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Evidence of pulmonary disease in the Poole-Rose Ossuary population: an analysis of the ribs

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EVIDENCE OF PULMONARY DISEASE IN THE POOLE-ROSE OSSUARY POPULATION: AN ANALYSIS OF THE RIBS

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Abstract

This study reports on the demographics and evidence of pulmonary disease in the Poole-Rose Ossuary which was excavated in 1990 under the direction of Heather McKillop. The bones are being studied at the request of the Alderville First Nation. Radiocarbon dated to A.D. 1550 ± 50 years, the skeletal material is a co-mingled collection that is consistent with a mass secondary burial event known as the Feast of the Dead often associated with the Huron.

The ribs were used in this study. The condition of the ribs was highly fragmented. The minimum number of individuals for this study was 49 based on the presence of the transverse facet of rib 1. The incidence of degenerative joint disease is low and affects the right side twice as much as the left. The most severe cases of degenerative joint disease occur in ribs 10 and 12. Periosteal reactions on the shaft of the rib suggest the presence of pulmonary disease. Lytic lesions present on the head and neck of the ribs suggest the presence of tuberculosis in the Ossuary. Overall, the ribs of the Poole-Rose Ossuary suggest a healthy population. However, lesions on the ribs occur in approximately eight percent of tuberculosis cases suggesting that there are cases of the disease within the population that are not reflected within the skeletal material.

Chapter One: Introduction

Paleopathologists seek out patterns both in the present and the past to find causes for human diseases. These patterns are both of a biological and sociocultural context. "Critical characteristics of environment result largely from sociopolitical influences; thus, man's infectious diseases, such as tuberculosis, are rightly considered social diseases" (Inhorn and Brown, 1990: 90). Present patterns of disease transmission and etiology are discovered by analyzing social patterns and habitats. Researchers identify specific social behaviors and behavioral patterns that will contribute to the spread of an infectious disease.

Past patterns of a more biological nature are often determined through paleopathology, the analysis of disease in ancient populations. The study of the ribs is useful in determining the presence of chronic pulmonary diseases within a past population. Rib lesions indicate the presence of pulmonary diseases. However, by themselves, they rarely serve as a diagnostic point of one specific disease. Although many pulmonary diseases can leave rib lesions, the most common cause is tuberculosis. Other pathologies, such as trauma and degenerative joint disease, can demonstrate stresses within a skeletal sample as an extension of vertebral pathologies.

Through the analysis of the rib pathologies within the Poole-Rose Ossuary, this research will provide an assessment of the presence of pulmonary diseases within the population. My goal is to study the ribs in the Poole-Rose Ossuary to ascertain demographic and health status information, as well as look for evidence of trauma.

In a 1999 thesis on the vertebrae, Dunne suggested the possibility of tuberculosis within the Poole-Rose population. Dunne found resorptive lesions and cavitations that were typical of tuberculosis. Pfeiffer (1991, 1984) also established the presence of tuberculosis within Iroquoian ossuary sites in Ontario.

In 1991, Pfeiffer studied the lesions on the ribs of the Uxbridge Ossuary collection for evidence of tuberculosis. She looked for different types of periosteal reactions and resorptions that may indicate a spread of pleural dissemination of pulmonary tuberculosis across the pleura onto the ribs.

The Poole-Rose Ossuary, accidentally discovered in 1990 during the renovations of a nineteenth century farmhouse, was excavated by Dr. Heather McKillop with cooperation of the nearest native band, Alderville First Nation (McKillop and Jackson, 1991). The ossuary collection fell under the Cemeteries Act of Ontario, as the site contained more than one burial. The Alderville First Nation would accept the remains

for reburial only if they were first studied by archaeologists and osteologists with respect to age, sex and health status (McKillop and Jackson, 1991). The material is currently located at Louisiana State University for the conclusion of that research.

An ossuary is a burial of multiple individuals that can include articulated or disarticulated remains (McKillop and Jackson, 1991). The Poole-Rose Ossuary, located in southern Ontario, is radiocarbon dated to A.D. 1550 +/- 50 years. Figure 1.1 shows the location of the Poole-Rose Ossuary on the Northern Shore of Lake Ontario. The excavation site was approximately 2.5 meters in diameter and 1.5 meters deep. The ossuary collection rested approximately 2.5 meters below the surface. The lack of soil layers between bone layers suggests a single burial event. The excavation was conducted in 20 centimeter levels once the disarticulated status made it apparent that noting the in-situ position of every bone would yield no useful information. The burial pattern was suggestive of the Feast of the Dead, a common burial practice during the Late Woodland Period, pre-European contact (McKillop and Jackson, 1991).

The Poole-Rose Ossuary contained the commingled remains of several hundred individuals representing a wide range of ages and including both males and females (Penney, 2005). These remains were found to be in good condition.

