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Archaeological Contributions of Skeletal Lead Analysis

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ABSTRACT
We developed a chemical method to quantitate lead in small skeletal specimens and used it to establish lead distribution and quantitation in modern skeletons for all age groups to standardize sampling sites. Application of the method to excavated ancient skeletal collections enabled prediction of socioeconomic status among Colonial Americans, as well as identification of lead poisoning in ancient Rome as related to lead production and in an 18th century Caribbean epidemic as related to distillation of rum. Depending upon the conditions of burial, bones may be contaminated by surrounding material. This can be a limiting factor for interpretation of lead levels, but multielement analysis and procedural modifications can permit continuing application of bone lead analysis to appropriately selected archaeological skeletal collections.

Introduction

This Account documents results of a series of chemical studies characterized by quantitation of human skeletal lead content, initially in specimens of modern origin and later of ancient archaeological populations. The lead analysis technique developed for this work was unique in the small sample size employed and the suppression of matrix interference problems. Most of these studies were carried out by the authors of this Account. This Account summarizes the work of the authors in this area over the past 20 years.

Even today, except as related to local ore deposits, lead is normally not present in high concentrations in air, water, or soil. Exceptions are principally foci of lead industrial use or automobile gasoline additives. Significant human exposure to lead, therefore, is a direct or indirect consequence of societies' processing of lead for one use or another. In humans, absorbed lead is concentrated physiologically in the hydroxyapatite crystal of bone mineral, where it can be stored for decades. Therefore, repeated or continuous exposure results in accumulation of lead in bone. Hence, with some assumptions and/or reservations, quantitation of modern human skeletal lead content is a measure of lead exposure during the individual's lifetime and could permit prediction of the human behavior that led to its absorption. Because an important part of the goal of archaeology is the reconstruction of past human life styles, measurement of bone lead content has the potential for making significant contributions to this effort.

The Archaeology of Lead

Lead's Antiquity and Use. Galena beads at Çatal Hüyük[1] about 6500 B.C.E. and lead use in Iraq about 5000 B.C.E. and in Egypt about 3000 B.C.E.[2] all testify that lead is one of the earliest metals used in antiquity. China used lead vessels by 1000 B.C.E., and the ancient world's largest lead mine at Laurion, Greece, began about 850 B.C.E.[3] Romans mined lead avidly during the Republic period (400−30 B.C.E.). Both China and Japan employed white lead as a pigment about 700 A.C.E.[4,5] The many industrial applications of lead resulted in recurrent episodes of lead poisoning during the Industrial Revolution.

Geochemistry and Lead Ore Processing. Lead ores include galena (PbS), white lead or cerussite ($PbCO_3$), red lead or minium ($2PbO{\cdot}PbO_2$), and lead monoxide (massicot and litharge: PbO).[6] Heating lead ore under specified conditions can separate the metal from its ore by differential absorption into the walls of a porous cup (cupel), a process known as early as the third millennium B.C.E.[2]

Applications of Lead Products in Antiquity. Romans' cosmetic and paint pigment use of white lead[7] and their employment of the pure metal as urns, pipes, and pewter (20% lead) for tableware and beverage containers are only a few examples of myriads of applications of this unique metal by ancient populations. Its widespread use during the Industrial Revolution increased the air, soil, and water levels in all but the remote areas of the earth.[8]

Clearly conditions in antiquity provided abundant opportunities for human exposure to lead. Its quantitation in archaeological bones gave promise for prediction of human behavior that led to its absorption.

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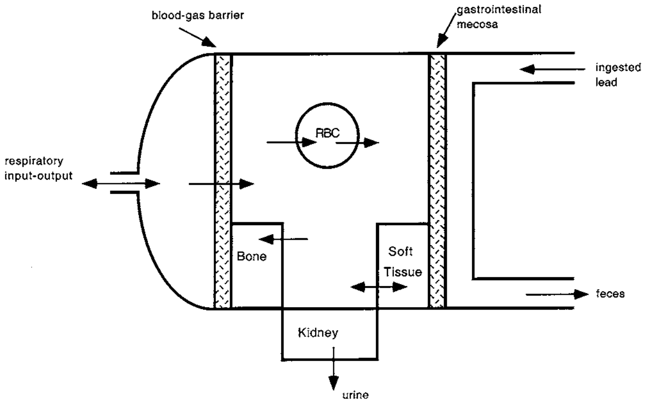

FIGURE 1. Schematic of lead physiology. The diagram demonstrates interrelationships between absorption, excretion, distribution, and compartmentalization of lead in humans.

