widest bandwidth system now in use. Since the signal-to-noise ratio for a wideband radio astronomy signal varies as the square root of the bandwidth, this wider bandwidth results in a significant improvement. Much larger bandwidths are possible with existing technology.

A further possibility is the development of a true phase-coherent interferometer by a two-way transmission of the local oscillator signal by way of the satellite, thus making possible compensation for the phase change over the satellite path. The preservation of phase would be an important step toward the removal of ambiguities associated with model fitting techniques. A precision in the angular measurements of the order of 10^{-4} arcsecond should also be possible. In order to reconstruct reliable brightness distributions, multistation experiments are essential. This type of experiment is more easily implemented in real time than with magnetic tapes.

Advances in technology are increasingly lowering the cost of satellite communication channels. Simple ground stations with antennas 5 to 10 m in diameter are adequate for the service. A real-time VLBI network based on the use of a communications satellite is technically feasible and may indeed become a real possibility.

Note added in proof: Following the successful system demonstrations described above, the transmitting equipment of ground station 1 was moved to the Owens Valley Radio Observatory, California Institute of Technology, in order to utilize the transcontinental baseline between there and Algonquin Radio Observatory. This extended-baseline interferometer was successfully placed in operation on 28 and 29 May 1977, using a 27.5-m equatorial paraboloid for data transmission and the 40-m altazimuth paraboloid for reception of cosmic radiation of 2.9-cm wavelength.

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21 OCTOBER 1977

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28 February 1977; revised 5 April 1977

Paleodemography of the Libben Site, Ottawa County, Ohio

Abstract. *The Libben site, a Late Woodland ossuary and occupation site from the Great Black Swamp of northern Ohio has yielded a well-preserved skeletal sample of 1327 articulated individuals. The outstanding preservation and completeness of the site and the utilization of an exhaustive aging methodology make this the largest and most comprehensively censused North American prehistoric cemetery. Survivorship data indicate a robust, successful population. Life expectancy at birth was 20 years. Among adults, male mortality was consistently higher than female, a condition possibly related to high interpersonal and intergroup aggression. Infant mortality was generally low, and a general hypothesis concerning the elevation of infant mortality and the simultaneous depression of adult mortality among aboriginal peoples after European contact is suggested.*

The Libben site, located on the north bank of the Portage River in Ottawa County, Ohio, was excavated in 1967–1968. The site lies 6 miles (9.6 km) upstream of Lake Erie and would have thus been located at the edge of the Great Black Swamp in aboriginal times (*1*). An area of approximately 30,000 square feet (2790 m^2) was excavated, constituting 85 to 90 percent of the extant site. All indications are of a perennial occupation (*2*) with a time span of 250 to 300 years (*3*). Radiocarbon dates place the site between A.D. 800 and 1100 (*4*). Faunal and floral analyses indicate a diet rich in animal protein (especially fish, small mammal, and migratory bird) with vegetable foods surprisingly sparse (with the possible exception of wild rice) (*5*). Mollusks and white-tailed deer are relatively rare. There may have been marginal corn agriculture at some time during the occupation. The site clearly belongs within the Western Basin Tradition of southern Michigan (*3*, *6*), although it constitutes a novel "Libben phase." While a small number of intrusive refuse pits representing a distinctly later Mississippian-related component were thinly scattered about the site, the vast majority of recovered cultural material is referable to the Libben phase.

A total of 1327 individuals (*7*) were removed from the site, and great care was taken to obtain all individuals of all age classes. Fine-mesh screening was employed to recover term and preterm infants. The age range of recovered burials was 16 weeks in utero to 70+ years. Because only articulated (*7*) remains were considered in the demographic census presented here, no skewing of adult representation should occur in our data; the sex ratio is .97 (*8*). There was no evidence of infanticide or of differential preservation of age classes. We believe that this is, therefore, the largest and best-preserved North American cemetery excavated and analyzed to date.

Infants were aged primarily by dental maturity and secondarily by long bone length and metaphyseal breadth. All dentitions were seriated with respect to crown and root development. Target ages at 1-month intervals for the first year and at 1-year intervals thereafter were judged on the basis of published standards (*9*). Long bone lengths, metaphyseal breadths, and cranial base metrics were then used to age specimens without dentitions from polynomial regressions. All correlation coefficients were .97 or greater.