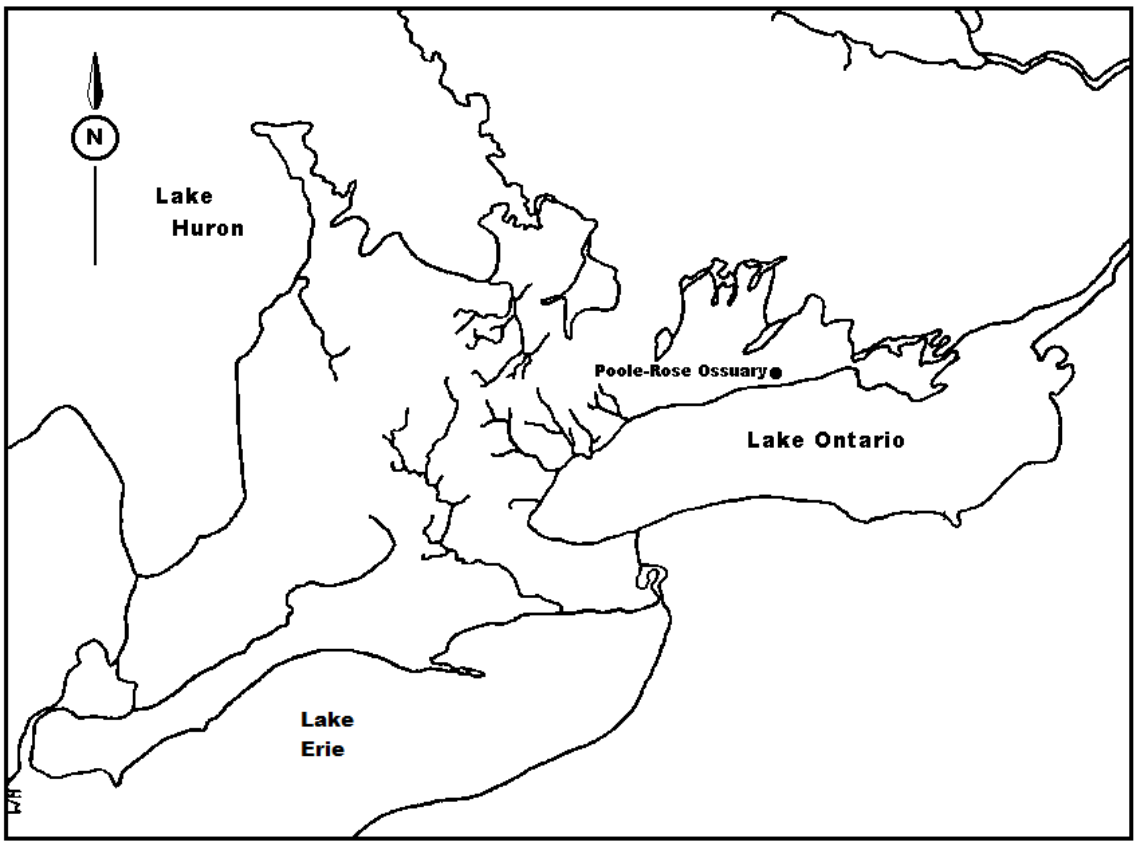

Figure 1.1 Location of the Poole-Rose Ossuary
(Adapted from Figure 1 in McKillop and Jackson, 1991: 13)

The Poole-Rose Ossuary is exceptional since it is one of the few undisturbed ossuaries that has been completely excavated. Ossuary burials are useful because they contain the remains of individuals who died over a short time span (McKillop and Jackson, 1991). However, because the bones were released into the pit and then commingled, the skeletons are too disarticulated to address each one as an individual. The full analysis of a single skeleton for factors such as demography and overall health is impossible. Analysis must then proceed on the

population level. Combined with research on other bones within the Poole-Rose Ossuary, this research will aid in reconstructing the health status of this population.

The people of the Poole-Rose Ossuary are a Late Woodland people of unknown cultural affiliation. Since the burial practice is analogous to the Feast of the Dead, the following chapters will include a brief discussion of the lifestyles of the Late Woodland Huron as pertains to the burial practices and the social organization that may have led to the transmission of disease. Barrett et al. (1998) studied the emergence and transitioning of infectious diseases. They found that patterns of disease can be related to both modes of subsistence and social structure. Other factors demonstrating the relationship between culture and disease included human demographics and behavior.

Chapter Two: Huron

The Huron belong to the Iroquoian language family which includes at least nine national groups. These groups ranged from northern Pennsylvania, New York, southern Ontario, and southern Quebec during the sixteenth and seventeenth centuries (Bamann et al., 1992). The Huron people settled in the Lower St. Lawrence River off the northern shore of Lake Erie and the southern shore of the Georgian Bay in the present day province of Ontario, Canada (Donnelly, 1975). By 1650 they were defeated and dispersed by the Iroquois. Most anthropologically relevant information about the Huron comes from the eyewitness accounts of seventeenth century French missionaries, Father Gabriel Sagard and Father Jean De Breboeuf (Sagard, 1939; Thwaites, 1896). The Poole-Rose Ossuary corresponds with the Huron burial pattern of the Feast of the Dead. Therefore, to understand the people of the Poole-Rose Ossuary, a discussion of the Huron is needed.

Territory and Environment

The Huron occupied the northern half of what is now Simcoe County, Ontario, Canada. The territory extended some 40 miles from east to west and 30 miles north to south and could be traversed over the course of three to four days (Donnely, 1975; Trigger, 1990). The members of the Huron Nation called themselves *Wendat* which meant "People of the Island." Although

they lived on a peninsula, the area is surrounded by the inlets of the Georgian Bay, the Severn River, Lake Simcoe, and the Nottawasaga River.

The surrounding area had arable land within a coniferous forest of evergreens, birch, oak, and maple. Small lakes and creeks dotted the area. Sagard (1939) noted that there were many open meadows with copious amounts of hay and many different types of wild fruits and vegetables that grew as thick as if they had been cultivated. The landscape was characterized by rolling hills without mountainous areas (Sagard, 1939). The area had a temperate climate with four well marked seasons. Soil type consisted of a loose sandy loam that was easy to plant (Donnelly, 1975; Johnston and Jackson, 1980; Tooker, 1964; Trigger, 1990).

Population and Settlement Patterns

Prior to 1635, when an epidemic of smallpox hit, the population was estimated to range between 20,000 and 30,000 (Johnston and Jackson, 1980). By 1640, an accurate census found 32 villages which housed approximately 12,000 Huron (Donnelly, 1975; Sagard, 1939).

Requirements for the location of a Huron village included accessible timber, a reliable source of water, a defensible position, and farmable land. The Huron tended to place their villages in the oxbow area of a river, allowing the location of

the creek or river to provide a natural defense against invaders (Johnston and Jackson, 1980). Villagers built a palisade with watch towers in front of the village for protection against attack. Inside the village's interior, longhouses were arranged closely to restrict traffic or confine it to narrow spaces while still leaving enough room to prevent the spread of fires (Donnelly, 1975; Johnston and Jackson, 1980; Sagard, 1939; Tooker, 1964).

The Huron constructed lodges and longhouses by burying thick poles in the ground then bending them together forming an arch. Builders then tied the poles together with cording. Cross poles, placed at regular intervals, created the framework. The frame was then covered with woven bark and mats. Holes were left in the roof so that smoke could escape. Longhouses averaged between 80 and 100 feet long, 25 feet wide and 25 feet tall (Donnelly, 1975; Johnston and Jackson, 1980). Huron longhouses tended to be shorter at either end (Trigger, 1990).

The interior of the longhouse followed a set pattern. Either end was used for storage. Along the center were a number of central hearths. Along each wall ran a platform raised about three feet off the ground. Two families, of four to six persons each, shared each hearth, one on each side. Houses contained anywhere from eight to twenty families (Donnelly, 1975; Johnston and Jackson, 1980; Tooker, 1964; Trigger, 1976).

Huron villages were not permanent residences. Every ten to twelve years the soil would become so exhausted that it could no longer yield an adequate crop. As well, the ready availability of firewood also became a problem. When both situations occurred, the men began clearing land, not too far off, so that fields would be ready when the village was moved. Villagers would then dismantle the houses and set them up again at the new village site (Donnelly, 1975; Johnston and Jackson, 1980; Tooker, 1964; Trigger, 1976).

Subsistence

The Huron diet consisted of a mixture of agriculture, hunting, gathering, and fishing. Subsistence duties followed a strict division of labor. Men cleared the fields, hunted, fished and traded. Women, however, tended the fields, gathered, and prepared the meals.