Relevant Aspects of Lead Physiology. (a) Body Accumulation of Lead. Lead entry into the body is possible via skin, lungs, and gastrointestinal tract (Figure 1). The skin route of lead uptake is a minor one, because the surface area is usually small and contact time is often short or intermittent. Lead in the atmosphere is absorbed efficiently by the lungs' large surface area whose blood then distributes it widely to the body's tissues. This route is significant in industrial exposures (smelting; gasoline additives). Ingested lead (food, drink, dirt, paint chips, etc.) is absorbed more efficiently by children (50%) than by adults (10%).[9]

Following absorption, blood distributes lead to all body tissues, but only a minor fraction remains in the soft tissues. Between 70 and 90% of body lead burden is deposited irreversibly in the crystalline matrix of bone (displacing calcium in hydroxyapatite),[10] where its half-life is more than two decades.[11,12] The initial deposition in bone is within the noncrystalline compartment (collagen, soft tissue, and marrow), probably in the subperiosteal region,[13] with subsequent transfer to the primary bone mineral. Since these two compartments may not necessarily be in the same bone area, this has potential implications for the selection of a bone specimen sampling site whose analytical value is expected to be predictive of total body burden of lead. Differing bone remodeling rates in various skeletal structures may also correlate differently with total body burden of lead.[14]

Lead excretion routes are principally the urine and feces. Only a minimal amount exits via sweat and saliva. Bone remodeling releases stored lead into the blood, which, if pathologically accelerated (hyperparathyrodism), may reach levels sufficient to produce symptoms of lead poisoning. This mobilized lead is either excreted or redeposited in bone.

(b) Relevance of Lead Physiology to Archaeological Interpretation. In the event of continuing lead exposure, the long half-life of lead in bone can be expected to result in a progressive, age-related increase in skeletal lead content. Because of the variables mentioned previously, the ability of a selected bone specimen sampling site to predict body total lead burden needed to be evaluated.

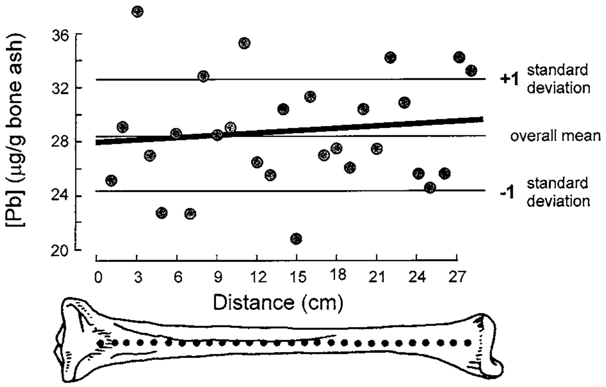

FIGURE 2. Distribution of lead within bone. Distribution of lead concentration in 3 mm core samples is shown in a single bone (adult tibia).

A lead analysis method was required that would accommodate the very small bone samples commonly mandated by curators of archaeological skeletal collections but with sufficient analytical precision to meet the intended applications as well as economy for the analysis of large numbers of specimens.

Development of a Chemical Micromethod for Lead Analysis in Bone

Method. A Perkin-Elmer 460 atomic absorption spectrometer (AAS) equipped with deuterium background corrector, HGA 2100 graphite furnace and AS-1 autosampler was employed to measure lead in a minimum of a 10 mg sample of bone ash.[15] Lanthanum ion was added to the samples to suppress matrix interference. Bone samples were usually acquired with hollow core drills of 3 mm diameter. Mean lead recovery values were 103.5% ± 12.9 (SD). Sensitivity was defined as the weight of Pb that produced 1% absorbance and proved to be $57.2 \pm 4.4 \times 10^{-12}$ g. Variance for either "within run" or "between daily runs" was 12.4%. When samples analyzed by our method were compared with results from an X-ray fluorescence technique, no evidence of a systematic difference between the two techniques of more than 1 part per million (ppm or micrograms of lead/gram of bone ash)[16] was obtained. These values satisfied our needs for sensitivity, precision, and sample size. The bone samples for this analysis were obtained from tibia and metatarsal sites, and the resulting lead levels ranged from 6.5 to 83 ppm or μg of Pb/g of bone ash. The small differences that did appear between methods could be accounted for by bone composition.

