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ORIGINAL ARTICLE

Restoring Identity to People and Place: Reanalysis of Human Skeletal Remains from a Cemetery at Catoctin Furnace, Maryland

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Abstract Nearly four decades ago, a highway expansion project resulted in the excavation of 35 unmarked graves at Catoctin Furnace, an industrial ironworking village in western Maryland. Initial analysis identified the remains as Africans or African Americans associated with the late 18th- and early 19th-century operation of the ironworks. Renewed efforts to learn more about these poorly documented individuals and connect the site's untold past to present generations through heritage tourism, prompted reanalysis of the skeletons. Updated assessments of demography and pathology, along with new analyses including heavy metals and carbon and nitrogen stable isotopes, elucidate the life histories of these early laborers and their involvement in furnace operations. Some data derived from recent testing differentiate the Catoctin Furnace individuals from their plantation-based contemporaries in the mid-Atlantic, suggesting regional differences in diet and possible occupational exposure to toxins.

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Extracto Hace casi cuatro décadas, un proyecto de expansión de carreteras resultó en la excavación de 35 tumbas sin marcar en Catoctin Furnace, una aldea industrial de hierro en el oeste de Maryland. El análisis inicial identificó los restos como africanos o afroamericanos asociados con la operación de la herrería de fines del siglo XVIII y principios del XIX. Los esfuerzos renovados para aprender más sobre estas personas poco documentadas y conectar el pasado inédito del sitio con las generaciones actuales a través del turismo patrimonial impulsaron el nuevo análisis de los esqueletos. Las evaluaciones actualizadas de la demografía y la patología, junto con nuevos análisis, incluidas las pruebas de metales pesados e isótopos estables de carbono y nitrógeno, aclaran las historias de vida de estos primeros trabajadores y su participación en las operaciones del horno. Algunos datos derivados de pruebas recientes diferencian a los individuos de Catoctin Furnace de sus contemporáneos en plantaciones en el Atlántico medio, lo que sugiere diferencias regionales en la dieta y la posible exposición ocupacional a las toxinas.

Résumé Il y a presque quarante ans, un projet d'expansion d'autoroute a conduit à l'excavation de 35 tombes sans inscription dans la Fournaise de Catoctin, un village où se pratiquait une industrie du fer dans le Maryland occidental. L'analyse initiale a identifié les restes d'individus africains ou africains-américains associés aux opérations de travail du fer à la fin du 18ème siècle et au début du 19ème siècle. Des efforts renouvelés pour en savoir plus sur ces individus médiocrement

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documentés et connecter le passé sans récit du site aux générations actuelles par le biais d'un tourisme de mémoire, a déclenché une nouvelle analyse des squelettes. Les évaluations mises à jour de la démographie et de la pathologie, menées conjointement à des analyses nouvelles, notamment les tests de recherche de métaux lourds et d'isotopes stables du carbone et du nitrogène, élucident les récits des vies de ces premiers travailleurs et de leur participation aux opérations d'exploitation de la fournaise. Certaines données obtenues à partir des récents tests différencient les individus de la Fournaise de Catoctin de leurs contemporains ayant vécu dans des plantations de la région mid-Atlantique, suggérant des différences régionales quant au régime alimentaire et une exposition professionnelle potentielle aux toxines.

Keywords ironworks · African · African American · isotopes · heavy metals · craniostenosis

Introduction

In the 1970s the Maryland State Highway Administration expanded U.S. Route 15 in Frederick County, Maryland, resulting in the partial archaeological excavation and removal of a largely forgotten cemetery (K. Orr and R. Orr 1977; Townsend et al. 1979; Thomas et al. 1980; Burnston and Thomas 1981). Known as the Renner Cemetery (18FR323), this series of 35 graves was located less than a half mile from Catoctin Furnace, a charcoal-fired blast furnace that produced iron from 1776 to 1903 (Fig. 1). The ensuing osteological and artifact analysis identified the remains as Africans or African Americans associated with ca. 1790–1840 furnace operations (Angel and Kelley 1983; Kelley and Angel 1983). Early proprietors of the furnace were recognized slave owners, but surviving documents for the ironworks provide few details about the identities and lives of the enslaved and, in some cases, possibly free workers. By the mid-19th century, the slave-labor economy in the region had transitioned to a system reliant on hired labor, fueled by the increasing number of European immigrants. The fate of the original labor force is unclear. Depending on their status, African Americans left the furnace or were sold out of the area. Today, no community traces its roots to these early workers, and, until recently, historical interpretation of the operation and success of the furnace has focused almost exclusively on the European American labor force (Anderson 2013).

In 2015, the Catoctin Furnace Historical Society was awarded a Maryland Heritage Areas Authority Non-Capital Grant to provide a data-grounded interpretation of the cemetery and skeletal remains for public presentation and heritage-tourism programming (Comer 2016). The renewed effort to learn more about these individuals and the rarely explored roles of free and enslaved African American men, women, and children in the iron industry challenges the notion that the early

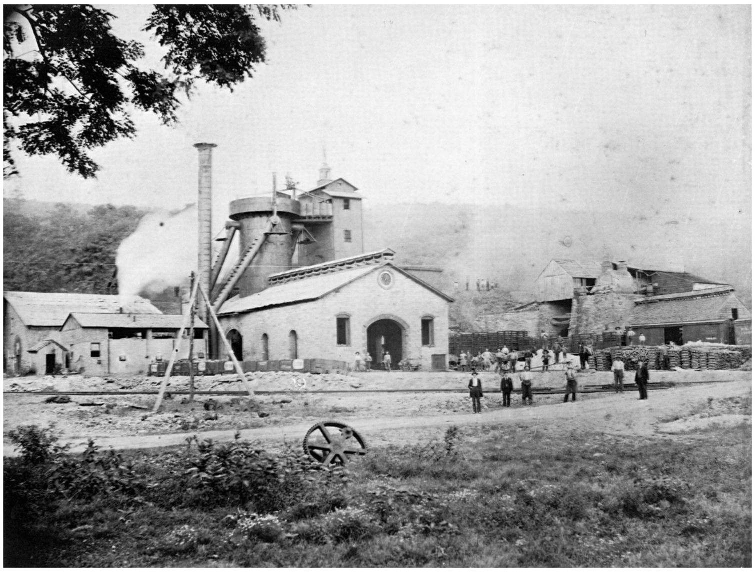

Fig. 1 A view of Catoctin Furnace, Frederick County, Maryland, looking west. Structures in the photograph indicate the picture was taken sometime between 1886 and 1893. By that time, the African American labor force had been replaced by European American and European-immigrant iron workers. (Image courtesy of the Emmitsburg Historical Society, Emmitsburg, Maryland.)

African American experience was solely defined by the plantation system. In fact, America's early iron industry relied heavily on the skills of African and African American workers for its operation and success (Dew 1974, 1994; Lewis 1979). Surviving records from a handful of other Chesapeake ironworks provide insight into these systems as they pertain to African American workers, but the Catoctin data are unique in that the biological consequences of life at an industrial village complex for African Americans can be directly assessed.

The project's first phase, documented here, involves updated analysis of the skeletal remains, including assessments of demography, dental pathology, carbon and nitrogen stable isotopes, and heavy metals, with perspective gained by comparison to other historical skeletal series. The project's second phase will expand on different aspects of this research, including incorporation of the data into public programming at the historic furnace site. Results add to a growing body of biological data on the varied experiences of early African Americans (Rose 1985; Owsley, Orser et al. 1987; Rathbun 1987; Rankin-Hill 1997; Blakey and Rankin-Hill 2009; Barrett and Blakey 2011) and demonstrate the benefit of examining skeletal remains using multiple lines of evidence and comparative approaches for studies of individual and group identity and health, particularly for people with limited recorded history.

The Catoctin Iron Furnace and Associated Cemetery

At its inception in the 18th century, Catoctin Furnace was one of 65 ironworks in Maryland and Virginia. The average furnace workforce was comprised of about 70 enslaved and itinerant laborers and craftsmen. Some may have been skilled ironworkers brought to the mid-Atlantic region from Africa or the Caribbean (Lewis 1979; Herbert 1993; Libby 1993). In the final decade of the 18th century, traveler Isaac Weld, Jr., noted that, in the mid-Atlantic, "the forges and furnaces are all worked by negroes, who seem to be particularly suited to such an occupation" (Lewis 1979:20). By the 19th century the number of Maryland and Virginia ironworks had increased, as did the size of the labor force (Lewis 1979). Ultimately, enslaved workers provided most of the skilled and unskilled labor, doing all but administrative jobs. Enslaved workers made the charcoal to fuel the furnace, dug the ore, controlled the furnace and forge, were wagoners, carpenters, potters, and smiths, and provided general support to the structures that maintained operations. Although these workers were mostly men, women and older children worked in the ore banks and the furnace and forge. Women and children also helped make charcoal (Dew 1974, 1994; Lewis 1979). A majority of the workers likely participated in making the fuel, which was labor intensive (Gordon 1996).

As a rural ironworks, Catoctin would have required a moderate labor force composed of skilled and unskilled workers. When needed, iron furnaces and forges would bring in additional hired laborers or rented slaves, but successful operations relied on a trained, resident workforce, usually composed of stable family units (Dew 1974, 1994; Lewis 1979). It was customary for children of enslaved workers to be trained in their parents' occupations, staying with their families until marriage. Marriage within the workforce was encouraged, and outside unions, particularly with free individuals, deterred. Allowing families to remain intact was an incentive furnace owners used to foster loyalty and productivity, exert control, and prevent runaways. There is no listing of slaves or free workers from the early decades of Catoctin Furnace. However, the start of this labor force may have included a 35-year-old man, a 37-year-old woman, and two teenage boys, ages 18 and 13, who were sold to James Johnson (1736–1809), first operator of the furnace, by a Virginia ironmaster who worked at Catoctin and then migrated elsewhere (Anderson 2013).

When excavated in 1979 and 1980, the 35 graves, 32 of which contained preserved human remains, were thought to represent a third of the cemetery. Its original size is uncertain due to extensive historical and 20th-century disturbance. A ground-penetrating geophysical survey in 2014 identified about 20 remaining burials (Wanner and Sonnemann 2014; Seiter 2016). The excavated and intact graves align east–west in north–south rows (Fig. 2). Head and foot fieldstones are in situ as well as scattered at the site; by the 1970s many had been displaced.

