THE PUEBLO GRANDE PROJECT, VOLUME 6:

THE BIOETHNOGRAPHY OF A CLASSIC PERIOD HOHOKAM POPULATION

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A BIOCULTURAL RECONSTRUCTION OF A CLASSIC PERIOD HOHOKAM COMMUNITY

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The osteological analyses conducted on the inhumations from Pueblo Grande illustrate the rich potential for combining modern analytical techniques with an integrative concern for the changing patterns of adaptation and biological well being of a prehistoric community. The degree to which our efforts have succeeded was constrained by the inevitable circumstances of preservation and, sadly, by the limited timeframe imposed upon us. Nevertheless, taken together, there is a continuity of result crosscutting each of the separate investigations.

By the early Classic period, the people of Pueblo Grande were living on the edge of survival. Their rate of mortality, particularly infant mortality, was enormous. Among the young survivors, the first decade of life was one of chronic nutritional stress and repeated episodes of disease. Over time, the burden imposed on working adults to maintain even that level of subadult survival increased and could not have been sustained without the influx of others from beyond the community. Whether these immigrants were the vestiges of other populations suffering more-severe circumstances cannot be said. However, one thing is clear: time brought diminished nutrition, increased mortality, and disease for all. The evidence suggests that by the Polvorón phase, the end of the Classic period, the cost had become too much to bear and the region was abandoned.

This, in essence, is our thesis. It is a circumstantial case because, after all, there are no witnesses to these events, only subtle clues left behind in the bones and teeth. Like detectives, we have built our case through the examination of evidence and the art of deduction. And, like a case in law, our argument stands or falls on the degree to which we can demonstrate that each and every line of investigation leads to a single inescapable conclusion -- that outlined above. In this final chapter we present a brief integrative summary of the evidence with an eye to the conclusion it reveals.

MORTALITY, NUTRITION, DISEASE AND THE DECLINE OF PUEBLO GRANDE

Outstanding reconstructions, such as Martin et al.'s (1991) analysis of Black Mesa, proceed from a demographic perspective. Whether presented in the form of simple survivorship curves or more-elabo-
rate composite life tables, mortality patterns provide an essential context describing risk of death throughout the life cycle, from which other interpretations can be made.

Viewed from either perspective, the rate of mortality at Pueblo Grande was high. The modal age at death was birth, with the mean life expectancy of a newborn only slightly above 15 years. Sixty-six people per 1,000 died each year, requiring a comparable birth rate to simply replace the population. Such a birth rate is beyond that observed in any contemporary population and implies a population either in decline or dependent upon immigration to maintain its numbers. Adding to the difficulty of everyday survival, there would have been a large number of consumers -- those under 15 and over 50 -- relative to producers, imposing a heavy burden on the young adult segment of the population. Nevertheless, the greatest burden fell on infants and subadults. Infant mortality was higher than that observed at Black Mesa, Casas Grandes, and Pecos Pueblo, and the percentage of individuals surviving beyond 18 years was low for populations in the region (Martin et al. 1991).

When the population entered the late Classic period, these severe conditions appear to have spread to the adult segment of the population. Between the early and late Classic period, infant mortality remained stable, but for individuals beyond age 10 there was an eight percent reduction in mean life expectancy.

We can never know with certainty if this is an accurate depiction of mortality and population structure at Pueblo Grande, but we can frame testable hypotheses based on the demographic evidence. For example, if this demographic profile is accurate, we would anticipate evidence for a high level of stress and morbidity among infants and children. We would also anticipate a decline in the health of adults between the early and late Classic period. Evidence for this decline should appear in the form of generalized indicators of dietary and disease stress. Each phase of our research program has confirmed these expectations, thereby supporting our demographic reconstruction.

**Childhood Stress at Pueblo Grande**

A critical measure of childhood stress and morbidity at Pueblo Grande was provided by enamel hypoplasias. Although a number of stress factors may underlie the appearance of these dental defects, it was clear that poor nutrition and bouts of infectious disease during tooth development were major contributors. As a result, patterns of childhood stress reflected in hypoplasias among the Pueblo Grande children corresponded precisely to those predicted from the demographic evidence. As with infant and childhood death rates, subadult stress was extreme by both absolute and regional standards. For example, 99 percent of the Pueblo Grande sample available for study exhibited hypoplasias, compared to 25 percent reported for the Grand Canal Ruins, 10 percent for La Lomita, 32 percent for Casa Buena, and 44 percent for La Ciudad (Martin et al. 1991).

Furthermore, the average Pueblo Grande child was sufficiently stressed to have 33 months of interrupted enamel formation during its first 84 months (7 years) of life. To appreciate the severity of this stress, it must be noted that the sample contained only individuals who lived to at least age 7 and therefore had teeth sufficiently developed for study.

A close correspondence between patterns of stress and mortality was observed when the probability of dying (qx) was compared to the timing of hypoplastic events. Second only to birth, the highest probability of childhood death occurred at age 3, which lay near the middle of the 2.5- to 5.0-year age range for peak hypoplastic activity.

