggested to represent the exchange of oxidized carbon species with meteoric groundwater at ambient temperatures, which is isotopically lighter than bone $\delta^{18}O$ (Wright and Schwarcz 1996).

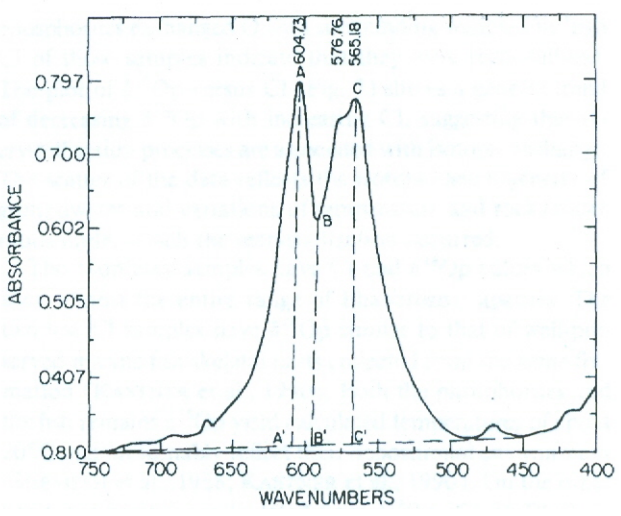


Figure 4.7: FTIR spectrum between 750 and 400 cm^{-1}. The CI index is determined by the formula: $(AA` + CC`)/BB`$ (Shemesh 1990: 2434).

4.8 Conclusions

Stable isotope analysis has greatly improved our understanding concerning the impact of environmental and dietary influences on the composition of human skeletal tissues. These methods have significantly refined the ways bioarchaeologists interpret human behavioural patterns in historic and prehistoric archaeological contexts using chemical techniques. Prior archaeological and physical anthropological research has

relied on material and skeletal evidence in order to decipher dietary and migratory patterns through the identification of material, faunal, and floral remains recovered from archaeological sites. Contemporary bioarchaeological analysis now has a suite of technical applications that have allowed a more nuanced understanding of these patterns through the analysis of human remains themselves. Furthermore, stable isotope analysis can be used in conjunction with other biomolecular techniques, such as nuclear and mitochondrial DNA (mtDNA) analysis, providing substantial data regarding human ancestry, kinship, and disease (e.g. Bentley et al. 2003; Wilson et al. 2007). The combined use of these methods has allowed modern bioarchaeological research to expand our current understanding of both the archaeological and historic records.

Thus far, research focusing on the dietary patterns of prehistoric and early post-contact indigenous populations using stable isotope analysis has focused primarily on the spread of maize throughout the North American continent, with less attention given to the European colonizers that followed. Yet a renewed interest in historic bioarchaeology, the lifestyles, behaviours, movements, and diet, of these recent inhabitants are becoming of great interest to anthropologists as this historic period in the United States and British Canada has largely been ignored. In advancing the literature that does exist, this research will contribute to prior research by addressing the complex traditions and customs regarding diet in early 19th century North America in a broad historical context, by assimilating the historical evidence regarding diet and migration with the isotopic results provided in Chapter 6. Instead of concentrating on small-scale geographic and historic scales, the results presented in this thesis are situated in the detailed historic documents

concerning intensive 19th century agriculture, spanning two continents. This research also adds to current literature by providing $^{87}Sr/^{86}Sr$ results from teeth, and is the first attempt to do so with 19th century soldiers who died on Canadian soil.

A second attribute of multi-isotopic analyses is the relationship between diet and locale. Incorporating the traditional dietary elements, C and N, with more the more recent applications of O and Sr to identify local and non-local dietary ranges have helped to narrow the gap between diet and geography. Advanced methods in bioarchaeological research are also partially dependent on advances in the fields of chemistry, physics, and biology. As instrumentation and detection become more sophisticated in these fields, our ability to apply new techniques to bioarchaeological materials will further refine the human-environment relationship of past human groups.

Chapter 5 Stable Isotope Methodology

5.1 Materials and Methods: Enamel Strontium

The Smith's Knoll tooth sample for strontium analysis consisted of 14 2nd molars. The extraction procedure for strontium analysis followed the protocol outlined by Dickin (2005). Each tooth was placed in an ultrasonic bath and washed in distilled water (dH_2O) until clean. Enamel powder was collected from each tooth using a hand-drill fitted with a diamond-tipped drill bit. More than 60 mg of enamel powder was collected from each sample in order to avoid the possibility of obtaining blank results from low sample yields. The amount of enamel powder per tooth sample is summarized in Appendix E.

The tooth powder was then dissolved in 2 ml of 2.5 M hydrochloric acid (HCl). After enamel dissolution the samples were centrifuged for approximately 10 minutes. Strontium separation was achieved via cation exchange resin, whose columns were cleaned with 20 ml of 6 M HCl before the samples were loaded. A 'spiked' sample (test sample) was used in order to calibrate the amount of solution and identify the stage of collection before loading any enamel samples (Dickin 2005).

The exchange columns were then cleansed with 10 ml of deionized H_2O, followed by another large concentrated wash of 60 ml of 6 M HCl, 10 ml of deionized H_2O, then 5 ml of 2.5 M HCl. Approximately 1 ml of each sample was added to the columns and washed in 1 ml of 2.5 M HCl, followed by another 3 ml wash of 2.5 M HCl. Each sample was eluted with 25 ml of 2.5 M HCl and collected in 4 ml intervals in Teflon beakers.

Strontium is collected near the end of elution. This is due to the increase in the atomic partitioning coefficient towards a solid phase (resin), which requires increasing volumes of solution (HCl) to release each element, a series which can be described in the following order: Fe, Na, Mg, K, Rb, Ca, Sr, Ba, and rare-earth elements such as Nd (Dickin 2005).

Each sample was then dried under a fluorescent heat lamp. At this stage the remaining substance in the Teflon beakers was clear (calcium crystals will be visible in the beaker if the sample is collected before strontium is released). Each sample was then deposited onto a single metal filament (composed of tantalum (Ta)), followed by the arrangement of each sample into a vacuum system. Enamel $^{87}Sr/^{86}Sr$ was measured with a thermal ionization mass spectrometer (TIMS) in the School of Geography and Earth Sciences at McMaster University. Results were normalized to NBS 987 ($^{86}Sr/^{88}Sr$) = .1197, with the total sample standard yielding an $^{87}Sr/^{86}Sr$ value of 0.71026 ± 18 (1σ).

5.2 Materials and Methods: Bone and Tooth Carbonates

The carbonate (CO_3) isotopic ratios of bone and tooth carbon ($^{13}C/^{12}C$) and oxygen ($^{18}O/^{16}O$) from 21 left femora, 1 mandibular fragment, and 14 2nd molars were prepared and analyzed following the procedures described by Sullivan and Krueger (1983) and Lee-Thorp and van de Merwe (1987). The bones and teeth were washed several times in dH_2O in an ultrasonic bath, then crushed (bone) and drilled (tooth enamel) using a pestle and mortar and drill, respectively. Approximately 30 mg of bone powder and over 10 mg of enamel powder were collected for isotopic analysis; all

samples were then placed in plastic culture tubes. The weights (mg) for bone and tooth carbonate are presented in Appendices F and G.

After weighing all bone and tooth samples, 0.04 ml of 2.5% bleach solution (NaClO) was added to each culture tube in proportions relative to sample weight. Each sample was agitated several times, leaving the bleached bone to react for two days (~48 hours) and tooth samples to react overnight (maximum of 24 hours) in order to dissolve organic compounds (e.g. lipids and collagen). All samples were centrifuged and rinsed 5 times with deionized water. Removal of diagenetic secondary carbonates was achieved using 0.04 ml of 1 M acetic acid-acetate (CH_3CO_2H) buffer per milligram of sample. These were agitated and left to react overnight (24 hours) before a second centrifuge and rinse (5 times with deionized water).

After removing the water, the samples were then placed in a drying oven at 60°C. Approximately 2 mg of powdered sample was placed in a steel cup for analysis on an OPTIMA Isocarb isotope ratio mass spectrometer (IRMS) in the MRSI (McMaster Research for Stable Isotopologues) laboratory. Oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotopic values were measured in parts per mil (‰), relative to VPDB; $\delta^{18}O$ values were then converted to VSMOW.

5.3 Materials and Methods: Bone Collagen

The collagen from 21 left femora segments and 1 mandibular section were extracted and analyzed following the preparatory methods described by Longin (1971), Chisholm et al. (1982) and Ambrose (1990) to obtain stable carbon ($^{13}C/^{12}C$) and nitrogen

($^{15}N/^{14}N$) isotopic ratios. Two femora segments were cut at mid-diaphysis; one segment for isotopic analysis and another for future histological research. Segments selected for isotopic analysis were broken down into smaller fragments using a hammer. Each sample was placed in an ultrasonic bath and washed several times with dH_2O. The samples were then placed in a drying oven at 60°C overnight (24 hours). Sample, collagen and vial weights (mg), as well as collagen yield (%) are presented in Table 5.1.

After washing, each sample was weighed and rinsed with 0.001 M HCl to remove any contaminants from the outer surface of the bone segments. Each sample was placed into glass culture tubes, acidifying the bone with 0.25 M HCl every 24 hours until demineralization was complete. Along with thick cortical bone, these samples were heavily mineralized, taking over a month to completely dissolve. Following mineral dissolution each sample was centrifuged and rinsed with deionized water 3 times. Humic and fulvic acids were removed using 0.1 M NaOH (sodium hydroxide) for approximately 20 minutes. Again, each sample was centrifuged and rinsed with deionized water 4 times. Hot water extraction was achieved by slightly acidifying each sample with 0.001 M HCl and placing the samples in an oven at 90°C overnight. Hot water collagen was extracted from glass culture tubes, added to Teflon beakers, and then placed in a drying oven at 60°C overnight. This procedure was repeated a second time the following day in order to maximize collagen weight for each sample. A small amount of deionized water was added to the Teflon beakers, liquefying the collagen, which was then added to glass culture tubes. These samples were left in a drying oven at 90°C overnight.

Approximately 0.45 mg of dried collagen was weighed and collected from the glass culture tubes and folded in tin cups for isotopic analysis. Bone collagen measurements were obtained using a Finnigan Delta Plus XP continuous flow isotope ratio mass spectrometer (CF-IRMS) in the MRSI laboratory at McMaster University. Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) values are expressed in ‰ relative to VPDB and AIR, respectively.

5.4 Methods for Identifying Diagenetic Alteration

The lack of time and resources has made it difficult to test diagenetic change in the bones and teeth analyzed in this thesis. Instead, prior FTIR analysis by Blyth (2003) has provided a basis from which the CI (crystallinity index) values of the bones and teeth sampled in this research can be compared. Since the entire Smith's Knoll collection had been subject to similar burial environments, Blyth's (2003) FTIR results are assumed to reflect similar mineral compositions of the bones and teeth isotopically analyzed here. Furthermore, quality assessment of bone collagen was achieved using the C:N ratio, C% and N% (wt.), and collagen yield (%). The atomic composition of bone collagen was obtained with the isotopic results, and is presented in the following chapter.

Table 5.1: Collagen Extraction Progress Chart

Sample ID	Bone Weight (mg)	Vial Weight After Washing (mg)	Vial + Collagen Weight (mg)	Collagen Weight (mg)	% Collagen Yield
SK 001	1092.8	7510.1	7601.3	91.2	8.3
SK 002	822.5	7472.2	7538.5	66.3	8.0
SK 034	1108.5	6065.5	6112.4	46.9	4.2*
SK 037	824.6	7495.5	7535.2	39.7	4.8*
SK 040	789.1	7479.1	7558.0	78.9	9.9
SK 042	1083.6	7546.0	7586.3	130.3	12.0
SK 045	518.9	7515.5	7516.5	1.0	0.2*
SK 054	828.4	7479.6	7563.4	83.8	10.1
SK 088	814.1	7469.1	7528.1	60.0	7.3
SK 089	948.2	7426.9	7523.8	96.9	10.2
SK 098	918.3	7518.5	7605.6	87.1	9.4
SK 099	744.6	7469.8	7291.2	21.4	2.8*
SK 101	657.6	7553.7	7578.3	24.6	3.7*
SK 103	1350.9	7472.6	7572.6	100.0	7.4
SK 105	820.4	7469.6	7503.8	34.2	4.1*
SK 104	730.4	7487.5	7531.7	44.2	6.0
SK 107	612.7	7391.8	7432.5	40.7	6.6
SK 110	605.2	7431.3	7490.0	58.7	9.6
SK 111	1117.6	7464.1	7520.0	55.9	5.0
SK 116	995.8	7531.2	7640.5	109.3	10.9
SK 119	915.5	7522.0	7551.0	29.0	3.1*
SK 122	1348.9	7495.2	7648.3	151.1	11.2
N = 22	*893.1*	*7417.1*	*7483.1*	*65.9*	*7.0*

5.5 Mass Spectrometry

Modern isotopic research of biological materials is routinely uses a multiple collection continuous flow isotope ratio mass spectrometer (MC-CF-IRMS) (Ambrose 1990; Pollard et al. 2007). Preceded by a relatively short preparation period, collagen samples are introduced into a mass spectrometer via a multi-turret holder, which are then deposited into a combustion furnace (800°C) where the samples are volatized to produce CO_2, NO_x, N_2 and H_2O gas (Ambrose 1990). Percentage results for C, O, and N are achieved by obtaining pressurized measurements of CO_2, N_2 and H_2O. Chromatographic columns (GC) separate the gases that are subsequently split by a magnetic sector device and measured by two or more detectors (Pollard et al. 2007).

Since strontium (^{87}Sr) is the decay product of the alkali metal rubidium (^{87}Rb), mass spectrometric applications used to yield $^{87}Sr/^{86}Sr$ ratios are the same as those interested in ascertaining parent to daughter atomic ratios for radioactive and stable rare-earth elements (REE). Initial separation from other metals is achieved using cation exchange resin, where samples are loaded into cation exchange columns, eluted, and then collected (Dickin 2005). After chemical separation, the remaining Sr salt solution is deposited on a metal filament and loaded into a thermal ionization mass spectrometer (TIMS). The ion source is then accelerated through an electromagnetic field and collected by multiple Faraday cups (detectors). Current heavy radiogenic and stable isotope analysis has moved towards multiple collection inductively coupled plasma mass spectrometric (MC-ICP-MS) and laser ablation applications, a move that has increased ion resolution and detection (Copeland et al. 2008, 2010; Pollard et al. 2007; Simonetti et

al. 2008). TIMS, however, continues to have the advantage of within-run correction due to smaller internal mass fractionation factors (Dickin 2005).

Chapter 6 Smith's Knoll Stable Isotope Results

6.1 Assessing Diagenetic Change in the Smith's Knoll Sample

In order to accurately interpret the isotopic results it must be shown that the original biogenic signal from bones and teeth are not affected by diagenetic influences. Unfortunately the time and scope of this research has made it difficult to subject the carbonate samples to FTIR testing. Blyth's (2003) prior isotopic analysis subjected her enamel and bone samples to FTIR analysis. The CI results obtained by Blyth (2003) are assumed to be representative of the preservation of bones and teeth analyzed in this study. In addition, bone collagen preservation was evaluated through % collagen yield, %C and %N, as well as C:N-atomic results, and are discussed below.

Blyth (2003) calculated the crystallinity index for the 33 teeth and 5 bones in her sample. The 9 reanalyzed teeth from Blyth's (2003) collection selected here and the additional 5 teeth and 22 bones are assumed to have similar CI values obtained by Blyth (2003) using FTIR analysis during her investigation. Infrared spectroscopy of tooth enamel yielded a CI range of 3.1 to 3.5 with a mean value of 3.4 (n = 33), suggesting low apatite recrystallization (Blyth 2003). Blyth's (2003) bone sample (n = 5) had lower CI values than teeth, ranging between 2.9 and 3.5 (mean = 3.1). Blyth's (2003) bone and tooth samples also showed no significant correlation between phosphate yield (Ag_3PO_4) and $\delta^{18}O_p$, an expected relationship if mineral dissolution had taken place during

diagenesis. The CI results for bones and teeth from Blyth's (2003) analysis are presented in Appendices H and K.

