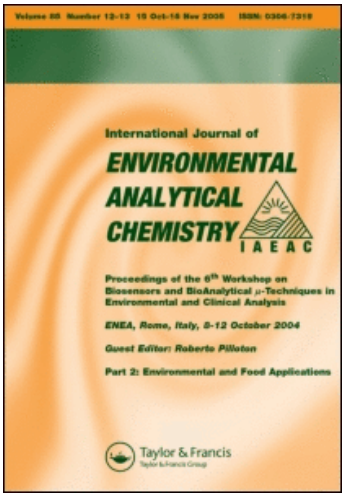

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LEAD LEVELS IN HUMAN TISSUES FROM THE FRANKLIN FORENSIC PROJECT*

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Elemental analyses of bone samples from members of the 1845 Franklin Arctic Expedition revealed the presence of high levels of lead. Initial studies using inductively coupled plasma atomic emission spectrometry (ICP-AES) on one bone indicated a level of 125 μg/g and prompted a more detailed analysis of lead levels by graphite furnace atomic absorption spectrometry in hair, tissues, and bone from various anatomical regions.

Results of lead analysis in 27 bone samples from sailors who succumbed on King William Island in 1848 ranged from 87–223 μg/g. Lead levels in bones taken from Inuit (Eskimo) of the same time period with the same geographical area ranged from 1–14 μg/g suggesting that environmental lead levels were not a contributing factor in the high bone lead levels in the British sailors. This is also confirmed by bone lead in two caribou samples found with one of the British sailors which had a lead level of 2 μg/g. Lead levels in bone of a modern population range from 18–50 μg/g.

The presentation will include detailed statistics on lead results of 58 individual bone samples. Explanations for the elevated lead levels in sailors has been attributed to the use of food preserved in crudely soldered tin cans. Examination of tin can residues found at Beechey Island substantiated the possibility of gross lead contamination of food consumed during the course of the three year expedition.

The implications of the above data on the ultimate fate of the Franklin Expedition will be discussed.

KEY WORDS: Lead, human organs, bones, hair, sample preparation, forensic anthropology, atomic absorption spectrometry, food contamination.

INTRODUCTION

This paper discusses the lead analysis of human tissue samples (specifically, bone

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and hair) collected during the Franklin Forensic Project in 1981, 1982, 1984, and 1986. The Franklin Forensic Project is a forensic anthropological investigation into the loss of the Franklin Arctic Expedition of 1845–48.

Since 1981, research teams from the University of Alberta have been employing methods of historical archaeology, forensic anthropology, and medical pathology in the investigation of the loss of the Third Franklin Arctic Expedition of 1845–48. This multidisciplinary scientific approach was used in the hope that it could offer new perspectives and answers through the observation, collection, and analysis of the surviving physical remains of the expedition. The primary focus of the investigation was centered on the biological tissues from members of the Franklin expedition. The research perspective was to identify health and disease conditions during the expedition which may serve to explain the eventual demise of the members of the expedition.

The role of the forensic anthropologist is expanding and many physical/forensic anthropologists have found that in addition to having expertise in human biology and osteology, knowledge of a wide range of scientific techniques is essential in order to advance the limits of their discipline. Modern analytical techniques permit the recovery of heretofore inaccessible information and have removed many of the restrictions faced by earlier investigators who often could only describe human remains in terms of their demographic or morphological features. Trace element analysis is becoming one of the most popular new techniques employed by forensic anthropologists.[1-3]

The Franklin Forensic Project's multidisciplinary team has employed traditional and newly-developed techniques of analysis in an attempt to maximize information from the limited amounts of surviving biological tissues. Results of some of the autopsies and other analyses have been reported previously.[4-7] One of the most surprising analytical results came from the preliminary trace element analysis of human bone material from King William Island, N.W.T.[7] This bone was analysed by ICP-AES yielded a lead value of 125 μg/g. This high lead value was entirely unexpected and raised the possibility that some or all of the expedition's members were suffering from lead intoxication. Subsequent analyses therefore became necessary to determine whether endemic lead intoxication could have contributed in a major way to the loss of the entire expedition.