The single, coffined interments were described as conforming to Christian burial practices, with bodies supine and heads to the west (Thomas et al. 1980; Burnston and Thomas 1981; Burnston 1997). Wide positioning of the arms, elbows, and legs, viewed in field photographs, argues against conventional use of shrouds, as had been previously reported (Burnston 1981, 1997; Kelley and Angel 1983). Thirty-two

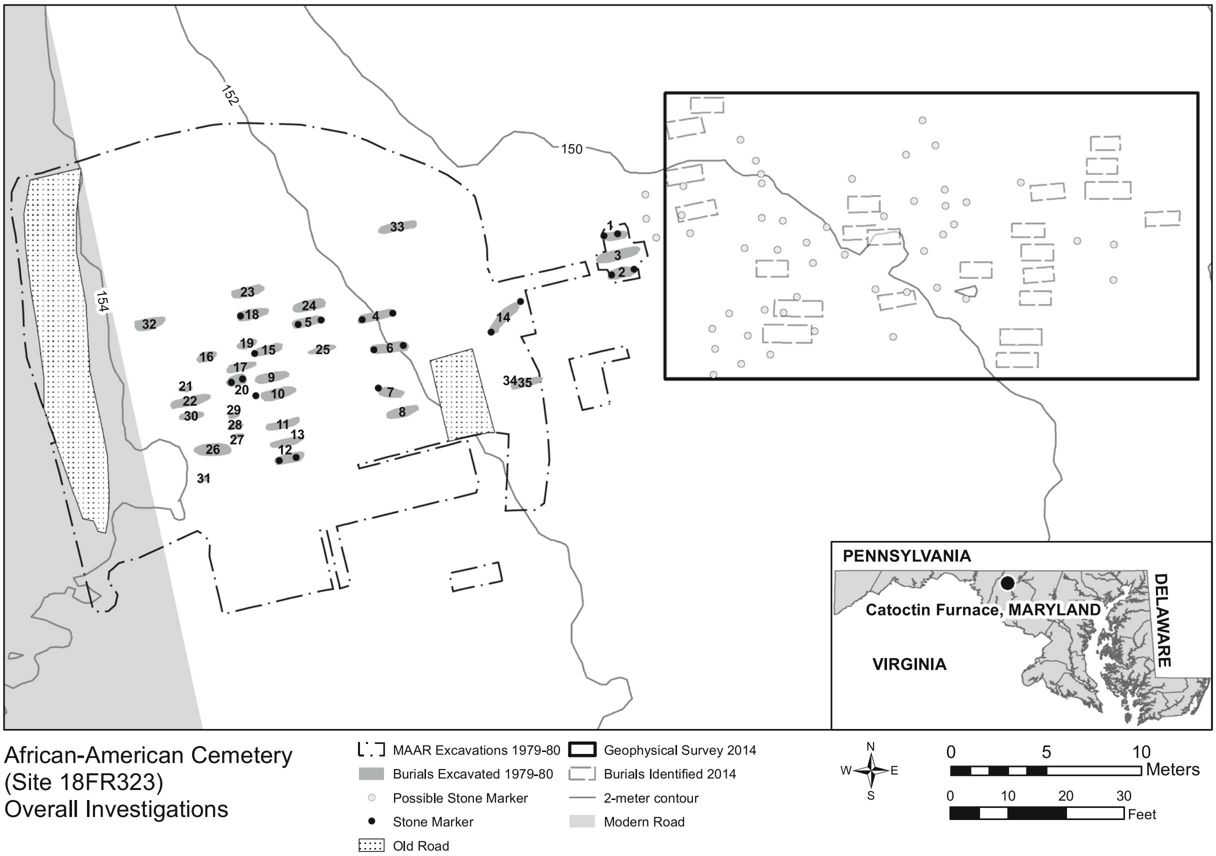

Fig. 2 Map of overall investigations at the Catoctin Furnace cemetery. (Map by Robert Wanner, 2017.)

cupriferous-metal straight pins found with seven infants and three adult females likely reflect wrapping the infants and use of an adult chinstrap or face covering. Additional mortuary artifacts include 22 buttons and botanical remains (possible funerary offerings) from three graves. The buttons indicate that at least four individuals were buried in clothing; this study's reassessment of sex determined that all four were males. These buttons, along with coffin nails, date ca. 1790–1840. During this period, Moravian clergymen served the Catoctin Furnace population, including the enslaved workers (Anderson 2013).

Initial skeletal analysis of the cemetery remains in the 1980s included measurements and observations of bones and teeth (Angel and Kelley 1983; Kelley and Angel 1983, 1987). Sex, age, and pathology were recorded for 31 of the 32 individuals. Ages ranged from fetal to elderly, including 7 infants, 9 children, and 15 adults. Equal numbers of males and females were reported, based on individuals for whom sex was determined. Adults were described as having average stature and a range of muscularity reflecting heavy physical labor. Pathology included fractures, arthritis, rickets, minor infections, premature suture closure, moderately poor teeth, and a possible cranial trephination (identified in this study as postmortem in origin). Arthritis and development of the upper limb bones were cited as occupational indicators of iron work. African ancestry with little to no admixture was recognized in the better preserved crania, leading to the interpretation that these were first- or second-generation enslaved workers. This was likely, given that the cemetery date range includes a period prior to the 1807 act prohibiting the importation of slaves (effective in 1808) and many individuals buried there were older adults. While informative, these initial studies were limited by analytical capability and the reporting styles of the past. A robust body of comparative African American data upon which to base interpretations was also lacking (Owsley 1990; Jackson et al. 2016).

Catoctin Revisited

Reassessment of the human remains is enhanced by methodological advancements and updated data-capture techniques. Each skeleton was inventoried and reevaluated for age, sex, ancestry, and bone and dental pathology. Data collection procedures followed standard methods in bioarchaeology and forensic anthropology (Buikstra and Ubelaker 1994); inventory and coding procedures are those specified by Owsley and Jantz (1989). In addition to postcranial measurements, three-dimensional metric coordinate data were collected for well-preserved crania using a 3-D digitizer. Visual documentation included radiography, computed tomography (CT), and photography. Twenty-four skeletons were analyzed for stable carbon and nitrogen isotopes. Twenty-three individuals were tested for concentrations of arsenic, lead, mercury, and zinc. All data were entered into the Human Skeleton Database at the National Museum of Natural History, Washington, D.C. This relational database includes 20 data categories, capturing information on bone and tooth inventories, pathology, and chemical testing for over 13,000 individuals (Barca 2014).

This first-phase Catoctin study draws from records of 1,200 African and African American individuals dating from 1600 to 1900 archived in the database. Specifically, data from 240 enslaved and free individuals contemporaneous with Catoctin from 26 archaeological sites in Maryland, Pennsylvania, Virginia, and West Virginia were used (Table 1). To ensure consistency in the recording of information, all comparative data were collected by Smithsonian Skeletal Biology Program researchers trained in standardized data-capture practices.

Demography

Summary data for the Catoctin skeletal remains are presented in Tables 2 and 3. Individual ages changed little from the previous analysis, with slight modifications based on dental radiographs and expanded ranges for adult estimates. Examination by 10- and 20-year age cohorts identifies infants and young children aged birth–4 years as comprising a majority of the series (children aged 5–9 years are not represented). Adolescents and teenagers aged 10–19 years are the next largest age group in the cemetery. By 20-year cohorts, most adults are aged 40–59 years at death. As a whole, individuals older than 20 years account for slightly more than a third of the burial assemblage.

Male and female demography is assessed for skeletons ≥15 years of age. Due to both biological maturation and the social roles assumed by this segment of the population, these remains are identified as "adults" in comparisons of bone and dental pathology. Females at Catoctin died primarily during the childbearing years. Male mortality was more frequent during the teenage years and toward the end of the life cycle. The seven females identified at Catoctin are younger on average than the nine males. The nine-year age difference between the mean ages of females and males (Table 3) differs slightly from the initial demographic profile of female and male (≥15 years) mean ages (mean=34.6, SD=14 and mean=41.2, SD=18.7, respectively) reported by Kelley and Angel (1987). This may be due to reassessments of adult age and the fact that one individual, Burial 10, was changed subsequent to the original assessment by J. L. Angel.

Dental Pathology

Dental observations provide updated information on subsistence and health that are compared within the Catoctin series and across groups. Dental data were recorded using a scoring format (Owsley and Jantz 1989; Barca 2014) that tabulates carious lesions, abscesses, and antemortem loss by tooth or socket base counts (Table 4), and age and sex (Table 5). Carious lesions, ranging from small fissures to complete crown destruction, are present in nearly a third of all represented teeth, with molars most affected, followed by premolars; the anterior dentition has the least decay. Slightly less than a third of observable tooth sockets show antemortem loss. Molars, especially mandibular molars, are most affected, with half lost in life. Mandibular canines are the least affected. A smaller proportion of sockets show alveolar abscesses, visually or radiographically identified as draining sinuses or apical pocketing in the alveolar bone at the root tip (periapical abscess), or, less frequently, as deep cupping around a tooth root (periodontal abscess). Molar sockets, followed by canines, have the largest number of abscesses.

