Bioarchaeology in Early Neolithic Iran:

Assessment of Health Status and Subsistence Strategy

By

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A Thesis Submitted to

the Faculty of Graduate Studies

in Partial Fulfilment of the Requirements for the Degree of

Doctor of Philosophy

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THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES
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ABSTRACT

This dissertation examines the largest human skeletal sample recovered from the eastern end of the Fertile Crescent, the central Zagros Mountains, that dates to early in the subsistence transition from hunting and gathering to agriculture. This monumental change in modern human behaviour has undoubtedly influenced the biological and cultural trajectories of human societies over the last 10,000 years. Macroscopic assessment of health status from the skeletal remains from the early Neolithic site of Ganj Dareh provides the basis for a bioarchaeological synthesis of climatic, environmental, biological, archaeological and cultural contexts of life in the Zagros Mountains ca. 7,000 bc. It further facilitates exploration of the relationships among health, subsistence strategy and human behaviour to assess the theoretical stances embodied in the myriad models of agricultural origins.

The oral health of the Ganj Dareh people suggests that their diet resembled the earlier Epipalaeolithic mixture of plant and animal foods. Although they experienced episodes of stress, recovery and catch-up growth did not adversely affect adult stature relative to contemporaries from other regions of Fertile Crescent. Two classes of skeletal lesions are also relevant to evaluation of subsistence: ectocranial porotic hyperostosis and resorption of vertebral bodies at the attachment sites of *anulus fibrosis*. Their presence supports the diagnosis of human brucellosis, a caprine-associated zoonotic infection.

These results corroborate the zooarchaeological and archaeological assertions that the morphologically wild goats recovered at Ganj Dareh were under extensive human control. The location of Ganj Dareh within the rocky, mountainous natural habitat of goats and the overall relatively good health of the people support the hypothesis that early pastoralism in the central Zagros Mountains developed in a situation of resource abundance. Subsistence transition at Ganj Dareh is best explained within a hybrid social model of agricultural origins.

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CHAPTER 1. INTRODUCTION

1.1 Introduction

The shift in subsistence strategy from hunting and gathering to agriculture, that began ca. 10,000 years ago in the Fertile Crescent of the Near East, has been recognized for almost a century as representing a monumental change in modern human behaviour. Archaeological research in the region has primarily been concerned with elucidation of the causes and timeline of the adoption of agricultural subsistence (for example, Binford, 1968; Braidwood and Howe, 1960; Childe, 1952; Flannery, 1969; Hayden, 1990; Kuijt, 2000; Rosenberg, 1990; Smith and Young, 1972). Although recent literature (Cohen, 1989; Cohen and Armelagos, 1984a and papers therein; Larsen, 1995, 1997) suggests that the adoption of agriculture may have had profound effects on human health, very little research has been conducted on the humans who generated the archaeological record, that is, on the human skeletal remains themselves (Cohen and Armelagos, 1984a). This is particularly true for the Zagros/Piedmont region of the Near East where sizes of most skeletal samples retained for study are small (Agelarakis, 1989; Rathbun, 1984; Schoeninger, 1981), where many of the early excavations explorations of agricultural origins were carried out and where ongoing political tensions preclude or limit further excavations.

There has been a growing awareness among palaeopathologists that the links among skeletal lesions, health status, and human behaviour are more complex than had been previously thought (Bush and Zvelebil, 1991; Larsen, 1995, 1997; Milner and Katzenberg, 1999; Ortner, 1991; Wood et al., 1992). This has led to the formulation of the discipline of bioarchaeology: the interpretation of human behaviour from skeletal evidence. This integration of archaeology and skeletal biology with the biological and cultural determinants of health in a biocultural approach to the study of past human behaviour recognizes that skeletal lesions observed in past populations may be the result of exposure to multiple interacting stressors, with multiple inter-related effects (Bush and Zvelebil, 1991). Although culture may buffer individuals and populations from the effects of exposure to stressors, cultural variables may themselves create new stressors and constraints (Goodman, 1991a), thereby further complicating issues of causation and interpretation. As a discipline palaeopathology, the study of disease in past populations, has developed from the biomedical paradigm of case-study methods, disease identification (Ortner, 1991) and comparisons with modern clinically-identified disease symptoms and outcomes. Through knowledge of biological and physiological processes occurring in normal bone, and of the responses of bone tissue to biological and physical, endogenous and exogenous stressors, normal variation in bone can be distinguished from the abnormal. This facilitates identification of lesion etiology within the individual. Since the 1970s, as more demographers and physical anthropologists have become involved in palaeopathology, the estimation of population health from skeletal remains has been increasingly considered a relevant avenue of research (Brothwell, 1972; Bush and Zvelebil, 1991; Ortner, 1991).

The study of health in human populations also requires incorporation of multiple cultural as well as biological variables, modelled in the Biocultural Model of Health (Armelagos et al., 1992; Goodman et al., 1988). This facilitates the application of population health to archaeological issues such as the origins of agriculture. It predicts that changes in human health, that are associated with the adoption of a food-producing economy and are inferred from the site-specific archaeological context, stem from changes in diet composition, from increased sedentism, population size and density, and scalar stress, and from changes in the timing, duration and type of pathogen exposure. Rather than considering health as one side of the dichotomy: health and disease, health is viewed as a dynamic yet complex continuum between these two extremes (Bush, 1991). Health, viewed in this way, can reflect a population's ability to adapt to myriad stressors (Goodman, 1991a), and as a result can be used to assess subsistence strategy and the population's success in exploiting site-, region- and population-specific ecological and cultural niches.

1.2 Problem Statement

This dissertation describes and quantifies the macroscopic, microscopic and radiographic morphology, non-specific indicators of health, and demographic parameters of the skeletal remains from the site of Ganj Dareh, in the Zagros Mountains of early Neolithic Iran, ca. 7,000 bc[1]. Through bioarchaeological analysis, the relationship between the estimated health status of the population and the subsistence strategy inferred from archaeological analyses is explored.

Population health of the Ganj Dareh skeletal sample is examined as a behavioural phenomenon, the product of interactions among settlement patterns and daily activities of its occupants, within the cultural, environmental and physical context of the site and region. The presence of house mouse, *Mus musculus* a commensal, in all but the lowest

[1] All dates cited are uncalibrated radiocarbon years bc. Since calibration does not affect the internal nor external consistency of the chronology or interpretation of the data for Ganj Dareh, calibration of radiocarbon dates was not attempted.

level suggests year-round occupation of the site (Hesse, 1978). Faunal (Hesse, 1982; Zeder and Hesse, 2000) and botanical (Kislev, 1989; but for an alternative view see van Zeist et al. (1984)) analyses indicate that a broad spectrum of morphologically wild animal and plant resources were utilized by the human inhabitants of Ganj Dareh. However, the age profiles of the ovicaprids (Hesse, 1982) and the presence of goat hoof prints in the mud bricks of dwellings (Smith, 1978) suggest that goats were under human control. The increased prevalence of grinding implements in later levels indicates that the wild plants were an important component of the diet and may have been under cultivation (Smith, 1990). Taken together, these lines of archaeological evidence suggest that the early Neolithic inhabitants of Ganj Dareh were in all likelihood proto-agro-pastoralists. Thus, this research addresses issues of health status of an early sedentary food-producing population and uses health status to evaluate the relative dependence of the inhabitants on food production.

The Ganj Dareh collection is the largest sample of Neolithic human remains from the Zagros region that is currently available for study. Its large size provides an excellent opportunity for application of bioarchaeological methodology and theory to the questions surrounding the health status of a proto-agro-pastoralist population. This research incorporates palaeopathology, knowledge of the physiological and biochemical processes occurring in living bone and the Biocultural Model of Health in a comprehensive bioarchaeological study of the Ganj Dareh inhabitants. Moreover, it explores the relationships among human health, subsistence strategy and human behaviour.

1.3 Dissertation Outline

Chapter 2 introduces the main theoretical frameworks used in the study of health from human skeletal remains: the Biocultural Model of Health, exposure to stressors, the "Osteological Paradox" and the post-"Osteological Paradox" population approach to research on human skeletal remains. Their influences on the methodological approaches of this research, and the analysis and interpretation of the skeletal data are discussed.

In keeping with bioarchaeological underpinnings of this research, the theoretical perspectives surrounding the origins of agriculture are presented in Chapter 3. How each theory affects the data predicted and the interpretation of observations is discussed.

In order to integrate the general models with the Zagros/Piedmont region of the Near East and specifically the site of Ganj Dareh, geographic features significant for the climate, vegetation and environment of the Near East are presented in Chapter 4.

In Chapter 5 the current knowledge of palaeoclimate of the Near East at the Pleistocene-Holocene boundary will set the ecological context within which the earliest subsistence transition from hunting and gathering occurred.

The culture history of the Fertile Crescent is presented in Chapter 6, specifically the Zagros/Piedmont region. Changes in technology, settlement patterns, site seasonality and climate are explored in light of their relevance for estimation of subsistence strategy.