Adolescents (12 to 18 years) were aged

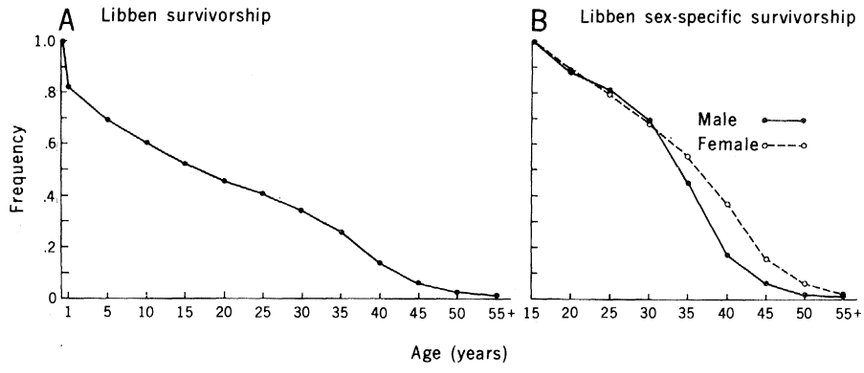

Fig. 1. (A) Survivorship curve for the total Libben population and (B) separate survivorships of males and females from age 15 to oldest age.

by epiphyseal development and closure. A predominant epiphyseal sequence was first established for the population. This was then justified to published ages of closure for other populations (*10*), and age was estimated by an individual's status within the sequence.

Adult ages were determined by means of a seven-criteria system: (i) functional dental age (*11*), (ii) and (iii) trabecular involution of the proximal femur and distal radius (*12*), (iv) metamorphosis of the pubic symphyseal face (*13*), (v) metamorphosis of the auricular surface (*14*), (vi) cranial suture closure (*10*), and (vii) vertebral osteophytosis. Each individual was given a single age estimate, called "summary age," which was a weighted mean of all available age indicators. Each age indicator was assigned a weight proportional to its reliability in measuring age.

Since actual age at death was, of course, unknown, reliability was taken to be an indicator's correlation with the first principal component (unrotated) of the age indicator correlation matrix. This procedure operationally identified "true age" variance with the largest component of covariation within the age measures. The approximation is strongly supported by the high proportion of variance accounted for by the first component (74.2 percent) and by the high loadings of the six age indicators used (*15*) on this component (.71 and above). Summary age correlated with the individual age measures at .83 and above. Weighting of combinations on the basis of reliability has its basis in the theory of tests (*16*).

The correlations obtained above are higher than those previously obtained between age indicators and known age at death (*17*). We attribute this to an elevated rate of degenerative change in populations under elevated musculoskeletal stress and to our technique of seriation.

Table 1. Abridged life table for the Libben site, Ottawa County, Ohio. Symbols: d_x, absolute number of dead of age x; l'_x, number of survivors to age x out of a radix of 10,000; E_x, life expectancy at age x; Q_x, probability of dying in succeeding age class for those reaching age x; C_x, percentage of population who are age x in an age distribution; FB_x, age-specific birthrates for age class x.

Age (years)	d_x	l'_x	E_x	Q_x	C_x	FB_x
0	226	10,000	19.884	.175	.046	
1	50	8,247	23.004	.047	.041	
2	52	7,859	23.115	.051	.039	
3	43	7,455	23.341	.045	.037	
4	25	7,122	23.408	.027	.035	
5	117	6,928	23.050	.131	.163	
10	94	6,020	21.150	.121	.142	
15	92	5,291	18.719	.135	.124	.054
20	63	4,577	16.249	.107	.109	.145
25	78	4,088	12.894	.148	.095	.145
30	115	3,483	9.699	.256	.076	.118
35	154	2,591	7.178	.461	.050	.082
40	97	1,396	6.182	.539	.026	.034
45	50	644	5.481	.602	.011	.007
50	33	256	5.000*	1.000	.006	
Total	1289					

* Last age class assumed to be 10 years in duration.

In applying each of the above criteria, we assessed a burial's age by comparing all individuals in series, grading each with respect to all others. This procedure minimized observer error and inconsistency and at the same time maximized the role of the biological aspects of the aging process in determining an age estimate.

A survivorship curve is provided in Fig. 1. It is clearly a class 2 curve providing the usual contrast of a nonindustrial population to the class 1 curve of modern societies (*18*). A life table (Table 1) yields an $E(0)$ (life expectancy at birth) of 20 years; the $E(15)$ was 19 years. Applying the human archetypal fertility curve (*19, 20*) (with the assumptions of a stable and stationary population) to these mortality data yields a crude birthrate of .050, a mean family size of 3.8, and a generation length of 26.6 years. These data are indicative of a robust, successful population.