Age and dental pathology are linked (Table 5). Chi-square tests show significant differences in the proportions of carious lesions, antemortem tooth loss, and abscessing in younger vs. older adults, with older adults having more dental disease. There is no clear association

Table 1 Smithsonian Human Skeleton Database comparative dataset

Site	Date	Reference[a]	Comparative Data		
			Dental Pathology	Stable Isotopes	Heavy Metals
MARYLAND					
Bowie (Prince George's County)	1850–1900	Jennifer Stabler 2010, elec. comm.	X	—	—
Brooke-Baden House (Prince George's County)	1830–1850	Imlay 2008	X	X	X
Chapel Point (18CH79)	1820–1830	Maureen Kavanagh 2007, elec. comm.; Rebecca Morehouse 2011, elec. comm.	X	X	X
Gott Site (18CV174)	1775–1880	Owsley, Kardash et al. 2016	X	X	X
Governor's Bridge (Prince George's County)	1850–1899	Owsley and Bruwelheide 2009	X	X	X
Hogan (18AP27)	1800–1899	Owsley, Kardash et al. 2016	X	—	—
Salisbury (Wicomico County)	1810–1852	McAndrew 2012	X	X	—
Serenity Farm (18CH839)	1790–1810	Julie Shablitsky 2015, elec. comm.	X	X	X
Seven Hills (18PR651)	1800–1899	Owsley, Bruwelheide, and Burgess 2003	X	X	X
Truitt (18WC99)	1850–1899	Owsley, Kardash et al. 2016	X	X	X
Twin Oaks (18WC70)	1800–1899	Maureen Kavanagh 2007, elec. comm.	X	X	X
PENNSYLVANIA					
First African Baptist Church, 8th Street Cemetery (36PH21)	1824–1842	Crist et al. 1997	X	X	—
First African Baptist Church, 10th Street Cemetery (36PH72)	1810–1822	Crist et al. 1997	X	—	—
VIRGINIA					
College Landing (44WB3)	1790–1820	Hudgins 1977	X	X	X
Robinson Cemetery (44HE950)	1775–1875	McDonald and Meacham 2001	X	X	X
Gloucester County Landfill (44GL394)	1810–1840	Cultural Resources, Inc. 2003	X	X	X
Rutland Cemetery (44HN356-864)	1800–1899	Brady et al. 2005	X	X	X
A. P. Hill (44CE326)	1700–1899	McLearen et al. 2003	X	X	X
Burke Lake (Fairfax County)	1837–1865	Imlay 2006	X	X	—
Jennings Property (Fairfax County)	late 18th/early 19th c.	Owsley 2002	X	X	X
Hot Water Tract/Freedom Park (44JC851)	1770–1810	Alain Outlaw 2011, elec. comm.	X	X	—
Marlboro Point (Stafford County)	pre-1830	Imlay 2011	X	X	X
York River (Gloucester County)	1780–1840	Imlay 2010	X	X	—
Medical College of Virginia (44HE814)	ca. 1840–1860	Owsley, Bruwelheide, Jantz et al. 2017	X	—	—
Fischer Site (Loudon County)	1780–1830	Imlay 2012	X	—	—
WEST VIRGINIA					
Spring Mills (Berkeley County)	1800–1850	Owsley and Sandness 1994	X	X	—

[a] References listed establish context and time period, but should not be considered definitive sources on these sites.

Table 2 Catoctin Furnace (18FR323) burials by sex and age

SI Catalog No.[a]	Burial No.	Sex	Age	Artifacts	Preservation[b]	Bone Pathology[c]
387788	1	Indeterminate	0–0.5	Nails, pins, fiber	Green stains	—
387789	2	Indeterminate	0–0.5	Nails, pins, fiber	Preserved hair	—
387790	3	Female	20–24	Nails, pins, fiber	Preserved hair	—
387791	4	Male	60+	Nails, charcoal	—	DJD, spinal ankylosis & kyphosis, TMJ erosion, osteoporosis, ulna fx
387792	5	Indeterminate	1.5–2.5	Nails, pin, fiber	—	Craniostenosis
387793	6	Male	45–54	Nails, metal buttons, fiber	Green stains	Metatarsal fx, vertebral osteophytosis
387794	7	Female	50+	Nails	Green stains	DJD, radius fx, vertebral degeneration
387795	8	Male	55–65	Nails, metal buttons	Green stains	Mandibular condyle fx, vertebral degeneration, Schmorl's depressions, DJD, periostitis, enthesophytes
387796	9	Female	13.5–14.5	Nails, seed	Green stains	—
387797	10	Male	16.5–17.5	Nails, screws, bone buttons, whiteware fragment	—	Craniostenosis, multiple Schmorl's depressions, spondylolysis
387798	11	Female	40–45	Nails, pins	—	Rib periostitis, vertebrae lytic lesions?, vertebral compression, DJD
387799	12	Indeterminate	2.5–3.5	Nails, screws, pin	—	Femoral bowing
387800	13	Male	12.5–13.5	Nails, shell buttons	Green stains	Shoulder dislocation and arm atrophy
387801	14	Female	30–34	Nails, screws	—	—
387802	15	Male	15.5–16.5	Nails, coffin wood, seeds, flake	—	Craniostenosis, Schmorl's depressions
387803	16	Indeterminate	1.5–2.5	Nails	—	—
387804	17	Indeterminate	3.5–4.5	Nails	—	Bowed femora, C1-cleft neural arch
387805	18	Female	18.5–21	Nails, pins, fiber	Green stains	Mastoid lesions, spinal compression, Schmorl's depression
387806	19	Indeterminate	1.5–2.5	Nails	—	Mastoid lesion
387807	20	Indeterminate	0–0.5	Nails, pin	—	—
387808	21	Indeterminate	0–0.5	Nail, seeds	—	—
387809	22	Male	19–21	Nails, quartz scraper, seeds	—	Craniostenosis
387810	23	Female	25–29	Nails	Green stains	—
387811	24	Probable Male	10.5–11.5	Nails	—	—
387812	25	Indeterminate	0.5–1.5	Nails	—	—
387813	26	Male	60+	Nails, peach pit	Green stains	C1 cleft neural arch, spinal degeneration, spondylolysis, myositis ossificans with fusion of tibia and fibula
—	27	—	—	—	No bone	—
387814	28	Indeterminate	0–0.5	Nails, pins, lithic flake	Green stains	—
387815	29	Indeterminate	0–0.5	Nails, pin, fiber	—	—
—	30	—	—	Nails	No bone	—
—	31	—	—	—	No bone	—

Table 2 (continued)

SI Catalog No.[a]	Burial No.	Sex	Age	Artifacts	Preservation[b]	Bone Pathology[c]
387816	32	Male	40–50	Nails	Disturbed by rodent burrow	Vertebral degeneration, Schmorl's depressions, tibiae periostitis
387817	33	Male	40–49	Nails	—	Slight DJD, possible lytic activity T12/L1
387818	34	Indeterminate	0.5–1.5	Nails, pins	Rodent activity; buried above Burial 35	Craniostenosis
387819	35	Female	30–35	Nails, ferrous bar	Green stains	Craniostenosis, femoral neck fx, acetabular degeneration

[a] The human skeletal remains are currently curated at the National Museum of Natural History, Smithsonian Institution, Washington, D.C.

[b] Green stains refer to copper-oxide discoloration from contact with cupriferous artifacts.

[c] Degenerative joint disease (DJD); temporomandibular joint (TMJ); fracture (fx); cervical (C), thoracic (T), and lumbar (L) vertebrae.

between dental pathology and sex, although small sample sizes and the disparate age profiles of females and males likely influence these results. Female teeth are affected by decay more often than those of males (Fig. 3). There is some difference between male and female antemortem tooth loss; males overall exhibit the condition slightly more often than females. The occurrence of alveolar abscesses is nearly equal for men and women. Because females are primarily represented by individuals aged 20–39 years, whereas males are represented by teenagers and the oldest adults in the series, higher rates of female tooth decay and male antemortem loss would be expected. Teenage males were younger and had less age-related exposure to carious foods than adult females, and elderly males had already lost teeth from decay. Tobacco use was not a factor in dental health; only one older adult male and one young adult female had slight pipe-wear tooth facets.

Compared to their mid-Atlantic, African American contemporaries, Catoctin dental pathology falls in an intermediate position among reference samples. All groups have moderate amounts of decay, loss, and abscessing indicative of a cariogenic diet, but there are statistically significant differences in the proportions of these conditions (Table 6). The Maryland plantation sites have the lowest proportion of teeth with cavities and the smallest amount of antemortem tooth loss. The small West Virginia group has the highest occurrence of both types of pathology. Virginia plantation and urban assemblages are nearly equal, with slightly greater proportions of tooth decay and loss than Catoctin. The Pennsylvania series has higher proportions of carious teeth and

Table 3 Catoctin Furnace burial demography

Age	No.	%	Indeterminate Sex	Female	Male
Birth–4[a]	16	46	16	—	—
5–9	0	0	—	—	—
10–19	7	20	—	2	5
20–39	4	11	—	4	—
40–59	5	14	—	2	3
60+	3	9	—	—	3
TOTAL	35	100	16	8	11
ADULT MEAN AGE (≥15 YEARS)[b]			—	32.3 (*n*=7, SD=11.5)	41.4 (*n*=9, SD=19.0)

[a] The graves of three infants or young children did not contain bone, but are identified by the size of the burial shaft and coffin.

[b] Female and male mean age is calculated by determining the median of each individual's age range and then averaging the median ages for the group.

Table 4 Pathology in Catoctin Furnace: permanent dentition by tooth

Teeth & Arcade	No. Teeth	No. Carious Teeth	Carious (%)	No. Sockets	Antemortem Loss	Antemortem Loss (%)	Alveolar Abscesses	Alveolar Abscesses (%)
Incisors	76	8	10.5	110	26	23.6	11	10.0
Maxillae	29	3	10.3	50	18	36.0	8	16.0
Mandible	47	5	10.6	60	8	13.3	3	5.0
Canines	49	9	18.4	57	6	10.5	8	14.0
Maxillae	20	5	25.0	25	5	20.0	5	20.0
Mandible	29	4	13.8	32	1	3.1	3	9.4
Premolars	84	35	41.7	110	27	24.5	14	12.7
Maxillae	40	21	52.5	49	11	22.4	8	16.3
Mandible	44	14	31.8	61	16	26.2	6	9.8
Molars	100	48	48.0	165	71	43.0	26	15.8
Maxillae	56	25	44.6	79	28	35.4	17	21.5
Mandible	44	23	52.3	86	43	50.0	9	10.5
Total	309	100	32.4	442	130	29.4	59	13.3

Note: Includes individuals ≥15 years of age.

antemortem loss than Maryland plantations, but lower than all other groups. Alveolar abscessing appears inversely related to the other forms of dental pathology.

Age could be a factor in this comparison, as the Maryland plantation group has the youngest mean age and West Virginia the oldest. Pennsylvania, which has a higher mean age than three other groups, but the second-

Table 5 Pathology in Catoctin Furnace permanent dentition by age and sex

Carious Lesions	Male			Female			Total			χ^2 Sex	χ^2 Age
Age	No. of teeth	No. carious	%	No. of teeth	No. carious	%	No. of teeth	No. carious	%	2.6, p=0.10	20.1, p<0.001
15–34	86	10	11.6	118	39	33.1	204	49	24.0		
35+	89	40	44.9	16	11	68.8	105	51	48.6		
Total	175	50	28.6	134	50	37.3	309	100	32.4	(df=1, n=309)	
Antemortem Loss	**Male**			**Female**			**Total**			**χ^2 Sex**	**χ^2 Age**
Age	No. of sockets	Lost antemortem	%	No. of sockets	Lost antemortem	%	No. of sockets	Lost antemortem	%	1.6, p=0.21	119.5, p<0.001
15–34	81	1	1.2	133	10	7.5	214	11	5.1		
35+	164	77	47.0	64	42	65.6	228	119	52.2		
Total	245	78	31.8	197	52	26.4	442	130	29.4	(df=1, n=442)	
Alveolar Abscesses	**Male**			**Female**			**Total**			**χ^2 Sex**	**χ^2 Age**
Age	No. of sockets	Alveolar abscess	%	No. of sockets	Alveolar abscess	%	No. of sockets	Alveolar abscess	%	0.007, p=0.93	10.6, p=0.001
15–34	81	3	3.7	133	14	10.5	214	17	7.9		
35+	164	30	18.3	64	12	18.8	228	42	18.4		
Total	245	33	13.5	197	26	13.2	442	59	13.3	(df=1, n=442)	

Note: Includes only individuals ≥15 years of age.