Estimation of health in past populations is predicated on knowledge of health status in living populations. Factors that influence health in modern ethnographic and clinical settings, such as degree of sedentism and subsistence strategy, are examined in Chapter 7. Their relevance and applicability to past populations are explored. The published archaeologically-derived evidence of health in the Zagros/Piedmont is reviewed with reference to current paradigms in bioarchaeology and palaeopathology. The potential population health and skeletal consequences of changes in sedentism and subsistence strategy are predicted.

Chapter 8 introduces the relevant concepts of bone growth, repair and reaction to inflammatory stimuli necessary for an understanding of normal variation in bone morphology and the identification of osseous anomalies. The current literature is reviewed for each of the lines of evidence used in health assessment from human skeletal remains. These include: palaeodemography, growth disturbances that are identified by the presence of Harris' lines and enamel hypoplasia, and by stature-for-age analysis, oral health, inflammatory processes, zoonotic disease manifestation and habitual repetitive activity identification. The reader is directed to the corresponding section of Appendix A for a detailed description of methods, calculations and statistical analyses employed, Appendix B for the recording forms, Appendix C for data coding and Appendix D for the tabular data upon which the analyses are based.

The site context for the skeletal remains analyzed in this research is summarized in Chapter 9. The site of Ganj Dareh is described, the archaeobotanical and zooarchaeological analyses are presented and the methods used in the analysis summarized. This chapter provides archaeological context for Ganj Dareh and examines the evidence for subsistence strategy of its inhabitants.

Chapter 10 outlines the results of the various analyses and the relationships identified. The age profile of the site and the frequencies of health markers are presented.

Chapter 11 provides a synthesis of the data. The evidence on which the assessment of Ganj Dareh health is based is critically examined within the paradigm of bioarchaeology and palaeopathology. Inferences concerning relationships among subsistence strategy, health and human behaviour are discussed. Conclusions of the study are presented.

In Chapter 12 issues identified during the course of the research but not directly addressed are outlined. They are presented as avenues for future research.

CHAPTER 2. BIOARCHAEOLOGY: THEORETICAL FRAMEWORK

2.1 Introduction

This study of the health of the Ganj Dareh human skeletal remains is approached from the perspective of bioarchaeology. Bioarchaeology applies the Biocultural Model of Health, the relationships among humans, the environment and culture (Goodman and Armelagos, 1989), to past human populations. This is achieved through examination of the people themselves, that is, their skeletal remains and through quantification of skeletal indicators of health. Interpretation of frequencies of skeletal indicators requires consideration of the many potential factors that influence lesion presence in the individual as presented in the "Osteological Paradox" (Wood et al., 1992). This is accomplished by taking a post-"Osteological Paradox" approach of population-based analysis utilizing multiple health indicators (Goodman, 1993; Larsen, 1997; Wright and Yoder, 2003) to assess the behaviour of past peoples within site- and region-specific archaeological and cultural contexts. It is within this conceptual framework that the relationship between health and subsistence in early Neolithic Iran is explored.

Bioarchaeology, the biocultural approach to the exploration of the general health of past populations, interprets human behaviour from skeletal evidence (Bush and Zvelebil, 1991; Goodman, 1991b; Larsen, 1997). It encompasses palaeopathology, palaeodemography, biomechanics, palaeodiet, biodistance and growth disruption (Larsen, 1997; Wright and Yoder, 2003). The present research focuses on two of these components: palaeopathology - the study of health in past populations, and growth disruption - the study of recovery from episodes of growth arrest.

The bioarchaeological approach assesses the biological condition of the individuals within its site- and region-specific archaeological context. However, it goes beyond description of individual skeletal remains and diagnoses of observed bone anomalies to explore lesion frequencies within and among skeletal samples. It acknowledges, and incorporates into the theoretical modelling and analysis myriad complex interactions among multiple components. These include human and non-human inhabitants of a region, the environmental conditions and constraints (climatic, ecological and physical), and the cultural variables that influence human behaviour, including both population and individual decision-making (Bush and Zvelebil, 1991; Goodman, 1991b; Larsen, 1997). The selective effects of culture on health status and on the biological and cultural reproduction of the society may thus be assessed (Bush and Zvelebil, 1991:5). The overriding mandate of bioarchaeology is the testing of hypotheses concerning important archaeological issues such as agricultural origins through the examination of human skeletal remains.

The integration of biological and cultural determinants of health in the biocultural approach recognizes that skeletal lesions observed in past populations have multiple interacting causes that, in turn, have multiple inter-related effects (Bush and Zvelebil, 1991). As a result biological and psychological responses vary within and among individuals of the same culture and local population (Bush, 1991). Inter-site variation in skeletal lesion prevalences is both predicted and expected. Although this precludes the generation of tidy metanarratives to explain archaeological observations, multiple possible explanatory models can be developed. Through the application of the

Biocultural Model of Health cogent meaning can be derived that is consistent with both the biological and the archaeological evidence.

2.2 Biocultural Model of Health

Health, a culturally-bound phenomenon, is defined as the biological and psychological condition of an individual. The exploration of health status as a behavioural phenomenon (Bush and Zvelebil, 1991; Goodman, 1991b) is facilitated through the Biocultural Model of Health (Fig. 2.1) that describes the relationships among health stressors, stress and adaptation (Goodman and Armelagos, 1989). The model facilitates understanding of the interactions among a variety of factors (Table 2.1).

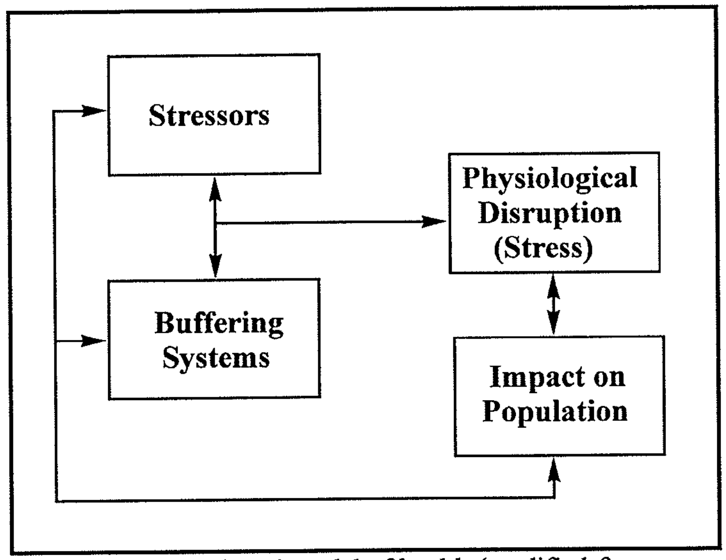

Figure 2.1. Biocultural model of health (modified from Goodman and Armelagos, 1989).

Factor	Properties
Humans	Biological and Culture-Possessing Organisms
Natural Environment	Organic Components: Flora and Fauna Physical Components: Soils, Climate, Seasonality, and Altitude
Culturally-Constructed Environment	Cultivation of Wild Plants Incipient Herding of Ovicaprids Settlement Patterns Dwelling Construction
Human Behaviour	Culturally-Influenced Practices Beliefs Buffering Mechanisms

Table 2.1. Interacting Factors Modelled in the Biocultural Model of Health (Modified from Goodman and Armelagos, 1989).

Culturally-constructed environments and human behaviours have the important potential to buffer individuals and populations from the effects of exposure to stressors. However, if buffers cannot adequately counteract the effects of stressors, adverse consequences may result. These may be recorded in skeletal tissues and observed as enamel hypoplasia, Harris' Lines and /or growth stunting. In addition, cultural variables may themselves create new stressors and constraints (Goodman, 1991a) that can inadvertently affect individual and population health. Thus exposure to stressors, buffering systems, and their myriad interactions can, through the production of physiological disruption (stress) and illness episodes, have a significant impact on the health and well-being of the living community.

For bioarchaeologists, the goal is elucidation of the impact of stress on the population within the context of the web of site-specific physical, environmental and cultural interconnections. Also integral is the assessment of the degree to which adaptation to local conditions had occurred. This leads to a variety of avenues of research that can be pursued to reveal health status of past peoples. For example, examination of frequencies of non-specific indicators of health across the age categories of the Ganj Dareh inhabitants can facilitate health status assessment. It can illuminate the extent to which individual and group choices concerning food procurement methods influenced daily life, behaviour, community health and an individual's ability to be effective contributing members of their society.

2.3 Stress

Stress is a force that is produced by an illness episode or period of malnutrition, that is, by stressors. Stress can cause physiological disruption by altering the trajectory of physiological processes that are involved in the development, growth, and maintenance of biological organisms and tissues and, specifically for this study, skeletal tissues (reviewed in Goodman et al., 1988; Ortner, 1994; Tsigos and Chousos, 1996). Skeletal lesions may arise when there is an imbalance between stressor demand and the response capability of the organism, that is, when there is a failure to adapt (Goodman, 1991a). Since Selye (1973) articulated his concept of stereotypic biochemical responses to stress-producing factors, stress and the body's homeostatic mechanisms have become integrated into epidemiology, biology, and psychology (Kasl, 1996). Ultimately stress has become an important concept in anthropology that is utilized through application of the Biocultural Model of Health (Goodman and Armelagos, 1989). However, in contrast to Selye's (1973) formulation of stress as solely a biochemical phenomenon, psychological and cultural variables are now considered to be essential factors affecting health status. They must be incorporated into the health research design for both past and present human populations (Bush, 1991).