HISTORICAL BACKGROUND

The history of Arctic exploration, and the search for the Franklin expedition has been well documented[8-10] and for the purpose of this paper it is not necessary to go into great detail on the subject. This paper will instead outline some of the details germaine to the current research under consideration.

By 1845 much of the Arctic had been mapped and explored. The British were confident that a properly equipped final expedition would complete the navigation of the remaining uncharted regions and thus lead to the discovery of the Northwest Passage. To this end, two ships, HMS *Erebus* and HMS *Terror* under the command of Sir John Franklin sailed to the Arctic regions in May of 1845.

The ships were well equipped and stocked with enough provisions to last a minimum of three years, though it was suggested that through careful management and by hunting and fishing, the supplies could be stretched to last four or more years. The archaeological evidence and contemporary Inuit accounts suggests that the food stores may have lasted three years or less. The ships were deserted in April of 1848, possible reasons being that food supplies had been depleted by this time.

This well-equipped expedition was commanded by officers with experience on numerous previous Arctic or Antarctic expeditions in order to ensure success. None of the expedition members was ever found alive, and the cause of this "mass-disaster" has never been established. In fact, few reasonable hypotheses have been offered as to the cause of the disaster. One hypothesis that has been vigorously debated is that there were problems with some of the food supplied to the expedition. The reason for this debate is that food preserved in tin-cans made up a large percentage of the provisions supplied to the expedition, and these foods were supplied to the British Navy by Goldner Provisioners who, as lowest bidder, obtained the contract to provision the ships. Because this firm was inexperienced in handling an order this large, it was later suggested that some or much of the preserved tinned food may have been spoiled. If this was the case, it would have serious implications on the survival of the large crew particularly if food supplies from the local environment were insufficient to supply their needs. This issue was debated in the British House of Commons, but it could not be resolved, and the matter was laid to rest.

Dr. Beattie, Director of the Franklin Forensic Project has revived the issue of problems with the food supply, but his argument is not that the food had "gone bad", but rather that the food may have been contaminated with high concentrations of toxic metals such as lead (Pb). After inspecting and visually analyzing the *ca.* 125 remaining tins from the Franklin expedition still at Beechey Island, N.W.T., he noted that they were generously sealed with lead/tin solder, and he hypothesized that lead from the solder could have contributed significantly to the lead body burden of the expedition members. Excessive body burden of lead could have seriously affected the mental and physical well-being of all or most of the members of the expedition.

PROPOSED RESEARCH

It was necessary to examine the available biological materials obtained from members of the Franklin expedition in order to assess the validity of Dr. Beattie's hypothesis. Bone, soft tissue and hair samples were therefore acquired for lead analysis. It was hoped that each sample would yield information specific to its own tissue type, and that the derived data could be correlated to modern published data to give a valid comparative assessment of total body lead burdens among the members of Franklin's crew.

The detailed lead analyses of the tissues were undertaken at the Government of Alberta's Community Occupational Health and Safety Laboratory equipped with

graphite furnace atomic absorption instrumentation. This laboratory routinely does trace lead analyses of human blood samples using graphite furnace atomic absorption spectrometry. The graphite furnace method employed in the lead analysis employs conventional internal quality control programs and proficiency testing material to assess the precision and accuracy of the lead analyses. The consistent application of acceptable quality control standards and criteria are of special significance for the trace lead analysis of the Franklin expedition biological materials because the sample materials are finite and not replaceable.

MATERIALS AND METHODS

The tissue samples to be used in the analyses were collected on Beechey Island, N.W.T. and King William Island, N.W.T. The samples from Beechey Island were collected during autopsies conducted on the well-preserved bodies of three Franklin expedition crew members exhumed from the permafrost in 1984 and 1986. These samples consist of hair, bones and soft tissues. The samples from King William Island were surficial finds (bones only) collected during foot surveys of much of the western and southern coasts of the island in 1981 and 1982. Twenty-seven bones were eventually analyzed, representing between 8 and 15 Franklin crew members.[6] Bones from Inuit and caribou from the same time period and the same geographical area were added to the sample population to ascertain if environmental lead was a possible source of lead contamination. As well, some calvaria samples from a modern cadaver population from Vancouver, British Columbia, Canada were included as a control group to assess the precision of our assay technique. A list of the sampled tissues is found in Table 1.