Fig. 3 Extensive decay and three-dimensional deposits of supra-gingival calculus (mineralized dental plaque) on the left posterior teeth of a Catoctin female aged 30–34 years (SI No. 387801, Burial 14). Catoctin diet was cariogenic and conducive to heavy accumulation of dental calculus. Pain from tooth decay and abscessing limited chewing on this side of the mouth, allowing calculus to accumulate. (Photo by Kate D. Sherwood, 2016.)

lowest percentage of tooth decay and antemortem loss, is the only exception to this pattern.

Stable Carbon and Nitrogen Isotopes

Stable carbon- and nitrogen-isotope testing was not part of the Catoctin analysis in the 1980s, but today it is frequently used to evaluate diet from archaeological remains. Relative contributions of specific types of foods to an individual's diet during approximately the last two decades of adult life can be estimated using stable-isotope ratios of carbon and nitrogen in bone collagen and stable carbon-isotope ratios in bone apatite. Applications of these studies are diverse and include the identification of European colonists in North America (Ubelaker and Owsley 2003), intense maize cultivation (Vogel and van der Merwe 1977; Tieszen and Fagre 1993), and gendered food behaviors (White 2005). The approach is based on differences in isotopic signals of foods and the transmission of these differences to the consumer (DeNiro and Epstein 1978, 1981). Dietary patterns are distinguishable by measuring these differences in bone or tooth enamel with an isotope-ratio mass spectrometer. The results are presented as $\delta^{13}C$ (delta carbon) and $\delta^{15}N$ (delta nitrogen) values in parts per mil (‰).[1]

[1] Delta values are expressed as $\delta R=([R_{sample}-R_{reference}]/R_{reference})*1000$, where R is the ratio of interest (i.e., $^{13}C/^{12}C$ or $^{15}N/^{14}N$) relative to the reference standards of V-PDB and atmospheric air for C and N, respectively.

Isotope values in collagen (organic portion) are routed to bone primarily from dietary protein, and, consequently, $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ values mainly reflect this source (Ambrose and Norr 1993; Tieszen and Fagre 1993; Jim et al. 2004; Fernandes et al. 2012). Isotope values in bioapatite (inorganic portion) derive chiefly from dietary carbohydrates and fats and, to a lesser extent, proteins. As such, $\delta^{13}C_{apatite}$ provides a different representation of the entire diet. The difference between the $\delta^{13}C$ value of the apatite and the collagen ($\Delta^{13}C_{ap\text{-}col}$) serves as a secondary indicator of protein input and grain-source use (Balasse et al. 1999; Hedges 2003; White 2005).

Human populations reliant on temperate-climate C_3 plants (e.g., wheat or rye) and animals feeding on these resources have negative $\delta^{13}C_{collagen}$ values around -20‰, while populations dependent on C_4 resources (e.g., maize/corn) and animals feeding on these plants have more positive values, around -10‰ to -9‰ (Vogel and van der Merwe 1977; van der Merwe 1982; Katzenberg and Pfeiffer 1995). For $\delta^{13}C_{apatite}$, people reliant on C_3 grains and resources show values around -11‰, while diets dependent on C_4 plants and resources show more-enriched $\delta^{13}C_{apatite}$ values around +1‰ (Kohn and Cerling 2002; Passey et al. 2005). While legumes and some algae have $\delta^{15}N$ values close to 0‰, other terrestrial and marine plants have values ranging from +2‰ to +6‰. Tissues of consumers are enriched in $\delta^{15}N$ by approximately 2‰ to 4‰ relative to the nitrogen values of their foods (DeNiro and Epstein

Table 6 Dental pathology: group comparisons

Groups	Males	Females	Age (Years)		No. Teeth	No. Carious Teeth	Carious (%)	No. Sockets	Antemortem Loss	Antemortem Loss (%)	Alveolar Abscesses	Alveolar Abscesses (%)
			Mean	SD								
Catoctin Furnace	9	7	37.4	16.3	309	100	32.4	442	130	29.4	59	13.3
Maryland Plantations	12	13	32.7	12.9	318	83	26.1	500	93	18.6	68	13.6
Pennsylvania	40	59	40.7	12.7	2035	583	28.6	2333	545	23.4	324	13.9
Virginia Plantations	35	53	39.8	14.5	1386	474	34.2	2404	852	35.4	263	10.9
Virginia Urban	15	10	43.5	13.1	313	106	33.9	602	208	34.6	69	11.5
West Virginia	2	1	51.3	12.5	26	14	53.8	62	28	45.2	1	1.6
χ^2 by Group						23.3, $p<.001$ (df 5, n=4,387)			126.8, $p<.001$ (df 5, n=6,343)		17.7, $p<.01$ (df 5, n=6,343)	

1981; Minagawa and Wada 1984; Schoeninger and DeNiro 1984; Schoeninger 1985). As a consequence, human consumers and marine and terrestrial animals higher ecologically in food chains have higher $\delta^{15}N_{collagen}$ values, reflecting this trophic-level increase.

Twenty-four Catoctin individuals were tested.[2] The isotope values (Table 7) reflect a mixed diet of C_3 and C_4 plants, and animals foddered on both C_3 and C_4 plants. Plotting individual $\delta^{15}N_{collagen}$, $\delta^{13}C_{collagen}$, and $\delta^{13}C_{apatite}$ values by sex (Fig. 4) indicates an age-dependent trophic-level shift with respect to $\delta^{15}N_{collagen}$ for the five youngest individuals listed under the category of indeterminate sex. Three infants, aged 0.5–2.5 years, show $\delta_{15}N_{collagen}$ values 2‰ higher than the group mean for individuals aged older than 10 years. This difference mirrors the breast-feeding trophic-level effect on nitrogen-isotope ratios documented as an increase of 2‰–4‰ relative to the mother (Fogel et al. 1989; Katzenberg and Pfeiffer 1995). Two children aged 2.5–4.5 years have $\delta^{15}N_{collagen}$ values approaching those of the adults, a decrease reflecting bone growth and remodeling following weaning, as the infant transitions to an adult diet. These five young individuals also cluster for carbon, which does not reflect the clear trophic-level effect that characterizes nitrogen, but does demonstrate how high-protein, breast-fed diets enrich the $\delta^{13}C_{collagen}$ value by approximately 1‰–2‰, thus

[2] The majority of samples were processed by the Augustana College Stable Isotope Lab. Select samples were tested by Paleo-Isochem, Inc., the Smithsonian's Museum Conservation Institute, and the Center for Applied Isotope Studies at the University of Georgia. Collagen-extraction methods entailed removing surface contaminants, followed by demineralization in 0.3N hydrochloric acid at 4°C, changing the acid daily until reaction ceased. The collagen pseudomorph was rinsed to neutrality, treated with 5% sodium hydroxide for 24 hours at 4°C, and again rinsed to neutrality. Approximately 100 mg of collagen were gelatinized in 5 ml of water (pH 3) for 24 hours at 90°C. Water-soluble and -insoluble phases were separated by filtration, and the former were lyophilized and weighed to obtain a collagen yield. The $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ values were determined by flash combustion to produce CO_2 and N_2 and measured against the appropriate reference gas on a VG SIRA 10 dual-inlet mass spectrometer with Carlo Erba EA118 CHN interface. Stable-isotope measurements and weight-percent C and N values were obtained from a single sample combustion. Analytical precision is ±0.1‰ for carbon and ±0.2‰ for nitrogen. Bioapatite analysis involved grinding portions of cleaned bone followed by submersion in 1.5% sodium hypochlorite for 48 hours. The samples were rinsed to neutrality, placed in 1M acetic acid for 24 hours, and again rinsed to neutrality. A minimum of 0.125 g of the bioapatite was loaded into the side arm of a reaction vessel with 4 ml of 100% phosphoric acid loaded into the straight arm of the vessel. Each vessel was evacuated, mixed, and incubated at 25°C for 48 hours. CO_2 was collected by cryogenic distillation, and the $\delta^{13}C_{apatite}$ was determined by a VG SIRA 10 dual-inlet mass spectrometer.

Table 7 Catoctin Furnace stable carbon- and nitrogen-isotope values

Catalog No.	Burial No.	Collagen Yield (%)	$\delta^{13}C_{collagen}$ (‰)	$\delta^{15}N_{collagen}$ (‰)	Wt % N	Wt % C	Atomic C/N[a]	$\delta^{13}C_{apatite}$ (‰)	$\Delta^{13}C_{ap\text{-}col}$
387790	3	27.9	-14.3	+10.1	15.7	43.1	3.2	-8.9	5.5
387791	4	24.6	-12.0	+9.2	15.5	42.9	3.2	-5.3	6.7
387792	5	21.2	-14.7	+11.6	15.8	44.1	3.3	-10.7	4.0
387793	6	3.3	-15.4	+10.0	13.8	38.4	3.2	-10.8	4.7
387794	7	7.8	-11.9	+10.8	14.5	40.2	3.2	-8.7	3.1
387795	8	12.0	-11.6	+9.5	14.8	40.9	3.2	-7.4	4.1
387796	9	6.0	-14.2	+9.0	13.5	38.4	3.3	-9.0	5.2
387797	10	9.0	-15.0	+9.5	14.6	40.8	3.3	-9.9	5.0
387798	11	27.1	-13.1	+9.6	14.7	40.4	3.2	-9.2	4.0
387799	12	14.5	-13.8	+10.1	14.6	39.9	3.2	-9.2	4.6
387800	13	14.0	-12.2	+9.3	10.5	29.5	3.3	-8.5	3.6
387801	14	22.7	-17.2	+9.5	15.8	43.6	3.2	-7.6	9.6
387802	15	3.6	-13.5	+9.1	15.9	44.5	3.3	-7.8	5.7
387804	17	3.2	-13.9	+10.8	13.2	38.6	3.4	-9.8	4.2
387805	18	7.3	-16.3	+9.2	14.5	40.7	3.3	-10.6	5.7
387806	19	5.3	-13.8	+11.7	14.1	40.2	3.3	-10.0	3.8
387809	22	4.4	-10.5	+8.3	8.1	23.1	3.3	-8.9	1.6
387810	23	24.9	-14.1	+9.7	15.6	43.4	3.2	-9.8	4.3
387811	24	19.2	-14.1	+9.5	15.5	43.3	3.3	-9.4	4.7
387813	26	5.6	-14.3	+9.2	14.4	39.9	3.2	-9.5	4.8
387816	32	4.9	-12.9	+10.2	14.3	40.6	3.3	-8.7	4.3
387817	33	20.4	-12.7	+7.5	18.1	48.7	3.1	-7.8	4.8
387818	34	14.6	-13.1	+11.6	14.8	41.0	3.2	-9.7	3.4
387819	35	22.8	-13.0	+10.3	15.6	43.1	3.2	-9.7	3.3
		Mean (≥10 years)[b]	-13.6 (*n*=19, SD=1.6)	+9.4 (*n*=19, SD=0.7)				-8.8 (*n*=19, SD=1.2)	4.8 (*n*=19, SD=1.6)
		Range	-17 to -10.5	+7.5 to +11.7				-10.8 to -5.3	1.6 to 9.6