The causes of physiological disruption are varied: trauma, malnutrition, infection, immune suppression, psychological disturbances, and scalar stress. However, in most cases the structure of bones and teeth preclude determination of the specific cause of the disruption. In addition, because the body's reactions to stressors follow a few common biochemical pathways, the indicators of stress are often indirect or partial, that is, non-specific (Kasl, 1996). The application of the concept of stress to past populations parallels that in living populations, so that palaeopathologists and bioarchaeologists also employ non-specific indicators in their attempts to quantify exposure to stress. However, in contrast to modern clinical medicine where disease process is an important component of diagnostics, examination of skeletal remains captures only the osseous evidence present at the time of death. Since the specific cause of the skeletal lesions cannot usually be determined from the skeletal evidence alone, archaeological and palaeoclimatic data for the site and region are required for the interpretation of skeletal lesions and lesion frequencies (Goodman et al., 1988; Rothschild and Martin, 1993).

Even in living populations, however, stress may be difficult to quantify (Kasl, 1996). Despite this, the adaptive reactions to stressors are conceptualised as unconscious physiological changes such as increased alertness and redirection of energy, nutrients and oxygen within the body (Tsigos and Chrousos, 1996) as well as culturally-determined behavioural changes to alleviate or minimize stress consequences (Goodman and Armelagos, 1989). When buffering mechanisms are not sufficient to counteract exposure to stressors, the physiological disruption (stress) may disrupt cell and tissue maintenance and repair, and within the skeletal system may alter bone morphology (Gowen, 1994).

During stress episodes, the growth of various tissues may be inhibited if the exposure to stress occurs during a period of tissue growth. Since growth is saltational (Lampl et al., 1992), not everyone who experiences stress will do so during periods of growth. In addition, because of slow response time of bone tissue relative to soft tissues following insults, exposure to stressors will not be recorded in the skeleton if death occurs during or soon after the period of stress. Thus, although presence of skeletal markers is sufficient to indicate survival of episodes of stress exposure, absence does not necessarily mean that stress exposure was absent (see section 2.5 for the theoretical implications of these observations and 2.6 for current bioarchaeological solutions for interpretation).

Despite these theoretical roadblocks, the health status in past populations can be estimated through examination of multiple skeletal indicators, so as to capture as much evidence as possible of physiological disruptions that occurred during the lifetime of the individual. Recovery from growth disruption may be seen in long bones as Harris' Lines (Harris 1931a, 1931b) and linear enamel hypoplasia (LEH) (Goodman, 1991a, 1991b; Skinner and Goodman, 1992; Suckling, 1989). Prolonged exposure to stress can reduce secretion of growth hormones. This may be expressed in past populations as decreased stature-for-age (stunting) if recovery periods that allow catch-up growth do not occur with sufficient duration and/or frequency. The reduction in DNA transcription factor synthesis can further reduce protein synthesis, suppress osteoblast activity, and reduce cortical bone density (Tsigos and Chrousos, 1996). Raised catecholamine levels associated with exposure to stressors may increase both adrenocorticotropic hormone (ACTH) and cortisol levels, reducing immune competence and predisposing individuals not only to become infected but also to develop active disease upon exposure to pathogens (Fisher, 1996). Increased infection rates may result in increased population prevalences of periostitis on long bones (Larsen, 1995; Mensforth et al., 1978) and/or in the maxillary sinuses. Other health indicators used in bioarchaeological assessments of health include porotic hyperostosis, dental caries and alveolar abscessing, secular trends in stature, the age structure of a skeletal sample, and bone mass (Cohen and Armelagos, 1984a; Goodman and Armelagos, 1989; Goodman et al., 1988; Larsen, 1995, 1997). These will be discussed in detail in Chapter 8.

Physiological disruption does not end with the biological organism, but pervades all aspects of human cultural, biological and physical existence. Ethnographic documentation of modern populations suggests that the impact of physiological disruption results in a generalized decline in health status, and reduced work and reproductive capacities. These effects are linked to the stressors and buffering systems through both positive and negative feed-back mechanisms as shown in Figure 2.1. Accompanying socio-cultural disruption (Goodman et al., 1987; Goodman et al., 1991b) can reduce the effectiveness of existing cultural buffering systems thus exacerbating cultural and biological maladaptive responses.

Health of individuals and populations are functions of the relative balance between exposure to constraints and buffering mechanisms. At the Pleistocene/Holocene boundary in the Zagros/Piedmont region, the warming trend that followed the last glacial maximum was accompanied by dramatic and rapid climatic fluctuations (COHMAP Members, 1988). This exacerbated conditions of environmental constraint and slowed or altered ecosystem changes as climate ameliorated. Biological constraints include illness episodes, periods of malnutrition, and exposure to chronic disease-producing pathogens such as *Mycobacterium tuberculosis* and *Brucella melitensis* associated with increased duration and intensity of contact with ovicaprid herds, and declining sanitary conditions associated with year-round site occupation. The psychosocial environment has been observed to have profound effects on the health in modern human populations (Arnetz, 1996). Similarly in the early Neolithic Zagros region, a lag between increased sedentism and corresponding cultural coping strategies may have precipitated periods of stress. Cultural constraints include the scalar stress associated with sedentism (Johnson, 1982), dwelling construction, subsistence strategy, and settlement patterns.

As with constraints, buffering mechanisms can also be classified as environmental, biological and cultural in origin. Environmental buffers such as local rapid changes in topography (see Chapter 4 for geography and topography of the Fertile Crescent) can facilitate access to areas of local or seasonal resource abundance and more favourable climatic conditions. Biological buffers can be of genetic origin affecting population level immune competence or acquired, for example, through pathogen exposure during childhood. Cultural variables such as subsistence strategy, technology, and ideology can positively affect health and well-being (Goodman and Armelagos, 1989).

Superimposed on these general constraints and buffers within a specific region and population is wide inter-individual variability in reactions to stress contributing to the variation in the type and severity of responses of bone tissue to stressors. In addition as we have seen from these examples, the same factors can act as both constraints and buffers. In order to assess the impact that these variables have on past human health, careful consideration of site-and region-specific archaeological contexts is essential as well as the formulation and application of a realistic multi-causal, multi-variable biocultural model of health. Without the application of the Biocultural Model of Health in a well-planned bioarchaeological research programme, inferences drawn from exposure to stressors recorded in skeletal remains can be severely compromised.

2.4 Exposure to Stressors

Exposure to stressors may occur during two inter-related processes: growth and development, and tissue maintenance and repair. During development and growth, prior to the attainment of adult size, exposure to stressors can result in temporary growth cessation. Skeletal indicators of recovery from the growth arrest that follows exposure to stressors include Harris' lines and enamel hypoplasia. Stature estimates have also been used to estimate stress exposure (King and Ulijaszek, 1999; Meiklejohn et al., 1984). Although catch-up growth can obscure evidence of stress when stature alone is examined (King and Ulijaszek, 1999), long bone lengths of non-adults from two mediaeval British samples were not systematically different in subsamples identified as more and less stressed (Ribot and Roberts, 1996). Experiencing stress and subsequent catch-up growth, that is, growing under sub-optimal conditions, can have severe consequences in later life. Studies in a variety of vertebrates suggest that growth compensation following nutritional deficit can negatively influence later life trajectory and health status, shortening over-all life expectancy and patterns of morbidity (Metcalfe and Monaghan, 2001).

Cell and tissue maintenance and repair occur throughout life. Thus alterations in patterns of tissue repair may be observed in both non-adult and in adult skeletons. Inflammatory processes such as periostitis on long bones (Larsen, 1995; Mensforth et al., 1978) and in the maxillary sinuses (Merrett, 2003; Merrett and Pfeiffer, 2000) have been used as non-specific indicators of stress in past populations in order to assess population health. Other health indicators include: porotic hyperostosis (Mensforth et al., 1978; Stuart-Macadam, 1985, 1987, 1992; Stuart-Macadam and Kent, 1992), dental caries and alveolar abscessing (Beckett and Lovell, 1994; Hodges, 1987; Lillie, 1996; Lubell et al., 1994; Lukacs, 1996; Meiklejohn et al., 1984) and bone mass (Pfeiffer and King, 1983; Waddell, 1994). Secondary demographic data have also been used to suggest levels of stress exposure, such as the age structure of a skeletal sample (Meiklejohn et al., 1997), and estimates of mean age-at-death for the population (Duray, 1996; Goodman, 1991a; Goodman et al., 1980). However, decreases in mean age-at-death in skeletal samples reflect increases in fertility. In contrast the same parameter change in a living population indicates increases in mortality (Jackes, 1994; Sattenspiel and Harpending, 1983).