Sample Size and Location Studies. Using the intact tibia from a modern adult male, 3 mm core samples were taken at one centimeter intervals (a total of 28 samples) along the cortex (cortical bone, a compact, dense bone just below the periosteum and above the spongy or trabecular bone) of the bone shaft (Figure 2). These data indicate no relationship between bone lead concentration and position along the bone shaft. Additionally, no differences in lead concentration could be demonstrated on paired analysis in samples acquired from the cortex of both tibial metaphysis (a conical section of bone between the epiphysis and the diaphysis) and diaphysis (shaft of

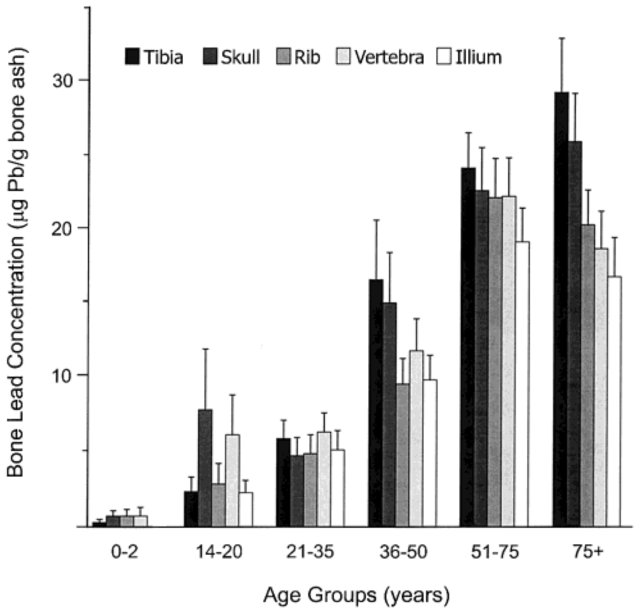

FIGURE 3. Lead distribution in modern human skeleton. Bars indicate one standard deviation.

Table 1. Mean Bone Lead Concentrations (μg of Pb/g of Bone Ash) as a Function of Age for the Five Sites Sampled[a]

age group (yr)	age (yr)	tibia	ilium	rib	vertebra	skull
>75 (31)	86.3	29.0	17.0	20.5	18.8	26.1
51−75 (42)	63.9	24.2	19.2	22.3	22.4	22.8
36−50 (15)	42.3	16.6	9.9	9.7	11.9	15.2
21−35 (18)	24.6	5.9	5.3	5.0	6.3	4.9
14−20 (13)	17.6	2.3	2.3	2.9	3.8	3.2
0−2 (12)	0.3	0.3	0.0	0.7	0.6	0.6

[a] Our skeletal sample included no subjects between the ages of 3 and 13 years. Numbers in parentheses represent the total number of samples contributing to the mean value. Column headed age (yr) represents the mean age for each age group.

the long bone) in 47 hospital autopsies or in samples from the right and left tibial cortex in 12 adults of a Colonial America skeletal collection.

A more extensive bone lead analysis was performed on 81 males and 50 females ages 0−90 years in successive, local hospital autopsies. Sample sites included tibia (compact bone), vertebra (trabecular bone), and skull, ilium, and rib (the latter three are mixtures of compact and trabecular bone). These results (Figure 3)[17] reveal a pattern of differences between compact and trabecular bone at all ages and a correlation of bone lead content and age, most consistently in the compact bone samples (Table 1). This led us to select the full thickness tibia diaphyseal cortex as the standard sample collection site for our archaeological studies. Rib, skull, or ilium were alternative sites, providing that all trabecular bone was removed from the sample before analysis.

Archaeological Applications

Lead Levels Related to Social and Economic Status of Colonial America. (a) History. Colonial Americans' lead exposure was principally via food containers made of British pewter whose composition averaged about 20% lead. In wealthy homes of that period tableware, goblets and beverage storage containers commonly were made of British pewter. Pewter milk containers were particularly popular because of a perception that the "spoiling" of milk kept in these was delayed (lead, leached into the milk, suppressed microbial proliferation). Acid fruit juices, including wine, were especially effective in leaching lead from pewter containers. It appears that most food ingested by the wealthier members of these populations would have been laced with lead to varying degrees. Plantation slaves, however, would have had little access to pewter and therefore lead contamination in any form. However, prior to our studies, no structured bone lead surveys on Colonial Americans addressing this particular hypothesis had been published.