[a] C/N ratios in the range of 3.1–3.4 and percent carbon and nitrogen in the ranges of 23.1–48.7 and 8.1–18.1, respectively, reflect bone collagen unaltered by significant diagenesis (DeNiro 1985; Ambrose 1990; McNulty et al. 2002).

[b] The calculated means exclude five infants and young children whose isotope values are influenced by breastfeeding and weaning (Fogel et al. 1989; Katzenberg and Pfeiffer 1995), and represent an age-dependent subset of Catoctin diet.

reducing the overall $\Delta^{13}C_{ap\text{-}col}$ (Katzenberg 1993). The $\Delta^{13}C_{ap\text{-}col}$ value in the infants and children (from 3.4‰ to 4.6‰) is lower than that previously observed (~5.4‰) for historical period North American adults (France and Owsley 2015).

Differences between male and female carbon- and nitrogen-isotope values are slight and not statistically significant, indicating dietary homogeneity. However, males show the two lowest in $\delta^{15}N_{collagen}$ values in the group, and the two lowest $\delta^{13}C_{collagen}$ values are from females. The female (Burial 14) with the most negative $\delta^{13}C_{collagen}$ value has the highest $\Delta^{13}C_{ap\text{-}col}$ value, indicating a diet notably different from others in the cemetery. One male (Burial 22) also presents an atypical dietary profile. He has the second lowest $\delta^{15}N_{collagen}$ value, the most positive $\delta^{13}C_{collagen}$ value, and the lowest $\Delta^{13}C_{ap\text{-}col}$ value; he is a distinct outlier within the group.

Catoctin's stable-isotope values are compared to four groups, defined regionally by state based on available data. An analysis of variance (ANOVA) indicates differences among the groups' mean isotope values are significant (Table 8). Regional differences are apparent in $\delta^{13}C_{collagen}$ and $\delta^{13}C_{apatite}$ values, with C_3 resources more prevalent in Catoctin, Pennsylvania, and West Virginia diets; Virginia and Maryland plantation sites consumed more C_4 plants and animals foddered on these crops. Catoctin has the lowest mean $\delta^{15}N_{collagen}$ value, indicating less protein in the diet or, more likely, greater dependence on a different protein source. The higher $\Delta^{13}C_{ap\text{-}col}$ mean values for Catoctin and Pennsylvania further differentiate these diets from Maryland, Virginia, and West Virginia plantations.

Heavy Metals

A multi-element approach is used to examine potential exposure to certain trace elements related to labor at Catoctin Furnace. During life, the skeleton accumulates trace elements in bones and teeth. Some are essential for normal metabolism, while others, such as heavy metals, may be toxic in high doses (Sandstead 1982, 1984; Tchounwou et al. 2012).

Heavy metal concentrations of mercury (Hg), arsenic (As), lead (Pb), and zinc (Zn) were measured in 23 Catoctin skeletons using inductively coupled plasma mass spectrometry (ICP-MS).[3] The concentrations of these elements (Table 9) are listed as parts per million (ppm)—micrograms (µg) of the element per gram of bone ash (e.g., µg Pb/g bone ash). All Catoctin individuals have extremely low concentrations of Hg and As. The values for both fall below or within reported normal averages for human bone ash (Iyenger et al. 1978; Aufderheide 1989). In contrast, data generated for Zn were widely variable throughout the assemblage. Additional testing must be done to determine whether the unpredictability of Zn levels is due to the variability of Zn distributions inherent in human bone. However, except for the highest value (reported for a male, aged 45–49 years), most concentrations are below 250 ppm, and Catoctin's mean Zn value approximates the normal mean in human bone ash (200 ppm) (Aufderheide 1989). The Catoctin skeletal Pb content also has a wide range, although most values cluster at low to modest levels. The group mean falls within the normal human range for Pb in bone ash of 0–50 ppm (Iyenger et al. 1978; Aufderheide 1989). In this recent study, only one individual above the age of 10 has a Pb value surpassing the normal range: a female, aged 30–34 years.

Catoctin males and females have no statistically significant differences in either Zn or Pb (Table 10), and variance in the values between these groups is similar; nor is there a significant difference between the mean Zn and Pb values of younger and older individuals. These groups also show similar variance. However, a scatter plot of Pb values by age and for sex (Fig. 5) reflects accumulation during life for females, but not for males. Certain young people of both sexes between the ages of 15 and 19 years also show slightly elevated Pb values.

Twenty-three Catoctin individuals were previously tested for Pb (Aufderheide, Angel et al. 1985) using atomic-absorption spectrometry (AAS), and 21 individuals have results from both AAS and ICP-MS methods (Tables 9, 10) (Fig. 5). Sampling locations differed between the two studies, likely accounting for dissimilarities in the individual results. Previous studies have attributed variances in lead levels to differing bone compositions (i.e., compact vs. trabecular) (Wittmers, Wallgren et al. 1988; Hu et al. 1990; Aufderheide and Wittmers 1992; Wittmers, Aufderheide et al. 2002). However, the 6.3 ppm difference between the mean Pb values of individuals (≥10 years) with data for both methodologies is not statistically significant, and variance between the results of these two methods was similar. A previous conclusion that Catoctin females have nearly three times as much Pb in bone as males (Aufderheide, Angel et al. 1985) was not validated by this analysis. However, both analytical methods identified the same adult female (Burial 14) as having the highest Pb value. There is also agreement that female Pb values trend upward with age, while Catoctin male values do not.

Catoctin heavy-metal data were compared to results from 57 Maryland and Virginia contemporaries. The comparative series followed sampling and processing

[3] ICP-MS is a highly sensitive analytical tool capable of differentiating a range of elements at concentrations below one part per million. Sample selection minimized skeletal impact, with preference given to identifiable bone fragments or hand and foot elements with adequate amounts of cortical bone. Exterior contaminants were removed with a silicon carbide tool before being rinsed with deionized water and ground to a powder in an agate mortar and pestle. Resulting powder was dried at 100°C overnight before digestion in a combination of 4 mL nitric acid and 1 mL hydrogen peroxide, with identical parameters being used for all bone and quality controls. A 100 mg aliquot of digestate from each sample was weighed into clean 15 cm^3 centrifuge tubes before being topped off to 10 g with 2% nitric acid, as described by Little et al. (2004). Diluted solutions were then introduced into a GBC Optimass 9500 inductively coupled plasma time-of-flight mass spectrometer (ICP-TOF-MS).

Table 8 Statistical comparisons of isotope and trace heavy-metal data by geographical location

	$\delta^{13}C_{collagen}$				$\delta^{15}N_{collagen}$				$\delta^{13}C_{apatite}$				$\Delta^{13}C_{ap\text{-}col}$			
	N	Mean	SD	*F*-test	N	Mean	SD	*F*-test	N	Mean	SD	*F*-test	N	Mean	SD	*F*-test
Catoctin Furnace	19	-13.6	1.6		19	9.4	0.7		19	-8.8	1.2		19	4.8	1.6	
Maryland	13	-10.3	0.6		13	10.7	0.9		13	-6.7	1.1		13	3.6	1.3	
Pennsylvania	5	-15.0	2.3	37.3	5	10.4	0.9	3.6	5	-9.4	2.5	19.3	5	5.6	0.8	5.4
Virginia	91	-10.0	1.4	(4, 126; p<.001)	91	10.0	1.0	(4, 126; p<.01)	90	-6.4	1.4	(4, 125; p<.001)	90	3.7	1.2	(4, 125; p<.001)
West Virginia	3	-12.9	0.6		3	10.5	0.4		3	-9.3	0.3		3	3.7	0.3	

	Pb				Zn			
	N	Mean	SD	*F*-test	N	Mean	SD	*F*-test
Catoctin Furnace	19	20.2	23.8		19	177.2	254.0	
Maryland	10	16.7	26.0		10	143.4	96.7	
Pennsylvania	No data			0.2	No data			0.3
Virginia	47	17.2	22.0	(2, 73; p=0.9)	47	139.7	138.2	(2, 73; p=0.7)
West Virginia	No data				No data			

Note: Includes individuals ≥10 years of age.

procedures similar to those employed for Catoctin. Means and standard deviations for Pb and Zn by group are presented in Table 8. Hg and As are not included in the comparative analysis because concentrations were negligible for all groups. The highest mean Pb and Zn values are reported for Catoctin, while African Americans comprising the Maryland group (not including Catoctin) have the lowest mean Pb value. Virginia has the lowest mean value for Zn. The means do not differ significantly, and amounts fall within normal ranges for human bone ash for both trace elements. Of the 76 individuals in the comparative analysis, the highest Pb and Zn concentrations were recorded at Catoctin: 105.9 ppm in a female and 1,195 ppm in a male, respectively. The next highest Pb value is 89.8 ppm, reported for a Virginia female. Only 6 out of 76 individuals have Pb values above 50 ppm. For Zn, the second-highest value is 719 ppm in a Virginia male. Only five of the study's 76 individuals had Zn values above 300 ppm.

Discussion

The biological consequences of life in an industrial village, as revealed in this first-phase study, draws attention to systems within the ironworks and possible associations with the longevity, diet, and health of the labor force. Some of these, such as diet, are of particular interest to researchers seeking to better understand the social and physical effects of slavery and other socioeconomic structures that not only create inequality and foster disparities among marginalized groups, but also shape identity.