Different subsistence activities occurred seasonally. During the summer and spring, the men traded while the women tended the fields. During the fall, men participated in fishing and hunting activities. Once the hunting concluded, everyone returned to the village for the winter (Tooker, 1964).

The primary staple of the Huron diet was corn, which accounted for three quarters of the entire diet (Trigger, 1990). The Huron planted corn in the fields during the spring and allowed it to grow over the entire summer. Planters dug a small

hole in the ground with a spade type object and then placed nine to ten kernels per hole. The kernels were pre-selected and soaked for this specific purpose (Tooker, 1964). Over the course of four months, the crop ripened. At harvest time, women picked, husked and then dried the corn by tying it to the rafters of the long houses. Once the corn was dried, the kernels were removed and stored in large casks until needed (Donnelly, 1975; Tooker, 1964; Trigger, 1990).

Each family cleared and tended as much land as they needed. Men cleared the forests by chopping down trees and stripping the branches, which were then burned at the base of the tree to kill it. Stumps were then left to rot for easy removal later. Women then cleared the land around the stumps and planted the corn (Tooker, 1964). As long as that field was tended, the field remained the property of the family. Once abandoned, however, the field could be planted by anyone willing to do the upkeep (Donnelly, 1975). During planting, Huron women would sow at least three to four years worth of corn. Over planting ensured abundance of corn should poor crop yield or crop failure occur in the future. This overabundance of corn also allowed the Huron to trade with other villages which might be experiencing a poor year (Sagard, 1939; Tooker, 1964). Serious drought occurred approximately once each decade, and less severe crop complications arose two to three times each decade. Crop

failures often only affected a few communities at a time and were usually solved by trading with neighboring villages for food (Trigger, 1990). As the population density of the Huron increased, Trigger (1990) suggests that crop failures resulted in starvation and death as well as periodic malnutrition.

Huron women generally prepared two meals a day. The typical meal consisted of ground corn mixed with water to form a mash. Corn was also boiled with beans, eaten as ears, used to make soup, or baked into bread (Tooker 1964).

The Huron also grew other vegetables for both consumption and ritual purposes. These vegetables included squash, beans, sunflowers, and tobacco (Donnelly, 1975). Squash was boiled or roasted under the ashes. Sunflower seeds were gathered for the oil (Trigger, 1990). Tobacco was smoked during ritual (Tooker, 1964).

During their growing seasons, the Huron also gathered and sun dried fruits which were used as a seasoning to the meals of corn mush (Donnelly, 1975). Gathered fruits included strawberries, raspberries, blackberries, cranberries and mulberries. Plums were picked and buried, allowing them to ripen (Tooker, 1964).

Hunting was the domain of men, and the meat was used as a supplement to the corn diet (Donnelly, 1975). Huron men would often cooperate for fish catches. Fishing occurred during late

fall to early spring and each type of fish had a different season. After the catch was divided among the families in the village, fish were either dried or smoked to preserve them (Tooker, 1964).

Hunting occurred during late fall to early winter. Unfortunately, during this period there was a scarcity of game. The primary animals hunted included deer, bear, and beaver. Deer were sometimes hunted in cooperative drives that occurred every two days. Hunters either drove the animals into a corral or into the river where they could be easily killed. Meat was reserved for use as seasoning during feasts (Tooker, 1964).

Disease

Huron People attributed disease to three causes. Natural illnesses were attributed to natural processes and were cured using natural remedies, through the use of poultices, sweating, and emetics. Medicines included herbs, roots, barks, and other types of plants. Included in these medicines was oo*rat*. *Oorat*, a type of turnip root that looked similar to a carrot, was used to help clear the phlegm and moisture in the heads of old people and to clear the complexion (Sagard, 1939; Tooker, 1964; Trigger, 1990).

Desires of the soul also caused disease. In these instances, the soul had a need that must be filled or the person would die. The need could be anything as simple as a canoe or a

feast held in honor of the ill individual. The causes and subsequent cures for such diseases were often discovered through dreams. Dreams also provided instructions that could be very specific and must be carried out as directed (Tooker, 1964; Trigger, 1990).

The third cause of disease was witchcraft, the casting of spells on the sick person to cause them misfortune. These could only be cured by finding the counter curse (Tooker, 1964; Trigger, 1990).

Two types of groups acted in aid of disease, curing societies and shamans. The former were groups of individuals that had inherited positions and would perform rituals for specific diseases. The latter was a male individual who either extracted spells cast or diagnosed and treated natural diseases (Trigger, 1976). Tooker (1964) gave reports of two medicine men who worked to put an end to an epidemic.

Death and the Feast of the Dead

The Huron believed that the dead had two souls. The first soul, called *atisken*, would stay with the body until the Feast of the Dead. After that, the soul would be reborn into the body of a child. The second soul was associated with the consciousness of the deceased. It too stayed with the body until the Feast of the Dead. Once released, the soul would

travel to the Village of the Dead where it would continue to live much the way it did in life (Tooker, 1964).

Not all souls traveled to the Village of the Dead. The young and aged were believed too weak to make the journey. Those who died violent deaths remained and were considered dangerous. The bodies of these individuals were disposed of immediately and not buried at the Feast of the Dead. Souls of those who died in battle would form bands, but would not travel to the Village of the Dead.

When someone died, the body was placed into a crouching position and wrapped in robes prepared ahead of time. A family member outside the immediate family arranged the funeral. A feast, called *ayochien atisken*, was then held in honor of the deceased. Three days after the passing, when the mourners had gathered bearing presents, the body was covered in furs and brought out to the cemetery where it was placed in a coffin that was elevated about three meters above the ground (Tooker, 1964).

The Feast of the Dead ceremony occurred in Huron villages approximately every ten to fifteen years when the village was moved, and the Feast took place over ten days. Scaffolding was set up on three sides and a trench was dug within its confines. Families carefully removed bodies from the cemeteries and brought them to the village where the Feast took place. Bodies of the recently dead were left in their current state and simply

covered in robes. Others were cleaned by removing the flesh. Once the bones were cleaned, they were placed in bags, adorned with presents, and displayed. The first seven or eight days were spent this way until all the bodies to be buried were collected (Donnelly, 1975; Kidd, 1953; Thwaites, 1896; Tooker, 1964).

During the night before the final ceremony, the bags containing the bones of those to be buried were brought up onto the scaffolding. On the day of the Feast, the complete bodies were placed below the scaffolding, then lowered into the pit and arranged around it. The next morning, the bags were cut open and dumped into the pit. The bones were then arranged with poles so that they would all fit. The pit was then covered in robes, mats, and bark, after which, the earth was replaced (Donnelly, 1975; Kidd, 1953; Thwaites, 1896; Tooker, 1964).