Table 2. Mean Skeletal Lead Concentrations of North (Plantation Owners) and South (Work Force) Cemeteries at Clifts Plantation[a]

cemetery group	mean skeletal lead content	range	no. of adults	no. of children
north (owners)	185	128−258	3	2
south (laborers)	35	8−96	10	1

[a] All lead concentrations are expressed in ppm (μg of Pb/g of bone ash).

(b) Clifts Plantation Study. This Virginia plantation operated between 1670 and 1730. Its proprietors were ranked as some of the wealthiest in the county. The owners' family cemetery was separate from that of the work force. The latter was made up of indentured servants until 1705, after which it was almost entirely replaced by African slaves. Excavation recovered 5 bodies from the owners' burial site, the North Group, and 11 from that of the work force, the South Group.

Mean skeletal lead content for the owners' bodies was more than five times higher than that of the work force: 185 vs 35 μg of lead/g of bone ash (μg of Pb/g of bone ash), nor did the range of values for each group overlap (Table 2).[18] Two individuals are of special interest. An 18-year-old Black female, buried in the workers' section, had a bone lead concentration of 96 μg of Pb/g of bone ash, a value approaching the lower end of the owners' bone lead range. Since the only source of lead on the plantation was in the owners' house, it seems probable that this worker's position was that of a domestic, possibly a cook, who ate all or part of her meals in the master's kitchen. In addition, with the exception of one, all work force bodies were Black. A single male Caucasian skeleton had a lead concentration approaching that of the work force's mean. This individual was most likely a British indentured servant who died on the plantation before his years of obligation had been fulfilled. His lead level, similar to that of the Black work force members, provides a clear statement of the social status of the Caucasian indentured servants during the Colonial period.[18]

(c) Other Continental Colonial Sites. Subsequent studies at other colonial sites also indicated that Caucasian owners had high bone lead concentrations, while slave groups had little lead in their bones (Table 3). Interest-

Table 3. Mean Bone Lead Concentrations at Four Colonial American Sites[a]

site	race	*N*	Pb	social status
Catoctin Furnace	B	16	28.9	slaves
College Landing	B	14	41.9	freedmen
Irene Mound	C	12	51.9	owners
Governor's Land	C	27	79.5	elite

[a] B = Black, C = Caucasian, *N* = number of individuals, and Pb = mean μg of Pb/g of bone ash.

Table 4. Skeletal Lead Concentrations for Newton Plantation Slaves[a]

age (yr)	Pb	*N*	age (yr)	Pb	*N*
10−19	57.8	4	40−49	135.8	6
20−29	109.3	17	50−59	148.2	8
30−39	111.8	14			

[a] Pb = mean lead concentration (μg of Pb/g of bone ash). *N* = number of sampled individuals.

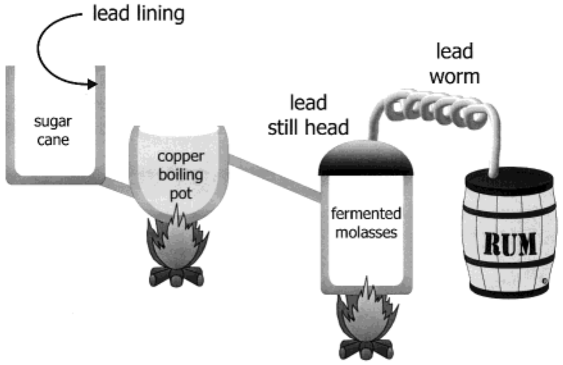

FIGURE 4. Steps in the processing of sugar cane into rum. Sugar is exposed to lead at every step of the process.

ingly, a group of free Blacks at College Landing, Virginia, revealed a wide range of values, probably reflecting varying degrees of economic success among these tradesmen.[19]

(d) Newton Plantation, Barbados. A group of 48 Black slaves from the Newton Plantation in Barbados (operated 1673−1920s) were studied.[20] Results revealed a clearly defined correlation between bone lead content and age (Table 4). These results are in sharp contrast to the low bone lead levels observed in Black slaves in the continental plantation groups. Intense scrutiny of Newton and Caribbean records by anthropologists and historians were required to unravel this paradox.[21]

During the 17th and 18th centuries Barbados and most of the Caribbean Islands were wracked by a serious epidemic of unknown cause affecting both Black and Caucasian residents. It was characterized by severe abdominal cramps without diarrhea ("dry bellyache"), hand and foot paralysis, and, in children, convulsions. These symptoms are characteristic features of lead poisoning. Eventually the difference between lead levels in Barbados compared with continental slaves was traced to the processing of Caribbean plantations' products: sugar.