Finally, the lack of evidence for a diachronic shift in subadult mortality also was reflected in the hypoplasia information. Although the late Classic children had an earlier peak frequency of hypoplastic activi-
ty and maintained that frequency longer than their early Classic counterparts, there was no significant difference between the two groups. In short, the severe childhood stress at Pueblo Grande, evidenced in the hypoplasia data, was consistent with the demographic profile. Also, as reflected in the demographic evidence, the level of subadult stress does not appear to have increased significantly between the early and late Classic period.

In addition to an assessment of dental hypoplasias, an investigation of bone growth and cortical bone maintenance among the Pueblo Grande children also shed light on subadult stress. Growth studies rarely have been conducted on archaeological remains; however, when assessed in the context of other stress indicators, such information can provide a fuller understanding of childhood stress and mortality. This was clearly the case at Pueblo Grande.

Long bone growth, reflected in incremental increases in femoral length between birth and age 15, appeared well maintained. Corresponding age changes in percent cortical area, however, revealed a pattern of stress consistent with the demographic and enamel hypoplasia evidence. Although some reduction in cortical tissue is common during the first nine months of life even among modern, well-nourished subadults, the Hohokam children continued to lose bone for their first four years of life. The most-plausible explanation for this continued loss, when combined with high rates of mortality and hypoplasia, was the stress associated with weaning, a syndrome in modern third-world populations known as weaning diarrhea.

Surprisingly, this subadult bone loss may have had an adaptive purpose. A second reduction during the later childhood years was associated with a period of rapid bone growth. It is possible that this adolescent growth spurt was indeed made possible by diverting energy from growth in cortical bone to growth in femoral size. Increased size and bone diameter, in turn, ensured increased bending strength (cross-sectional moments of inertia) in spite of reduced cortical area. In other words, under the conditions of nutritional stress that prevailed at Pueblo Grande, juvenile cortical bone loss (osteopenia) functioned to divert energy expenditure into growth without sacrificing the functional (mechanical) integrity of the appendicular skeleton.

**Nutritional Stress and Disease**

The most-common nutritional deficiency in the world today is iron-deficiency anemia. Among ancient populations, evidence for the condition appears among children as a cranial lesion (porotic hyperostosis) and among adults as progressive diploic thickening. Our analysis of the Pueblo Grande remains revealed evidence for extensive iron-deficiency anemia among both sexes across the entire age range. Here again, the ubiquity of the condition, as well as its severity, was consistent with our hypothesis of extreme population stress and mortality.

From the standpoint of porotic hyperostosis, infants and children were inadequately preserved for an effective quantitative assessment. However, among those that could be examined, over 19 percent expressed the condition. Lesion frequency among adults reached 54 percent with reproductive-age females consistently more affected than males.

The same pattern of heightened female anemia appeared in our analysis of diploic thickening. Thickening of the diploic space between the internal and external cranial tables has been associated with the expansion of blood producing tissue. On average, females were one percent over the thickness associated with clinical anemia, whereas males averaged 14 percent below the boundary. Most important, the pattern of age changes in diploic thickening reinforced our hypothesis of high reproductive stress based on the demographic data.

A large body of research on living populations has demonstrated a consistent-
ly higher rate of anemia among women related to menstruation, pregnancy, partu-
rition, and lactation. It is significant to note 
that pregnant women lose an average of up 
to 2.5 mg of iron (Fe) per day. Among the 
women of Pueblo Grande, the period of 
greatest diploe expansion corresponded 
precisely to the middle of the reproductive 
years. Pueblo Grande males, on the other 
hand, responded like modern males. Diploe 
thickening developed progressively and 
became most pronounced as part of old age 
and senescence. Diachronic changes also 
were consistent with the demographic 
evidence for heightened adult stress prior 
to abandonment of the area. Overall, there 
was an 18 percent increase in diploe thick-
ening between the early and late Classic 
period.

Arguments for nutritional stress in 
an cient populations typically rest on the 
indirect evidence provided by bones and 
teeth. Trace-element analysis of the Pueblo 
Grande remains provided a body of direct 
dietary information based on the actual 
chemical composition of bone tissue. The 
results provided strong support for the 
iron-deficiency hypothesis. For example, Fe 
levels among nursing infants (defined as 0 
to 3 years, based on the strontium-to-calci-
um [Sr to Ca] ratio), were 163 percent 
higher than the levels of older children (4+ 
years).

This pattern was consistent with the 
modern clinical pattern. Research on living 
populations indicates that Fe levels among 
newborns and nursing infants are typically 
well maintained first by maternal stores 
during gestation and subsequently by mo-
ter's milk. Fe deficiency commences with 
weaning and the combined effects of nutri-
tional stress and parasitic infection associ-
ated with an adult dietary regime.