Chapter Three: Ribs and Rib Pathology

The ribs have two primary functions, to protect the heart and lungs and to provide attachment of the muscles used in respiration. They articulate with the spine at the body and the transverse processes of the vertebrae and with the sternum through a bridge of cartilage. Due to their close proximity with the lungs, the ribs are most likely to reflect evidence of pulmonary diseases. This chapter discusses how respiration and disease affect the ribs. Tuberculosis is discussed in detail as it is the most likely disease to leave evidence on the ribs.

Periostitis

The inner layer of the periosteum of bone remains osteoblastic throughout life. Periostitis occurs as a reaction to changes in underlying bone. Although periostitis is not always an expression of inflammation or restricted to infection, it can be caused by specific and non-specific infections. "Hematagenous foci predilict the area near the osteocartilaginoaus border and may involve cartilage" (Ortner and Putschar, 1981: 162). Lytic lesions with fusiform enlargement of the involved area, and often, perforation of the cortex, lead to chest wall abscesses. In such cases, the deposition of new bone due to periosteal reaction is usually meager. Generally, periostitis is unevenly distributed and of varying thickness.

Arthritis

Degenerative joint disease, or osteoarthritis, is the most commonly seen joint disease in ancient populations. Osteoarthritis only occurs in synovial joints. Any synovial joint may be affected (Rogers and Waldron, 1995). The systemic factors include age, stress, and degenerative changes within the joint. As age increases, so does the incidence of degenerative joint disease. Occupational
stresses also positively correlate with the increased incidences (Bridges, 1991; Jurmain, 1977; Macones et al., 1989).

Arthritis will manifest itself in four ways: proliferations, erosions, osteoporosis, and eburnations. Proliferation is new bone growth resulting from osteophytic activity as the joint attempts to repair to the cartilage. Osteophytes are found around the joint margins. They often phlange outward and may surround a joint. In erosions, the cortical bone is lost and the trabeculae underneath are exposed. Erosions may begin at either the edges of the joint or the center. Osteoporosis occurs when the cortical bone becomes thinner and the amount of trabeculae underneath decreases. When the cartilage in a synovial joint is destroyed, the bones come in direct contact with one another. As they rub together, they become highly polished, or eburnated. Eburnation is a diagnostic sign of osteoarthritis (Rogers and Waldron, 1995).

Degenerative joint disease has been established on the ribs alone, as well as an extension of the vertebrae. The ribs have two points of articulation with the vertebrae. The head of the rib articulates with the vertebral body and the transverse facet articulates with the transverse process. Both are synovial joints. These are supported by a fibrous capsule and ligaments. Respiration and trunk movements cause simultaneous movement in both articulations (Huang et al., 1993). Costovertebral joints may "exhibit marginal lipping and porosity but rarely eburnation" (Ortner and Putschar, 1981: 430). Other studies have noted radiographic changes in the ribs associated with hyperostosis, an excessive or abnormal thickening or growth of bone tissue.

Macones et al. (1989) examined tomography, ct scans, and radiographs of living patients for hyperostosis of the ribs. They noted the occupational history and symptoms of 80 patients. They found that in 56 of the cases the right rib cage displayed cortical thickening in ribs four through ten. Six were affected on the left side only. The other 18 were affected bilaterally. Almost half of the patients afflicted held occupations that required heavy lifting. One of the patients died during the course of the study. After autopsy, the researchers had access to the bones directly. They discovered that the thickened cortical bone had concentric lamellae and normal cancellous

bone. They theorized that the hyperostosis on the bones was caused by repeated use and stressing of the iliocostalis thoracis muscle. This muscle becomes stressed from front and side bending and twisting.

Huang et al. (1993) examined rib ossification with relation to costal vertebral articulations. They found hyperostosis in the third through eleventh ribs. The most commonly affected ribs were ribs five and eight. Rib hyperostosis involved mainly the head.

Tuberculosis

Tuberculosis is a disease which can affect the skeleton. It may be contracted either through pulmonary droplet inhalation or by drinking infected milk. *Mycobacterium tuberculosis* is the bacterium that causes tuberculosis, and it is believed to be a mutation of the bovine strain *Mycobacterium bovis*. The human form is most often seen in urban areas where direct person-to-person contact is frequent.

Skeletal tuberculosis is the result of hematogenous dissemination from the initial focus. Dissemination to the bones is rare and only occurs in five to seven percent of all cases of tuberculosis and thirty percent of all extra-pulmonary cases. While tuberculosis can occur in any bone, it is most common in the red marrow cavities of the vertebrae, ribs, and sternum where both circulation and metabolic rates are increased

through the cancellous bone (Ortner and Putschar, 1981). It will also attack synovial joints by movement through the epiphyseal cartilage into the joint space. In juveniles, tuberculosis will attack the growing long bones, epiphyseal plates, hands and feet, and cranial vault (Ortner and Putschar, 1981).

There are two phases to skeletal tuberculosis. The exudative phase permeates the marrow spaces and causes caries in the cancellous bone. The granulomatous phase causes cavitations of the cancellous bone. The bacillus retards new bone growth in the infected areas. In the long bones, the metaphyseal and epiphyseal portions are affected. If the synovium only is affected in the joints, the disease causes little damage. However, if the organism manages to penetrate the synovial cap and affect the bone, it creates caries and destroys the epiphysis and articular surface (El-Najjar, 1981; Ortner and Putschar, 1981). If healing does begin to occur, the bone only forms a spongiosa around the infected area along new stress lines and will not regain its former density. If this destruction occurs in juveniles, it has the potential to destroy the epiphyseal plate, causing growth deficits and physical deformities.

The most common place for skeletal tuberculosis is the spine. Infections occur in the lumbar vertebrae most often, and

the probability of infection decreases as you move up the spinal column into the cervical vertebrae. In the cervical vertebrae, tuberculosis affects the axis and atlas. Eighty percent of the time the infection affects two adjacent vertebrae (Ortner and Putschar, 1981).

Tuberculosis of the rib has been the most debated point of diagnosis. Lesions on the ribs are attributed to a number of diseases. As well, the occurrence of lesions is inconsistent and depends on outside factors. Mays et al. (2002) stated that between one and eight percent of all skeletal cases involve the ribs. Tuberculosis has been reported in nine percent of individuals within the Hamann-Todd collection and at 62 percent in the Terry collection (Kelley and Micozzi, 1984; Roberts et al., 1994). Rib lesions are more common with a diagnosis of tuberculosis than with other pulmonary diseases.

Rib lesions due to tuberculosis arise in two ways. As an extension from the spinal lesion, rib involvement is seen primarily in the head and neck as contact infections and lesions. The rarest type is direct contact with the chest and absorption of disease through the lungs, pleura, or lymph system (Ortner and Putschar, 1981).