To apply clinical medical knowledge to past human populations, disease processes in modern humans must be causally related to changes in skeletal morphology. For example, bone tissues from orthopaedic patients of known medical history may be processed for dry bone assessment to establish links between disease processes in the living and the morphology of skeletal lesions (Ragsdale, 1993). Once causal pathognomic relationships have been established in modern reference samples, inferences concerning causation of lesions in past human populations may be possible (Ortner, 1991). However, the relationships between disease processes and the presence of diagnostic skeletal lesions are not straightforward (see below, and discussion of stress and stressors above).

Individual variation in rate and degree of disease progression and the absence of exclusively diagnostic skeletal lesions may preclude definitive diagnosis. This can hinder inter-observer agreement on lesion etiology when diagnosis is based solely on skeletal evidence (Miller et al., 1996). The spatial distribution of lesions within the skeletal element and the pattern of elements affected within the skeleton may narrow the number of disease processes included in the differential diagnosis. However, inter-individual variation in susceptibility to disease and to lesion development in osseous tissues may preclude specific disease identification in past skeletal populations where diagnostic procedures such as those applied in the practice of clinical medicine cannot be applied (Ortner, 1992). This may confound interpretation of health status (Wood et al., 1992). In addition, comparisons of health status among past populations have been hindered by a lack of standardization in language used by researchers to describe skeletal lesions in dry bone specimens (Ortner, 1991, 1992, 1994). Consistency and standardization of meaning among the disciplines of skeletal biology, palaeopathology/bioarchaeology and medicine are presently facilitated through workshops conducted at the annual meeting of the Paleopathology Association and publications in scholarly journals to ensure that future inter-site and inter-observer comparisons of data are possible.

Skeletal changes observed in dry bone by palaeopathologists may be diagnostically invisible in living individuals, particularly if the diagnosis is contingent on radiographic identification of osseous changes (Ortner, 1991). For example lesions on the pulmonary aspect of ribs, that may be associated with tuberculosis (Pfeiffer, 1991), are not in the clinical repertoire of criteria for the diagnosis of tuberculosis. These rib lesions may not be recognized as possibly indicative of tuberculosis in skeletal samples. Thus, different pathognomic criteria may be required for diagnosis of a given disease or condition in past and in living populations (Ortner, 1991). However, caution must be exercised in the development of new pathognomic criteria. In a much broader study of the same reference collection, Roberts and colleagues (1994) found that although proliferative lesions on the inner aspects of ribs were associated with cause of death that was identified as of respiratory origin, lesion presence was not sufficient for a specific diagnosis of tuberculosis.

Disease is a dynamic process such that in clinical medicine, the progression of disease may be observed in both hard and soft tissues. An array of diagnostic procedures, for example, the culture of pathogens, or diachronic radiographic documentation, may be applied to facilitate diagnosis and treatment. In addition, the clinical populations utilized as reference samples for skeletal analysis are biased towards individuals with symptoms that present for medical intervention, for example in Ragsdale (1993). Other reference samples, such as the Terry and the Hamann-Todd Collections from the early twentieth century, may be biased by the population affinity, age and sex distribution and socio-economic status of the individuals. Medical history of individuals in these collections is unknown and cause of death was assessed without the assistance of modern medical diagnostics. In all cases, the range of normal variation in the disease-absent portion of the population is not known, decreasing the distinction between pathology and normal variation (Ortner, 1991).

In the individual, illness episodes may occur within the dynamic system of growth and development. For lesions indicative of growth disruption to be present in skeletal remains, the individual must be in a period of skeletal growth or of dental crown formation during the episode of stress, and the individual must have survived long enough to resume skeletal/dental growth (Ortner, 1979; Goodman, 1991a; Wood et al., 1992). Alternatively, growth disturbances may be recorded, but stress episodes may not be clinically recognizable. For example, studies in modern populations suggest that elevated acute-phase immune responses that result in growth disruption may occur in cases of subclinical infection (King and Ulijaszek, 1999). From examination of osseous indicators of growth arrest, these people would be correctly identified as having experienced exposure to stressors. However, with a subclinical infection, their daily life, work productivity and contributions to the community may not have been affected, making attempts to utilize non-specific indicators of stress as measures of health status of the individual problematic.

Individuals who do not exhibit skeletal lesions may or may not have experienced episodes of illness or exposure to stressors (Wood et al., 1992). Lesion absence may indicate no exposure to stressors, the "healthy but mortal" scenario (Jackes et al., 1997), exposure to stressors during a quiescent phase of the growth cycle (Lampl et al., 1992), or alternately may indicate exposure to stressors with death occurring before the stress episode could be recorded in the skeleton (Ortner, 1979; Goodman, 1991a; Wood et al., 1992). In addition, individual heterogeneity in response to stressors, the result of the interactions among various biological, psychological and cultural factors, as well as of inter-individual variation in disease/malnutrition exposure can influence development of skeletal lesions (Bush and Zvelebil, 1991; Goodman, 1994; Mensforth et al., 1978). For the individual, a "healthy" skeleton may be derived from individuals who experienced malnutrition or illness episodes and thus, lesion presence in skeletal remains is open to multiple interpretations.

Many researchers (Bush and Zvelebil, 1991; Goodman, 1994; Larsen, 1997; Mensforth et al., 1978; Wright and Yoder, 2003) suggest that interpretation is facilitated through the use of multiple indicators of health, at both the individual and especially at the population level. When used in conjunction with the archaeological, behavioural and cultural context of the sample, multiple lesion frequencies may indeed allow assessment of population health status (Bush and Zvelebil, 1991; Goodman, 1994; Larsen, 1997; Mensforth et al., 1978; Wright and Yoder, 2003). In contrast, Wood and colleagues (1992) suggest that estimations of health in past populations are severely confounded as outlined in the "Osteological Paradox".

2.5 The "Osteological Paradox": Interpreting Health Status from Human Skeletal Remains

The "Osteological Paradox" (Wood et al., 1992) questioned the use of non-specific indicators of stress for the estimation of health status of past populations and specifically the interpretation that the presence of skeletal lesions was an indication of poor health (Goodman, 1993). In particular, the "Osteological Paradox" suggested that the increased prevalence of skeletal lesions associated with changes in behaviour, such as the transition to agriculture, is subject to multiple contradicting interpretations.

The "Osteological Paradox" has addressed some of the apparent theoretical ambiguities and anomalies previously recognized by many researchers concerning interpretations of skeletal lesions (Bush, 1991; Bush and Zvelebil, 1991; Goodman, 1991b; Ortner, 1979, 1991). The sources of ambiguity in analysis and interpretation stem from the inherent assumptions about past populations and the difficulty of applying methods to skeletal samples that were developed to model living populations. Firstly, past populations have been modelled as if they were stationary, that is, without migration or changes in mortality and fertility rates. Secondly, skeletal samples are assumed to demographically reflect the living population from which they are derived, despite being the result of selective mortality. Lastly, the issue of inter-individual variation in risk of death, heterogeneous frailty, has not been taken into account in skeletal analyses (Wood et al., 1992). To ignore these issues can hinder the interpretation of lesions within the individual and of lesion frequencies at the population level.

Demographic Stationarity. The demographic modelling procedures used in skeletal population analysis are based on those developed to describe observable living populations. The mathematical modelling used assumes that the population is stationary, that is, the age distribution is in equilibrium and population size is not increasing or decreasing (Wood et al., 1992). Although factors that can disrupt equilibrium such as migration, fluctuating age-specific fertility and growth rates are measurable in living populations, they may be unknown in past populations and estimation of these elucidating variables may not be possible. Thus, although the age distribution of the population may not be at equilibrium, it is assumed to be (Wood et al., 1992:344). In addition, parameters of the living population from which the skeletal sample is derived, such as the proportion of those at risk of exposure to the stressor, are not available for supplemental analysis as they are in living populations. Lesion frequencies in the past skeletal sample may not be directly representative of the frequencies that existed in the living population, negating the use for past populations of the demographic modelling techniques developed for living populations. This creates the potential for errors of interpretation of the demographic parameters calculated from a skeletal sample (Wood et al., 1992).

Selective Mortality. A skeletal sample is also necessarily intrinsically selective by definition, in that those in each age category are those who died, not those who survived.

The age profile of a skeletal sample is in reality a mortality profile. Within each age category, those who exhibit lesions may be at increased risk of death and thus be over-represented in a skeletal sample. Alternately, the proportion with lesions in the skeletal sample may under-represent the proportion with the condition in the living population, since for most conditions that affect the skeleton only a small percentage of those afflicted will develop osseous lesions. In addition, a series of extrinsic, largely unknowable factors bias the parameters of the living population during the formation of the subsequent skeletal sample. For those buried at a site of archaeological interest, depositional conditions must favour bone preservation. The skeletons within the area to be excavated must represent a random and unbiased sample of the population under consideration and recovery for analysis must occur (Waldron, 1994; Wood et al., 1992).