Collagen is subject to a variety of post-mortem diagenetic effects, such as soil pH, polypeptide fragmentation from pore water inclusion (hydrolysis), and enzymatic breakdown by microorganisms (Brown and Brown 2011; Harbeck and Grupe 2009; Pollard et al. 2007). For this reason, C:N ratios were obtained from bones in order to identify the amount of collagen degradation in the Smith's Knoll bone collection. Bone collagen from 21 femora segments and 1 mandibular section yielded a C:N range between 3.2 and 3.4 (mean = 3.2) (Table 6.1). The mean C:N ratio for the 22 bones overlap with the C:N value of 3.2 ± 0.2 proposed by Ambrose (1993) and van Klinken (1999); these values also conform to the broad C:N range put forward by DeNiro (1985), who suggested that a C:N value falling between 2.9 and 3.6 indicated well preserved collagen. All C:N values derived from bone collagen are consistent with low post-mortem organic alteration, and as a consequence, the $\delta^{13}C$ and $\delta^{15}N$ values reported here are assumed to reflect the original chemistry of these individuals prior to death.

Another method to detect post-mortem alteration is by measuring the weight percentage of collagen (% collagen), carbon (%C), and nitrogen (%N) in bone. As discussed in chapter 4, Ambrose (1993) and van Klinken (1999) suggested that collagen yields <5%, as well as elemental concentrations of C <3 wt.% and N <1 wt.%, indicate poor preservation. Per cent collagen, %C and %N, for the Smith's Knoll bone sample yielded mean results of 7.0%, 49.5%, and 17.5%, respectively, suggesting low post-mortem organic degradation. Although SK 045 registered a collagen yield of 0.2 wt.%,

the C:N value of 3.34 for this individual is within the acceptable C:N range of unmodified collagen.

Table 6.1: Per Cent collagen, %C, %N, and C:N ratios from 22 left femora.

Sample ID	**%C**	**%N**	**C:N Ratio**	**%Collagen**
SK 001	47.3	16.9	3.2	8.3
SK 002	50.2	17.9	3.3	8.0
SK 034	48.4	17.1	3.3	4.2
SK 037	47.2	16.3	3.4	4.8
SK 040	48.2	17.1	3.3	9.9
SK 042	50.6	18.1	3.3	12.0
SK 045	43.7	15.3	3.3	0.2
SK 054	47.8	16.8	3.3	10.1
SK 088	44.7	15.7	3.3	7.3
SK 089	47.9	17.0	3.3	10.2
SK 098	47.8	17.0	3.3	9.4
SK 099	47.6	16.9	3.3	2.8
SK 101	45.2	15.3	3.4	3.7
SK 103	48.1	17.3	3.3	7.4
SK 105	46.8	16.5	3.3	4.1
SK 104	47.4	17.0	3.3	6.0
SK 107	47.3	16.7	3.3	6.6
SK 110	47.6	16.7	3.3	9.6
SK 111	46.2	16.7	3.2	5.0
SK 116	48.2	17.5	3.2	10.9
SK 119	47.4	16.3	3.4	3.1
SK 122	48.3	17.0	3.3	11.2
Mean *n* = 22	*49.5*	*17.5*	*3.3*	*7.0*
SD	*1.5*	*0.7*	*0.1*	*3.2*

6.2 Using Stable Oxygen and Strontium Isotope Ratios to Track Geographic Origin

Meteoric $\delta^{18}O_w$ varies significantly across North America and the islands of the United Kingdom. These isotopic effects are due to large fractionation processes, as rainclouds progressively become depleted in ^{18}O with latitude and distance from the coast

(Gat 2005). The regional $^{18}O/^{16}O$ ratio of water and food is reflected in bone and tooth PO_4 and CO_3 components of bone mineral hydroxyapatite, indicating the source of water and food consumed during life. As discussed in Chapter 4, it is possible to reconstruct childhood origins and long-term residency of these soldiers by regressing the $\delta^{18}O_p$ value of human skeletal tissue with meteoric $\delta^{18}O_w$, the isotopic value of drinking water. The raw carbonate-oxygen results were produced relative to VPDB, and were converted to VSMOW using the following equation (after Faure and Mensing 2005):

$$\delta_{(VSMOW)} = 1.0309\ \delta_{(VPDB)} + 30.91$$

In order to compare the isotopic results from this thesis to those obtained by Blyth (2003) and Schwarcz et al. (1991), the oxygen results from bone carbonate ($\delta^{18}O_c$) were converted to phosphate ($\delta^{18}O_p$) values using the $\delta^{18}O_c/\delta^{18}O_p$ relationship formulated by Iacumin et al. (1996):

$$\delta^{18}O_p = 0.98\ \delta^{18}O_c - 8.5$$

A baseline meteoric water comparison was achieved using the $\delta^{18}O_p/\delta^{18}O_w$ plot and regression equation generated by Daux et al. (2008). Their study showed that prior attempts by Luz et al. (1984) and Levinson et al. (1987) to compute linear $\delta^{18}O_p/\delta^{18}O_w$

models were erroneous due to small data sets; they also failed to indicate whether their samples were archaeological or modern, and omitted other biological variables such as weaning and diet from their investigation. Daux et al. (2008) used a much broader range of bone and enamel isotopic compositions to generate their equation. For this reason, conversion of $\delta^{18}O_p$ to $\delta^{18}O_w$ values was achieved using the following formula, after Daux et al. (2008):

$$\delta^{18}O_w = 1.54\ \delta^{18}O_p - 33.72$$

Enamel and bone $\delta^{18}O_w$ results were compared to both weighted annual meteoric $\delta^{18}O_w$ values for North America (Figure 6.1; see Appendix J for a detailed $\delta^{18}O_w$ map of the United States) and the United Kingdom (Figure 6.2) obtained by GNIP and groundwater stations from both geographic regions (Darling and Talbot 2003; Kendall and Coplen 2001; IAEA 2003). During the early 19th century the national borders of the United States was predominantly confined to the eastern half of what is today the continental, coterminous United States. Delta $^{18}O_w$ variation along the eastern North American continent is broad, with a range from -12.5‰ in the north, extending northwest and northeast into Ontario and Québec, to -3‰ in the southern United States. In contrast, the

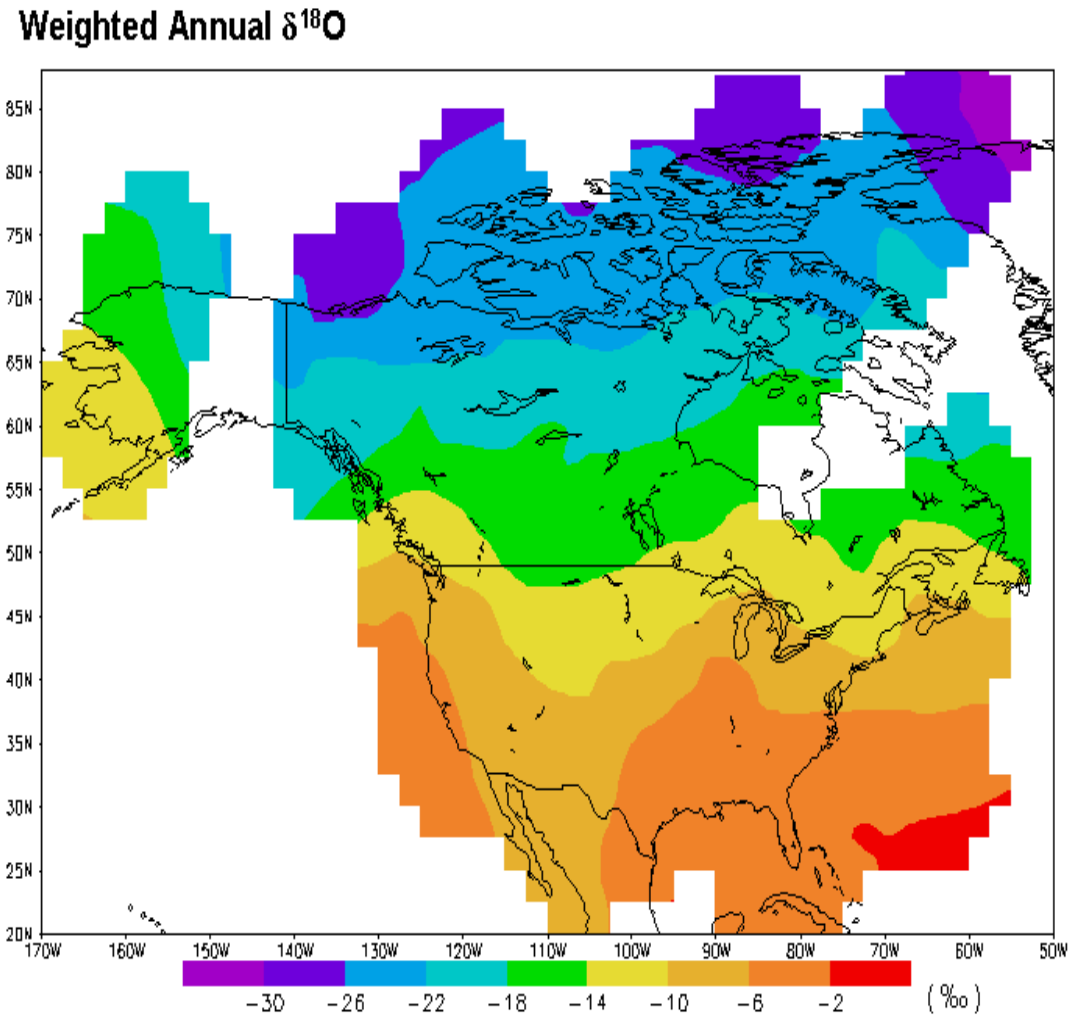


Figure 6.1: Weighted annual $\delta^{18}O_w$ for North America (IAEA – (GNIP), 2003. (http://www-naweb.iaea.org/napc/ih/IHS_resources_gnip.html)

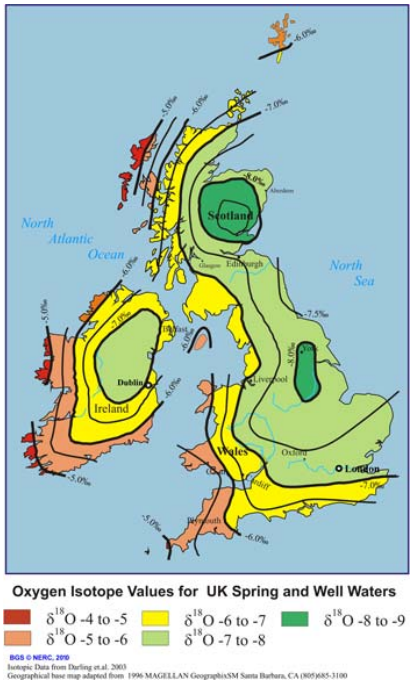


Figure 6.2: Weighted $\delta^{18}O_w$ values for the United Kingdom (Darling and Talbot 2003: 163-181) (image generated by: http://www.bgs.ac.uk/nigl/SBA_Methodology.htm).

$\delta^{18}O_w$ range of the United Kingdom is less broad, ranging between -9‰ in the highlands of Scotland and northern Britain, to -4‰ along the West coasts of Ireland and the Scottish islands of the Outer Hebrides (Figure 6.2). Blyth's (2003) research drew on stable oxygen isotopes to discern regional origins and long-term residency, as well as information from secondary historical sources to define states in favour of military conflict with the British; however these sources did not mention potential areas of military enlistment in the United States and United Kingdom. It was not until 2009 that the task of documenting the areas of military enlistment of both British and American soldiers were thoroughly compiled by Elliott (2009), with detailed appendices indicating name, rank, and area of recruitment (see Elliott 2009, Appendices G and H for the list of American and British casualties at

the Battle of Stoney Creek). This information is useful for the present study as it narrows the possible geographic states and territories from which some of these soldiers likely resided, particularly along the eastern North American coast where $\delta^{18}O_w$ variation is significantly greater, and provided that the soldiers who died during the Battle of Stoney Creek originated from the areas they were recruited.

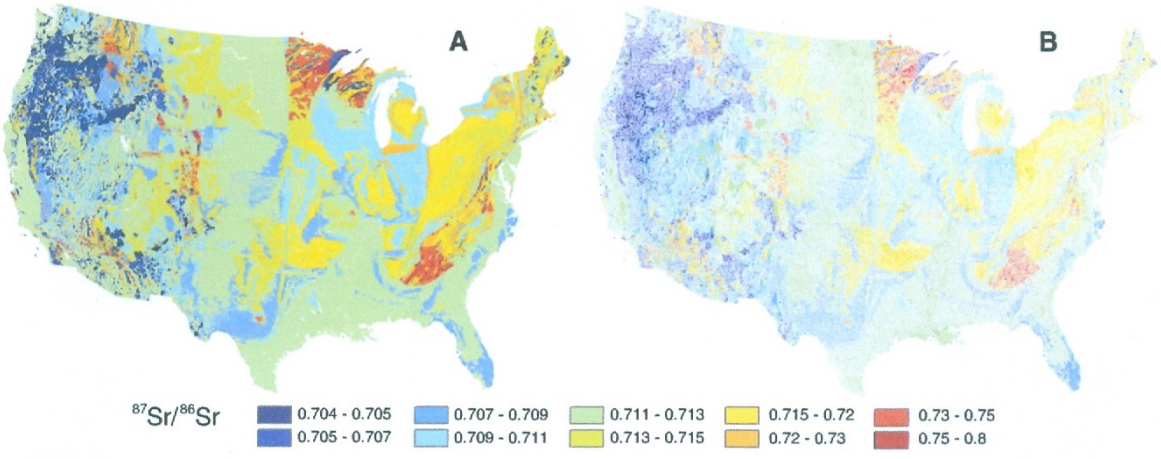


Figure 6.3: Modeled $^{87}Sr/^{86}Sr$ based on: A) local water, and B) flux-weighted catchment across the United States (Bataille and Bowen 2012: 49).

While oxygen isotopes from human skeletal tissue require calibration and conversion to meteoric $\delta^{18}O_w$ values, enamel $^{87}Sr/^{86}Sr$ values do not. This is due to the chemical nature of strontium as it is passed through the food chain and incorporated into the vertebrate skeleton, unaltered by the physiological mechanisms of the metabolic system (Bentley et al. 2003, 2004; Giblin 2009). Since $^{87}Sr/^{86}Sr$ values from human teeth and bones reflect the bioavailable strontium of the local geological substrate, it is possible

to match enamel $^{87}Sr/^{86}Sr$ to a regional $^{87}Sr/^{86}Sr$ variation map. Fortunately, a recent study by Bataille and Bowen (2012) constructed an $^{87}Sr/^{86}Sr$ variation map of the United States using lithological and hydrological parameters (Figure 6.3). Strontium variation for the eastern United States is complex, although the geology of the surrounding Appalachian mountain range offers relative uniformity, with a small approximate $^{87}Sr/^{86}Sr$ range of 0.715 to 0.720. In total, the $^{87}Sr/^{86}Sr$ range for the eastern United States spans as high as 0.750 and 0.800 in parts of Georgia, Tennessee, South and North Carolina, to 0.705 – 0.707 along the east coasts of North Carolina and Virginia, and 0.709 – 0.711 in northern Pennsylvania and southwestern New York.

Across the Atlantic, Evans et al. (2010) documented the spatial variation of $^{87}Sr/^{86}Sr$ in Britain and Scotland using plants and water from various geological locations, as well as enamel, dentine, and soil leach from previous British $^{87}Sr/^{86}Sr$ provenance investigations (Figure 6.4). The geology of Britain spans an immense period of geological of time, from the 3600 Ma Gneiss of northwestern Scotland to more recent Tertiary volcanic and Quaternary glacial deposits in Britain. Their data indicate that $^{87}Sr/^{86}Sr$ values for Britain range between 0.707 and 0.722. The highest $^{87}Sr/^{86}Sr$ mean value was recorded in plants growing on Cairngorm granite and metamorphic Daldarian rocks from Scotland (shown as small areas of red in Figure 6.4) (Evans et al. 2010).