Kelley and Micozzi (1984) studied the Hamann-Todd collection where they had access to information regarding the demography and cause of death of the individuals. Ribs in

contact with the pleura showed a thickening on the internal face. When ribs were put into anatomical position, they displayed a midshaft periostitis that covered more than one rib and took on a round overall shape. In six of the individuals studied, the periostitis correlated with the anatomical position of the intrathoracic lesion. Only in a small number of cases was the cortex breached. This type of infection is often mutually exclusive from other skeletal types of tuberculosis. The most common type of rib lesion is caused through hematogenous dissemination of a local focus in the soft tissue. Hematogenous spread "produces lytic changes with little or no reactive bone regeneration" (Mays et al., 2002: 27). These lesions either begin internally or at the costo-chondral junction. The end result is either enlargement of the rib or destruction of the head. Resorption of the bone is expressed as "shallow circumscribed lytic lesions" (Mays et al., 2002: 28).

Pfeiffer (1991) studied rib lesions in the Uxbridge and Glen Williams ossuaries where tuberculosis had been suggested in previous studies. She identified three different types of lesions: plaque, expansion, and resorption. Plaque consisted of distinct layers of periosteal spongy growth that had a tendency to flake off dried bone. Expansion is the formation of cortical bone which retains a porous appearance and its edges are not visible. Resorptions occurred on the head and neck and were

erosive lesions that transferred from lesions on the vertebral body. Both plaque and expansion appeared on the internal aspect of the midshaft and could be seen when vertebral lesions were present. The most common lesion was plaque on ribs three through ten. Although she admitted that some rib lesions of the plaque or expansion nature may be due to tuberculosis, Pfeiffer argues those lesions were not diagnostic because the overall patterning was not consistent with a tuberculosis infection. Instead, she suggested that lobar pneumonia was a possible cause.

Rib remodeling is not a clinically diagnostic feature of tuberculosis. However, radiographic images of infected ribs do not usually show some of the macroscopic changes that can be seen in dry bone. When x-rayed superiorly to inferiorly, thickening of the shaft can be seen (Santos and Roberts, 2001).

One of the newest methods of searching for types of tuberculosis within skeletal samples is to use DNA. In 2002, Mays et al. used those techniques to identify varying rib lesion patterns as tuberculosis.

Differential diagnoses of resorptive rib lesions include metastatic carcinoma, nonspecific osteomyelitis, and treponemal disease. These three diseases more commonly cause bone destruction within the shaft than tuberculosis. Respective lesions are also not localized to the visceral surface of the

rib, but instead appear on all aspects of the shaft. Acute lobar pneumonia and bronchiectasis will both cause pleural transfer reactions on the visceral surface. In lobar pneumonia only the third developmental stage, known as red hepatistation of the lung, causes pleural inflammation. When placed within the context of disease progression, tuberculosis is more likely to cause lesions. Roberts et al. (1994) suggest that some cases of pneumonia have been misdiagnosed. Bronchiectasis results from streptococci and staphylococci infections. It may cause pleural infections that have associated rib involvement, but typically it causes sufficient pus accumulation in the body cavity (Roberts et al., 1994). Blastomycosis is a fungal disease caused by *Blastomyces dermatitidis*. It often enters the body through the respiratory tract. Two-thirds of cases display bone involvement, and the most infected bones are the vertebrae and the ribs. Lesions associated with blastomycosis will show up as purely lytic with sharp borders. Periosteal reactions may occur (Hershkovitz et al., 1998; Ortner and Putschar, 1981; Shadomy, 1981).

Roberts et al. (1994) reviewed the rib lesions in the Terry Collection. In their analysis, lesions were both pits and plaques of new bone. Lesions were primarily localized in nature, exhibiting in short segments as well as multiple level unilateral and bilateral extensive lesions. Five types of

pulmonary disease were listed as causes of death: tuberculosis, pneumonia, bronchitis, emphysema, and pleurisy. Of the 380 individuals with rib lesions, 157 had tuberculosis listed as the cause of death. Only 10 of these individuals had associated Potts disease. They found that, of those with lesions, a significant difference could be found in three areas between those with tuberculosis and nonpulmonary causes of death. Tuberculosis patients died at a younger age. The site of lesions will occur more on the right than left in persons with tuberculosis. The weakest association was the site of the infection. Tuberculosis was more likely to occur in the head, neck, and angle of the rib, while those listed with nonpulmonary diseases had lesions on the anterior portion. Roberts et al. (1994) also suggest that individuals with nonpulmonary diseases may still have had tuberculosis at the time of death.

Pfeiffer (1984) also examined the skeletal remains from the Uxbridge ossuary. She found vertebral lesions consistent with tuberculosis in the population. She also noticed that these lesions were found mainly in the younger individuals based on the maturity level of the vertebrae. She calculated that 257 cases of tuberculosis actually existed among the population based on ratios suggesting that the number of skeletal to pulmonary tuberculosis cases was between 3-7%.

The large number of differential diagnoses within a skeleton led Byers and Roberts (2003) to examine the feasibility of the Bayes' theorem in paleopathological diagnoses. "Bayes' theorem describes how knowledge of prior probabilities can be used to calculate the probability of unknown events" (Byers and Roberts, 2003: 2). Physicians often utilize Decision Support Systems (DDSs) based on Bayes' theorem. These systems used computer applications and observed frequencies within functional relationships to calculate the most probable diagnoses. Byers and Roberts (2003: 2) believe that similar techniques could be used to discover the "prevalence of pathological conditions and their likelihoods of signs found within those conditions." They studied the ribs in a southern Louisiana ossuary collection. Ribs in this collection were disarticulated and highly fragmented. To establish lesion prevalence, they used the standards discovered in Robert et al.'s (1994) study of the Terry Collection discussed above. Since they were unable to arrange spatially the fragments into either side or number, they used the side on which lesions appeared as the likelihood index. After final calculations were completed, tuberculosis was ascertained to have been the most likely cause of the lesions. They also noted, however, that of the 95 vertebral bodies found, only one had a lytic lesion typical of tuberculosis.

Tuberculosis is well documented in the New World. While variation in the appearance of tuberculosis in the skeleton happens, it is possible to diagnose. More than one aspect should be looked at if possible. The paleopathologist should also remember to keep in mind the environment of the population under study. He or she should also remember that skeletal tuberculosis compromises only a small sample of the total cases in the population (Mayes et al., 2001).

Chapter Four: Materials and Methods

For this study I used the rib fragments recovered from the Poole-Rose Ossuary. The ribs used in this study had not been cleaned or catalogued previously. They were fragmented into many small pieces. There is some other highly fragmented skeletal material that has been difficult to identify and may include some more rib fragments. I began by cleaning the fragments, then sorting out the articular facets from the shaft fragments. I then separated out the costal ends from the rest of the shaft fragments.