Heterogeneous Frailty. The third characteristic of living populations considered in the "Osteological Paradox" is that of heterogeneous frailty: individuals differ with respect to their relative risks of death. Life and illness history, as well as genetic, environmental and cultural factors can all affect an individual's susceptibility to disease exposure, development of disease and death. Although potentially measurable in living populations, variation in frailty in skeletal samples is largely unknown. Thus, characterization of the health of a living past population through observations of selected individuals, those in a skeletal sample, can be problematic (Wood et al., 1992).

Publication of the "Osteological Paradox" created a flurry of responses over the last decade (Byers, 1994; Cohen, 1994; Goodman, 1993; Jackes, 1993; Wright and Yoder, 2003). In retrospect, the discussion consolidated a growing awareness among researchers that past human population health is a complex phenomenon that cannot be solved by construction of simple metanarratives. As demonstrated in section 2.6, attempts to resolve the issues raised in the "Osteological Paradox" have strengthened bioarchaeology as a discipline.

2.6 Post-"Osteological Paradox": The Population Approach

Although the factors presented in the "Osteological Paradox" (Wood et al., 1992) are recognized as potential confounders of interpretation, Goodman (1993) suggests that the skeletal evidence is only paradoxical if single skeletal indicators are used to infer health status of a past population. When multiple indicators are used in bioarchaeological analyses, as has been advocated by many researchers (for example, Agelarakis, 1989; Goodman, 1991a; Harpending, 1990; Meiklejohn and Zvelebil, 1991) prior to the publication of the "Osteological Paradox", alternate possible explanations may be assessed and several most plausible are isolated from among the many. The prevalence of lesions in the skeletal sample may not be equivalent to the prevalence of disease in the past living population (Ubelaker, 1992; Wood et al., 1992). However, lesion presence does suggest that periods of exposure to biological, psychological and cultural stressors were experienced by the living population (Bush and Zvelebil, 1991; Goodman, 1994; Jackes et al., 1997; Lubell et al, 1994; Lukacs, 1996; Meiklejohn et al., 1997; Waddell, 1994). In addition, lesion presence can be taken as a measure of cumulative health history over the lifetime of each individual (Wright and Yoder, 2003).

In many ways the Post-"Osteological Paradox" approach to bioarchaeological research focuses more directly on the measures of health and morbidity in the living than does strict adherence to the clinical approach of explicit diagnosis of the individual as the

Osteological Paradox suggests. Indeed, as Milner and colleagues (2000) suggest, the paradoxical factor of hidden heterogeneity of frailty is only hidden if the variables scored in analysis fail to capture measures of the relative risk of death. This has opened new avenues of inquiry to devise and estimate measures of both morbidity and mortality. The estimation of lesion frequencies facilitates the estimation of quality of life measures of the individual such as work capacity (Goodman, 1993) and the impact of physiological and psychological stressors on the population (Goodman and Armelagos, 1989). However, the presence of lesions may not preclude meaningful involvement in the life of the community by the individuals affected, and lesion absence does not preclude exposure to stressors. Thus, significance of the lesions for population health may only be inferred if examination of the archaeological, social and cultural context is an integral component of the research design (Ortner, 1994).

Post-paradox research emphasizes the complexity of disease etiology, the ecological factors that may affect the interactions among nutrition, immune competence and infection (King and Ulijaszek, 1999), and the incorporation of the analysis of contextual complexity in the research design. Recent bioarchaeological research emphases the temporal, spatial and cultural context of skeletal samples for the elucidation of the health status of past population. This has, in turn, strengthened the theoretical foundations of the palaeopathology component of bioarchaeology (Larsen, 1997; Ortner, 1994) and thus bioarchaeology as a whole.

As the preceding discussion illustrates, many of the points raised by the "Osteological Paradox" (Wood et al., 1992) were not new at the time of its publication. Already clearly entrenched in the literature was concern for issues such as the representativeness of the skeletal sample, hidden heterogeneity, selective mortality and demographic non-stationarity, emphasis on population-based studies, integration of the cultural, archaeological and taphonomic contexts in hypothesis formulation, and consideration of multiple explanations of the skeletal data (for example: Brothwell, 1972; Bush, 1991; Bush and Zvelebil, 1991; Goodman, 1991a; Goodman et al., 1988; Ortner, 1979, 1991). This suggests that the "Osteological Paradox" (Wood et al., 1992) may have been a needed impetus for the consolidation and formal articulation of theory in palaeopathology/bioarchaeology, as Lukacs (1992) had predicted. Through the application of the Biocultural Model of Health (Goodman et al., 1988) within the realm of bioarchaeological research (Larsen, 1997), health status of a population can be estimated through the quantification of multiple non-specific indicators of stress (see Chapter 8). Post-paradox research in bioarchaeology has made explicit the pre-paradox change of focus from the elucidation of specific disease processes to the understanding of the consequences of health status change on the community, human behaviour and human biological adaptation (Goodman, 1991a; Larsen, 1997).

CHAPTER 3. ORIGINS OF AGRICULTURE

3.1 Introduction

Before proceeding to the details of this bioarchaeological study of the Ganj Dareh human skeletal sample, the theoretical underpinnings of the origins of agriculture and sedentism research will be explored. The transition from hunting and gathering to agricultural subsistence and from nomadic to sedentary settlement patterns are complex multi-faceted processes. Increased sedentism and changing patterns of subsistence procurement added activities such as the herding of animals and the cultivation of plants to the human behavioural repertoire. Diverse traces of these new human behaviours can be gleaned from the archaeological record, including human skeletal remains. Interpretation of this archaeological evidence is facilitated through theoretical debate and model building. Within this context, the conceptualization of the subsistence transition is examined. Where possible theory and bioarchaeological evidence are presented within the general context of the Near East, then within the specific context of the Zagros Mountains and the Ganj Dareh hinterland. Theoretical modelling of pastoralism provides the context of early ovicaprid herding in the Zagros and at the site of Ganj Dareh. Specifically, the evidence that the first "food-producing" economies of the Zagros/Piedmont area were primarily centred on animal domestication rather than on the domestication of plants is assessed.

The adoption of agriculture has been approached from many perspectives (Table 3.1) that began with deterministic and progressivist models. More recently more holistic approaches have been incorporated. Models for the origins of agriculture have focused on the location of primary centres of domestication, the role of climate change and resource availability at the end of the Pleistocene in initiating changes in human

	Model	Proponents
Early	Oasis	Childe (1934, 1952)
	Nuclear Zone	Braidwood and Howe (1960)
	Marginal Zone	Binford (1968); Flannery (1969)
1970s - 1980s	Population Pressure and Sedentism	Smith and Young (1972); Cohen (1977); Redding (1988)
	Early Social	Cauvin (1977); Henry (1985); Ingold (1996b)
Recent	Recent Social	Hayden (1990); Rosenberg (1990); Kuijt (1996, 2000)

Table 3.1. Progression of model-building concerning the origins of agriculture.

behaviour, the role of human agency in these changes and the recognition of plant cultivation and of plant and animal domestication from materials recovered from archaeological contexts.

Early models placed emphasis on the location of agricultural beginnings in relation to climate and resource availability. For example, domestication has alternately been proposed to have occurred in oases (Childe, 1934, 1952), in nuclear zones, in the natural habitats of the wild plants and animals (Braidwood and Howe, 1960), and in the marginal zones where human intervention in the environment was required to counteract low ecological productivity (Binford, 1968; Flannery, 1969). Similarly, a variety of environmentally deterministic climate change stances have been espoused incorporating the additional progressivist assumption that, given the presence of the appropriate driving force, hunting and gathering would inevitably give way to agricultural subsistence (Braidwood and Howe, 1960; Childe, 1952; Wright, 1968). More recently, multidisciplinary research suggests that climate change at the end of the Pleistocene resulted in a complex mosaic of different climates within the region (COHMAP Members, 1988; Wright, 1993). Models no longer seek to explain human behaviour in terms of uniform responses to simple unidirectional changes such as increasing aridity or increasing temperature. Nor do they assume that the transition to agriculture is irreversible or inevitable.

Population pressure models of the late 1960s and early 1970s placed emphasis on interactions among population growth, resource availability and technological innovations while continuing to accept the premise of late Pleistocene climate change (Cohen, 1977; Smith and Young, 1972). These concepts were expanded upon in Redding's (1988) multistage model of human behavioural responses to subsistence change.

Cauvin (1977) and Henry (1985) asserted that initial stages of sedentism were successful because concomitant changes in social organization had occurred. Recent social model theorists (Gebauer and Price, 1992; Hayden, 1990; Kuijt, 2000; Rosenberg, 1990) have proposed that long-term changes in social organization and ideology were indeed necessary for substantial changes in subsistence strategies to become entrenched. New relationships among the environment, plants, non-human animals and humans develop only within a cultural milieu that is conducive to such changes. For example, architectural features with possible ceremonial functions that suggest a new emerging cultural environment have been excavated at numerous sites such as Jerf el Ahmar (Stordeur et al., 1997), Çayönü (Özdoğan and Özdoğan, 1989) and Ganj Dareh (Smith, 1972) and "ancestor cults" indicative of developing social complexity are inferred from recovery of human figurines, plastered skulls and secondary burials at 'Ain Ghazal (Rollefson, 1983, 1986) and Çayönü (Özbek, 1988) among others.