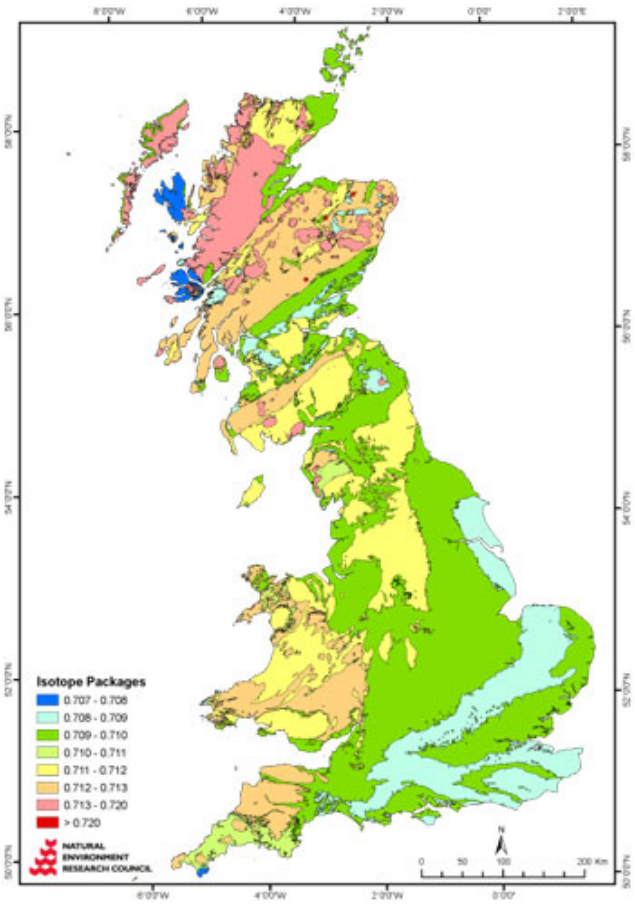


Figure 6.4: $^{87}Sr/^{86}Sr$ biosphere variation across England and Scotland (Evans et al. 2010: 2).

6.3 Stable Isotopic Evidence for Regional Origins and Diet from Teeth

Enamel isotope results from the 14 2nd molars analyzed in this study show significant dietary and regional variability. Since the 2nd molar forms early in childhood, beginning and terminating between the ages of 2 and 8 years, the isotopic composition of tooth enamel reflects the food and water consumed during this period of development. Table 6.2 presents the $^{87}Sr/^{86}Sr$, $\delta^{18}O$, and $\delta^{13}C$ data for the Smith's Knoll tooth sample.

Enamel $^{87}Sr/^{86}Sr$ values are highly varied, ranging from 0.708 to 0.713 (mean = 0.710). These values are consistent with childhood origins in both North America and the United Kingdom.

Table 6.2: Stable strontium, oxygen, and carbon isotope composition of 14 2nd molars from the Smith's Knoll tooth collection.

Sample ID	$^{87}Sr/^{86}Sr$	$\delta^{18}O_c$ (‰) VSMOW	$\delta^{18}O_p$ (‰) VSMOW	$\delta^{18}O_w$ (‰) VSMOW	$\delta^{13}C$ (‰) (VPDB)
SC 29	0.709	24.4	15.9	-9.2	-9.8
SC 40	0.713	25.0	16.5	-8.2	-10.3
SC 41	0.709	23.8	15.3	-10.1	-11.5
SC 45	0.709	25.5	17.0	-7.4	-11.3
SC 47	0.709	25.2	16.6	-8.0	-13.9
SC 339	0.709	25.4	16.8	-7.7	-11.0
SC 344	0.708	24.6	16.1	-8.9	-12.9
SC 346	0.709	24.5	15.9	-9.1	-13.1
SC 393	0.711	25.0	16.4	-8.3	-10.5
SK 110	0.710	22.4	13.9	-12.2	-13.1
SK 283	0.711	25.0	16.4	-8.3	-12.9
SK 286	0.709	25.0	16.5	-8.3	-13.3
SK 288	0.708	25.9	17.3	-6.9	-11.3
SK 294	0.711	23.8	15.2	-10.1	-12.3
Mean *n* = 14	*0.710*	*24.7*	*16.1*	*-8.8*	*-13.3*

However, the $^{87}Sr/^{86}Sr$ values for this sample exclude individuals growing up in the northwestern regions of Georgia and Tennessee, as these areas have geological $^{87}Sr/^{86}Sr$ compositions outside the $^{87}Sr/^{86}Sr$ enamel range.

Furthermore, historical evidence indicates that a very small number of Canadian militiamen fought at the battle of Stoney Creek, yet the exact figures are unknown. Elliott

(2009) provides reference to a few complimentary artificers and militiamen taking part in battle, so it is possible that some of the individuals represented in both the tooth and bone sample were Canadian-born.

The majority of enamel samples (n = 8) have an $^{87}Sr/^{86}Sr$ composition (0.709 – 0.711) consistent with the geological $^{87}Sr/^{86}Sr$ composition of the northeastern states of Pennsylvania, New York, Connecticut, New Hampshire, Rhode Island, Vermont and Massachusetts. Alternatively, they are also indicative of an overseas childhood upbringing, possibly originating from the British regions of South West and South East England, East of England, West and East Midlands, Yorkshire and the Humber. Three enamel samples with $^{87}Sr/^{86}Sr$ values between 0.711 and 0.712 are consistent with an upbringing in closer proximity to the American eastern seaboard, as well as the east coast of Georgia, South and North Carolina, Virginia, Delaware, Maryland, Vermont, New Hampshire, and Maine. These values are also consistent with a British upbringing, specifically in the regions of Wales, West and East Midlands, North West England, and Yorkshire and the Humber. The two lowest values (SC 344 $^{87}Sr/^{86}Sr$ = 0.708; SK 288 $^{87}Sr/^{86}Sr$ = 0.708) are characteristic of small stretch of land along the North Carolinian and Virginian coastline but are consistent with a significant portion of geology of southern Britain, ranging from South West England, through London, to the East of England. SC 40 yielded the highest $^{87}Sr/^{86}Sr$ value in the sample ($^{87}Sr/^{86}Sr$ = 0.713), and would be characteristic of an origin in northern Scotland or the Outer Hebrides. However, $^{87}Sr/^{86}Sr$ values this high are also characteristic to regions of the northeastern United

States. The strontium isotope evidence on its own, therefore, does not help to distinguish the geographic origins of the majority of this sample.

Before combining the $^{87}Sr/^{86}Sr$ data with $\delta^{18}O_w$, it is important to discuss the 9 reanalyzed 2nd molars (Table 6.3). Blyth's (2003) $\delta^{18}O_p$ mean (17.0‰; 1σ = 0.6‰) result differs from the converted mean $\delta^{18}O_p$ (16.3‰; 1σ = 0.5‰) value obtained for this

Table 6.3: Comparison between $\delta^{18}O_p$ values obtained by Blyth (2003) and this research. $\Delta^{18}O_p$ denotes the difference between $\delta^{18}O_p$ values.

Sample ID	$\delta^{18}O_p$ (‰) VSMOW (Blyth 2003)	$\delta^{18}O_p$ (‰) VSMOW (Emery 2012)	$\Delta^{18}O_p$ (‰) VSMOW
SC 29	16.2	15.9	-0.3
SC 40	15.8	16.5	0.7
SC 41	17.5	15.3	-2.2
SC 45	17.6	17.0	-0.6
SC 47	17.5	16.7	-0.8
SC 339	17.2	16.5	-0.7
SC 344	17.3	16.1	-1.2
SC 346	17.0	16.0	-1.1
SC 393	16.5	16.5	-0.01
Mean *n* = 9	17.0	16.3	-0.8

research by -0.8‰. These isotopic discrepancies may be due to error in the carbonate-phosphate conversion formula (Iacumin et al. 1996). However, an error in this equation could result at most in a constant offset since the slope of the equation is ~1.0, whereas the offsets here appear to be random. A further problem may be attributed to differences in sampling, wherein enamel was removed indiscriminately anywhere from the cusps to the cervical margin of the teeth. This may have indeed been the case here as well as for Blyth (2003), particularly given the degraded nature of the tooth enamel during Blyth's

(2003) initial study, and subsequent destruction of the reanalyzed teeth used in this thesis. Figure 6.5 depicts the differences of phosphate ($\delta^{18}O_p$) values on the order of 1σ.

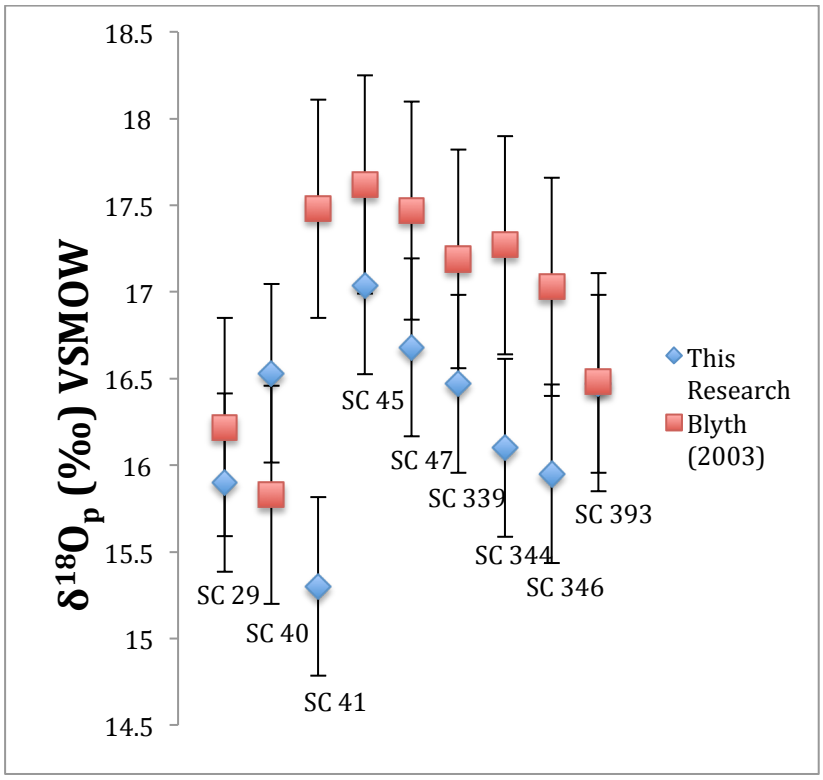


Figure 6.5: $\delta^{18}O_p$ values for 9 reanalyzed M2s. Capped bars indicate 1 standard deviation from the mean for reanalyzed teeth (1σ = 0.51) and original results obtained by Blyth (2003) (1σ = 0.62).

Meteoric $\delta^{18}O_w$ values for drinking water for all 14 teeth sampled range between -7.0‰ to -12.3‰ (mean = -8.8‰), and closely approximate the mean value of -8.2‰ obtained by Blyth (2003) using the fractionation equation devised by Longinelli (1984) (i.e. $\delta^{18}O_p = 0.64\ \delta^{18}O_w + 22.37$) for drinking water (Appendix I). The $^{18}O_w$ calculated for

the tooth data suggest that not all of these individuals were obtaining water from the same location during their childhood (Table 6.2). In total, 9 individuals have $\delta^{18}O_w$ values

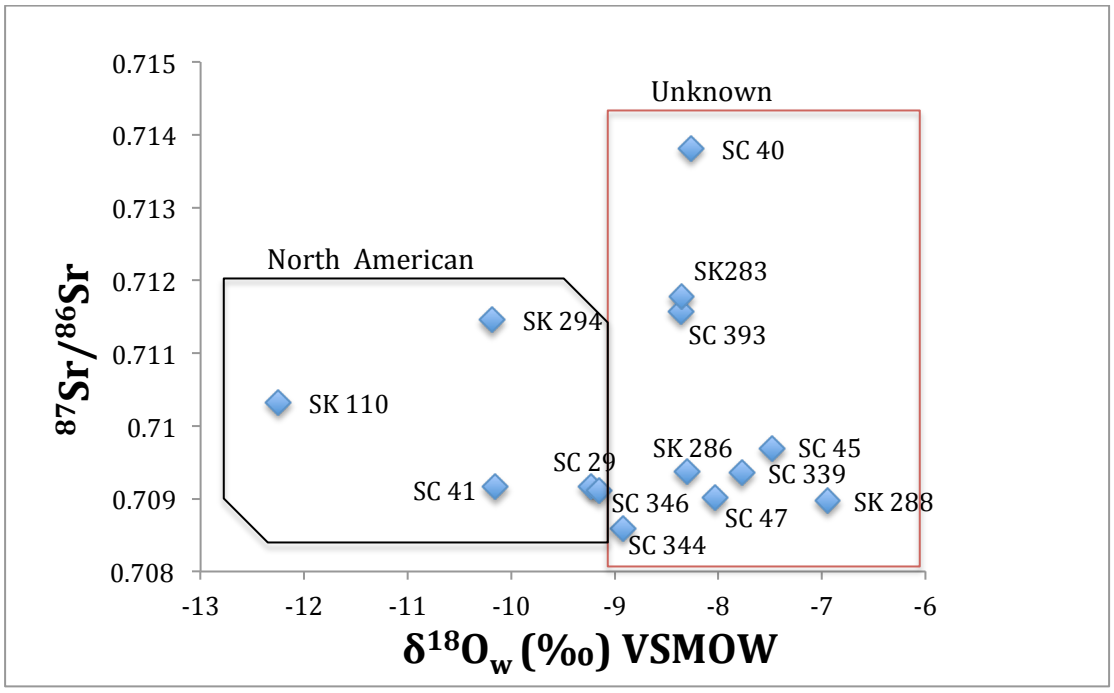


Figure 6.6: Enamel $^{87}Sr/^{86}Sr$ versus $\delta^{18}O_w$ relationship for 14 2nd molars. Although $^{87}Sr/^{86}Sr$ variation between the United States and United Kingdom overlap, 5 individuals (SK 110, SC 41, SK 294, SC 29, and SC 346) have $\delta^{18}O_w$ values lower than those found in the United Kingdom, suggesting that these individuals originated from North America. SK (or Smith's Knoll) refers to the sample identification used in thesis; SC (or Stoney Creek) refers to the sample identification for teeth in Blyth's (2003) study.

characteristic of both North America and the United Kingdom (-9‰ to -4‰). Similarly, the $^{87}Sr/^{86}Sr$ values for 8 of these individuals (SC 45, SC 47, SC 339, SC 344, SC 393, SK 283, SK 286, and SK 288) overlap with $^{87}Sr/^{86}Sr$ variation in both the United States and United Kingdom. The relationship between enamel $\delta^{18}O_w$ and $^{87}Sr/^{86}Sr$ is shown in

Figure 6.6. Due to isotopic overlap, unfortunately, the regional origin of these soldiers remains unclear. If however these individuals were American born, then it is likely they spent their childhood in the states of Ohio, Virginia, Kentucky, Delaware, New York or Rhode Island. If these results represent a United Kingdom origin, then it is possible that these individuals derived from Britain and Scotland proper, although the $\delta^{18}O_w$ compositions of these teeth also overlap with meteoric $\delta^{18}O_w$ values measured in Ireland.

SC 29 ($\delta^{18}O_w$ = -9.2‰; $^{87}Sr/^{86}Sr$ = 0.709) and SC 346 ($\delta^{18}O_w$ = -9.2‰; $^{87}Sr/^{86}Sr$ = 0.709) are slightly more depleted than the lowest $\delta^{18}O_w$ value obtained for the United Kingdom (i.e. -9‰). These two results are consistent with $\delta^{18}O_w$ water from northern Ohio, New York, Pennsylvania, Massachusetts and New Hampshire; their $^{87}Sr/^{86}Sr$ values are also characteristic of these regions. Further, SC 41, SK 110, and SK 294 are significantly depleted relative to the lowest $\delta^{18}O_w$ value for the United Kingdom, by at least 1.2‰. SK 110 yielded the lowest $\delta^{18}O_w$ value, measured at -12.3‰. Delta $^{18}O_w$ values this low are consistent with the northeastern states of Vermont, northern New Hampshire, and Maine. The $^{87}Sr/^{86}Sr$ value (0.710) of SK 110 is consistent with the geology of this region, specifically the states of Vermont and New Hampshire. SC 41 ($\delta^{18}O_w$ = -10.2‰; $^{87}Sr/^{86}Sr$ = 0.709) and SK 294 ($\delta^{18}O_w$ = -10.2‰; $^{87}Sr/^{86}Sr$ = 0.711) also have $\delta^{18}O_w$ and $^{87}Sr/^{86}Sr$ compositions consistent with these northern states, including New York and Pennsylvania, although the $^{87}Sr/^{86}Sr$ result (0.709) yielded from SC 41 might suggest a coastal rather than interior origin. The remaining outlier, SC 40 ($\delta^{18}O_w$ = -8.3‰; $^{87}Sr/^{86}Sr$ = 0.713), has an $^{87}Sr/^{86}Sr$ value within the $\delta^{18}O_w$ range of -8‰ to -10‰ characteristic of the mid- to northeastern United States. Interestingly, his enamel

composition is also consistent with $^{87}Sr/^{86}Sr$ and $\delta^{18}O_w$ geological and meteoric water compositions of the Grampian Mountain range in Scotland. It is possible that this individual grew up in the Scottish Highlands, enlisted into the British military as a young adult, and died fighting at the Battle of Stoney Creek, a possibility that is supported by the large number of Scottish recruits listed in the ranks of the 49th and 41st Regiments (Elliott 2009).