The articular facets were then sorted into right and left. I identified and separated ribs 1, 11, and 12 from the rest. Ribs 2-10 are classified as "typical ribs" for the purpose of this research. Rib 1 was easy to identify due to its unique morphology. Ribs 11 and 12 were also easy to identify as they only had one facet in the head and no transverse facet as they do not articulate with the transverse process of the thoracic vertebrae. I did not separate rib 2 from the rest as the fragmentary nature of the specimens prevented a consistent identification. Rib 10 is also problematic as it only has a single facet on the head and occasionally has no transverse facet. However, its neck and tubercle are more defined than that of ribs 11 and 12.

Articular fragments were evaluated individually to determine age. Age was classified as either adult or sub-adult. A designation of sub-adult was given to any bone in which the epiphysis of the transverse facet was not fused. Full fusion of the transverse facet occurs at approximately 18 years of age. Fusion of the head occurs between the ages of 17 and 25 (Scheuer and Black, 2000).

The minimum number of individuals (MNI) was calculated using the presence of the transverse facet of rib 1 since many of the rib heads were not present. I am aware that, by using the transverse facet, I am underestimating the number of juvenile bones since the epiphysis of the transverse facet fuses before that of the head. Where the head was present, the state of fusion was noted.

The MNI, evidence of pulmonary disease, evidence of arthritis and other osteological particularities were recorded in a Microsoft Excel 2003 spreadsheet. A binocular microscope was used to examine the bone fragments.

Several researchers have noted periosteal reactions along the visceral surface of the ribs (Kelley and Micozzi, 1984; Mays et al., 2002; Pfeiffer, 1991, Roberts et al., 1994). These researchers classified periosteal reactions into two categories. This study also classifies periosteal reactions into two

categories and makes note of any evidence of healing within the lesions:

1. Mild – A thin layer periosteal plaque that lays close to the surface and occurs in localized spots. In some cases it is only differentiated from weathering under a microscope.
2. Moderate – a thick porous layer of woven bone that covers the visceral surface of the rib.

Arthritis was noted on both the transverse facets and the head. Both proliferative lesions and erosive lesions were noted with their severity. Proliferative lesions were mild to moderate. Erosive lesions ranged from mild, a single pit, to severe, complete destruction of the articular surface. Eburnation was noted.

Other osteological particularities noted were cut marks, raised lesions, and evidence of cremation.

Chapter Five: Results

Minimum Number of Individuals in the Poole-Rose Ossuary

Table 5.1 lists the minimum number of individuals calculated for this study. The MNI, 49, was determined using the transverse facet of the rib 1 since it is the most distinctive rib. As a check, MNI was also calculated using the transverse facet of ribs 2 through 10 as well as the heads from ribs 11 and 12. Both groups were sided and sorted according to adult or juvenile. For ribs 2 through 10, the total number from each side and age group was divided by 9. For ribs 11 and 12, each group was divided by two.

Table 5.1 Minimum Number of Individuals Based on Ribs in the Poole-Rose Ossuary

Bone	**Adult**	**Sub-adult**	**Total**
Left Rib 1	27	13	40
Right Rib 1	33	16	49
Left Rib 2-10	38	11	49
Right Rib 2-10	44	9	53
Left Rib 11-12	33	12	45
Right Rib 11-12	32	15	47

Within the count of ribs that were classified as adult due to the complete fusion of the transverse facet are fragments in which the head displayed incomplete or unfused surfaces. On Rib 1, four right fragments displayed incomplete fusion of the head.

In the typical ribs, ribs 2 through 10, 20 left fragments and 27 right fragments exhibited the same differential fusion.

Cut Marks in the Ribs of the Poole-Rose Ossuary

Only one of the costal ends has shallow cut marks. Three of the shaft fragments have cut marks, one of which is a series of shallow marks on the outside (Fig. 5.1). Two of the other fragments have an indention with a starburst pattern surrounding it occurring on the interior surface (Fig. 5.2).

In the head and neck area of the ribs, five incidences of cut marks on the bones occurred - four on left bones and one on a right. All of these are shallow marks of the exterior surface. The affected left bones included one rib 1 and two ribs 11-12.

Figure 5.1 Cut Marks on a Rib in the Poole-Rose Ossuary

Figure 5.2 Starburst Pattern Cut Marks on Two Ribs in the Poole-Rose Ossuary

Cremation in the Ribs of the Poole-Rose Ossuary

Evidence of cremation occurs in 20 mid-shaft fragments - seven costal end fragments and 15 of the fragments with the angle and head.

Animal Activity in the Ribs of the Poole-Rose Ossuary

The ribs in the ossuary did display some evidence of rodent activity. Three of the mid-shaft fragments as well as two of the head fragments had gnaw marks on the exterior surfaces.

Arthritis in the Ribs of the Poole-Rose Ossuary

Table 5.2 lists the incidences of lipping of the head that occurred on 23 of the fragments. Of these 23 fragments, 13 of the typical ribs and 10 of ribs 11-12 displayed lipping of the head.

Table 5.2 Incidences of Lipping on the Heads of Ribs in the Poole-Rose Ossuary

Severity	**Right**			**Left**		
	Rib 1	**Ribs 2-10**	**Ribs 11-12**	**Rib 1**	**Rib 2-10**	**Rib 11-12**
Mild	0	6	4	0	2	1
Moderate	0	3	1	0	2	4

Of the typical ribs, 13 fragments displayed lipping on the head. Six of the right ribs have minor lipping of the head and three displayed moderate lipping. Only four of the left ribs showed any kind of lipping of the head. Two had evidence of mild lipping and two others had evidence of moderate lipping. Figure 5.3 shows the lipping on two of typical ribs. The rib on the left has moderate lipping circling the entire head. The other has a single lip between the demifacets.

The remaining 10 heads displaying lipping exhibit it on ribs 11-12. Five of these occurred on the right with only one displaying moderate lipping; the others had mild lipping. Five left heads of ribs 11 and 12 displayed some form of lipping. Of these, only one displayed mild lipping. The lipping on the others is moderate.

Figure 5.3 Lipping of the Head on Two Typical Ribs in the Poole-Rose Ossuary

The transverse facet also showed lipping. Table 5.3 lists the incidences. There are 45 instances of lipping around the transverse facet. Twenty-four of these instances are mild, with 17 on the right and seven on the left. Sixteen instances are moderate, with 11 on the right and five on the left. In five cases, lipping was severe with three instances on the right and two on the left. Figure 5.4 shows severe lipping around the transverse facets of two ribs.

Two cases of eubernation were found on the transverse facet. Both occur on right adult ribs; neither shows lipping nor pitting around the joint. Figure 5.5 shows the most severe of the two cases.