Early accounts suggested that agriculture had been invented, that is, agriculture had been developed through conscious human agency (Binford, 1968; Braidwood and Howe, 1960; Childe, 1952; Flannery, 1969). In contrast, Rindos (1989) denies the need to postulate human agency. Viewing cultural changes using a Darwinian model, he suggests that agriculture evolved through biological coevolutionary mechanisms with no inherent direction of change assumed. As in other biological systems, "change is the result of selection acting upon the undirected variant cultural forms existing at earlier points in time" (Rindos, 1989:28). Recent research suggests that although human agency was involved, domestication was not inevitable. Both plant and animal domestication are postulated to be the result of unintended consequences of human activities (Hillman and Davies, 1990; Zohary et al., 1998).

Although theorization can facilitate archaeological interpretation, it is a product of archaeologists, culture-possessing humans. The formulation of hypotheses, situated within the Western intellectual environment of the discipline of archaeology, says more about the culture of the archaeologists than that of the early Neolithic inhabitants of the Near East (Ingold, 1994). The transition to agriculture is framed within the Western paradigm of the Cartesian dichotomy between "humans" and "nature". This may influence the array of unstated assumptions that guide the definition of domestication and the interpretation of evidence for species domestication. Causal explanations for the adoption of agricultural subsistence can also be skewed and relevant issues missed (Ingold, 1994).

The remainder of this chapter introduces the important role which archaeology of the Zagros has played in theoretical modelling of the origins of agriculture. The models of agricultural origins are presented: early environmental determinism, population pressure models and the role of sedentism in subsistence transition, social models, and biological determinants of subsistence change. The final section discusses the issues surrounding domestication and its recognition in the archaeological record.

3.2 Archaeology of the Zagros and Theory Building

Archaeology of the Zagros has played a significant role in the development of models of the origins of agriculture in the Near East. In his formulation of the Neolithic Revolution Childe (1934, 1952) was influenced by the development of complex civilization in Mesopotamia in regions to the south of the Zagros Mountains. Braidwood's (Braidwood and Howe, 1960) excavations in the Zagros/Piedmont region attempted to place the theoretical formulation of subsistence transition in the Near East in archaeological context through recovery of relevant archaeological evidence. In his hypothesis, agriculture was thought to have originated in the natural habitats of the species domesticated, the nuclear zone (Braidwood and Howe, 1960). In contrast, the Marginal Zone Hypothesis (Binford, 1968; Flannery, 1969) asserted that agriculture in the Zagros/Piedmont had developed in suboptimal habitats. By the 1970s, population pressure and the development of sedentism prior to the adoption of agriculture had been incorporated into models of agricultural origins by archaeologists working primarily in the Zagros/Piedmont region (Mortensen, 1972; Smith and Young, 1972)[1].

More recently, hypotheses of the origins of agriculture have challenged the unilinear approach of cultural evolution that assumes an invariant order of the transition from hunter/gatherers first to the cultivation of cereals and only later to the herding of

[1] The population pressure and marginal zone hypotheses are not necessarily independent of each other.

animals. Hole (1984, 1989) proposed a two-stage model of domestication in the Near East. Geographical and temporal separation of the earliest evidence of plant and animal domestication placed the first plant domestication in the Levant two thousand years earlier than the first evidence of animal domestication in the Zagros. This introduces the possibility of inter-site and inter-regional variation in the order in which species were domesticated (Hole, 1984, 1996; McCorriston and Hole, 1991) and the species involved in early animal domestication (Rosenberg et al., 1998). Indeed, in the final report of Abu Hureyra, Moore and colleagues (2000) challenge the current assessment that ovicaprid domestication occurred exclusively in the Zagros region.

Separation of plant and animal domestication in time and space in many ways simplifies the analysis of a complex situation (Hole, 1984) and is possibly academic wishful thinking. The generation of many models with myriad variables influencing early Neolithic human behaviour suggests that reality was in fact far more complex than any of the models imply. This realization is consistent with the maturation of scientific inquiry wherein relationships among identified variables are never as simple as they at first appear. The earliest development of agricultural subsistence occurred within specific cultural contexts and local environments in the Near East, a region of complex topography and climate. This set up localized conditions that facilitated changes in human behaviour and in relationships between humans and non-human inhabitants. A finding of skeletal evidence of ovicaprid-borne zoonoses in Ganj Dareh inhabitants would support a conclusion of intensified interactions among humans and goats and lend credence to the hypothesis that ovicaprid domestication was in progress in the central Zagros region ca. 7,000 bc.

3.3 Early Models

Early Models of the transition to agriculture incorporated many implicit assumptions (reviewed in Moore, 1985; GA Wright, 1971). The appearance of permanent architecture meant complete sedentism. In turn, sedentism was equated with agricultural subsistence. This theoretical stance invoked environmental determinism, that is, changes in environmental conditions dictated the types of changes that could occur in human societies. In addition, agricultural subsistence was thought to be preferable to a hunter/gatherer existence so that where climate permitted, the progression to agriculture was assumed to be a natural progression. This teleological thinking supported the idea that modern food-producing economies were the inevitable and necessary outcome of changes in human behaviour once the appropriate technology was acquired (Braidwood and Howe, 1960). Pastoralism was postulated to be a highly specific subsistence strategy that is dependent on the existence of, and trade with, plant cultivators nearby (Gilbert, 1982) rather than a direct outgrowth of hunter/gatherer interactions with non-human inhabitants of mutual environments.

The importance of the subsistence transition from Palaeolithic hunter/gatherers to civilizations of southeastern Mesopotamia had been recognized by the 1930s (Childe, 1934) forming the basis of the Oasis Hypothesis of the 1940s and 1950s (Childe, 1952). The Oasis Hypothesis assumed that increasing aridity accompanied the temperature increases following the last pleniglacial. Childe's work (1952), highly influenced by the excavations of Kathleen Kenyon (1953) at Jericho, suggested that plants, animals and humans were forced to concentrate in the vicinity of oases such as Jericho. Dense stands of wild cereals would be harvested as a source of food. Through selective harvesting, morphological changes that are associated with domesticated grains would ensue. In addition, ovicaprids, goats and sheep, could easily have been tamed at oases. Provisioning of the animals and domestication were the inevitable results (Childe, 1952). However the Oasis Hypothesis did not provide a mechanism for the human behavioural transition. At the time, it was sufficient to invoke the implicit assumption that agriculture was a better subsistence strategy than hunting and gathering, and would thus ultimately be invented.

In contrast to the Oasis Model, Braidwood (Braidwood and Howe, 1960) argued that there was no evidence to support increasing aridity in the Near East at the end of the Pleistocene. His theoretical work, the Nuclear Zone Hypothesis, was based on his excavations at Karim Shahir and Jarmo in the foothills of the Zagros Mountains of eastern Iraq. It suggested that domestication occurred within the natural habitat of the domesticated species rather than at oases. Only after humans gradually developed the technology required for grain and caprine exploitation could agricultural subsistence be pursued although wild potentially domesticated resources were previously present. Two stages in the transition were proposed: incipient agricultural villages without permanent architecture such as Karim Shahir (Braidwood and Howe, 1960; Howe, 1983), and permanent agricultural villages such as Jarmo (Braidwood, 1983; Braidwood and Howe, 1960).

In the 1960s, in keeping with the current environmental determinism, climatic change was an essential component of the transition to agricultural subsistence. HE Wright (1968) suggested that at the end of the Pleistocene there was a climatic shift to warmer and wetter conditions (cf. warmer and drier proposed by the Oasis Hypothesis

(Childe, 1952)), allowing expansion of cereals into the foothills of the Zagros. Establishment of increasing early Holocene resources provided the ecological basis for postulation of increasing population sizes in the Near East, laying the foundations for the subsequent emergence of population pressure models of agricultural origins and Flannery's (1969) broad spectrum revolution.

3.4 Population Pressure Models

Through the 1960s major developments in diverse disciplines coalesced with the development of the population pressure models of agricultural origins. Contributing components include developments in palaeoclimate analysis (Wright, 1968), formulation of relationships among population size, fallow crop periods and agricultural technology (Boserup, 1965), and between sedentism and reproductive physiology (Frisch and Revelle, 1970) and the ecological concept of carrying capacity of the environment (Odum, 1971). The separation of sedentism and agriculture, the archaeological evidence of increasing population size in the Zagros (Smith and Young, 1983), that is increases in site number and site size, and the importance of the technological base of human populations played large roles in formulation of population pressure models (Flannery, 1972; Smith and Young, 1972).