6.4 Enamel $\delta^{13}C$ and Diet

Enamel $\delta^{13}C$ carbonate values range between -9.9‰ and -13.9‰ (mean = -13.4‰) (see Table 6.2), indicating a bulk diet composed of both C_3 and C_4 foods (Figure 6.7). Katzenberg (1995) showed that infants recovered from the early 19th century cemetery at Prospect Hill, Newmarket, Ontario, were weaned onto external foods between 6 and 14 months of age, a weaning trend practiced in the United States, Upper and Lower Canada, and Great Britain during this time. Given that weaning occurred relatively early in infant life, the isotopic signatures obtained from 2nd molars are expected to indicate the bulk diet (protein, lipids, and carbohydrates) composition of post-weaned foods. Enamel $\delta^{13}C$ values suggest that these individuals, as children, were likely eating foods common to their geographic birthplace. In North America these food items included wheat, oats, vegetables, maize, rice, beef and pork, and possibly small amounts of sugar cane in the form of molasses (Katzenberg et al. 2000). British citizens also consumed many of these food items, albeit with less C_4 foods like maize. In addition, fodder in the form of wheat and rice (both C_3 plants) was used in raising domestic livestock (Raynor and Kennett 2008). It is not surprising that enamel $\delta^{13}C$ values are

significantly more negative than the carbonate $\delta^{13}C$ composition of prehistoric Ontarians consuming large quantities of maize; enamel $\delta^{13}C$ values for these individuals are notably enriched, reaching upwards of -2.0‰ (van der Merwe et al. 2003).

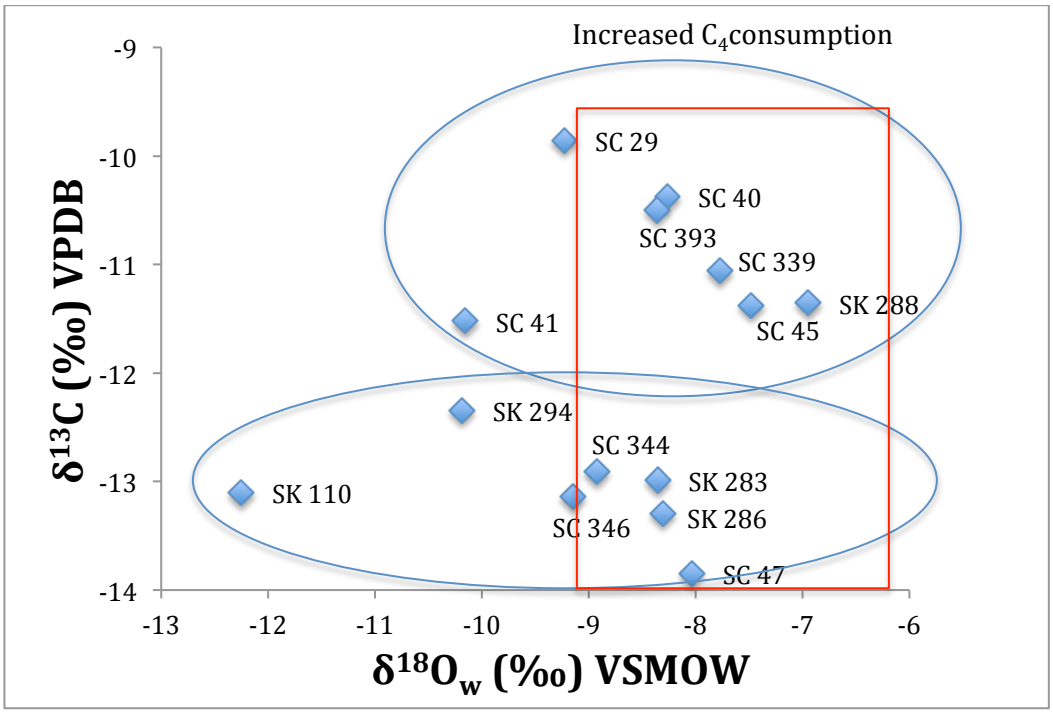


Figure 6.7: Enamel $\delta^{13}C/\delta^{18}O$ relationship showing differences between bulk diet and regional water consumption. Top circle shows individuals with increased C_4 consumption. The red box indicates $\delta^{18}O_w$ overlap between the United States and United Kingdom.

The 5 individuals (SC 29, SC 41, SC 346, SK 294, and SK 110) outside the United Kingdom $\delta^{18}O_w$ range, as previously indicated, likely represent soldiers born in North America. However, enamel $\delta^{13}C$ indicates that 7 soldiers (SC 29, SC 40, SC 393, SC 339, SC 45, SK 288, and SC 41) were consuming C_4 products, a combination that may have

included maize proper, or meat and milk supplied from domestic cattle fed maize as fodder. Mintz (2012) suggested that this dietary pattern was practiced in the southern states, an area of North America where maize production was much more intensive. SC 41 and SK 294 have intermediary $\delta^{13}C$ values as a result of dietary C_3 and C_4 mixing, while SK 110 and SC 346 appear to have subsisted primarily of C_3 food items. Historic documentation suggests that the inhabitants of British Canada and the northern United States had similar diets (i.e. based on wheat), so it is possible that these results indicate either an upbringing in Upper Canada or the northeastern United States (Mintz 2012; Henderson 2012).

6.5 Stable Carbon, Nitrogen, and Oxygen Isotopic Results from Bone

British soldiers of the King's (8^{th}) and 49^{th} Regiments were stationed in British Canada for up to 10 years before they died at Stoney Creek. The $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$ composition of bone collagen and carbonate is therefore a reflection of the food and water consumed by these soldiers up to approximately 10 to 20 years before dying in combat (Manolagos 2000). Bone $\delta^{13}C_{co}$ values vary significantly, ranging between -13.5‰ and -20.8‰ (mean = -18.3‰) (Table 6.4). Since consumers of C_3 or C_4 foods have $\delta^{13}C_{co}$ values of -22‰ to -19‰ and -16‰ to -7‰, respectively, it is possible to identify the proportion of C_3 versus C_4 foods in their diet (Pollard and Heron 2008; Raynor and Kennet 2008). The mean Smith's Knoll $\delta^{13}C_{co}$ value suggests that these soldiers were consuming a predominantly C_3 diet, with complementary amounts of C_4 foods (Figure 6.8). Yet the Smith's Knoll $\delta^{13}C_{co}$ range suggests that individual dietary intake was

varied, with some individuals consuming more C_4 foods than others, likely in the form of cornbread and/or molasses (circled in blue in Figure 6.8).

Table 6.4: Bone collagen $\delta^{13}C_{co}$ and $\delta^{15}N$ values for 21 left femora and 1 mandibular fragment. %C and %N, C:N-atomic ratio, and % collagen yield were received in conjunction with collagen isotopic results.

Sample ID	$\delta^{13}C_{co}$ (‰) VPDB	$\delta^{15}N$ (‰) AIR	%C	%N	C:N Ratio	%Collagen
SK 001	-20.2	10.9	47.3	16.9	3.2	8.3
SK 002	-20.2	10.9	50.2	17.9	3.3	8.0
SK 034	-19.8	10.8	48.4	17.1	3.3	4.2
SK 037	-18.4	11.1	47.2	16.3	3.4	4.8
SK 040	-20.8	11.0	48.2	17.1	3.3	9.9
SK 042	-19.8	11.7	50.6	18.1	3.3	12.0
SK 045	-19.7	10.7	43.7	15.3	3.3	0.2
SK 054	-13.5	10.5	47.8	16.8	3.3	10.1
SK 088	-14.9	11.2	44.7	15.7	3.3	7.3
SK 089	-15.4	9.9	47.9	17.0	3.3	10.2
SK 098	-18.4	12.1	47.8	17.0	3.3	9.4
SK 099	-19.3	12.5	47.6	16.9	3.3	2.8
SK 101	-18.5	11.4	45.2	15.3	3.4	3.7
SK 103	-14.4	11.1	48.1	17.3	3.3	7.4
SK 105	-19.2	9.7	46.8	16.5	3.3	4.1
SK 104	-20.0	11.6	47.4	17.0	3.3	6.0
SK 107	-18.8	10.7	47.3	16.7	3.3	6.6
SK 110	-20.2	11.9	47.6	16.7	3.3	9.6
SK 111	-20.4	12.3	46.2	16.7	3.2	5.0
SK 116	-16.1	11.7	48.2	17.5	3.2	10.9
SK 119	-16.6	10.3	47.4	16.3	3.4	3.1
SK 122	-18.8	11.1	48.3	17.0	3.3	11.2
Mean *n* = 22	*-18.3*	*11.2*	*49.5*	*17.5*	*3.3*	*7.0*
SD	*2.2*	*0.7*	*1.5*	*0.7*	*0.1*	*3.2*

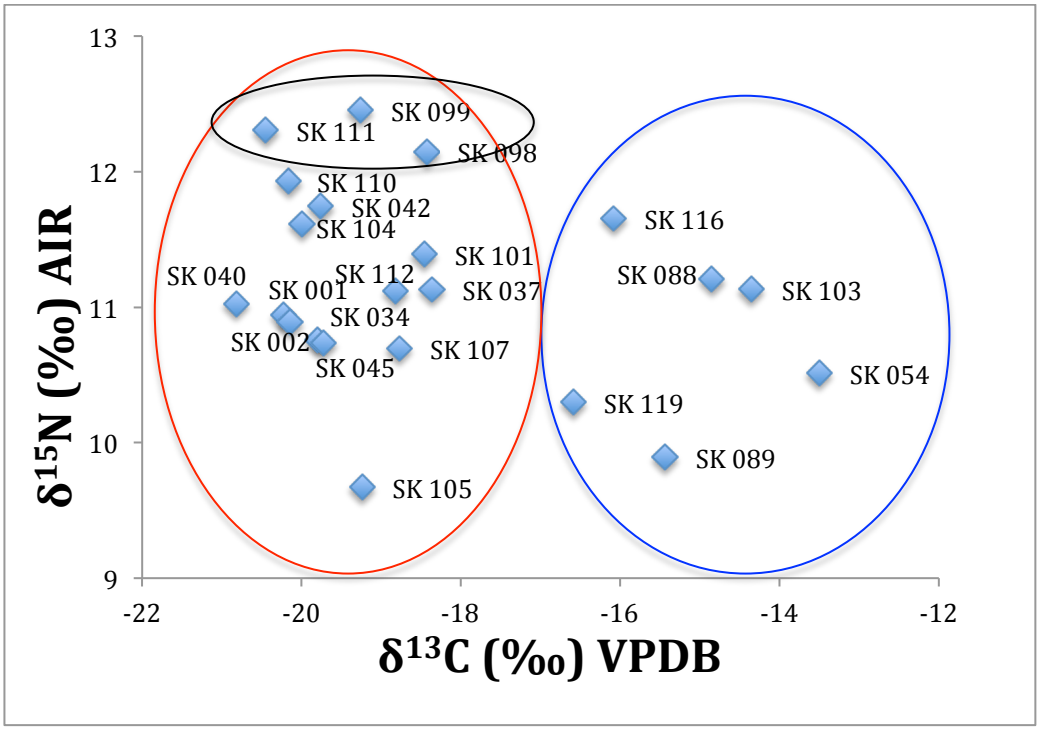


Figure 6.8: $\delta^{13}C_{co}$ and $\delta^{15}N$ obtained from bone collagen from 21 femora and 1 mandibular fragment. Blue circle indicate individuals with significant dietary contribution from C_4 sources, possibly maize or sugarcane. Red circle shows individuals with more C_3 contribution to diet. The black oval indicates soldiers who may have included fresh water fish as a supplementary protein component.

Of the 22 bones sampled, 11 soldiers have $\delta^{13}C_{co}$ values within the C_3 dietary range of -22‰ to -19‰; the most negative value was measured for SK 040 ($\delta^{13}C_{co}$ = -20.8‰). These isotopic values are consistent with early 19th century individuals from Upper Canada and soldiers (sailors) from the United Kingdom, whose major staple dietary items included bread, salt pork, beef, and cooked vegetables (Roberts et al. 2012). In contrast, 6 soldiers (SK 116, SK 088, SK 103, SK 054, SK 119, and SK 089) have $\delta^{13}C_{co}$ values indicative of increased C_4 consumption, diets which likely included maize.

These soldiers have $\delta^{13}C_{co}$ values closer to the isotopic results obtained by Raynor and Kennett (2008) (Figure 6.9) and Katzenberg (1991), whose mean $\delta^{13}C_{co}$ signatures measured -15.8‰ ± 1.3 and -16.1‰ ± 1.9, respectively. SK 054 yielded the least negative value ($\delta^{13}C_{co}$ = -13.5‰), and falls within the range of $\delta^{13}C_{co}$ signatures found in prehistoric populations from North America (Ambrose et al. 2003; Schwarcz et al. 1985; Harrison and Katzenberg 2003). The remainder of the sample (*n* = 7) likely had mixed diets composed of both C_3 and C_4 foods.

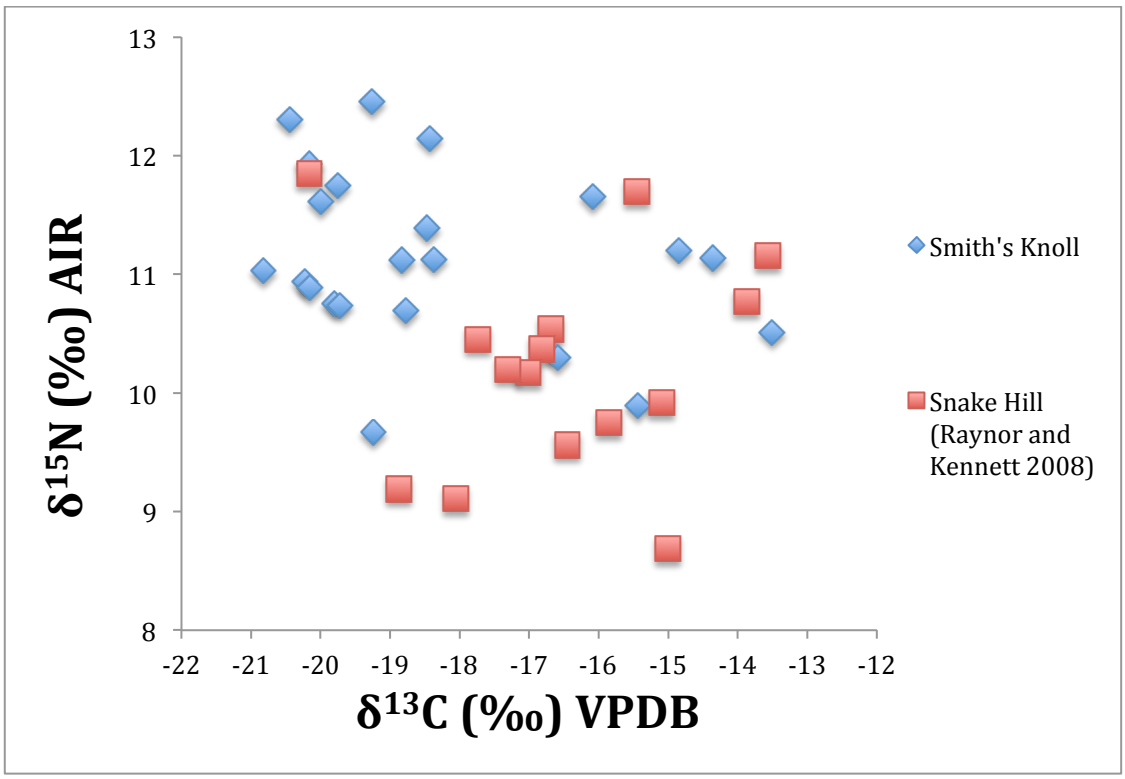


Figure 6.9: Delta ^{15}N versus $\delta^{13}C_{co}$ collagen values obtained from Smith's Knoll (this study) and Snake Hill (Raynor and Kennett 2008) soldiers. Higher $\delta^{13}C_{co}$ values for the Snake Hill sample suggests significant C_4 contribution, a historical trend consistent with southeastern American diets. Delta ^{15}N results for the Smith's Knoll sample suggest increased marine consumption.