Table 5.3 Incidences of Lipping Around the Transverse Facet on the Ribs in the Poole-Rose Ossuary

Severity	Right		Left	
	Rib 1	Ribs 2-10	Rib 1	Rib 2-10
Mild	1	16	0	7
Moderate	1	10	0	5
Severe	0	3	0	2

Figure 5.4 Lipping around the Transverse Facet on Two Ribs in the Poole-Rose Ossuary

Figure 5.5 Eubernation on the Transverse Facet of a Right Rib in the Poole-Rose Ossuary

In the typical ribs, resorptive pitting occurs on the transverse facet. Table 5.4 lists these incidences. Of the 66 instances recorded, only seven, four right and three left, displayed moderate pitting; three ribs, two right and one left, had severe pitting. The other 37 right and 19 left transverse facets only displayed mild pitting. Figure 5.6 shows examples. Only one instance of moderate pitting showed up on the head of a left rib 1. For ribs 11-12, seven of the right and five of the left also displayed pitting of the head. In this instance, four of the right and one of the left showed mild pitting. The last six had severe pitting of the head. One had evidence of new bone growth. Figure 5.7 shows examples of pitting in ribs 11 and 12.

Table 5.4 Incidences of Pitting on the Articular Facets of the Ribs in the Poole-Rose Ossuary

Area on the Bone	**Right**			**Left**		
	Mild	**Moderate**	**Severe**	**Mild**	**Moderate**	**Severe**
Transverse Facet	37	4	2	19	3	1
Head of Rib 1	0	0	0	0	1	0
Head of Ribs 11-12	4	0	3*	1	1	3

*Evidence of new bone growth on one rib.

Lytic Lesions in the Ribs of the Poole-Rose Ossuary

Three of the heads and one of the angles on the typical ribs had lytic lesions consistent with tuberculosis. One lytic lesion occurs near a transverse facet of a right rib (Fig. 5.8). There is one incidence of a lytic lesion on the shaft (Fig.

Figure 5.6 Pitting on the Transverse Facets of Three Ribs in the Poole-Rose Ossuary

Figure 5.7 Pitting on the Heads of Ribs 11 and 12 in the Poole-Rose Ossuary

5.9). The fragment has a long lesion with rounded boundaries that follow the costal groove.

One of these heads has no attached transverse facet. The superior demifacet is fully fused while the inferior demifacet is no longer recognizable due to extreme periostitic growth.

The second fragment (Fig. 5.10) is a right rib with a fused transverse facet. Only a small fragment of the inferior demifacet has been preserved. The lesion occurs on the exterior surface right next to the inferior demifacet. The inferior surface of the neck has accompanying periostitis.

The third fragment (fig. 5.11) is a left rib with a fused transverse facet. The head is broken off. The lesion occurs on the interior, inferior surface of the angle. The interior surface and the inferior surface of the neck and angle have moderate periostitis.

The fourth fragment is a right rib (Fig. 5.12 and Fig. 5.13), with fully fused head and transverse facet. The head has been fully remodeled through resorption. The periostitic growth on the interior surface of the neck is thick and solid.

Periostitis in the Ribs of the Poole-Rose Ossuary

Periostitis occurred on the neck, angle, and shaft of the ribs, some of which show evidence of healing. On fragments containing the rib's articular facets, there are no instances of

Figure 5.8 Small Resorption Behind the Transverse Facet of a Right Rib in the Poole-Rose Ossuary

Figure 5.9 Resorption on the Interior Surface of a Rib Shaft Fragment in the Poole-Rose Ossuary

Figure 5.10 Small Resorptive Lesion by Inferior Demifacet of a Right Rib in the Poole-Rose Ossuary

Figure 5.11 Resorption in Angle of a Left Rib in the Poole-Rose Ossuary

Figure 5.12 Interior View of the Head of a Right Rib in the Poole-Rose Ossuary that has been Remodeled through Resorption

Figure 5.13 Articular Surface of the Head of a Right Rib in the Poole-Rose Ossuary that has been Remodeled through Resorption (Same Specimen as in Figure 5.12)

periostitis in rib 1. Mild periostitis occurs on the necks of three left ribs 11-12. On the typical ribs, mild periostitis occurs on the necks of five rights and 13 lefts (one of which showed signs of healing) and on the angles of three rights and one left. Only on one right rib did the bone growth extend from the neck into the angle. Moderate periostitis occurrences included the necks of three rights and six lefts and in the angles of two rights and one left. It extends from the neck into the angle on three left ribs. Severe periostitis occurs on the necks of two ribs, one right and one left, and in the angle of five left ribs. Table 5.5 lists the incidences of periostitis on the neck and angle of the typical ribs.

Table 5.5 Incidences of Periostitis on the Necks and Angles of Ribs 2-10 in the Poole-Rose Ossuary

Area on the Rib	**Mild**		**Moderate**		**Severe**	
	Right	**Left**	**Right**	**Left**	**Right**	**Left**
Neck	5	12 *1	3	5 *1	1 *1	1
Angle	2 *1	1	2	1		3 *2
Both Neck and Angle	1	0	0	3	0	0

*With evidence of healing.

The shaft fragments also displayed periostitis on both the interior and exterior surfaces. Seven fragments had mild forms on the interior, two of which showed signs of healing. Moderate periostitis occurred on the interior surface of 34 fragments, two of which showed signs of healing. Seven fragments had

moderate growth on the exterior surface only. Only two fragments had mild and moderate occurrences on both the exterior and interior surfaces of the ribs. Expansions occur on one of the outer shaft fragments and eight of the inner shaft fragments. Figures 5.14 and 5.15 show periostitis on the shafts. At the sternal costal ends, one fragment had mild periostitis, and eight fragments had moderate bone growth. One of these incidences occurred on the external surface. Another showed signs of healing.

Figure 5.14 Shaft Fragments of Ribs with Periostitis in the Poole-Rose Ossuary

Figure 5.15 Shaft Fragment of a Rib with Periostitis in the Poole-Rose Ossuary

Other Markers

Other markers include remodeling of the rib, puffy vascularization (Fig. 5.16), raised ridges on the interior surface, plaques, circumscribed lesions, and breaks. Remodeling occurs on two of the sternal costal ends, one of which is a rib 1. Four of the mid-shafts have odd formations. One has striations and another has ridges on the superior edge. One of the sternal costal ends is enlarged. Three shaft fragments have become puffy, and one left, adult transverse facet fragment is heavily remodeled and puffy. Only one circumscribed lesion occurs in the ossuary, in the angle of a left adult rib.

Figure 5.16 Puffy Vascularization of a Rib Fragment in the Poole-Rose Ossuary

The mid-shaft has one raised ridge on the interior surface. On the head fragments, five of the right angles and five of the left have areas of raised bone. Raised ridges (Fig. 5.17) occur on 10 of the right necks and five of the lefts. On only one left fragment did the ridge extend from the neck into the angle.