The tissue samples from the three crew members were kept refrigerated from the time of collection until they were brought to the laboratory. Each of the samples was washed in Type I deionized water, and the wash water was kept for recovery analysis. All laboratory test tubes and apparatus used in the analyses were soaked in 20% (v/v) nitric acid for 24 hours and then were washed three times with Type II deionized water and three times with Type I deionized water. (See Tables 2, 3 and 4 for sample preparation and digestion procedures.)

ANALYSIS

Analytical instrumentation employed throughout this study consisted of a double beam Varian 1475 Atomic Absorption Spectrophotometer mounted with a Varian GTA 95 graphite furnace. The instrument was equipped with a deuterium background correction unit. Varian pyrolytically-coated graphite tubes and platforms were used for the lead determinations.

Sample digests were diluted 1:30 using a diluent of 0.1% (w/v) Triton-X and 0.03% (w/v) ammonium dihydrogen orthophosphate. The ammonium dihydrogen orthophosphate acted as a modifier to minimize matrix interference. The operating parameters of the carbon furnace are outlined in Table 5.

Table 1 Source of tissues sampled (Franklin Expedition)

Bones	*No.*	*Soft tissues*[a]	*Hair*
British sailors, Beechey Island, N.W.T. (1984, 1986)			
Femur	1	Liver	Nape
Rib	2	Kidney	
Radius	1	Aortic arch	
Skull	1	Muscle septum	
Vertebra	1	Spleen	
		Rectum	
		Lung	
		Bowel	
		Stomach	
		Bladder	
		Skin	

British	*No.*	*Inuit*	*No.*	*Caribou*	*No.*
Bone samples, King William Island (1981, 1982)					
Tibia	13	Femur	2	Rib	2
Femur	3	Ulna	4		
Ulna	2	Scapula	4		
Vertebra	1	Rib	2		
Rib	1	Humerus	5		
Metacarpal	1				
Parietal	2				

[a]Analyses presently in progress: Results not reported here.

Table 2 Hair sample washing procedure[a]

Bundled hair
Cut into 1-cm lengths (average weight 30 mg)
Place individual segments into test tubes
Wash three times in 0.05% Triton-X, vortexed for 1 minute
Wash three times in Type I deionized water
Dry at 95 °C for 24 hours
Equilibriate to room temperature (20–25 °C) for 4 hours
Weigh in clean test tubes

[a]Personal communication, Dr. Jean-Philippe Weber, Director, Centre de Toxicologie, Laval University, Quebec.

Table 3 Bone sample preparation

Cut approximately 10 mm-square samples from each bone (autopsy saw)
Place samples in liquid nitrogen (−196 °C)
Crush with plastic hammer on teflon board
Use only central fragments of bone that did not make contact with the autopsy saw-blade
Place samples in test tubes
Dry at 95 °C for 24 hours
Equilibrate to room temperature (20–25 °C) for 4 hours
Weigh samples in clean test tubes

Table 4 Bone sample digestion

Place bone sample (~ 100 mg) in a teflon digestion bomb
Add 1.5 mL ultra pure HNO_3
Place bomb in oven for 2 hours at 145 °C
Open and allow NO_2 gas to escape
Transfer digestate quantitatively to 10-mL volumetric flask
Bring to volume with Type I deionized water and mix

Table 5 Furnace operating parameters

Step no.	*Step*	*Temperature*	*Time (sec)*
1	Dry	130	20
2	Dry	200	20
3	Ramp	200	15
4	Ash	700	15
5	Ramp	700	20
6	Atomize	2200	1.0
7	Ramp	2200	1.5
8	Clean	2600	3.5

No. of replicates: 3; Injection volume: 20 μL; Purge gas: Argon; Wavelength: 283.3 nm.