Delta ^{15}N values are relatively uniform, ranging between 9.6‰ and 12.3‰ with a mean value of 11.2‰. This value overlaps with the mean $\delta^{15}N$ result of 10.2‰ ± 0.9 obtained by Raynor and Kennett (2008), falls within the $\delta^{15}N$ range (9.6‰ to 11.8‰) of Katzenberg's (1991) study, and is similar to the mean femoral value of 11.7‰ calculated by Roberts et al. (2012), who obtained the $\delta^{15}N$ composition of bone from early 19th century British sailors buried in southern Britain. Although the Smith's Knoll $\delta^{15}N$ range suggest a meat diet composed of terrestrial herbivores (i.e. pig and cow), higher $\delta^{15}N$ values indicate that some of these individuals (SK 098, SK 099, and SK 111) may have included fish as a supplementary part of their diet. It is important to note that these 3 soldiers have $\delta^{13}C_{co}$ signatures within a C_3 dietary range, consistent with traditional European consumption. It is possible that these were British regulars stationed in Upper Canada who deviated from traditional military rations by including fresh water fish with other high protein foods, such as salted pork and beef (Henderson 2012). Delta ^{15}N signatures for the remainder of the sample are consistent with a diet whose primary protein contribution was likely from terrestrial herbivores fed C_3 fodder, possibly wheat and/or rice (Katzenberg 1991; Raynor and Kennett 2008).

Bone $\delta^{13}C_{ca}$ variation suggests that at an individual level, these soldiers were consuming C_3 and C_4 in different proportions (Table 6.5). For example, 6 soldiers (SK 037, SK 054, SK 088, SK 089, SK 103, and SK 116) have bone $\delta^{13}C_{ca}$ values greater than -10‰, indicating that maize may have composed 45% of the total dietary intake (van der Merwe et al. 2003). Delta $^{13}C_{co}$ values for at least 5 of these soldiers are consistent with increased C_4 consumption. This pattern complements historical claims that unlike the

Table 6.5: Bone $\delta^{13}C_{ca}$, $\Delta^{13}C_{ca\text{-}co}$, $\delta^{18}O_c$, $\delta^{18}O_p$ and converted $\delta^{18}O_w$ results for the Smith's Knoll bone sample.

Sample ID	$\delta^{13}C_{ca}$ (VPDB)	$\Delta^{13}C_{ca\text{-}co}$ (‰)	$\delta^{18}O_c$ (‰) VSMOW	$\delta^{18}O_p$ (‰) VSMOW	$\delta^{18}O_w$ (‰) VSMOW
SK 001	-12.7	7.6	25.6	17.0	-7.5
SK 002	-12.3	7.9	25.6	17.1	-7.5
SK 034	-11.2	8.6	25.8	17.2	-7.2
SK 037	-9.8	8.5	24.5	16.0	-9.2
SK 040	-12.8	8.0	26.4	17.9	-6.2
SK 042	-12.3	7.4	26.3	17.7	-6.4
SK 045	-10.3	9.5	24.1	15.7	-9.8
SK 054	-8.5	5.0	25.7	17.1	-7.4
SK 088	-8.9	5.9	26.2	17.7	-6.5
SK 089	-9.2	6.2	26.4	17.9	-6.2
SK 098	-11.5	7.0	26.1	17.6	-6.6
SK 099	-11.6	7.7	25.1	16.5	-8.3
SK 101	-10.2	8.2	25.3	16.7	-8.0
SK 103	-7.1	7.2	25.8	17.2	-7.2
SK 104	-11.8	7.8	25.4	16.8	-7.8
SK 105	-11.5	8.2	25.5	16.9	-7.6
SK 107	-10.3	8.5	25.0	16.4	-8.4
SK 110	-12.2	8.0	26.3	17.7	-6.4
SK 111	-12.3	8.2	25.6	17.0	-7.5
SK 116	-9.62	6.5	26.3	17.7	-6.5
SK 119	-10.1	6.5	25.2	16.7	-8.1
SK 122	-12.5	6.4	26.4	17.8	-6.3
Mean n = 22	*-10.8*	*7.5*	*25.7*	*17.1*	*-7.4*
SD	*1.5*	*1.0*	*0.6*	*0.6*	*1.0*

traditionally regimented diets of the British army, American soldiers may have taken advantage of cheap, mass-produced food items, some of which included maize (Mintz 2012). The isotopically lighter $\delta^{13}C_{ca}$ values obtained for the remaining 16 soldiers are also consistent with $\delta^{13}C_{co}$ values reflective of a European based, C_3 diet. As previously indicated, these soldiers would have been consuming larger quantities of wheat and oats,

while a further C_3 contribution came in the form of beef and pork, domestic livestock raised on C_3 foods like wheat and rice (Raynor and Kennett 2008).

The linear offset between the $\delta^{13}C$ composition of bone collagen and apatite (or carbonate) often denoted as $\Delta^{13}C_{ca\text{-}co}$ has been suggested to indicate an organism's trophic level (Lee-Thorp et al. 1989). Lee-Thorp et al. (1989) showed that the $\delta^{13}C$ composition of food and subsequent fractionation of these items differed between herbivorous, omnivorous, and carnivorous consumers. Their study indicated that carnivores had lower $\Delta^{13}C_{ca\text{-}co}$ values (4.3 ± 1.0‰) than herbivores (6.8 ± 1.4‰), while omnivores yielded intermediary $\Delta^{13}C_{ca\text{-}co}$ values (5.2 ± 0.8‰). Taking this into account, it should be possible to approximate the relative amounts of meat and plants included in the diets of these soldiers. Table 6.5 lists the $\Delta^{13}C_{ca\text{-}co}$ values of the Smith's Knoll bone sample; these values were calculated using the following carbonate-collagen spacing equation:

$$\Delta_{ca\text{-}co} = \delta_{ca} - \delta_{co}$$

$\Delta^{13}C_{ca\text{-}co}$ values are broad, from as low as 5.0‰ to as high as 9.5‰ (mean = 7.5) (Table 6.5). The $\Delta^{13}C_{ca\text{-}co}$ data indicate that a significant portion of the Smith's Knoll diet was composed of plants, placing the $\Delta^{13}C_{ca\text{-}co}$ mean value within $\Delta^{13}C_{ca\text{-}co}$ range obtained by Lee-Thorp et al. (1989) for terrestrial herbivores.

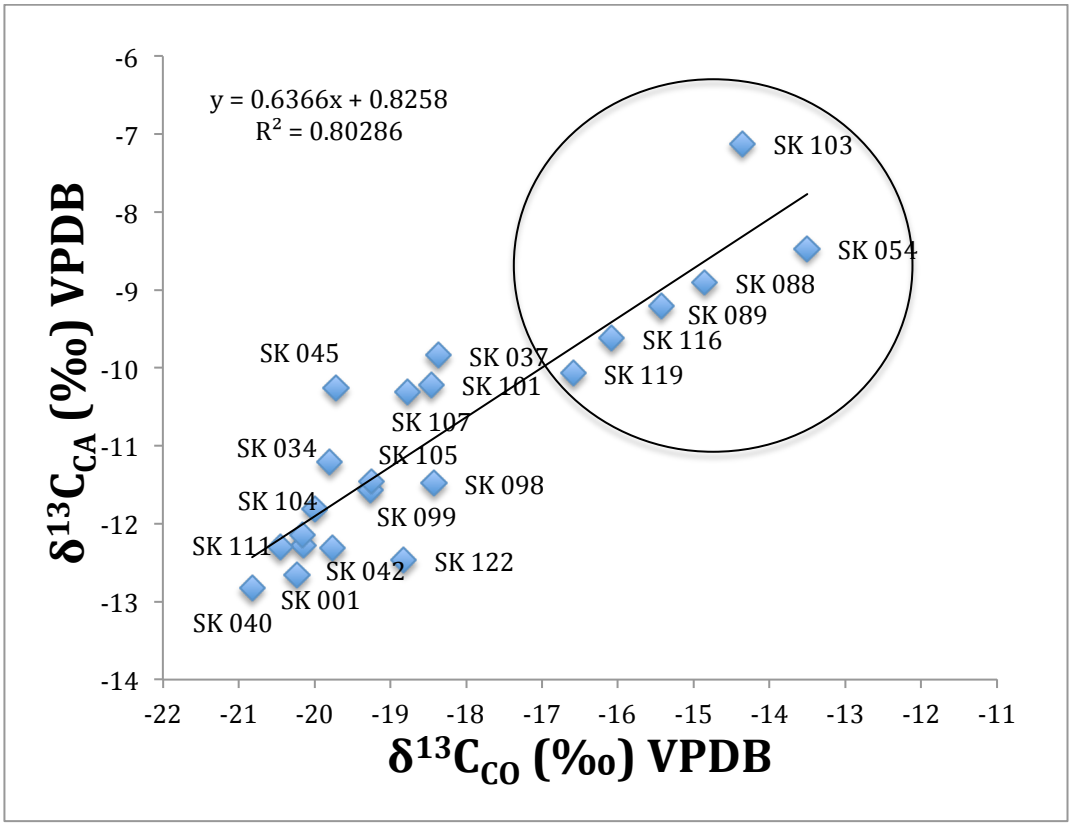


Figure 6.10: Linear relationship ($R^2 = 0.80$) between $\delta^{13}C_{ca}$ and $\delta^{13}C_{co}$. Circled individuals are enriched relative to the remainder of the sample; a notable pattern seen with the introduction of C_4 plants in ecologically dominated C_3 biomes.

In North America, where the natural floral substrate is also dominated by C_3 vegetation, the adoption and widespread consumption of maize has shifted the isotopic composition of human tissues (and domestic livestock fed maize) towards less negative values. While metabolic mechanisms affecting the isotopic routing, and thus the composition of human bones and teeth are beyond the scope of this research, the wide $\Delta^{13}C_{ca\text{-}co}$ values obtained from the Smith's Knoll sample likely reflect this newly introduced cultigen. For instance, Harrison and Katzenberg (2003) suggested that in

circumstances where the $\delta^{13}C$ value of dietary protein is depleted in ^{13}C relative to whole diet, a contribution of C_4 carbohydrates and C_3 protein is likely. This would result in $\Delta^{13}C_{ca\text{-}co}$ values greater than 4.4‰. Again, and as predicted by Figure 6.8, 6 soldiers (SK 119, SK 116, SK 089, SK 088, SK 054, and SK 103) are enriched relative to the rest of the sample. Since $\delta^{13}C_{co}$ reflects carbon atoms from dietary protein, and $\delta^{13}C_{ca}$ from total diet, it is plausible that the bulk diets of these soldiers were primarily composed of C_4 foods, with a further C_4 contribution from livestock fed C_4 fodder, such as maize (it is important to note that there is more or less a constant offset between $\delta^{13}C_{ca}$ and diet, of ~ -11‰ for humans who are principally herbivores) (Henry Schwarcz, personal communication, 2012). Unlike the agricultural industry in early 19th century Britain and Upper and Lower Canada, historical data suggest that American farmers were including maize as a form of domestic feed, a practice common to the mid to southern states during this time (Mintz 2012). In addition, Katzenberg et al. (2000) estimated that vegetables comprised 70% and baked goods 20% of the total diet in the 19th century Belleville skeletal sample; meat was estimated at 10%. Overall, the data indicated in Figure 6.10 suggests that most, if not all of these soldiers had diets high in C_3 and C_4 carbohydrates, with minimal to moderate amounts of protein derived from meat.

The range for bone $\delta^{18}O_p$ is less than enamel $\delta^{18}O_p$, falling between 16.0‰ and 17.9‰ (mean = 17.1‰) (Table 6.5). Bone $\delta^{18}O_p$ is considerably higher than the bone $\delta^{18}O_p$ values obtained by Schwarcz et al. (1991) and Blyth (2003) (see Appendices L and M). Comparison of the mean bone $\delta^{18}O_p$ values from Schwarcz et al. (1991) and Blyth (2003) show that they differ from the calculated $\delta^{18}O_p$ of this study by 4.5‰ and 2.8‰,

respectively. The $\delta^{18}O_p$ values for these soldiers are depleted relative to the converted $\delta^{18}O_p$ values obtained by this thesis, and by Blyth (2003). Blyth (2003) suggested that since the early 1990s, methodological precision has drastically increased the precision of measurement, leading to more accurate results. She also noted that the $\delta^{18}O_p$ discrepancy might have been due to error associated with the regression equations devised by Luz et al. (1984) and Longinelli (1984) for drinking water. The source of difference between the $\delta^{18}O_p$ of this study and the $\delta^{18}O_p$ values obtained by Blyth (2003) may then be attributed to error within the $\delta^{18}O_c$ /$\delta^{18}O_p$ linear model constructed by Iacumin et al. (1996).

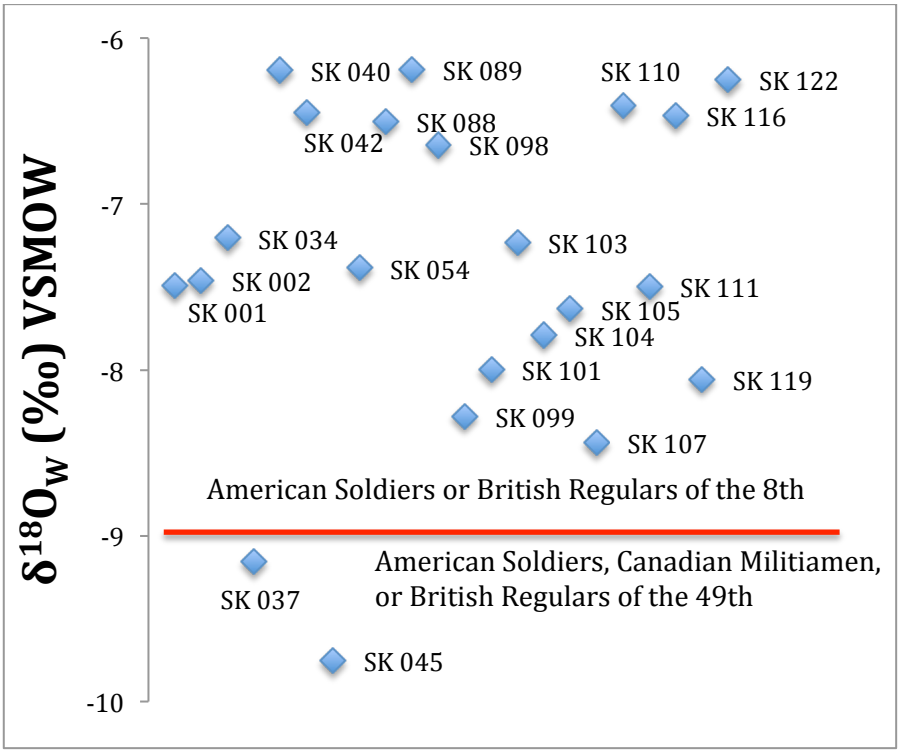


Figure 6.11: Bone $\delta^{18}O_w$ values for 21 left femora and 1 mandibular fragment. Note that $\delta^{18}O_w$ variation for the United States and the United Kingdom overlap between -9‰ and -6‰. $\delta^{18}O_w$ values more depleted than the lowest United Kingdom $\delta^{18}O_w$ value are likely American soldiers.