The ecological approach adopted from biological studies of ecosystem dynamics (Odum, 1971) suggests that each environment and its components can support a finite maximum population. Application of ecological models to origins of agriculture research (HE Wright, 1968) concurred with Braidwood's analysis that, at the end of the Pleistocene, warmer and wetter conditions prevailed in the Near East. This facilitated expansion of forests from local refugia. The concomitant expansion of wild cereals into the foothills of the Zagros was postulated to provide an increased resource base for local human populations and result in increased population size. However more recently, the steppe forests, the natural habitat for cereals, are shown to have expanded much later in the Zagros than in the Levant (Hole, 1984). This is consistent with recovery of the earliest evidence for increased intensity of cereal exploitation from sites in the Levant (Bottema, 1986; van Zeist, 1967; zan Zeist and Bottema, 1977; van Zeist and Woldring, 1978). Other than in local refugia, cereals would not be expected to figure prominently in the diets of human inhabitants in the Zagros.

As a population increases in size and the carrying capacity of the environment is approached, some form of change is postulated to occur. A lack of human intervention could result in starvation of a portion of the population and/or a lowered birth rate. A return to lower population levels with no change in technology or subsistence strategy would result. Alternately, migration of a segment of the population could alleviate the population pressure on the environment, again with no change in technology or subsistence strategy. Both of these scenarios are proposed to account for the continued existence of arctic and subarctic hunter/gatherer populations. In contrast, Near Eastern hunter/gatherers responded in a fundamentally different manner by changing subsistence technology and ultimately subsistence strategy. The results of Near Eastern behavioural changes resulted in increased carrying capacity of the local environments. An important factor contributing to differing outcomes in the Arctic and the Near East is the sedentism of Near Eastern Epipalaeolithic hunter/gatherers (Smith and Young, 1972). This explanation is consistent with the gradual shift from the earlier models to the recognition in the 1960s that hunter/gatherers could be sedentary (Flannery, 1972).

Sedentism has been inferred in the archaeological record through the analysis of settlement patterns (Mortensen, 1972), architecture, lithics, bone and ground stone artefacts and burials (Henry, 1985; Moore, 1982; Redding, 1988). More recently, sedentism has been recognized through the identification of increasing frequencies of human commensal organisms such as the house mouse, house sparrow and rat (Tchernov, 1991). The year-round occupation of sites in the Levant has also been suggested from the season of death of gazelles, determined through the analysis of incremental markers in dental cementum (Lieberman, 1993).

The addition of sedentism to the population pressure and climate amelioration model (Smith and Young, 1972) incorporates the Critical Fatness Model (Frisch and Revelle, 1970). Assessment of the relationship between critical body weights and fertility in modern adolescents had suggested that sedentism disrupts reproductive physiology (Frisch and Revelle, 1970). Sedentism may thus contribute to the population pressure through a biological mechanism that causes increased female fertility. Levels of body fat above a critical proportion of body mass facilitate a more rapid return to menstruation after childbirth (Frisch and Revelle, 1970; Frisch and McArthur, 1974). If sedentism is also associated with an increased percentage of body fat, then sedentism would effectively shorten the birth interval, increasing fertility and thus population size. In skeletal samples increased fertility would be seen as a higher proportion of infant and young children (Jackes, 1994; Sattenspiel and Harpending, 1983). However, inter-population differences in critical body fat levels, methodological errors in the original studies and many inter-related variables affecting fertility call these relationships into question (Scott and Johnson, 1982). With increased sedentism, the absolute level of body fat may be less important than proportional change in fatness, that is, deviations from the former population norm. The relationship among fertility, body fat and subsistence strategy is highly complex and population and context specific. The adoption of a sedentary lifestyle is not necessarily followed by an increase in body fat or fertility (Bentley, Goldberg and Jasieńska 1993; Bentley, Jasieńska and Goldberg, 1993; Howell, 1979). Wood (1990) suggests that mechanisms affecting fertility are behavioural rather than physiological, although high workloads and malnutrition in intensive agriculturists can negatively affect fertility. Although the relationships among sedentism, birth spacing and population growth are far more complex than initially thought, the Critical Fat Hypothesis is nevertheless historically important in its contribution to the development of population pressure models of agricultural origins.

In addition to the focus on sedentism and reproductive physiology, location of optimal food resources was an important component of analyses (Binford, 1968; and Flannery, 1969). In the early Epipalaeolithic, the resource base exploited in the Near East expanded. A similar variety of resources recovered from later Neolithic archaeological sites, such as Ali Kosh ca. 7,500 to 6,700 bc, resulted in the formulation of Flannery's (1969) broad spectrum revolution concept. With climate warming at the end of the Pleistocene (amelioration from a human perspective), the intensive exploitation of an increased number of resources resulted in increased population in the core zone of optimal resources. However, in contrast to the earlier Nuclear Zone Hypothesis of Braidwood (Braidwood and Howe, 1960), Flannery (1969) suggested that pressure exerted on the intensively exploited resources by an expanding population would be felt most severely in marginal areas. If agricultural pursuits began in response to resource stress, it would be expected in ecologically marginal zones. As people were forced to leave optimal areas, familiar plants and animals of the nuclear zone might also be moved. Through human intervention, the local carrying capacity could be increased. Over time, this would lead to the adoption of agriculture in marginal areas through processes of human agency (Binford, 1968; Flannery, 1969).

The Marginal Zone Hypothesis assumes that human intervention was required to increase the productivity of these marginal regions or to increase the success of the potential domesticates in areas to which they are not native. It provided the motivation for change in subsistence strategy as well as a criterion for recognizing early domestication, the appearance of potential domesticates in regions to which they were not native. Moreover, it suggests that once the move to the marginal zone is made, a return to the core region cannot happen without a decrease in overall population (Binford, 1968; Flannery, 1969). In a time of wide climate fluctuations (COHMAP Members, 1988), marginal zones would not be limited to physically peripheral regions but could be due to environmental catastrophe in isolated ecozones. Local nuclear zones could rapidly become marginal zones, eliminating the need to postulate population migration. This expanded the regions where early domestication was thought to have occurred (see below for the significance of this).

In the mid 1980s Hole (1984) introduced two additional concepts into the exploration of the origin of agriculture. Firstly, he suggested that domestication of plants and animals were spatially and temporally separate events. Evidence of plant use by at least 13,000 bc has been inferred from the strontium/calcium rations of the human skeletal remains recovered from the site of Kebara (Schoeninger, 1981), and evidence of grinding tools and sickle blades, indicative of wild cereal use, is present throughout the Epipalaeolithic in the Levant. This is consistent with recent archaeological evidence and refined radiocarbon dating of sites (Hole, 1984, 1989) that suggest that the centre of cereal domestication was in the Levantine hills rather than in the foothills of the Zagros. In contrast, in the Taurus and Zagros, where a longstanding tradition of cereal processing is suggested to be absent (Hole, 1984, but see archaeological evidence in Chapter 6), early analyses of strontium/calcium ratios suggest a much higher meat component in the diet than in the diet of Levantine Natufian complex hunter/gatherers. However, the strontium levels in the Ganj Dareh bones are much higher than those in the Levantine samples, potentially skewing the results (Schoeninger, 1981). Although Perkins (1964) suggested that the sheep at Zawi Chemi, ca. 9,000 bc were from managed herds, his interpretation is not widely accepted (Zeder, 2000). In spite of this, many researchers have concluded that caprine domestication occurred in the Zagros rather than in the Levant (Hole, 1984, 1996; Zeder, 2000).

Secondly, Hole (1984) suggests that changes in subsistence strategy result in changes in the interrelationships between humans and their environment. These behavioural changes are only suggested to be accommodated when concomitant changes are made in social organization (Hole, 1984) (cf. changes in technology of the Nuclear Zone Hypothesis (Braidwood and Howe, 1960)). The concept of social changes is elaborated on in more recent social models of Hayden (1990), Rosenberg (1990) and Kuijt (2000). Redding (1988) suggests that no single factor may be adequately invoked as the cause of the adoption of agricultural subsistence. Rather, subsistence transition occurs along a continuum of behaviour that is influenced by many diverse factors. Redding's (1988) model proposes four stages of behavioural responses that occur as population increases approaching the carrying capacity of the local environment (Figure 3.1). In a simple hunter/gatherer society, Stage I, the response to population pressure is emigration. However, as hunter/ gatherer societies become more complex,