Demography and labor practices at the ironworks appear connected and affect all segments of the population. No labor listings for Catoctin Furnace have been found to assist in interpreting the shorter life span of females from the site, but records from the Virginia Oxford Iron Works list female slaves working the furnace and forges, coaling grounds, and ore banks (Dew 1974). Strenuous demands of the labor force likely had detrimental effects on pregnant women already exposed to the inherent risks associated with childbirth in a premodern age. This is relevant given that women's roles in creating and maintaining families was a central feature of slavery in the iron industry due to the advantages provided by a sustained, stable workforce. One Virginia furnace owner recorded his investment in a

Table 9 Catoctin Furnace trace-element testing by ICP-MS and AAS

Catalog No.	Burial No.	ICP-MS					AAS[a]	
		Sample Description	Mercury (Hg)	Arsenic (As)	Zinc (Zn)	Lead (Pb)	Sample Description	Lead (Pb)
387788	1*	Not tested					Long bone	72.2
387789	2*	Not tested					Tibia	233.1
387790	3	Hand phalanx	0.03	B.d.	89	12	Tibia	29.2
387791	4	Metacarpal	0.01	B.d.	103	6.1	Metatarsal	33.9
387792	5*	Cranial fragment	0.07	0.4	182	30.5	Not tested	
387793	6	Metatarsal	0.05	B.d.	105	7.7	Tibia	12.3
387794	7	Metatarsal	0.04	0.2	84	29.8	Tibia	45.4
387795	8	Metatarsal	0.04	0.2	85	16.1	Tibia	24.5
387796	9	Radius	B.d.	B.d.	93	6.8	Tibia	14.1
387797	10	Clavicle	B.d.	B.d.	144	22.6	Tibia	42.2
387798	11	Metatarsal	0.02	B.d.	96	20.6	Tibia	20.9
387799	12*	Tibia	B.d.	0.5	217	66.4	Long bone	39.6
387800	13	Metatarsal	B.d.	0.3	194	14.7	Tibia	14.7
387801	14	Talus	0.01	0.5	260	105.9	Tibia	79.2
387802	15	Navicular	0.06	1.1	219	53.8	Tibia	10.8
387804	17*	Petrous temporal	B.d.	B.d.	123	14.5	Not tested	
387805	18	Hand phalanx	0.05	0.1	89	25.8	Tibia	52.6
387806	19*	Metacarpal/metatarsal	0.23	0.7	299	33.9	Femur	33.8
387809	22	Ulna	B.d.	B.d.	242	4.5	Tibia	2.4
387810	23	Metatarsal	B.d.	0.2	62	9.7	Tibia	25.6
387811	24	Clavicle	B.d.	B.d.	84	6.3	Tibia	14.1
387813	26	Foot phalanx	0.05	0.1	91	10.7	Tibia	30.2
387816	32	Radius	0.04	0.2	1195	8.4	Tibia	9.3
387817	33	Metatarsal	B.d.	B.d.	71	6.3	Tibia	0
387819	35	Metacarpal	0.06	B.d.	61	16.6	Tibia	43.2
		Range	B.d. to 0.23	B.d to 0.7	61 to 1195	4.5 to 105.9		0 to 233.1
		Sample mean (≥10 years)[b]	0.02 (*n*=19, SD=0.02)	0.15 (*n*=19, SD=0.27)	177.2 (*n*=19, SD=254.0)	20.23 (*n*=19, SD=23.9)		26.56 (*n*=19, SD=19.6)

Note: Results are reported in parts per million (ppm); B.d.=below detection.

[a] Aufderheide, Angel et al. (1985).

[b] Results of infants and young children (*) were not included in the mean due to the porous nature of their bones. Trabecular bone, which is more prevalent in infants, can give highly variable results from a single individual, with compact bone giving more reliable representation of heavy metal content for the total individual (Grupe 1988). Eliminating infant values from the mean provides a more accurate representation of the assemblage. Trace elements below detection by the instrument are included in the mean as 0.0.

"breeding woman" as advantageous to business, a sentiment shared by other owners (Dew 1994:26). The deleterious effect of heavy labor on pregnant females and their potential exposure to toxins was likely overlooked by these owners, jeopardizing maternal health and infant survival. Nearly half (46%) the Catoctin interments were infants and young children. The burial of a woman, 30–35 years of age (Burial 35),

Table 10 Statistical comparisons of Catoctin Furnace zinc and lead

		Zn			Pb		
	N	Mean (ppm)	*T*-test	Levene's test for variance	Mean (ppm)	*T*-test	Levene's test for variance
Females	8	104	-1.07[a]	F=0.88; p=0.36	28.4	1.29[a]	F=1.31; p=0.27
Males	11	230	(df 17, p=0.30)		14.3	(df 17, p=0.21)	
Younger Adult	11	140	-0.74[a] (df 17, p=0.47)	F=1.77; p=0.20	25	1.1[a] (df 17, p=0.29)	F=1.27; p=0.28
Older Adult	8	229			13		
AAS	19	—	—	—	26.56	-0.89[b]	F=0.18; p=0.67
ICP-MS	19	177	—	—	20.23	(df 36, p=0.38)	

Note: Includes only individuals ≥10 years of age.

[a] Two-sample *t*-test assuming equal variances.

[b] Paired two-sample *t*-test for means.

and a young infant (Burial 34) in the same grave, possibly mother and child, is a poignant example of the ironwork's female and infant mortality.

A noticeable proportion of Catoctin deaths involved teenagers, particularly males, an age cohort typically characterized by low mortality. These young people died at ages at which they would have been entering into jobs directly related to furnace operations. This usually occurred by age 14, although children as young as 10 or 11 were involved in making charcoal (Dew 1974, 1994; Lewis 1979). Advertisements for hired, seasonal slave labor typically requested males aged 15–20 years to fill unskilled positions. Enslaved hired laborers were potentially subject to harsher treatment and exploitation due to the employers' "lack of permanent interest in his well-being" and emphasis on the "maximization of production" (Lewis 1979:81). Some young males at Catoctin may represent unskilled seasonal hires or inexperienced local youth entering the labor force, both potentially more susceptible to accidents.

The oldest individuals in the cemetery are males, and this segment of the population seems to have benefited most from access to the "overwork" system. Special treatment was also afforded to skilled laborers, usually men, at iron furnaces. Although the owner obtained additional work from an already-exploited labor force, the "overwork" arrangement also compensated slaves in material goods or money for doing more than their required labor (Dew 1974, 1994; Lewis 1979). Males received the greatest advantage, since "[s]killed slaves were normally in the best position to earn overwork pay ... and were able to improve the material quality of their lives by purchasing extra provisions" (Lewis 1979:161). Nevertheless, overwork allotments had a potential physical cost. This may be the case for the oldest male in the Catoctin series. Severe degenerative joint disease and spinal ankylosis fused his vertebrae at a 90° angle at the waist, making him unable to stand erect. His debilitating condition reflects age and a lifetime of hard work, as well as care and support for the elderly by the community. The benefit of the overwork system may not necessarily have been greater longevity and improved health, since there were increased occupational risks and physical labor, but it gave bonded individuals the ability to assert themselves "in strengthening the family and bolstering their position within it" (Lewis 1979:162).

Access to overwork may have been especially important from a dietary perspective. Those accessing this system were able to obtain extra provisions, including meat, flour, sugar or molasses, and coffee (Lewis 1979). These foods elevated the consumer's status by emulating diets of the European American ironmaster and furnace owner, and delivered nutrition beyond owner-provided rations. At ironworks, these are typically described as cornmeal and pork or beef distributed to individual slaves according to their positions. Skilled workers received more than unskilled workers did, and men got more than women and children. In addition to rations purchased by furnace owners, some strove to create a "well-ordered and self-sufficient community" (Dew 1994:9) that included growing crops (wheat, corn, oats, buckwheat, and rye); maintaining draft animals; and raising pigs, cattle, and sheep to feed the workforce,