Conversion to $\delta^{18}O_w$ yielded a range between -6.2‰ and -9.8‰ (mean = -7.4‰) (Table 6.5; Figure 6.11). Bone $\delta^{18}O_w$ results indicate that several of these soldiers were obtaining water from sources consistent with North American and British meteoric $\delta^{18}O_w$ (see Figures 6.1 and 6.2). If these results represent British regulars stationed in parts of southern and/or southwestern Ontario, they would have needed to be garrisoned in Upper Canada for approximately 10 years, long enough for bone $^{18}O/^{16}O$ to reach equilibrium with meteoric water from this region (~ -11‰). However, historical documents indicate that the 49th Regiment was commissioned to Montreal in 1802, where they stayed until the onset of war (Hitsman 1999). Thus it is unlikely that these results represent British regulars from this regiment. However, the King's (8th) Regiment also participated in the battle. British soldiers affiliated with the 8th had been re-commissioned to North America in 1809, at a time when tensions between the United States and Britain were beginning to mount (Hitsman 1999). Given that these soldiers were stationed in Upper Canada for much less than 10 years, their bone $\delta^{18}O_w$ value should, theoretically, reflect British residency. It is entirely possible that the $\delta^{18}O_w$ results (for the exception of SK 037 and SK 045) represent British regulars from the King's Regiment; it is also possible that these results represent American soldiers. SK 037 ($\delta^{18}O_w$ = -9.2‰) and SK 045 ($\delta^{18}O_w$ = -9.8‰) are slightly more depleted than the maximum United Kingdom $\delta^{18}O_w$ value, consistent with $\delta^{18}O_w$ from northern Ohio, Pennsylvania, New York, New Jersey, western Connecticut and Massachusetts.

Finally, SK 110, represented by an M2 embedded in mandible, offers an isotopic comparison or regional and dietary change from childhood to adulthood. Enamel $\delta^{18}O_w$

(-12.3‰) and $^{87}Sr/^{86}Sr$ (0.710) indicated that this individual originated from the northeastern United States, possibly New Hampshire, Vermont, or Maine, and as a child subsisted off both C_3 and C_4 foods, his close proximity to the Canadian border facilitating close cultural ties to the settled loyalists. As an adult, SK 110 migrated further south to participate in the war. This is indicated by his bone $\delta^{18}O_w$ signature (-6.4‰), which is characteristic to Ohio, Virginia, Maryland, New Jersey, and Rhode Island. Bone $\delta^{13}C_{co}$ (-20.2‰) suggests little dietary change into adulthood, particularly in the choice of dietary protein, which continued to include salted pork and beef raised on C_3 fodder. However, his bone $\delta^{13}C_{CA}$ value is slightly enriched by 0.95‰ over his enamel $\delta^{13}C_{CA}$ signature, indicating increased C_4 consumption.

Overall, the bone and tooth data suggests that most of the individuals isotopically analyzed here included C_3 based foods in their diets, consistent with the historical claims that the inhabitants of British Canada and the northern United States were consuming large quantities of C_3 grain in the form of bread and domestic livestock fed wheat and rice as fodder. Tooth $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values, although overlapping with bedrock $^{87}Sr/^{86}Sr$ and meteoric $\delta^{18}O$ values across North America and the United Kingdom, suggest that a small number of individuals (n = 5) originated from North America, with the origins of 9 individuals remaining inconclusive. Stable $\delta^{13}C$ and $\delta^{15}N$ are similarly consistent with historic documentation concerning early 19th century diet throughout North America and United Kingdom; the evidence indicating that at least 6 individuals from bone were consuming maize in greater quantities than the rest. For bone, unfortunately, 20 individuals are within the overlapping meteoric $\delta^{18}O$ range for both North America and

the United Kingdom, although 2 soldiers are below the lightest $\delta^{18}O_w$ value measured in the United Kingdom, indicating that these are indeed American, Canadian militiamen, or British regulars of the 49th Regiment. The following chapter discusses the behavioural and historical implications of these results in greater detail.

Chapter 7 Discussion and Conclusions

7.1 Implications for Regional Origins and Diet from Tooth Enamel

The isotopic results obtained from 14 2nd molars show that as young children these soldiers were consuming water and food from different geographic locations. Unfortunately, the compositional geology and isotopic gradients of $^{87}Sr/^{86}Sr$ and $\delta^{18}O_w$ across North America and the United Kingdom overlap (see Chapter 6 for baseline comparisons), making the provenance of 9 individuals inconclusive. Although the enamel $^{87}Sr/^{86}Sr$ range is within the overlapping range for both continental regions, the most negative $\delta^{18}O_w$ value measured in the United Kingdom (-9‰) offers a threshold for which the rest of the sample can be compared. As previously shown in Figure 6.6, 5 individuals have $\delta^{18}O_w$ further depleted than the lowest British $\delta^{18}O_w$ value, indicating a childhood upbringing in North America. If, however, we include diet as a regional indication of two culturally distinct agricultural populations (i.e. one C_3 based; the other C_4 based), then of the 5 known North Americans, 1 individual (SC 29; $\delta^{13}C$ = -9.9‰) has a $\delta^{13}C$ signature characteristic of the dietary habits of the mid to southern United States, that is, the consumption of a significant proportion of C_4 foods (Mintz 2012). The remaining 4 individuals (SK 110, SK 294, SC 41, SC 346) have $\delta^{13}C$ values consistent with a C_3 diet, placing them in a dietary category characteristic of traditional European diets practiced in both British Canada and the northeastern United States during the early 19th century (Katzenberg et al. 2000; Roberts et al. 2012). Given that dietary patterns between the

United States and Great Britain are sufficiently different, it may also be possible to infer regional origins based on traditional diets whose bulk composition relied heavily on C_3 or C_4 foods. Of the 9 enamel samples of indeterminate geographic origin, 4 (SC 47, SC 344, SK 283, SK 286) individuals have $\delta^{13}C$ values more consistent with a C_3, European diet (see Figure 6.7). However, it is also possible that these individuals were consuming a predominantly European diet as children, yet lived in British Canada or the northeastern United States, regions of North America where wheat remained the dominant cultigen used in feeding livestock and making bread. The remaining 5 individuals (SC 40, SC 393, SC 339, SC 45, SK 288) have $\delta^{13}C$ signatures indicative of increased C_4 consumption, and thus of North American dietary origins. Table 7.1 documents the possible regions of origin for each tooth sample.

Table 7.1: Multi-isotopic evidence for regional origins from tooth enamel.

Sample	$\delta^{18}O$	$^{87}Sr/^{86}Sr$	$\delta^{13}C$	Final Interpretation
SC 29	North America	North America	C_4 – North America	North American
SC 40	North America or Scotland	North America or Scotland	C_4 – North America	North American
SC 41	North America	North America or United Kingdom	Intermediate C_3/C_4 diet	North American
SC 45	North America or United Kingdom	North America or United Kingdom	Intermediate C_3/C_4 diet	Indeterminate
SC 47	North America or United Kingdom	North America or United Kingdom	C_3 – European diet	United Kingdom origins
SC 339	North America or United Kingdom	North America or United Kingdom	Intermediate C_3/C_4 diet	Indeterminate
SC 344	North America	North America	C_3 – European	United

	or United Kingdom	or United Kingdom	diet	Kingdom origins
SC 346	North America	North America or United Kingdom	C_3 – European diet	Indeterminate
SC 393	North America or United Kingdom	North America or United Kingdom	C_4 – North American	North American
SK 110	North America	North America or United Kingdom	C_3 – European diet	Indeterminate
SK 283	North America or United Kingdom	North America or United Kingdom	C_3 – European diet	United Kingdom origins
SK 286	North America or United Kingdom	North America or United Kingdom	C_3 – European diet	United Kingdom origins
SK 288	North America or United Kingdom	North America or United Kingdom	Intermediate C_3/C_4 diet	Indeterminate
SK 294	North America	North America or United Kingdom	C_3 – European diet	North American

The historical information concerning the broad areas of enlistment of soldiers into the American army are clear, though it is widely cited that the southern states (Georgia, Virginia, and Tennessee) were most in favour of war with the British. The isotopic evidence presented here, along with prior investigations confirmed that soldiers were being recruited from Maine to Virginia, spanning the entirety of the nascent United States. The isotopic results from teeth indicate this broad distribution, including several soldiers whose origins may be traced back to the United Kingdom. One problem in using $\delta^{13}C$ as a regional indicator is that the diets of 19th century inhabitants in North America were highly varied, consuming both C_3 and C_4 foods. Mintz (2012) suggested that maize

was widely consumed in the mid- to southern United States, and was also used as livestock feed. Conversely, the inhabitants of British Canada and the northern United States consumed less maize, substituting this C_4 cultigen with wheat, oats, and possibly rice, all C_3 plants. Individuals of North American origin would then be indistinguishable in diet from individuals originating from the United Kingdom. For this reason, the final interpretation presented in Table 7.1 includes the historical dietary information regarding differences in maize consumption patterns, and that culinary practices in British Canada and the United States were similar to those practiced in the United Kingdom. In sum, the broad isotopic distribution from teeth suggests that these soldiers may have been regulars in both the British and American armies, militiamen or artificers (as suggested by Elliott 2009), or First Nations warriors.

Oxygen and strontium isotopes paired with dietary indicators (i.e. carbon and nitrogen) have narrowed the possible regions of childhood residency. However, with significant dietary mixing taking place throughout the North American continent during the 19th century, dietary measures should not be considered as regional indicators alone. In effect, the exact location of origin for the 9 unidentified individuals remains unknown.

7.2 Dietary Implications from Bone Collagen

The isotopic composition of bone collagen has provided insight into the staple dietary items available to these soldiers during the early 19th century. The mean $\delta^{13}C_{co}$ value (-18.3‰) suggests that a significant portion of the diet consumed by the men buried at Smith's Knoll was composed of C_3 food items such as wheat, rice, and oats, with a

smaller number of soldiers consuming large quantities of C_4 foods that included maize and/or sugar cane in the form of molasses. C_3 and C_4 contribution also came in the form of terrestrial meat consumption, in other words, livestock fed C_3 and C_4 fodder, or a combination of the two.

The isotopic data fit with the historic information concerning the consumption of these two plant types (or animals feeding on fodder), namely the wheat-rich northern North America and United Kingdom, and a maize-rich mid- and southern United States. Complicating matters further, these foods may have been consumed according to traditional patterns of subsistence. With continued cultural ties between the northeastern United States and the Loyalists residing in Upper and Lower Canada, 19th century Americans occupying the border regions of the United States may have had identical dietary patterns to their British and Canadian counterparts. Historical sources indicate that after the American War of Independence in 1783, defectors in British Canada kept in close contact with family members in the United States (Berton 1995; Suthren 1986; Stanley 1983; Turner 2000). These cultural and kin-based ties may have reinforced the culinary practices common to the initial British settlers of the North American continent. This is further indicated by the fact that populations residing in close proximity to the borders of British Canada and the United States – farmers in particular – smuggled and traded livestock across border regions during times of scarcity (Berton 1995; Hickey 1989).

Dietary variation in the Smith's Knoll bone collection is primarily due to increased C_4 consumption among 6 soldiers, with 4 individuals (SK 054, SK 088, SK

089, and SK 103) in the C_4 non-overlapping dietary range (Figure 6.8). Interestingly, these soldiers also have $\delta^{18}O_w$ values consistent with a long-term residency in the mid to southern United States, a historical area known for its wide use of maize as fodder for livestock. It is possible then that these 4 soldiers resided in the mid to southern United States before engaging in combat along the Niagara frontier. SK 119 ($\delta^{13}C_{co}$ = -16.6‰) and SK 116 ($\delta^{13}C_{co}$ = -16.1‰) are slightly more depleted relative to the lowest C_4 dietary value of -16‰; they also have $\delta^{18}O_w$ values characteristic of the northeastern and southern United States, respectively. In contrast, 11 soldiers have $\delta^{13}C_{CO}$ values within a C_3 dietary range (i.e. -22‰ to -19‰). As previously discussed in Chapter 6, the isotopic results for these soldiers are compatible with Upper Canadian diets during this time, as well as the diets of early 19th century British sailors (Katzenberg et al. 2000; Roberts et al. 2012), which included C_3 grains in the form of bread and rice, vegetables, maize in the form of cornbread, meat from domestic cattle and pig, and fresh water fish. Note, however, that two soldiers – SK 037 and SK 045, identified as American inhabitants by their $\delta^{18}O$ values (Figure 6.11) – are within a C_3 dietary range. Presumably, given the dietary habits of individuals residing in the northeastern versus those in the southern states, it is possible that these individuals had traditional diets similar to their counterparts residing in British Canada. The remainder of the bone sample (n = 7) has intermediary carbon values that suggest both C_3 and C_4 consumption. These 7 soldiers are also within the overlapping $\delta^{18}O_w$ range of the United States and United Kingdom. Consequently, the long-term residency and thus geographic origins of these soldiers remains indeterminate.

Delta $^{13}C_{ca\text{-}co}$ and $\delta^{15}N$ values indicate that the Smith's Knoll soldiers relied heavily on C_3 grain in the form of bread, vegetables, staple items such as wheat or maize, with moderate to low amounts of protein derived from meat (see Katzenberg and Pfeiffer 1995; Katzenberg et al. 2000). The $\delta^{15}N$ values similarly suggest that when meat was consumed, terrestrial herbivores, including domestic cows and pigs were the main sources (Katzenberg 1991; Raynor and Kennet 2008). However, 3 soldiers (SK 098, SK 099, and SK 111) have elevated $\delta^{15}N$ values indicating that these individuals included higher tropic level organisms in their diets, such as fresh water fish (i.e. $\delta^{15}N$ values higher than 11.7‰ – according to Raynor and Kennett 2008). Even though some historical texts have alluded to the fact that the British, in the very least, refrained from fish consumption due to fear of dysentery, with the hardships of battle, dwindling rations and lack of supplies, these and other soldiers would have undoubtedly become opportunistic, making use of all available resources (Henderson 2012). It is not surprising that at least some of these individuals consumed aquatic resources when terrestrial meat was unavailable. The $\delta^{13}C$ and $\delta^{15}N$ results obtained for this research are consistent with those reported by Roberts et al. (2012), in that a significant majority of the Smith's Knoll soldiers sampled here were consuming more C_3 foods. In contrast, the $\delta^{13}C$ and $\delta^{15}N$ results obtained by Raynor and Kennett (2008) suggest that the individuals in their sample were consuming a larger proportion of maize than the individuals represented here. The results presented by Raynor and Kennett (2008) are consistent with the events that unfolded between the onset of the 1812 war and the subsequent occupation of Fort Erie by the Americans in the summer of 1814, meaning that the individuals buried in the adjacent Fort Erie cemetery

included a larger number of American casualties who died during the siege on July 3rd, 1814 (Dale 2001).

7.3 Implications for Long-Term Residency from Bone Phosphate

Bone oxygen isotope results are less variable than enamel oxygen values, an expected trend given the participants of the 1812 conflict; in other words, most of the participants of the Stoney Creek conflict had been stationed in North America for at least 10 years (with the exception of the King's 8th Regiment, who were re-commissioned back to Upper Canada in 1809). Since the converted $\delta^{18}O_w$ for 20 individuals overlap with the observed meteoric oxygen isotope gradients of both the United States and United Kingdom, the long-term residency of these individuals remains indeterminate. Nevertheless, 2 soldiers (SK 037 and SK 045) are depleted relative the lowest meteoric oxygen value obtained for the United Kingdom, suggesting that these individuals were indeed American soldiers or Canadian militiamen who spent a considerable amount of their lives before the war living in the northeastern United States or Upper Canada (Figure 6.11). Although the British 49th and King's (8th) Regiment constituted the bulk of the British regular force, the oxygen isotope results suggest that the 20 unidentified soldiers were either British regulars of the 8th Regiment, Canadian militiamen or American soldiers. This is due to the fact that the British 49th Regiment had been garrisoned at Montreal since 1802, a ten-year period before the onset of war (Hitsman 1999). If individuals of the 49th had been represented in this sample, their bone oxygen isotopes should theoretically indicate residency at this latitude, an area where meteoric oxygen is isotopically lighter than -10‰. It is more likely that if some of these individuals

are British regulars, they represent individuals from the King's (8^{th}) Regiment, since they were re-commissioned back to Canada in 1809 when tensions between America and Britain, again, began to escalate. Or, an even less probable scenario due to an extremely small presence on the battlefield, represent Canadian militiamen who spent a large portion of their lives living in the Niagara region; individuals whose isotopic compositions would be indistinguishable from British soldiers of the 8^{th} Regiment as well as American soldiers from the northeastern United States.