Every step of the process exposed the sugar solution to lead (Figure 4). Even the concentrated boiling process was carried out in an enclosed room whose atmosphere must have contained a high level of vaporized lead. The resulting molasses was stored in lead-lined containers until fermented and then distilled in an apparatus whose coiled condensing tube ("worm") was composed of lead (Figure 5). The consequence of these processes was not only massive exposure to lead fumes in the boiling house, but also consumption of rum inadvertently laced with lead from the distillation coils. Furthermore, in contrast to continental plantation practices, the plantation owners on Barbados employed rum as a work incentive among the slaves.

FIGURE 5. An 18th century distillation tube ("worm"). This fine example was photographed in the Grenada National Museum. Photo courtesy David Mohrman, Ph.D.

But were the bone lead values high enough to account for the historically identified symptoms? Unfortunately the medical literature relates symptoms to *blood* lead levels. To convert our bone lead to blood lead levels we applied a regression equation created from a database of British industrial lead workers whose blood lead levels had been measured every 6 months for many years and recently also had bone lead measurements in vivo using an X-ray fluorescent technique.[22] These investigators related integrated blood lead values (blood lead × time) to bone lead levels, generating a regression of the two measurements: bone Pb (μg/g) $= 0.03$ blood Pb (μg/100 mL) $\times$ time (years of exposure) $- 0.9$,[20] allowing an estimate of blood lead from a bone measurement. This approach, applied to population bone lead values, resulted in blood lead values that would indicate that 27% of the population had blood leads that could have been associated with moderate to severe symptoms of lead poisoning. It appears that this study firmly identified Pb poisoning as the cause of a severe Caribbean epidemic 2 centuries after it occurred.[21]

(e) Soldiers at Fort Erie, Ontario. During the 1812 war between the United States and Great Britain, a major battle was fought at Fort Erie, Ontario, about 24 km above Niagara Falls. The American army suffered many casualties; the bodies were hastily buried in the sandy soil. The site (Snake Hill) was excavated in 1987. The skeletal remains of 27 young adults, aged 15 to 40 years, were exhumed and sampled for skeletal lead analysis. Bone lead content was related to age (Table 5). Overall mean values, including two outliers, were 31.3 ± 24.3 μg of Pb/g of bone ash. These are quite modest quantities, suggesting that the majority of the soldiers had been recruited from low socioeconomic families. The two outlier values were 82.9 μg of Pb/g of bone ash (age 20) and 113.1 μg of Pb/g of bone ash (age 23). Either these two were recruited from

Table 5. Lead Concentrations of Fort Erie Soldiers' Age Groups[a]

age (yr)	Pb	*N*	age (yr)	Pb	*N*
14−19	16.8	6	35+	46.3	4
20−34	23.8	17	all	31.3	27

[a] Pb = mean skeletal lead concentration expressed as ppm (µg of Pb/g of bone ash). For each indicated age group, *N* = number of individuals in each age group.

very well-to-do families, or they had unusual occupational exposure (e.g. production of lead shot). When these bone lead values are translated into blood lead estimates using the previously noted regression equation,[22] in terms of health effects, 16 of the 27 skeletons were in a range expected to be asymptomatic, 8 might have had occasional mild symptoms (abdominal cramps), and only two outliers (estimated blood lead level of 104 µg/dL) would have been susceptible to abdominal cramps with mild to moderate hand or foot loss of muscular strength.

(f) Separation of Commingled Bones. Construction activity at a South Carolina site[23] unexpectedly uncovered evidence of a Colonial period plantation. Bones commingled by earth-moving machines included some from the plantation owner's crypt as well as others from the plantation's work force. Attempts to reassemble the bones of the owner resulted in a grouping whose bone lead content was zero for the mandible, ulna, and tibia, 3.0 µg of Pb/g of bone ash for a rib, 12.7 µg of Pb/g of bone ash for the ilium, and 52.1 µg of Pb/g of bone ash for the skull. We concluded that the skull and possibly the ilium were those of the plantation owner, but the remainder most likely represented slave burials.