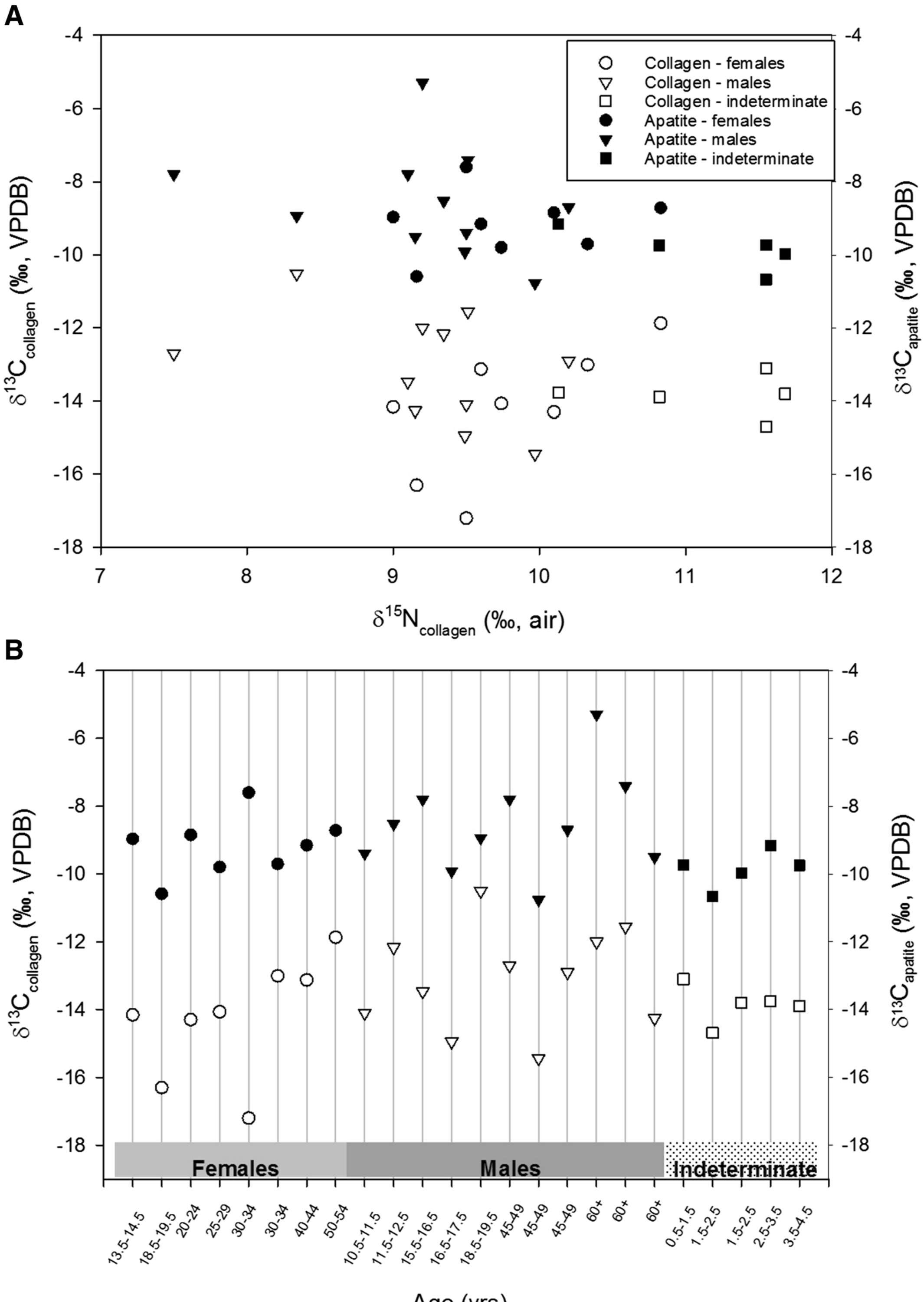

Fig. 4 (*A*) Individual $\delta^{15}N_{collagen}$, $\delta^{13}C_{collagen}$, and $\delta^{13}C_{apatite}$ values plotted by sex. Individuals aged 6 months to 4 years of indeterminate sex have the most positive nitrogen values from breastfeeding, which decrease with weaning. (*B*) $\delta^{13}C_{collagen}$ and $\delta^{13}C_{apatite}$ values plotted by sex and age show generally similar spacing, with two exceptions. (Plots by Christine A. M. France, 2017.)

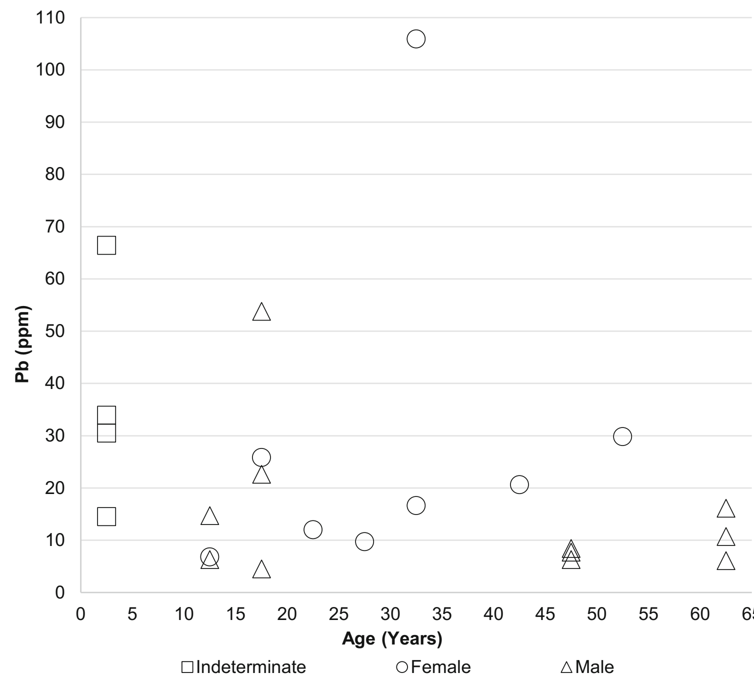

Fig. 5 Catoctin lead values plotted by age and sex. (Plot by Kathryn G. Barca, 2017.)

with enslaved laborers rotating between iron work and field agriculture as needed. Greens and produce grown in individual gardens sometimes supplemented the ironworkers' diet (Lewis 1979; Dew 1994).

Similar subsistence strategies relying on owner-provisioned rations and slave-produced and -procured food sources have been described for plantation diets of enslaved Virginians. Historical records and faunal studies show domestic livestock (swine and cattle, but especially swine) were fundamental to the plantation-slave diet, although preference for particular types of protein sources, cuts of meat, and the diversity of mammal species, fish, and shellfish at and within sites varied (Crader 1990; McKee 1999; Franklin 2001). Botanical studies of plantation diets acknowledge the equivalent importance of field crops, such as corn and wheat, but also document a diversity of slave-grown and -gathered plants that supplemented provisioned foods and may also have been used as medicines (Franklin 2001; Mrozowski et al. 2008; Bowes 2011; Bowes and Trigg 2012). Variations in faunal and botanical resources by time period suggest plantation management or ownership may have had a direct effect on rations and the ability of the enslaved population to produce or gather these foods (Bowes 2011; Bowes and Trigg 2012).

The system of food procurement and distribution at Catoctin Furnace is undocumented. Operational similarities with other rural ironworks are likely, but ownership and management of the furnace changed frequently (nine times from 1776 to 1856 [Anderson 2013]) and may have altered systems over time. No botanical or faunal materials, with the exception of funerary offerings, are directly associated with the African American ironworkers, whose dwelling areas have never been identified. One can infer from the geographical setting what may have been grown or procured at the site, although operation of the blast furnace and charcoal production would have affected the landscape. Discussion of Catoctin diet necessarily relies on the human remains and draws from limited historical documents relating to systems at other ironworks, as well as archaeological evidence on slave diets in the mid-Atlantic.

Numerous researchers (Owsley, Orser et al. 1987; Rathbun 1987; Rankin-Hill 1997; Rathbun and Steckel 2002; Mack et al. 2009; Nystrom 2013; Hosek et al., this issue) have based assessments of diet and oral health on the prevalence of dental disease, which results from a combination of factors, particularly consumed foods, personal hygiene, and the absence of professional dental care. At Catoctin, the relationship between dental pathology and age, and the high incidence of molar involvement, is characteristic of dental disease in agricultural populations (Hillson 2001, 2008). Combined with moderate rates of tooth wear and periodontal disease, these changes indicate the diet was cariogenic. Catoctin residents experienced a pattern of significant tooth loss by middle age and eventual loss of nearly all teeth in later life. Dental-pathology differences between Catoctin males and females exist, but varied age profiles by sex likely account for the higher proportion of female teeth with cavities and greater male antemortem tooth loss. Tooth decay and poor dental health were likely a concern for all and certainly a source of discomfort.

Most 19th-century diets promoted tooth decay and periodontal disease, regardless of gender or social class, due to the consumption of refined carbohydrates and sugars, including cornmeal, flour, and molasses (Owsley, Orser et al. 1987; Covey and Eisnach 2009; Nystrom 2013; Mant and Roberts 2015; Hosek et al., this issue). However, in the comparison of Catoctin dental pathology with regional contemporaries, subtle but significant differences exist. While the mean ages of these groups vary, possibly accounting for some of the differences, the free Black series from Pennsylvania has fewer carious and lost teeth than all but the youngest group in the comparative study, despite having an older mean age than other groups. Considering age, dental health seems to have been somewhat better in this group. The difference is noteworthy, since this assemblage represents the only free Black population in the analysis. Increased sample sizes and comparison with dental data from other free Black series not in the database (Nystrom 2013) has the potential to clarify these patterns.

Regional availability and selection of foods influence differences in dental pathology and may be significant to both Catoctin dietary studies and broader analyses of African American dietary homogeneity. This study's stable-isotope comparison of groups by region shows that corn, which is high in sticky carbohydrates and traditionally a staple in African American and Southern diets, was less of a dietary component for African Americans living in regions that emphasized C_3 crops, such as wheat, barley, and rye.

Observed dietary differences in these mid-Atlantic groups are, in part, geographical, as $\delta^{13}C_{collagen}$ values are linked to region of origin in North American historical populations (France et al. 2014). Although all groups in this study show a mixed C_3/C_4 diet in their protein source, the Maryland and Virginia plantation series are set apart by more positive $\delta^{13}C_{collagen}$ values, indicating a shared, greater reliance on animals foddered on C_4 resources, particularly corn-fed swine and cattle. West Virginia, Catoctin, and Pennsylvania groups consumed protein sources raised on more regional C_3 fodder and wild C_3 forage, which decreased their $\delta^{13}C_{collagen}$ values and increased the $\Delta^{13}C_{ap\text{-}col}$ values, at least for Catoctin and Pennsylvania. Mean $\delta^{13}C_{apatite}$ values also differentiate by region. West Virginia, Catoctin, and Pennsylvania series show greater C_3-resource use and lower C_4 consumption in the overall diet, although to varying degrees. Diets of Maryland and Virginia plantation series were much more dependent on C_4 resources, with little variation between the two regions.

Catoctin stable isotopes show within-group homogeneity that characterizes a diet unique from the other mid-Atlantic assemblages. A combination of C_3 and C_4 plants and animals foddered on a mix of these plants characterizes the diet, with little distinction between men and women. Given that the wild flora and forage surrounding the furnace, located on the eastern edge of the Blue Ridge Mountains, were almost entirely C_3, consumption of domesticated animals foddered on at least some C_4 plants occurred based on the $\delta^{13}C_{collagen}$ values. The amount of C_4-foddered protein was less than that noted for the Maryland, Virginia, and West Virginia plantation sites of this study. Some of this may have come from wild game with C_3-isotope signatures. Colliers who made charcoal and periodically lived in huts away from the furnace (Gordon 1996) may have procured wild game and other resources to supplement their diets. However, given the period, much of the animal protein would have been domesticated and raised locally, or brought in as barreled meat. The majority of $\delta^{13}C_{apatite}$ values between -11‰ and -8‰ suggest a mixed C_3/C_4 grain source, but C_3 grains were more prevalent in the diet based on these values. Likely sources include wheat and rye, both grown and milled in central and western Maryland. These regions intensified wheat production during the late 18th and early 19th centuries, while southern Maryland continued to focus on tobacco cultivation (Reed 2011). Pennsylvania and West Virginia diets had even more C_3 resources in their overall diet than Catoctin.