Taking both the evidence of diet and long-term residency into consideration, some preliminary conclusions can be made regarding the geographic origins of these soldiers, based on the $\delta^{13}C$ and $\delta^{18}O$ results from bone. It is possible that the 6 soldiers (SK 116, SK 088, SK 103, SK 054, SK 119, and SK 089) with enriched $\delta^{13}C$ values represent, in the long-term, diets consistent with traditional staple items, maize, of the mid to southern United States (Figure 6.8; Table 6.2). This conclusion is also consistent with their bone $\delta^{18}O_w$ values, which are characteristic of the $\delta^{18}O_w$ composition of drinking water from these regions (Figure 6.11). In addition, 2 soldiers (SK 037 and SK 045), whose $\delta^{13}C$ values suggest a traditional European diet, have $\delta^{18}O_w$ values consistent with water from the northeastern United States. In total, 6 (27%) individuals may have been American soldiers who engaged in the Niagara campaign beginning in the early spring of 1813. The remaining 16 (73%) soldiers have $\delta^{13}C$ values indicative of C_3 consumption, and a smaller number of soldiers who included C_3 food items with complimentary amounts of C_4 foods like maize or sugarcane in their diets (see Table 7.2 for possible areas of long-term residency). The possibility that these soldiers were Canadian-born militiamen,

American soldiers from the northern and/or northeastern United States, or British Regulars of the King's (8th) Regiment, however, remains unclear.

Table 7.2: Isotopic evidence for long-term residency from bone.

Sample	$\delta^{18}O$	$\delta^{13}C$	Final
SK 001	American or British soldier	C_3 – European diet	British regular or American soldier form the northern U.S.
SK 002	American or British soldier	C_3 – European diet	British regular or American soldier from the northern U.S.
SK 034	American or British soldier	C_3 – European diet	British regular or American soldier from the northern U.S.
SK 037	American soldier or Canadian militiaman	Mixed C_3/C_4	Indeterminate
SK 040	American or British soldier	C_3 – European diet	British regular or American soldier from the northern U.S.
SK 042	American or British soldier	C_3 – European diet	British regular or American soldier from the northern U.S.
SK 045	American soldier or Canadian militiaman	C_3 – European diet	Indeterminate
SK 054	American or British soldier	C_4 – North American diet	American soldier
SK 088	American or British soldier	C_4 – North American diet	American soldier
SK 089	American or British soldier	C_4 – North American diet	American soldier
SK 098	American or British soldier	Mixed C_3/C_4	Indeterminate
SK 099	American or British soldier	C_3 – European diet	British regular or American soldier

			form the northern U.S.
SK 101	American or British solider	Mixed C_3/C_4	Indeterminate
SK 103	American or British soldier	C_4 – North American diet	American soldier
SK 104	American or British soldier	C_3 – European diet	British regular or American soldier from the northern U.S.
SK 105	American or British soldier	C_3 – European diet	British regular or American soldier from the northern U.S.
SK 107	American or British soldier	Predominantly C_3 diet	British regular or American soldier from the northern U.S.
SK 110	American or British soldier	C_3 – European diet	British regular or American soldier from the northern U.S.
SK 111	American or British soldier	C_3 – European diet	British regular or American soldier form the northern U.S.
SK 116	American or British soldier	C_4 – North American diet	American soldier
SK 119	American or British soldier	C_4 – North American diet	American soldier
SK 122	American or British soldier	C_3 – European diet	British regular or American soldier from the northern U.S.

7.4 Isotopic and Historical Limitations to Interpreting Regional Origins and Diet in the Smith's Knoll Sample

As in all areas of research, there are several limiting factors that make interpretation problematic. The isotopic composition of the human skeleton (and other

biological and non-biological systems) is extremely complex, complicated by both internal and external biochemical interactions and reactions between organisms, the environment, and in the case of humans, culture. Thus for the purpose of this research, delineating social categories (i.e. nationality) based on stable isotopes alone should be considered tentative (Katzenberg 1991). This aside, given the known distribution of the stable isotopes relevant to bioarchaeology, it is possible to make preliminary claims regarding the nature of past human behaviour, especially in cases where historical documents provide substantial information at both regional and individual scales. This statement is not meant to discredit prehistoric isotopic applications, but rather addresses the documented social dimensions from which these 19th century soldiers originated, in a historical bioarchaeological context.

The first, and perhaps most obvious problem with historical analysis are the inconsistencies in the historical record. This seems to be particularly true for casualty figures, which can sometimes differ from tens to hundreds depending on the historian, historical perspective, and year of publication (Cruikshank 1902; Dale 2001; Elliott 2009; Fryer 1986; Geary 1912). It is also true that historians cannot agree on who or how many individuals, soldiers, militiamen, artificers or otherwise, participated in battle. For example, Fryer (1986) and Stanley (1991) noted that with the arrival of several British companies of the King's (8th) Regiment from Fort Erie, General Vincent had subsequently dismissed the militia to their homes upon retreat to Burlington Heights; they further stated that only the British 49th and 8th Regiments were engaged in the night raid at Stoney Creek. These historical claims are countered by Elliott's (2009) account of the

Battle of Stoney Creek, who indicated that several soldiers of the 41st Regiment of Foot, and an unaccounted number of Lincoln Militia of the 1st, 2nd, and 4th Regiments, York Militia of the 2nd Regiment, and Niagara Provincial Dragoons, had also become casualties by battles end. The more recent historical interpretation by Elliott (2009), gathered from primary historical archive material, means earlier narratives concerning the complete dismissal of local militia and other Canadian-born forces by General Vincent are inaccurate. Furthermore, this also means that Canadian-born soldiers and a few indigenous warriors engaged and died at Stoney Creek, and as a consequence might be represented in the Stoney Creek skeletal collection. If this were indeed the case, then Canadian-born individuals would be indistinguishable from American and British soldiers living in regions of North America and the United Kingdom where meteoric oxygen and strontium isotopes overlap.

Isotopic overlap is another factor limiting interpretations concerning the regional origins and long-term residency of these soldiers. This is a consistent limitation in isotopic research, particularly in archaeological contexts that may contain individuals from several geographically distinct regions, a case in particular for any major battlefield site. As previously noted in Chapter 6, both $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ baseline compositions of the geological substrate and meteoric water gradients of North America and the United Kingdom overlap. In fact, distinguishing North American-born versus United Kingdom-born individuals from enamel was primarily due to isotopically lighter values falling below the maximum United Kingdom value of -9‰. This was similarly true for bone phosphate values, where 2 individuals fell below this cutoff, indicating they spent the

majority of their time residing in the northeastern United States or Upper Canada, and that these men were either American or Canadian soldiers. Until further isotopic research is conducted, or other methods of geographic individuation are employed on the Smith's Knoll skeletal sample, the origins of these soldiers will remain unidentified.

Another important factor to consider when interpreting bone isotopic data from individuals who are known to have included a variety of foods in their diets is the issue of dietary mixing, and the long-term turnover of bone collagen. As a consequence of these long-term turnover rates, the isotopic results from bone collagen and carbonate represent the average long-term diet of the individual over a period of 10 to 20 years. In North America, where individuals were consuming a highly variable diet of C_3 and C_4 foods, as well as deriving protein from terrestrial and aquatic resources, an interpretation concerning the long-term residency becomes complex.

7.5 Future Considerations

Since the recovery of human remains from Battlefield Park at the turn of the millennium, the Smith's Knoll collection has been the subject of persistent anthropological inquiry. These excavations were undertaken in the hope of distinguishing American from British soldiers, and perhaps even Canadian-born individuals, buried at Stoney Creek. Much of the historical and bioarchaeological analysis primarily concentrated on the skeletons themselves, with preliminary investigations into the trauma sustained by these soldiers during battle (Liston 2000). This thesis has added to previous investigations through the multi-isotopic analysis of 14 2^{nd} molars, 9 of which were

isotopically reanalyzed from Blyth's (2003) earlier thesis. In addition, the carbon, nitrogen, and carbonate-oxygen composition of 21 left femora and 1 mandibular fragment were also measured to obtain general insight into the main dietary patterns of these soldiers approximately 10 to 20 years prior to death. The isotopic data from this study has shown that some soldiers had drastically different diets, most with traditional European diets, fewer with North American diets characterized by maize.

Additional $^{87}Sr/^{86}Sr$ analysis of the Smith's Knoll bone and tooth collection would also provide a broader understanding of where these soldiers originated, instead of measuring the strontium isotope composition of teeth alone. Since historical documents have suggested that some of the participants of the battle originated from Upper Canada, this might help determine whether or not this military contingent was larger than historically suggested, provided that a strontium baseline map is constructed using agricultural soil from southern Ontario and Québec. This is one limiting factor encountered during this research. Since Blyth's (2003) CI results for bone indicated little post-mortem alteration and recrystallization, $^{87}Sr/^{86}Sr$ analysis of these samples would compliment the $\delta^{18}O$ results obtained from bone, further narrowing the areas long-term residency for soldiers and allow a thorough comparison with the historical data on areas of recruitment documented by Elliott (2009). Given that only 6 individuals analyzed in this research had higher $\delta^{13}C$ values, a larger sample might elucidate if whether or not dietary variability was much broader than these data suggest. This would also support the historical claim that the midwestern and southern states were generally in favour of war with the British. These soldiers may be distinguished by their heavier oxygen and carbon

isotopic compositions, an assumption that may be tested if more isotopic research is undertaken. Conducting mitochondrial DNA (mtDNA) analysis on the Smith's Knoll sample might also be another important application, particularly if some of the individuals represented in the Smith's Knoll sample are of First Nations ancestry.

A concerted attempt to define the actual ^{87}Sr bioavailability of the United Kingdom and North America should be considered in the near future if we are to interpret the $^{87}Sr/^{86}Sr$ composition of prehistoric and historic remains originating from these regions. Although no such study exists, the provenance of human remains using maps based on lithological, time-specific parameters and water catchments may in fact be problematic (Bataille and Bowen 2012; Evans et al. 2010). This may be due in part to the processes that form crop producing, agriculturally rich soils. In low-lying valleys and basins soils are generated through weathered glacial till, and other glaciological structures as the ice-sheets retreated during the end of the last Ice Age. In other words, humans residing on hilly terrain or in small valleys between hills should theoretically reflect the $^{87}Sr/^{86}Sr$ ratios the local bedrock, bedrock eroded by wind and water processes from adjacent mountain regions. Alternatively, humans residing in large valleys, prairies, or basins, where pedogenesis (soil formation) is a function of glacially derived structures and rocks (i.e. moraines and glacial till); their $^{87}Sr/^{86}Sr$ ratios should then reflect the $^{87}Sr/^{86}Sr$ composition of the parent rocks. As a consequence, the dominant agricultural soils of Canada, the northern United States, and United Kingdom, should theoretically reflect geological $^{87}Sr/^{86}Sr$ compositions of non-local geological substrates (Henry Schwarcz, personal communication, 2012).

7.6 Conclusions

This research has demonstrated that the specific geographic origins of a small number of the Smith's Knoll soldiers (*n*=5) could be discerned through the examination of a suite of isotopic analyses. Although some of the soldiers could not be assigned to a specific geographic location, this study confirmed that their origins did indeed span the landscapes of the nascent United States and Canada, and across the Atlantic to the United Kingdom. In terms of dietary practices, the isotopic evidence points to the historically suggested patterns of traditional food consumption, namely the European C_3-based diet, and C_4 diet of North America. This research has contributed another anthropological dimension to prior historic investigations into the lives of 19th century Upper Canadian, British, and American inhabitants.

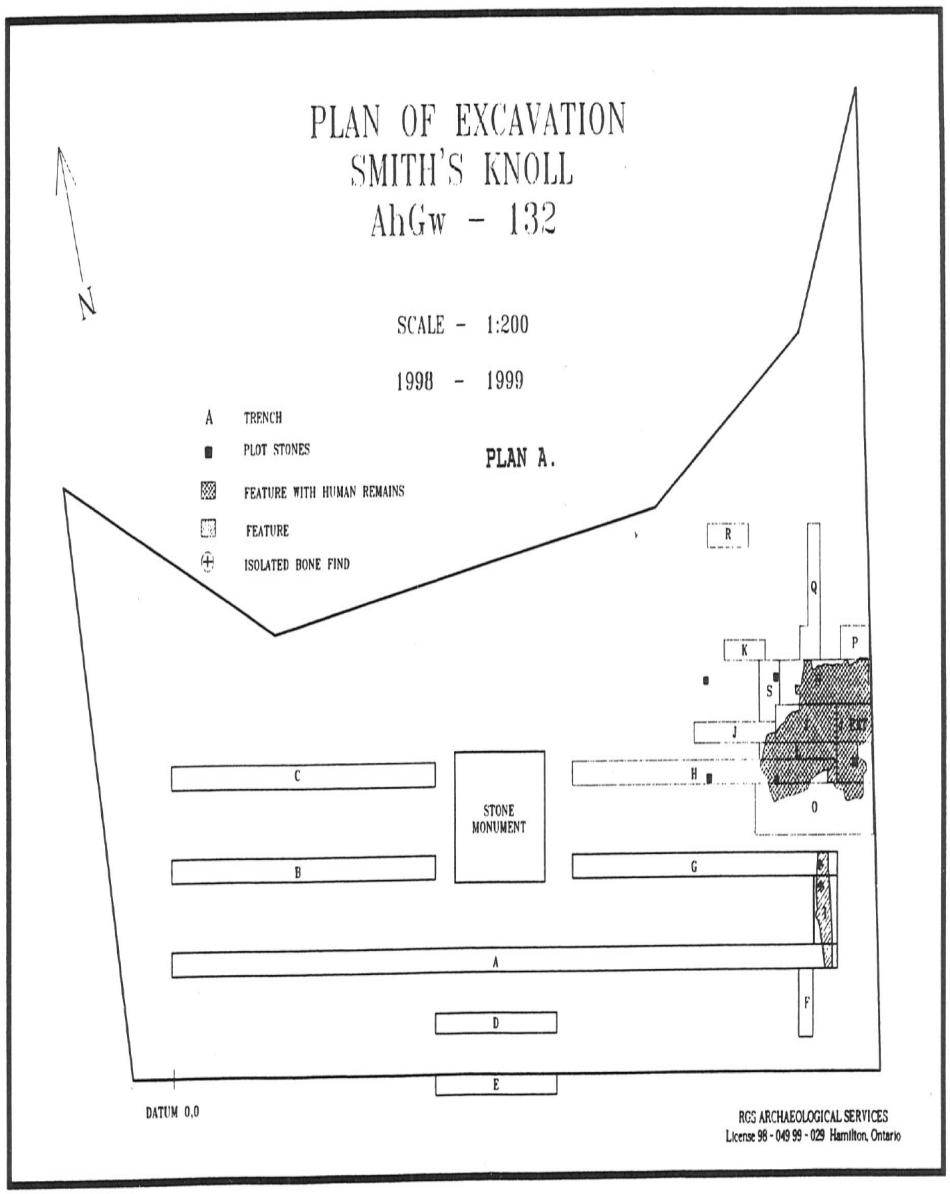
Second, this study is the first attempt to document the strontium composition of teeth from 19th century soldiers stationed and killed on Canadian soil. Interestingly, this research has brought a number of questions to light, particularly in respect to the rigid historical claims of highly regimented military diets (i.e. Henderson, accessed 2012), as well as the geopolitical landscape of the Midwestern and southern United States; the states most in favour of war. Instead, these results suggest that soldiers enlisting into the American army to serve in British Canada originated, or spent a significant portion of their lives in the northern, Midwestern, and southern regions of the United States, a much broader spectrum than historically claimed (Strum 1980).

By doing this type of multi-isotopic bioarchaeological analysis, embedded within the historical context of the period, we may gain a deeper understanding of the social dynamics of 19th century warfare and the national identities of the participants in these historic battles.