The graphite furnace was calibrated using fresh aqueous standards of 10, 20, 40, 60 and 80 μg of Pb/dL prepared in the matrix modifier above. Blood quality control samples were used after every five samples, and the aqueous lead standards were analyzed at the end of the sample run to verify instrument stability, within run variance, between run variance, interlaboratory precision and intralaboratory precision. Accuracy of the analyses was established through the use of National Bureau of Standards traceable calibration materials and recovery of known lead concentrations in the sample matrix. Standard reference materials consisting of bovine bone (H-5) obtained from the International Atomic Energy Agency and certified hair samples from the National Institute for Environmental Sciences (NIES) were analyzed with each run to validate the analytical procedure.

RESULTS

The results of the bone/lead analyses are given in Table 6 with the values expressed in μg/g dry weight. The lead content of the hair and the bone are markedly elevated compared to modern control samples. Lead content in whole hair samples had a mean value of 379 μg/g, while the root segments had a mean value of 269 μg/g. Control samples taken from laboratory staff and family members had a mean value of 4 μg/g. NIES hair standard reference materials consistently gave values approximating the consensus value of 8 μg/g.

Bones from the three individuals buried at Beechey Island had a mean lead content of 128 μg/g. The bones found and collected on the coast of King William Island had a mean value of 138 μg/g. Inuit bones found in the same geographical

Table 6 Results of lead analysis

Sample group	*No.*	*Range*[a]	*Mean Pb values*[a]	*S.D.*
a) Bone analysis				
British (Beechey Island)	6	69–183	128.3	±45
British (K.W.I.)	27	87–223	138.1	±35
Inuit (K.W.I.)	17	1–14	5.1	±4
Caribou (K.W.I.)	2	–	2.0	–
Modern-Vancouver (average age 55 years)	5	18–50	29.8	±13

Sample group	*Segments*	*Root*[a]	*Range*[a]	*Mean Pb values*[a]	*S.D.*
b) Hair analysis					
Torrington	10	330	330–707	565	±117
Hartnell	10	265	222–510	326	±110
Braine	10	211	158–317	225	±90
Modern (15 indiv.)	10	4	1–8	4	±2

[a]Pb values expressed in μg/g dry weight.

area (King William Island) and from the same time period had a mean value of 5 μg/g. Caribou bones found intermingled with some of the Franklin bones on King William Island had a mean value of 2 μg/g. The calvaria from the modern control population (Vancouver) had a mean value of 30 μg/g.

DISCUSSION

The first analyses were performed on the hair samples collected during the autopsies of the three Beechey Island Franklin crew members to determine if these individuals may have been exposed to high lead levels. The findings indicated that all three men had been exposed to large amounts of lead. While there is no equivocal means of establishing whether the hair lead originated from endogenous or exogenous sources, these results strongly suggest these individuals were exposed to large amounts of lead during the time of the expedition.

The bone analyses indicate that all members of the expedition had very high body burdens of lead, which suggests lead exposure for an extended period of time.

Values of the bone lead analyses from the sailors who succumbed on King William Island ranged from 87–223 μg/g. Lead levels in bones taken from Inuit (Eskimo) of the same time period and same geographical area ranged from 1–14 μg/g suggesting that local Arctic environmental lead contamination was not a contributing factor in the high bone lead levels in the British sailors. This conclusion is substantiated further by the low bone lead levels in the caribou bone samples found with one of the British sailors.

At present we can only speculate as to the possible symptomology of lead intoxication expressed by individuals with bone lead levels as high as those in our

sample. Perhaps when the soft tissue analyses are completed a better assessment of the level of intoxication and possible symptomology can be made. Results of the soft tissue analyses may also offer additional clues as to the origin of the lead stored within the biological tissues.

Tinned foods were of crucial importance to the Franklin Expedition; the loss of some of this food to spoilage, combined with the more insidious problem of lead contamination, may have had profound effects on the fate of the expedition after the departure from Beechey Island. The ability to analyze well-preserved human tissues from the expedition crew members is of critical importance in implicating or vindicating the food supplied to the expedition as a major contributing factor of the disaster.

Tin can remnants collected in 1986 from Beechey Island are presently undergoing metallurgical analysis. This will be augmented by a replication experiment on the tin manufacturing process and preservation methods employed by Stephan Goldner, the tinned food supplier to the Franklin Expedition, in order to shed further light on the possible extent of food lead contamination under these conditions.

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