Lead Levels in the Ancient World. (a) History. In the 6th century B.C.E. the Lydians popularized the use of silver coinage. In Greece, Italy, and some other areas silver occurs as a minor but important component of lead ore. This led to extensive mining of lead ore in pursuit of its silver content in Italy beginning about the onset of the Roman Republic ca. 400 B.C.E., peaking at 50 B.C.E., and plummeting shortly after the onset of the Imperial Age when Italy's lead ore sources became exhausted.[3] The Romans found a vast number of practical applications for the lead "byproduct". Lead pipes distributed their drinking water, and its use for wine storage and other food containers is well-known.[24] They even grew accustomed to the taste imparted by the lead leached into the wine, and a gracious host commonly provided vials of lead acetate at the table to be added to the wine to flavor it to suit the individual's preference (Pliny 34: 52). Indeed, the erratic behavior of some emperors and well-known Romans has been attributed to chronic lead poisoning[24] and some even suggest it contributed to the fall of the Roman empire.[24,25] Data on bone lead content from Italian sites using current laboratory methodology were meager.

(b) Lead in Italian Populations Study. Bone samples from a total of 240 individuals representing 20 ancient archaeological populations dated from 800 B.C.E. to A.C.E. 700 distributed from the northern to the southern end of the Italian peninsula were analyzed for bone lead content (Figure 6). Data relevant to the extent of mining on the Italian peninsula were drawn from Patterson (1972)[3] and Patterson et al. (1987).[8] From about 800 B.C.E. to the beginning of the Roman Republic, the production of lead mining rose from almost nil to a modest level but then rose rapidly, peaking at the beginning of the Imperial Age, but thereafter declining as rapidly as it rose to nearly nil again about A.C.E. 800. The bone content of the studied Italian populations parallels this pattern quite closely, but the curve is shifted about 200 years to the right (more recent) of the production curve. Bone lead content remains low through the Etruscan period, rising rapidly about 200 B.C.E., and peaking just before the fall of Rome, about A.C.E. 350. By A.C.E. 750 it has returned to its pre-Etruscan level. A conservative interpretation of these findings implies that the bone lead content pattern parallels the pattern of lead production and supports the historical evidence of behavior suggestive of instances of lead poisoning among the Roman population.[26] A more pointed discussion of the fall of the Roman Empire and lead poisoning has been presented by Gilfillan in 1990.[25]

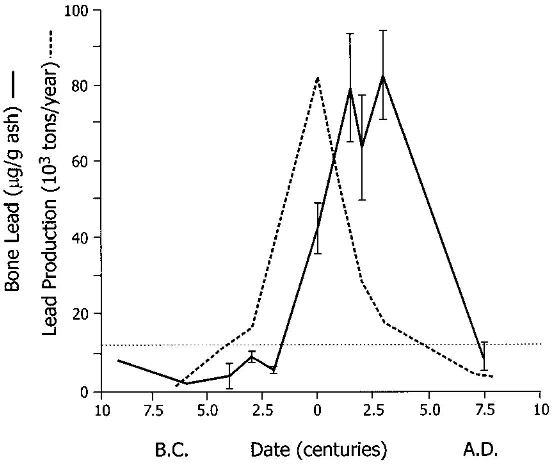

FIGURE 6. Temporal relationship of lead production in Italy and Italian population bone lead concentration. The bone lead concentrations represent the mean values of 20 sampled populations on the Italian peninsula. The mining production data were extracted from Patterson (1972)[3] and Patterson et al. (1987).[8]

Some of the oldest bones available for comparison with Italian populations were from the Nippur site in Iraq. Five adults were sampled from the Neobabylonian and Achaemenid Period (700−300 B.C.E.), and 9 adults and subadults, from the Seleucid Period (312−141 B.C.E.). Excluding 3 "outlier" values, the mean bone lead values for these two groups were virtually identical: 4.1 ± 4.0 and 4.8 ± 3.0 µg of Pb/g of bone ash, respectively. The mean value for the three "outliers" (two adults and one infant) was 39.7 ± 9.5 µg of Pb/g of bone ash. These values suggest a minor degree of lead exposure for most of the individuals in either group but a moderate degree of exposure in an adult of the first group and both an adult and infant (<2 years) in the second. The nature of such exposure is speculative;[27] however, we may look at this group as baseline bone lead values with respect to the Italian population.