Small whitish plaques (Fig. 5.18), which can be chipped off, occur on both the interior and exterior surfaces of some fragments. On the mid-shaft fragments, there are 17 incidences of internal plaques and three of external plaques. On the head and angle fragments there are two incidences of internal plaques, one on the neck and one in the angle of right ribs, and one incidence of an external plaque on a left rib.

Three of the fragments containing the sternal costal ends have lipping on the exterior surface (Fig. 5.19). There are two heads, for which I was unable to determine their side, which are severely remodeled and covered in woven bone (Fig. 5.20).

Figure 5.17 Raised Ridge on the Interior Surface of a Typical Rib in the Poole-Rose Ossuary

Figure 5.18 Plaque on the Exterior Surface of a Shaft Fragment of a Rib in the Poole-Rose Ossuary

Figure 5.19 Lipping on Costal Ends of Ribs in the Poole-Rose Ossuary

Figure 5.20 Head Remodeled and Covered in Woven Bone from a Rib in the Poole-Rose Ossuary

Three of the shaft fragments had breaks. Two shaft fragment had breaks that had fully healed (Fig. 5.21). The other had a crack along the edge of the rib with evidence of growth over the crack (Fig. 5.22). In the transverse facet fragments, there is one break in a right adult rib.

Figure 5.21 Two Rib Shafts with Evidence of Healed Breaks in the Poole-Rose Ossuary

Figure 5.22 Rib Fragment with a Crack and Evidence of Initial Healing in the Poole-Rose Ossuary

Chapter Six: Discussion and Conclusion

Previous studies have been conducted on different bones of the Poole-Rose Ossuary. Most of these researchers have also calculated a MNI. Table 6.1 lists these studies and the MNI each calculated.

Table 6.1 Elements Previously Studied in the Poole-Rose Ossuary and Their Minimum Number of Individuals

Study	Element Used	Minimum Number of Individuals	Minimum Number of Sub-Adults
Penney (2005)	Talus	212	-
Bodin (2002)	Ulna	221	-
Schiess (2002)	Femur	300	58
Parks (2002)	Radius	205	-
Kelly (2001)	Third Metacarpal	145	-
Lundin (2000)	Humerus	249	52
Seidemann (1999)	Cranium	337	-
Dunne (1999)	Vertebrae	204	26
Tague et al. (1998)	Innominate	242	-*
Smith (1997)	Cranium	161	-
Bordelon (1997)	Tibia	193	-
Listi (1997)	Tibia	-	-

*Sub-adult 24%, no actual number given.

Based on other aspects of the skeleton, the MNI in the Poole-Rose Ossuary ranged from 161 to 337. However, in this study, the MNI is 49 based on the first rib. The burial practices of the Huron could explain the MNI differences among the studies. The ossuary is a secondary burial. The primary burial pattern of the Huron was to place bodies on elevated

platforms. At the time of the Feast of the Dead, the skeletons were recovered and transported to the ossuary pit. The process of commingling the remains fragmented the ribs into many smaller fragments. Probably, some of the transverse facets for ribs 1-10 and heads for ribs 11 and 12 are no longer identifiable.

The incidences of arthritis of the articular facets of the ribs in the Poole-Rose Ossuary are minor, with the right side being affected twice as often than the left. Unfortunately, there is no way of knowing exactly how many individuals are affected. However, the lipping and pitting in ribs 11-12 suggest that there are at least three individuals. The most severe cases occurred in those two atypical ribs. This is in discordance with modern living studies in which the typical ribs are remodeled most often and side is congruent with handedness (Huang et al., 1993; Macones et al., 1989).

A raised ridge along the inside of the rib has been noted in other North American burials (Lambert, 2002; Molto, 1990). However, the literature does not give an explanation as to the cause.

The lytic lesions of the head are consistent with a diagnosis of tuberculosis as an extension of the vertebrae. Dunne (1999) looked at the vertebrae of the Poole-Rose Ossuary. She found three resorptive lytic lesions in the lumbar vertebrae. Two of these lesions were multilocular and one was

unilocular. In the thoracic area there were 29 lytic lesions, and 11 of the vertebral bodies were collapsed, two of which were in association with lesions. Dunne also found one lesion among the cervical vertebrae. Collectively, she suggested these lesions were the result of tuberculosis. Based on this study, at least one individual had tuberculosis of the rib transferred from contact with the vertebrae.

Periosteal reactions on the ribs by themselves cannot be diagnostic of a specific pulmonary disease. In conjunction with other lesions, however, they serve as an aid in diagnosis. When combined with lytic lesions near the head and neck, they support the probability of tuberculosis within the population. Reactions on the interior surface of the shafts are a diagnostic point for pulmonary disease. Unfortunately, the ribs of the Poole-Rose Ossuary are too fragmented to note the positioning of each lesion along the shaft.

According to Kelly and Micozzi (1984), 8.6 percent of pulmonary tuberculosis cases produce rib lesions. With an MNI of 49 based on ribs, the Poole-Rose Ossuary could have as many as 4 cases of pulmonary tuberculosis.

Ramenofsky et al. (2003: 249) note that "tuberculosis epidemics typically last 300-400 years." Modern research, both through visual inspection and DNA analysis, places strains of *M. tuberculosis* in the New World before contact with Europeans

(Lambert, 2002; Roberts and Buikstra, 2003; Shadomy, 1981). If the population of the Poole-Rose Ossuary had housing and a community arrangement similar to that of the historic Huron, the living situation would have aided in the spread of the disease. Increasing population densities and a reliance on corn as a food source would have increased the chances of contracting the disease (Ramenofsky et al. 2003; Roberts and Buikstra, 2003). Reliance on a crop that could fail increases the chances of malnutrition during lean years, and decreased protein intake decreases resistance to *M. tuberculosis* (Roberts and Buikstra, 2003). A decline in sanitary conditions combined with poor air quality within the longhouses would have also increased the susceptibility to tuberculosis (Merrett and Pfeiffer, 2000). Warrick (2003) also suggests that endemic tuberculosis among the Huron as well as 15th century St. Lawrence Iroquoians made them more susceptible to European pneumonia. The highest frequencies of tuberculosis would show up in individuals who died in infancy to young adulthood (Roberts and Buikstra, 2003).

The overall general appearance of the ribs in this population suggests that the people of the Poole-Rose Ossuary were healthy. However, the general health of the ribs could be misleading as evidence of tuberculosis was found. Since skeletal tuberculosis is rare and tuberculosis of the rib even

rarer still, the presence of lesions suggests that the disease may have been prevalent within the population.

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Vita

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