Catoctin's relatively low mean $\delta^{15}N_{collagen}$ value could indicate slightly less reliance on animal protein than other groups in this study, although furnace owners generally subscribed to the belief that their workers needed to be well fed and clothed. However, rations, including meat, were sometimes distributed or withheld as a form of control. At other times, resources were difficult to obtain. Barreled meat was particularly apt to spoil. The Virginia Oxford Iron Works periodically suffered shortages of meat due to poor management (Lewis 1979). At another Virginia ironworks, slaves occasionally lacked adequate meat, flour, and corn during the winter months (Dew 1994). Catoctin may have experienced similar shortages of dietary protein. It is also possible that the protein source differed from the other groups of the comparative study, either due to market systems in place at the furnace or due to consumer choice. Preliminary isotope data of Chesapeake faunal remains shows the bones of cattle have lower $\delta^{15}N_{collagen}$ values than swine (Reitsema et al. 2015). These differences would be passed on to the consumer. Beef raised locally or barreled may have been part of the rationed provisions at Catoctin. Beef may also have been the preferred meat purchased by enslaved workers earning overwork compensation. Parallel analysis of faunal reference samples from mid-Atlantic localities will aid future dietary interpretations. Whatever the source, Catoctin's $\delta^{15}N_{collagen}$ values show limited group diversity, with individuals (≥10 years) having values within ~3‰ of one another. As nitrogen isotopes are often indicative of social demographics (France et al. 2014), the data suggest relatively homogenous social and dietary habits.

And, yet, isotopic variability within Catoctin is noted for a few individuals. These outliers may indicate different roles served within the community or origins outside it. One female, aged 30–34 years, had greater access to C_3 protein resources, expressed as a negative $\delta^{13}C_{collagen}$ value (-17.2‰) and high $\Delta^{13}C_{ap\text{-}col}$ value (9.6‰). She also was identified by Aufderheide, Angel et al. (1985) and this study as having the highest lead content in the series. Consumption of foods prepared and served on pewter and lead-glazed wares in the owner's house may have exposed this woman to higher amounts of lead during her lifetime (Aufderheide, Angel et al. 1985). This may explain her isotope values as well, since foods in the owner's household, namely protein sources, likely differed from those of the enslaved ironworkers. Another female, aged 18.5–21 years, has the second most negative $\delta^{13}C_{collagen}$ value (-16.3‰) and the second-highest lead value (Aufderheide, Angel et al. 1985). She, too, may have been a domestic in the owner's household, but died before accumulating the same degree of dietary distinction and lead as the older female.

A young male also shows dietary distinction, as he has the most-positive $\delta^{13}C_{collagen}$ value (-10.5‰) and lowest $\Delta^{13}C_{ap\text{-}col}$ value for the group. His $\delta^{15}N_{collagen}$ value is also low. This young man may have been brought into the community from another region. Runaway-slave advertisements of the 1780s describe men, born elsewhere, fleeing from Catoctin furnace (Windley 1983). However, this man shares unusual mortuary and skeletal features with another young male in the group. Both had sassafras seeds placed on top of their coffins. Both individuals also display craniostenosis, or premature suture closure, in this case involving the sagittal suture. This condition has an hereditary component and shows an unusually high occurrence in the Catoctin cemetery; 6 of the 28 individuals with cranial-vault bones show the condition (28%) vs. the reported expected incidence rate of 1 in 2,500 live births (0.04%) today (Panigrahi 2011). This evidence suggests a degree of biological relatedness within the community.

Stable-isotope results from infants demonstrate additional variability within the group related to breastfeeding and weaning. These results not only reflect the age and development of the infant, but also can be viewed in relation to the choices mothers made or had to make in raising their children. While nonspecific skeletal and dental markers of stress, such as enamel hypoplasia and growth-arrest lines, have been used to estimate the time of weaning (Corruccini et al. 1985; Blakey et al. 1994), $\delta^{15}N_{collagen}$ values from five of the youngest in the Catoctin cohort provide a more direct measure of how long some Catoctin mothers breastfed their children. No infant aged younger than 1.5 years shows evidence of weaning. A child aged 2.5–3.5 years has isotope values approaching adults, indicating the process began earlier, between 1.5 and 2.5 years, while a slightly older infant, aged 3.5–4.5 appears less advanced in the weaning process. These results correspond to the high occurrence of enamel hypoplasia between 2 and 4 years, as previously documented in Catoctin dentitions (Blakey et al. 1994). Combining the two measures may help assess the relationship between enamel hypoplasia and weaning, and can be repeated for biocultural comparisons within and between skeletal assemblages.

As these results show, diet is "situational, dynamic, and highly dependent upon the particular context within which it is defined and lived" (Franklin 2001:90). Catoctin stable isotopes reveal more than regional access to resources. Relationships of power and control, intersections of cultures, status within a group, and expression of identity for the consumer are also expressed through diet (Crader 1990; McKee 1999; Franklin 2001; Mrozowski et al. 2008; Covey and Eisnach 2009; Bowes 2011; Bowes and Trigg 2012; Pezzarossi et al. 2012; Springate and Raes 2013). These possible factors need consideration when interpreting results, especially at the individual level.

Exposure to environmental contaminants and heavy metals is also situational and is considered a potential aspect of Catoctin life through working and living at an industrial ironworks. Mining, foundries and smelters, and other metal-based industries can result in human exposure to heavy metals (Tchounwou et al. 2012). Catoctin zinc and lead content in bone are above normal levels in specific individuals, but mean values are within normal ranges and only slightly higher than comparative Maryland and Virginia data.

Zinc is an essential trace element stored in bones and teeth. Studies of zinc have tested for baseline human levels (Ericson et al. 1991) and accumulation associated with past diets and health (Harritt and Radosevich 1992; Sandford 1992, 1994; Crist 1995). However, the validity of using zinc as a paleodietary indicator has been questioned due to the lack of a theoretical model based on physiological principles (Aufderheide 1989; Ezzo 1994). This study examines zinc, not as a dietary indicator, but as evidence for occupational exposure during ironworking.

One extremely high concentration was detected in an older Catoctin male (1,195 ppm). This value is nearly twice as high as the next-highest zinc level in the reference samples, and over five times the normal bone content for zinc in human bone ash (approximately 200 ppm). No other individuals in the cemetery have similarly high zinc values, and past studies have shown soil zinc to be relatively inert, lessening the likelihood for diagenesis (Aufderheide 1989). Although postmortem contamination cannot be completely ruled out, some factors support exposure in life.

Zinc was a byproduct of ironworking at the furnace. One report on Catoctin notes: "The zinc fumes line the furnace with a crust that has to be removed, and from which zinc has been made with ease, and used in the manufacture of the United States standard brass weights" (Lesley 1859:588). An 1893 report prepared for the Board of World's Fair Managers states: "[O]xide of zinc constantly accumulated in the upper part of the Catoctin furnaces, indicating the presence of this element either in the iron-ores or limestone used as flux" (Williams 1893:148). Workers at Catoctin may have been inadvertently exposed.

At Bath Iron Works in Virginia, the hazardous job of removing the crust that formed on the inner walls of the furnace stack was described as an "ugly job" that "makes the hands faint sometime" (Dew 1994:78). This was evidence of "fume fever," a short-term reversible disease caused by inhaling zinc dust or fumes. Tolerance to the fumes can develop with repeated metal-oxide exposure (Agency for Toxic Substances and Disease Registry 2005), but little is known about concentration levels in bone after long-term, repeated contact. Exposure to zinc fumes was potentially a problem for "fillers," laborers tasked with dumping ore, charcoal, and limestone into the furnace continuously while it was in blast. The extremely high concentration of zinc in the older Catoctin male may be evidence of this practice.

Like zinc, during life lead is taken into the body from the environment through inhalation or ingestion. Absorption levels vary between children and adults, and all have a limited ability to excrete lead. What cannot be excreted is retained in the bone. As such, lead content in archaeological skeletons represents accumulation of this heavy metal over a lifetime. Several studies have examined bone lead levels for anthropological interpretations of diet, eating utensils, health, social status, immigration, and occupation (Handler et al. 1986; Sealy et al. 1986; Aufderheide, Wittmers et al. 1988; Aufderheide, Rapp et al. 1992; Crist 1995; Keenleyside et al. 1996; Rasmussen et al. 2008; Turner et al. 2009; Qin et al. 2015). In historical American populations, researchers have found higher bone lead content in individuals of higher social status, such as property and plantation owners, than in lower-status individuals, such as tenant farmers, indentured servants, and slaves. This has been attributed to availability and use of pewter and lead-glazed food storage and serving vessels by the wealthy. Those less affluent used wooden or clay vessels (Aufderheide, Neiman et al. 1981; Aufderheide, Angel et al. 1985; Aufderheide 1989).

Comparative data for African Americans report low group lead levels, as is the case for Catoctin. The highest lead level at Catoctin and in the comparative analysis overall is reported for a female (105.9 ppm). Her lead content is roughly double the level at which exposure becomes symptomatic (Aufderheide 1989), and she likely had health consequences. Symptoms could have included damage to the nervous system, anemia, intestinal cramping, aborted pregnancy, and sterility (Hernberg 2000).

Although lead poisoning was known as the "miners' disease" (Hernberg 2000:245), this elevated case was probably occupational, but unrelated to the furnace. No other Catoctin individual aged ≥10 years expressed abnormal levels; slightly increasing lead accumulation during life was evident for females, not males. This particular female's lead level most likely reflects regular access to the furnace owner's household (Aufderheide, Angel et al. 1985), a conclusion supported by the isotope data, which distinguish her from others in the series and indicate greater consumption of C_3 protein sources.

Conclusion

Through multifaceted analyses, connections between cultural and physical environments can be made, and effects on population demography and health can be measured. These "life course approaches" (Agarwal 2016) are particularly useful for historically obscure groups, like Catoctin, lacking primary source data (Shuler 2011). For African Americans and others whose histories have been neglected in the written record, "archaeology offers a tangible association with real places and the people who once lived at those places" (Singleton 1997:151). When integrated into public education and heritage-tourism programming, results from studies of past remains have the power to "bring forth elements of a more interesting story to communities that would traditionally never see themselves connected with or interested in archaeology as part of understanding their collective pasts" (Battle-Baptiste 2011:71).

The individuals once buried in the Catoctin Furnace village are not "invisible," as once described (Burnston 1997:102). Their struggles and aspirations may never be fully known, but their physical presence and life experiences are being elaborated through careful study of the skeletal remains. What the bones reveal helps in understanding who they were, how they lived and died, and what their contributions may have been to a place recognized as significant to the nation's shared past. Within the broader framework of African diaspora studies, the remains expose another aspect of a complex history from which there is much to learn. As the comparative dataset expands, these study topics will be explored in greater detail, and researchers with differing perspectives and theoretical approaches can move beyond interpretive frameworks to new insights on African American life at Catoctin Furnace.

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