Separate survivorship curves for males and females are also provided in Fig. 1, which show elevated male mortality throughout most of the adult lifespan. This is in sharp contrast to most skeletal populations, and is possibly relatable to high levels of warfare. Ecological reconstructions of the Sandusky Bay region (*1*) suggest unusual game abundance. It is possible that such "wealth" was a hazard to a population that lived within it and relied upon undisturbed trap and weir systems. Trapping is identified as the major source of food by the low frequency of deer and other large mammals and the correspondingly high frequency of small mammals (*2*). There are frequent indications of violent death among males, and a substantial number of "trophy" skulls were recovered. The most likely "ethnic" identity of the population is proto–Central Algonquin (*3*). Among recent Algonquin groups, private ownerships of hunting and trapping grounds could not be violated under "pain of death at sight" (*21*). It is possible that antecedent precepts were responsible for the elevated male mortality at Libben.

The Libben population also exhibits the more typical low infant mortality and high adult mortality of many skeletal series and thus contrasts inversely with most extant "anthropological populations" (*20*). This general discrepancy between skeletal and ethnographic censuses is usually attributed to underenumeration of infants and errors of age estimation among adults from skeletal series. As pointed out above, however, the care taken during excavation, the ex-

clusive enumeration of only articulated remains, and the multifactorial aging of adults all tend to maximize census accuracy at Libben. Yet the $\bar{B}$ (*22*) of the population (.083) is only half the average given by Weiss for anthropological populations (*20*). To raise the Libben figure to the average for these populations would require the undetected loss (nonenumeration) of more than 225 children. Archeologically, this would have been virtually impossible at Libben.

Recent work has demonstrated a marked decrease of adult mortality in cohorts subjected to elevated disease stress in early years (*23*). This is most probably a direct result of intensified selection for "immunological competence." Those with less adequate genomes are removed from the cohort in early childhood, and the more hardy survivors consequently display depressed mortality. This provides a possible solution to the skeletal-ethnographic sampling discrepancy. Modern "anthropological" populations are virtually all contact societies and remain under the selective influence of a battery of novel pathogens. Skeletal series are for the most part remains of smaller and more isolated groups. It is very possible that these two kinds of populations are showing mortality profiles reflective of distinctly different levels of early selection for immunological competence. If so, a major shift in the selective process in human evolution may not have received its due emphasis. This hypothesis will require further examination in future demographic studies of aboriginal populations.

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9 March 1977; revised 6 May 1977

Gravitational Compression of Crystallized Suspensions of Polystyrene Spheres

Abstract. *In a crystallized suspension of polystyrene spheres, the earth's gravitational field, acting on a vertical column of material several centimeters high, produces an elastic deformation that can be readily observed through its effect on the crystal lattice constant. This effect has been used to determine that Young's modulus for the crystalline material ranges from 1 to 3 dynes per square centimeter, depending on the concentration of spheres.*

Spherical polymer particles, suspended in a liquid, can arrange themselves to form a crystal lattice (*1–6*). A typical system is a monodisperse aqueous suspension of polystyrene spheres, 1000 Å in diameter (*5, 6*). Each particle has a bound negative charge, Q, of about 2000 electron charges and a compensating positive charge on protons distributed in the surrounding water. When the suspension is carefully purified to remove other ions, the Debye radius becomes comparable to the distance between polystyrene particles. Each particle then exerts a significant screened Coulomb force on its neighbors, and the array of particles crystallizes under the influence of purely repulsive forces (*1, 5, 6*). The interparticle distance can be as much as eight particle diameters. Well-defined crystallites form and show brilliant Bragg diffraction of visible light. Normally, the lattice is body-centered cubic (*5*). There is a sharp melting temperature that depends on the particle concentration (*6*). Most of the properties normally associated with a crystalline solid are present. However, the dimensions are scaled up from those of the usual crystal by a factor of several thousand. By adjusting the particle concentration, one can vary the crystal lattice constant by more than a factor of 2 without changing the lattice type (*5*). This indicates that the ordering is due to purely repulsive forces. Such repulsive ordering is the central feature of the Wigner crystal (*7*), based on a model of electrons moving in a uniform background of positive charge. For electrons, no experimental system is known that shows such ordering, although it has been proposed that electrons moving on the surface of liquid helium might be an example (*8–12*).

The macroscopic interparticle distances and the unusual ordering force in the system of polystyrene spheres should make elastic properties especially