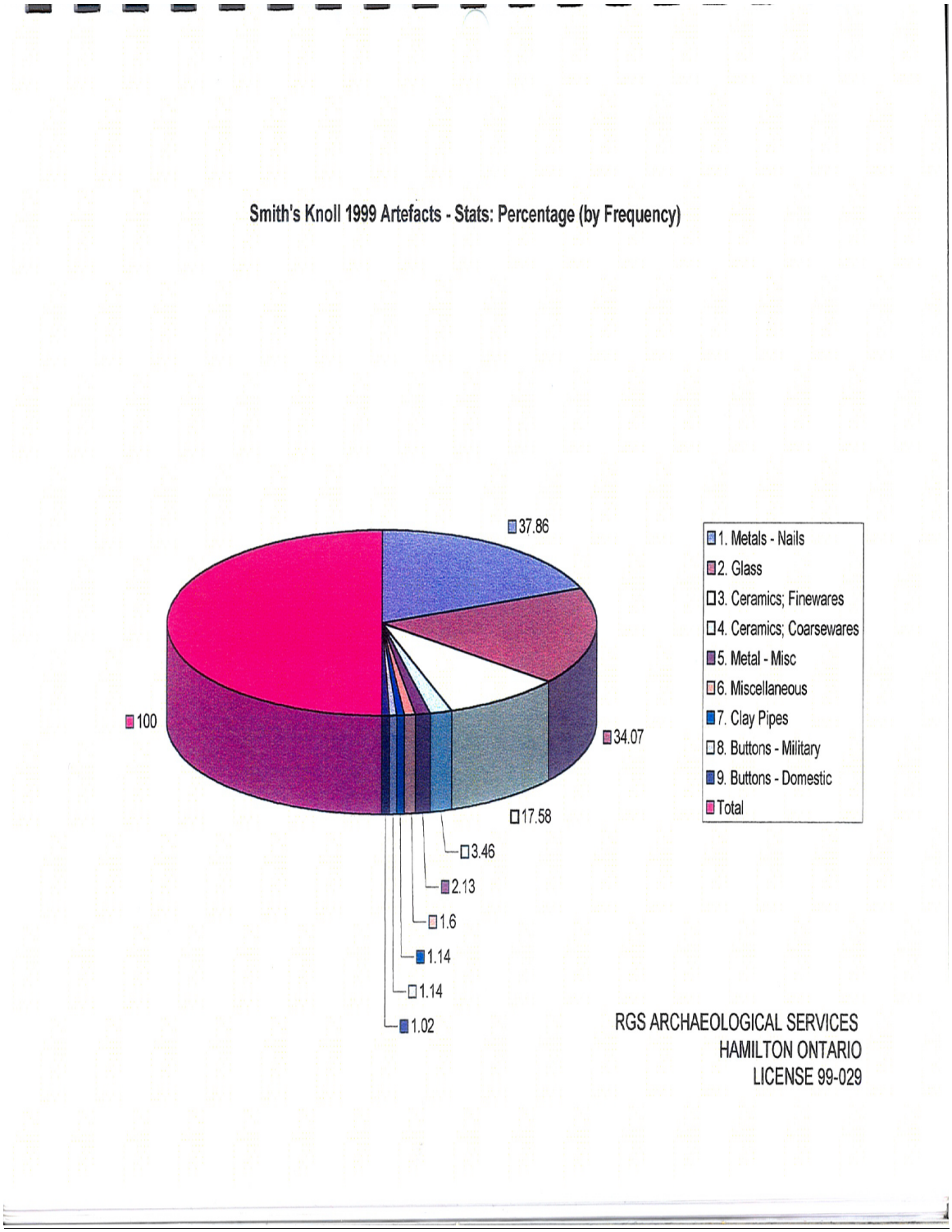
Appendix A: Map showing the location of Stoney Creek (Griffin-Short 2000: 2)

Appendix B: Location of Battlefield Park and Smith's Knoll (Griffin-Short 2000: 3)

Appendix C: Trench Plan of Excavation, Smith' Knoll (Griffin-Short 2000: Appendix A)



Appendix D: Smith's Knoll Artifacts (%) (Griffin-Short 2000: 13)



Appendix E: Enamel powder weight for $^{87}Sr/^{86}Sr$ analysis (mg)

Sample ID	Weight (mg)
SC 29	80.4
SC 40	66.9
SC 41	81.7
SC 45	82.6
SC 47	83.9
SC 339	90.5
SC 344	89.5
SC 346	78.8
SC 393	70.9
SK 110	80.1
SK 283	98.7
SK 286	111.5
SK 288	92.0
SK 294	84.7
Mean	85.2

Appendix F: Bone carbonate weight

Sample ID	Weight (mg)
SK 105	32.6
SK 098	32.1
SK 037	32.1
SK 089	34.5
SK 116	33.1
SK103	31.1
SK 088	33.3
SK 111	32.4
SK 042	33.3
SK 001	31.8
SK 119	30.8
SK 034	33.0
SK 002	30.9
SK 054	31.4
SK 101	31.9
SK 099	31.6
SK 040	30.4
SK 110	30.6
SK 045	30.7
SK 122	30.9
SK 104	32.7
SK 107	30.4
Mean	31.8

Appendix G: Tooth enamel carbonate weight

Sample ID	Weight (mg)
SC 29	22.0
SC 40	17.6
SC 41	19.7
SC 45	18.7
SC 47	24.7
SC 339	25.0
SC 344	23.4
SC 346	25.1
SC 393	17.7
SK 110	23.5
SK 283	23.1
SK 286	32.7
SK 288	24.6
SK 294	18.4
Mean	22.5

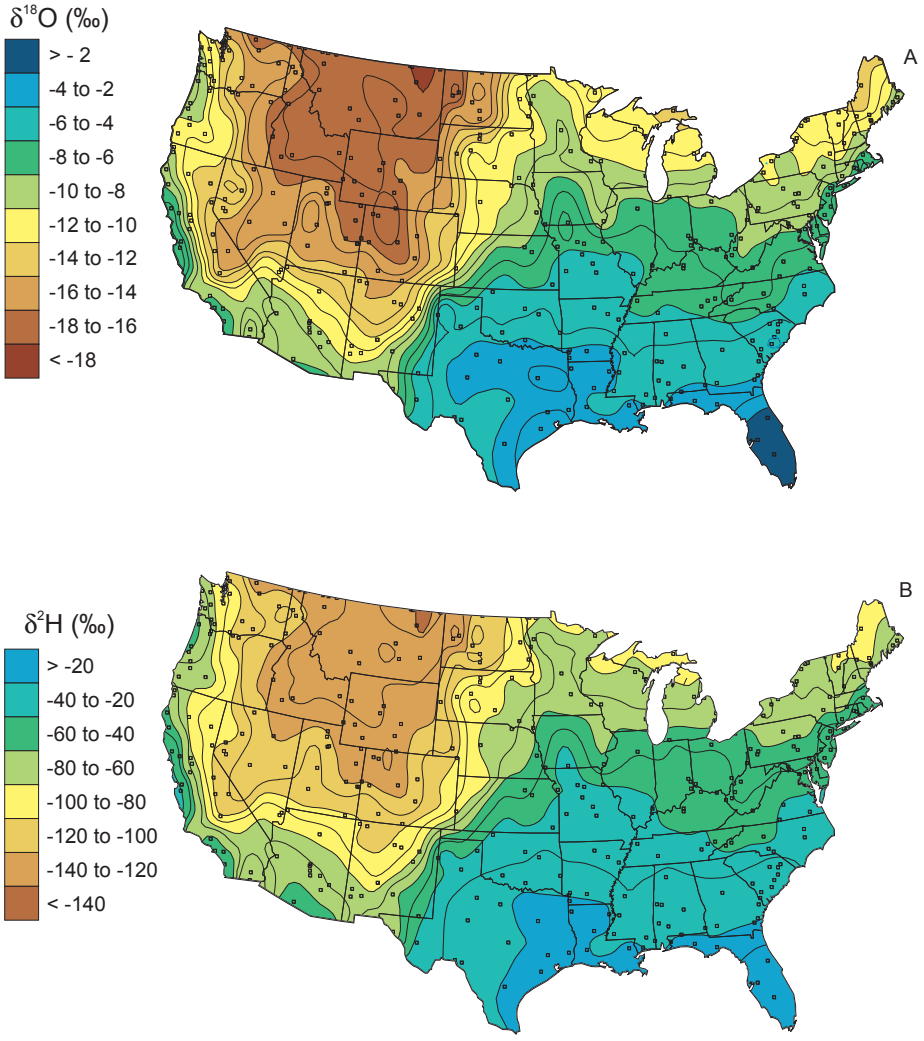
Appendix H – Enamel Oxygen-Phosphate Isotopic and CI Results Obtained by Blyth (2003).

Stoney Creek Sample ID	Element	$\delta^{18}O_p$ (‰)	Adjusted* $\delta^{18}O_p$ (‰)	Yield[1] CO_2 VSMOW	Yield[2] Ag_3PO_4 VSMOW	CI
SC 5	I1	17.1	16.4	4.6	1.6	---
SC 6	I2	16.0	15.3	4.9	1.2	3.48
SC 7	I2	15.9	15.2	4.6	1.3	3.50
SC 28	M3	15.9	15.9	4.8	1.5	3.36
SC 29	M2	16.2	16.2	4.5	1.7	3.34
SC 30	M1	16.8	16.1	4.8	1.6	3.45
SC 31	M3	15.4	15.4	4.7	1.6	3.46
SC 32	M3	15.2	15.2	4.7	1.5	3.47
SC 36	M3	15.2	15.2	4.8	1.4	3.55
SC 40	M2	15.8	15.8	4.5	1.7	3.46
SC 41	M2	17.4	17.4	4.8	1.7	3.32
SC 42	M1	17.4	16.7	4.8	1.6	3.56
SC 43	M3	16.5	16.5	4.7	1.7	3.35
SC 44	M3	16.4	16.4	4.7	1.7	3.46
SC 45	M2	17.6	17.6	4.8	1.5	3.32
SC 46	M3	15.2	15.2	4.8	1.0	3.44
SC 47	M2	17.4	17.4	4.8	1.6	3.54
SC 335	M3	17.1	16.1	4.7	1.7	3.39
SC 336	M1	16.2	15.5	4.3	1.7	3.39
SC 337	M3	17.8	17.8	4.6	1.6	3.41
SC 338	I1	16.5	15.8	4.7	1.5	3.39
SC 339	M2	17.1	17.1	4.7	1.5	3.37
SC 343	M1	17.9	17.2	4.7	1.4	3.42
SC 344	M2	17.2	17.2	4.8	1.5	3.37
SC 345	M1	17.0	16.3	4.7	1.6	3.30
SC 346	M2	17.0	17.0	4.6	1.5	3.19
SC 372	M3	17.0	17.0	4.6	1.6	3.40
SC 390	M3	16.5	16.5	4.5	1.7	3.37
SC 391	M1	16.1	15.4	4.7	1.4	3.34
SC 392	M1	16.9	16.2	4.7	1.6	3.28
SC 393	M2	16.4	16.4	4.7	1.5	3.42
SC 394	PM1	17.5	17.2	4.9	1.6	3.46
SC 423	M1	15.9	15.2	4.6	1.5	3.26
SC 425	M3	15.8	15.8	4.6	1.4	3.46
Mean * $n = 34$		16.6	16.3			3.40
SD		0.77	0.80			0.08

Appendix I – Enamel $\delta^{18}O_w$ results obtained by Blyth (2003)

Stoney Creek Sample ID	$\delta^{18}O_p$ (‰) VSMOW	$\delta^{18}O_w$ (‰) VSMOW $\delta^{18}O_p = 0.78\ \delta^{18}O_w + 22.7$ (Luz et al. 1984)	$\delta^{18}O_w$ (‰) VSMOW $\delta^{18}O_p = 0.64\ \delta^{18}O_w + 22.37$ (Longinelli 1984)
SC 5	17.12	-8.0	-9.3
SC 6	16.00	-9.4	-11.0
SC 7	15.95	-9.5	-11.1
SC 28	15.91	-8.7	-10.0
SC 29	16.22	-8.3	-9.6
SC 30	16.86	-8.3	-9.7
SC 31	15.49	-9.2	-10.7
SC 32	15.26	-9.5	-11.1
SC 36	15.25	-9.5	-11.1
SC 40	15.83	-8.8	-10.2
SC 41	17.48	-6.6	-7.6
SC 42	17.48	-7.5	-8.7
SC 43	16.57	-7.8	-9.0
SC 44	16.49	-7.9	-9.1
SC 45	17.62	-6.5	-7.4
SC 46	15.27	-9.5	-11.0
SC 47	17.47	-6.7	-7.6
SC 335	17.14	-8.3	-9.6
SC 336	16.26	-9.1	-10.6
SC 337	17.82	-6.2	-7.1
SC 338	16.51	-8.8	-10.2
SC 339	17.19	-7.0	-8.0
SC 343	17.90	-7.0	-8.0
SC 344	17.27	-6.9	-7.9
SC 345	17.00	-8.2	-9.4
SC 346	17.03	-7.2	-8.3
SC 372	17.05	-7.2	-8.3
SC 390	16.51	-7.9	-9.1
SC 391	16.13	-9.3	-10.8
SC 392	16.92	-8.3	-9.6
SC 393	16.48	-7.9	-9.2
SC 394	17.55	-7.0	-8.0
SC 423	15.90	-9.6	-11.2
SC 425	15.83	-8.8	-10.2
Mean * $n = 34$	16.61	-8.1	-9.4
SD	0.77	1.0	1.2

Appendix J – $\delta^{18}O_w$ variation for the continental United States (Kendall and Coplen 2001: 1373).



Appendix K – Bone Oxygen-Phosphate and CI Results Obtained by Blyth (2003).

Sample	Element	$\delta^{18}O_p$ (‰) VSMOW	Yield[1] CO_2 VSMOW	Yield[2] Ag_3PO_4 VSMOW	CI
SC 29B	Bone	13.3	4.6	0.9	2.9
SC N-1	Bone	14.8	4.8	1.1	3.5
SC N-2	Bone	14.1	4.7	1.0	3.0
SC J-2	Bone	14.5	4.7	1.0	3.2
SC J-3	Bone	14.8	4.8	1.0	2.9
Mean* $n = 5$		14.3	4.7		
SD		0.6	0.07		0.2

Appendix L – Bone $\delta^{18}O_w$ results obtained by Blyth (2003)

Stoney Creek Sample ID	$\delta^{18}O_p$ (‰) VSMOW	$\delta^{18}O_w$ (‰) VSMOW $\delta^{18}O_p = 0.78\ \delta^{18}O_w + 22.7$ (Luz et al. 1984)	$\delta^{18}O_w$ (‰) VSMOW $\delta^{18}O_p = 0.64\ \delta^{18}O_w + 22.37$ (Longinelli 1984)
SC 29B	13.3	-12.0	-14.1
SC N-1	14.8	-10.1	-11.8
SC N-2	14.1	-10.9	-12.8
SC J-2	14.5	-10.4	-12.2
SC J-3	14.8	-10.1	-11.8
Mean* $n = 5$	14.3	-10.7	-12.5
SD	0.6	0.8	0.9

Appendix M – Bone $\delta^{18}O_p$ and Estimated $\delta^{18}O_w$ Values for Snake Hill Soldiers (Schwarcz et al. 1991).

Snake Hill Sample ID	$\delta^{18}O_p$ (‰) VSMOW	$\delta^{18}O_w$ (‰) VSMOW $\delta^{18}O_p = 0.78\ \delta^{18}O_w + 22.7$ (Luz et al. 1984)	$\delta^{18}O_w$ (‰) VSMOW $\delta^{18}O_p = 0.64\ \delta^{18}O_w + 22.37$ (Longinelli 1984)
4	12.1	-13.5	-15.9
8	12.7	-12.8	-15.1
14	12.6	-12.9	-15.2
23	12.3	-13.2	-15.6
24	12.8	-12.5	-14.8
30	12.6	-12.8	-15.1
Mean* $n = 6$	12.5 ± 0.2	-13.0 ± 0.2	-15.3 ± 0.3
SD	0.2	0.3	0.4

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