Although adult Fe levels remained 
stable at the lower post-weaning level of 
older children, other aspects of nutritional 
stress became apparent. For example, 
females at Pueblo Grande had significantly 
higher concentrations of magnesium and 
vanadium, as well as a higher ratio of 
strontium to zinc (Sr to Zn) when com-
pared to males. This pattern of female-male 
difference suggests that females were con-
suming more plant resources, whereas 
males had greater access to meat. Female 
elevations in Sr also may have been the 
result of pregnancy and lactation. These 
conditions, combined with high reproduc-
tive demands, would have exacerbated 
female dietary stress and increased the 
likelihood of mortality during the reproduc-
tive years, as observed in the demographic 
data.

In addition to male-female differences 
in dietary stress, the trace-element data 
provided insight into the adaptive decline 
at Pueblo Grande. Over time, levels of 
barium and Zn were reduced, while sex 
differences in the Sr-to-Zn ratio are in-
creased. These changes indicate a general 
decrease in animal protein consumption 
combined with an increased reliance on 
domestic as opposed to wild plant resour-
ces. These changes are precisely what the 
skeletal evidence for a diachronic increase 
in iron-deficiency anemia would predict. 
The most-important source of Fe in the 
human diet comes in the form of heme-iron 
provided by animal protein. Maize is a poor 
source of bio-available Fe.

Taken together, the evidence for nutri-
tion and disease at Pueblo Grande provides 
an extremely coherent picture of dietary 
stress. Weanling diarrhea produced high 
rates of anemia among children that be-
came a chronic malady among adults. This 
condition no doubt contributed greatly to 
the high rates of infant and reproductive-
age female mortality. In addition, the avail-
ability of animal protein became diminished 
over time, and an increasing reliance on 
domestic cultivars such as maize com-
ounded the nutritional stresses acting on 
the population. The consequences of life 
under these conditions were expressed 
ultimately in the progress of aging and the 
appearance of age-related degenerative 
conditions.
**Age-Related Degenerative Conditions**

Patterns of age-related degenerative disease reflect both the cumulative wear and tear of everyday living as well as the effects of physiological stress. Age changes such as degenerative joint disease (osteoarthritis and osteophytosis) and osteopenia provide yet another view of a population's adaptation.

Particularly among aging females at Pueblo Grande, spinal joint disease (osteophytosis) was both frequent and severe. Most notably, it appears that women were subjected to stresses, especially on the lower back, at an earlier age than were men. A likely cause of this difference was, once again, the cumulative stress of childbearing in a reproductively stressed population. This interpretation is also reinforced by the higher frequency of prolapsed vertebrae, notably in the lower back, among the Pueblo Grande women when compared to males.

Although conditions such as vertebral osteophytosis provide a record of the mechanical stresses imposed on prehistoric populations during the course of individual lives, patterns of bone maintenance reflect the cumulative effects of physiological stresses related to nutrition and disease. As is typical for all human populations, patterns of adult age-related bone loss at Pueblo Grande showed substantial sexual dimorphism. Males typically maintained cortical bone from young adulthood through old age, but female losses were significant. The average female at Pueblo Grande lost over 30 percent of the cortical bone in her femur between her second and fifth decade of life, with a major portion of that loss occurring during the reproductive years. Unlike modern, well-nourished women, who typically maintain bone tissue until menopause, the young, reproductive-aged females at Pueblo Grande were literally mining their skeletons for nutrients vital to pregnancy and lactation.

Although the pattern of female bone loss is typical of many ancient and poorly nourished modern populations, a diachronic analysis of bone loss at Pueblo Grande produced results that could have been anticipated only from the mortality, morbidity, and dietary information. Whereas bone loss among females increased slightly between the early and late Classic period, the male transformation was pronounced. Early Classic males maintained their cortical bone with advancing age in a manner consistent with most ancient and modern populations, but their late Classic counterparts underwent a significant degree of bone loss. Among all previously studied modern and prehistoric populations, this pattern of male loss is comparable only to a historic Afro-American population from Cedar Grove, Arkansas (Martin, Magennis, and Rose 1987). It is significant that Cedar Grove also had a high rate of infant mortality and widespread dietary deficiencies including deficiencies in Fe.

**CONCLUSIONS**

In his book *Bone, Bodies and Disease*, Calvin Wells (1964:17) observed that

*The patterns of disease or injury that affects any group of people is never a matter of chance. It is invariably the expression of stresses and strains to which they were exposed, a response to everything in their environment and behavior... It is influenced by their daily occupations, their habits of diet, their choice of dwellings and clothes, their social structure, even their folklore and mythology.*

Our reconstruction of life and death at Pueblo Grande has proceeded in the spirit of Wells's view. Indeed, each deduction was based ultimately on Wells's belief in the connection between human culture and biology. The facts of prehistory tell us that the Hohokam were "effective environmental managers" who created a stable culture for upwards of 1,000 years (Fish 1989). The
human remains tell us that by the Classic period, the Pueblo Grande Hohokam had lost much of that effectiveness. They were a people living on the edge of survival, nutritionally and reproductively stressed and struggling to maintain their numbers. By the end of the Classic period it appears that the struggle was lost.