The Question of Diagenesis

Diagenesis refers to all the changes in a tissue resulting from interaction with the environment. With respect to the data presented here, we are most interested in lead addition or removal from the bone crystal. Among investigators working on trace elements in bone, concerns about the possible contamination (one aspect of diagenesis) of buried bones by groundwater elements were spurred by the use of measured bone strontium concentrations as a marker for plant food ingestion in an effort to recreate an ancient population's diet. Initial studies compared archaeological bone strontium concentrations with those in teeth,[28] in trabecular vs compact bone,[29] in archaeological and modern bones,[30] and in archaeological bones and their related soils.[31] These earlier studies suggested no exchange of strontium between buried bones and the soil within which they were interred. Later, however, failure of fossil specimens to conform to dietary expectations[32] and other studies led to unequivocal evidence of diagenetically altered strontium levels in archaeological bones.[33]

Among studies that addressed lead directly, the earlier reports were also reassuring. Bolter et al. (1975)[34] noted that alkaline soils preserved archaeological bones well and that lead was firmly bound at such high pH levels. However, Waldron (1981)[35] used energy-dispersive X-ray analysis (EDXA) to demonstrate a distinct zone of high lead concentration at or near the bone surface in some archaeological bones that had elevated lead content that he thought represented a layer of lead ions derived from groundwater. However, the feeding of thorium to *living* animals by Sieber had revealed a similar pattern as early as 1936.[13] Furthermore, Specht and Fischer (1959)[36] had also found such a distribution in unburied bone and felt this could well represent a physiological distribution. Nevertheless, Waldron (1981)[35] found bone lead concentrations up to 10 000 μg of Pb/g of bone ash in skeletons buried in lead coffins. Our own experience also included high lead concentrations in 19th century skeletons buried in what is now part of Philadelphia (First African Baptist Church site; unpublished data). These were not easily attributable to lead exposure. Lead distribution within these bones, as demonstrated by examination using Brookhaven National Laboratory's synchrotron, revealed multiple patterns varying from diffuse to those with a prominent peripheral dispersion.

If it is known that lead could enter archaeological bone under some circumstances, attention then shifts to the recognition of diagenesis and methodological efforts to minimize its effects. Development of instrumentation that permits the simultaneous measurement of multiple elements (e.g., inductively coupled plasma technique) has enabled the identification of certain elements common in soil but that do not usually accumulate to high concentrations in living normal persons.[37] A massive study by Buikstra et al. (1989)[38] found that these include manganese, aluminum, and even iron. Substantial elevations of such elements can serve as diagenetic "markers".[39]

Development of methods enabling recognition of diagenesis in archaeological bones was followed by efforts to minimize its effects. A simple but effective practice is the routine removal of about 1 mm of bone from the surface of a skeletal sample before measurement.[40] Another is the overnight immersion of a bone sample in a sodium acetate solution buffered at pH 4.5. This latter practice is based on the observation that postmortem hydroxyapatite crystals formed from groundwater ions are soluble at this pH but biological apatite is not.[41] More complex analysis resulted from the suggestion by Waldron (1981)[35] that lead isotopes could perhaps be employed to separate biological from diagenetic lead in archaeological bones. Kowal et al. (1991)[42] used this approach to trace the source of lead (found in the bones of victims of a 19th century arctic expedition) to the solder used to deal the expedition's food tins. Similarly, Reinhard and Ghazi (1992)[43] identified lead-based paint as the source of high lead levels in archaeological bones of a North American population.

Whenever skeletal material is interred in an environment that may produce diagenetic changes, chances for contamination of lead levels are possible. It will be the investigators' responsibility to evaluate the surrounding environmental history and make a case that interpretation of the data is reasonable. Methods are now available to detect a diagenetic effect, and a variety of techniques ranging from the simple to the sophisticated[44,45] can be employed to minimize or compensate for these complicating factors. With these factors under consideration, skeletal lead analysis of appropriately selected and corrected material can continue to make major contributions to the understanding of cultural (social and medical) features of ancient populations.

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