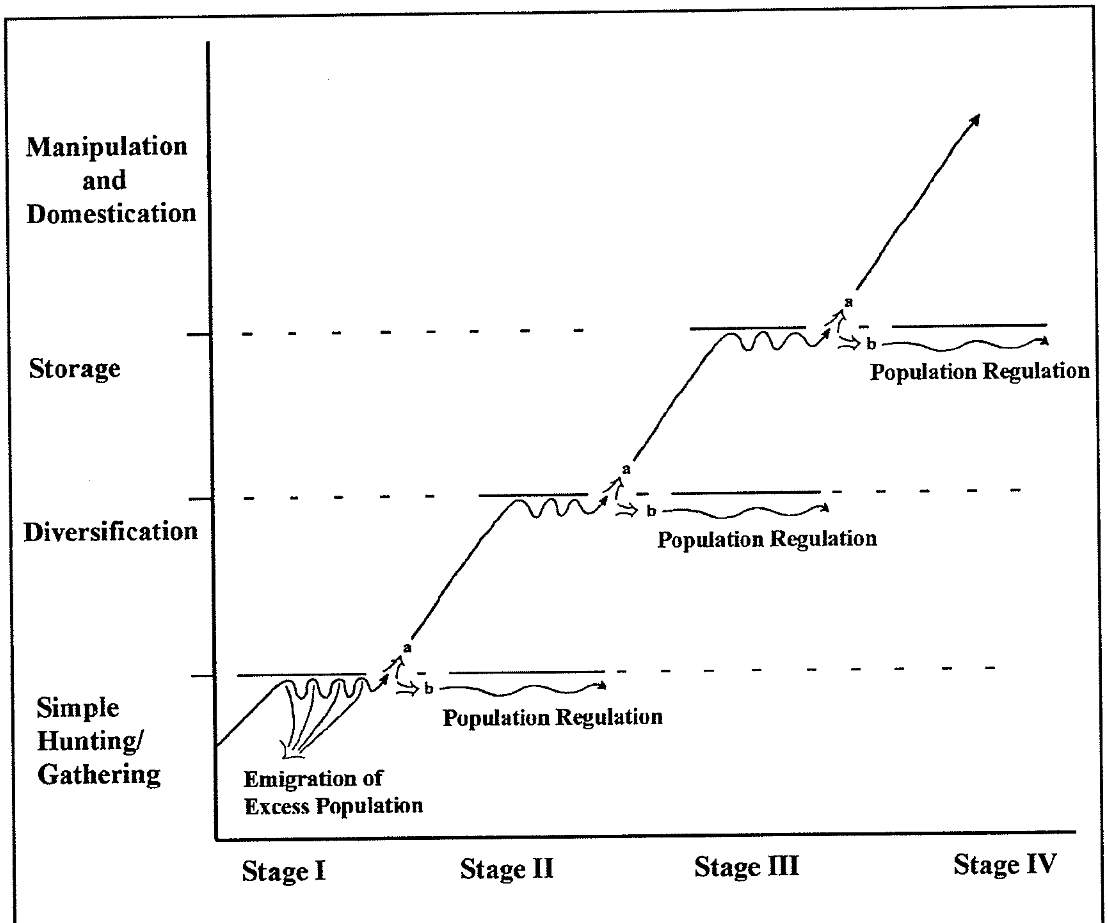

Figure 3.1. Stages of behavioural response to increasing population (y axis). Modified from Redding (1988:76,79).

diversification, Stage II, allows further increase in population size. This is observed by 20,000 bc in the archaeological record as the increased resource variety (Flannery's

(1969) broad spectrum). Further increase in local carrying capacity, Stage III, by 9,000 bc is indicated by the presence of storage facilities at Zawi Chemi (RL Solecki, 1983; RS Solecki, 1963) and Karim Shahir (Braidwood and Howe, 1960; Howe, 1983). The final stage, Stage IV, in this proposed continuum is the manipulation of resources and the eventual domestication of plants and animals. Only with animal and/or plant domestication can population size continue to increase beyond that which the carrying capacity of a non-agricultural economy would allow (Redding, 1988).

The transition from hunting and gathering to agricultural subsistence can be also envisioned as two separate transitions (Henry, 1985; Hole 1996). The first and more behaviourally profound transition from simple to complex hunting and gathering is accompanied by the shift to sedentism. Based on archaeological evidence from the southern Levant, sedentism developed during the Epipalaeolithic. Specifically, the Geometric Kebaran and Mushabian cultural traditions ca. 13,000 to 9,000 bc are thought to be simple hunter/gatherers with circulating, unspecialized camps (Henry, 1985), Stage I of Redding's (1988) Model above (Fig. 3.1). The Natufian tradition ca. 10,500 to 8,500 bc is interpreted, from the radiating pattern of base and satellite camps, as being complex hunter/gatherers (Henry, 1985; for more detailed discussion see Perlès and Phillips, 1991). Early Natufian sites fit Redding's Stage II, whereas, the Late Natufian sites are thought to be Stage III (Fig. 3.1). In contrast, the adoption of agricultural subsistence, by definition occurring in the early Neolithic, can be envisioned as merely an elaboration of the Natufian sedentary complex hunting and gathering traditions (Henry, 1985) and fits Redding's (1988) Stage IV classification. Although the archaeological evidence from any given site can fit within Redding's (1988) framework, present theoretical stances reject its implicit progressivist viewpoint by recognizing that the readoption of hunting/gathering subsistence is indeed possible and is observable in the archaeological record (Rowley-Conwy, 2001).

In contrast to the long slow timeline of Redding's model of population increase, other researchers (Birdsell, 1953; Diamond, 1987; Boone, 2002) have suggested that hunter/gatherer populations can increase far more rapidly. If this had happened in the Fertile Crescent beginning at 20,000 bc as suggested above, and it potentially could have (Boone, 2002), archaeological evidence of storage facilities (Redding's Stage III) would be expected at sites in the middle Epipalaeolithic at Geometric Kebaran sites rather than at the earliest at Zawi Chemi ca. 9,000 bc in the late Epipalaeolithic. This calls into question population pressure as the prime mover of the subsistence transition in the Fertile Crescent.

Most complex hunter/gatherer societies identified have relatively short duration, 2,000 to 3,000 years at most, and have been dated to the terminal Pleistocene (Henry, 1985). In a progressivist view, their position in the culture history sequence between simple hunter/gatherers and agricultural societies suggests that the properties of complex hunter/gatherer systems are integral to the subsistence transition. Their short duration could indicate that the social organization is inherently less stable than that of their predecessors the simple hunter/gatherers. However, the instability has also been attributed to the geographical limitations of sedentism when fluctuations in local resources cannot be resolved through migration (Henry, 1985). In addition, social organization of complex hunter/gatherers is not more inherently unstable than that of simple hunter/gatherers or agriculturists. Where resources are extremely abundant and the threat of over-exploitation is minimal, for example on the North American Northwest Coast, complex hunter/gatherers endured (Hayden, 1990). These observations in sedentary societies and the recognition of the importance of social mechanisms for dealing with the scalar stress of sedentism have lead to a revamping of models of agricultural origins to include important cultural variables.

3.5 Social Models

Recent models of the origins of agriculture are based on the intensification of the social system and the acquisition of specialized knowledge (Hayden, 1990; Rosenberg, 1990). Social models propose different social responses to climatic, demographic and environmental changes thought to have occurred at the end of the Pleistocene. Hayden (1990) suggests that no increase in population size or resource stress occurred to elicit changes in behaviour. The adoption of agriculture is proposed to have been the result of behavioural strategies that increase prestige. In contrast, Rosenberg's (1990) model can be classified as a population pressure model as well as a social model. Increased population and resource stress are suggested to result in the development of territoriality and resource ownership.

The adoption of agricultural subsistence is proposed to be a consequence of social reorganization and increasing levels of social complexity that in already sedentary communities resulted from attempts to diffuse stress in an atmosphere of climatic and environmental instability. Social systems, especially in small-scale societies, are thought to be conservative by nature and may not rapidly embrace change. When a social system is under pressure, elaborate systems for maintaining the "status quo", that is an egalitarian social system (Kuijt, 2000) are invoked. However, the systems may not be wholly effective and may, in fact, facilitate social change while trying to maintain the norm. Social models suggest that the shift to food production may have been the unintended result of changes that were initially meant to maintain the hunter/gatherer social system.

The Accumulator model (Hayden, 1990) assumes that domestication developed as a result of behavioural strategies that increased prestige in the context of food abundance and growing social complexity. It suggests that all humans actively seek wealth and power by collecting, and then controlling the allocation of prestige-creating goods. Prestige may be increased through the conspicuous destruction of wealth. Hayden (1990) suggests that the first domesticates may have developed as non-essential prestige items. Thus although their accumulation and destruction would not compromise group survival, the potential for broad changes in social organization were created (Hayden, 1990). In the Zagros, as the oak-pistachio steppe-forest expanded out of the pleniglacial refugia, acorns become a obvious candidate for a non-essential prestige food resource, as do the possibly domesticated pigs at Hallan Çemi (Rosenberg et al., 1998). In creating a scenario for agricultural origins in regions of resource abundance, Hayden (1990) has set the Accumulator Model within the Nuclear Zone of Braidwood (Braidwood and Howe, 1960), albeit without the necessity of postulating population increase and subsequent resource stress.

Rosenberg's Territoriality and Allocation Model (1990) suggests that population increase at the end of the Pleistocene led to resource stress. The conflicts and animosity that ensued over wild food resources resulted in the development of territoriality, constraints on mobility and ownership of the specific resources. Rather than being non-essential food items as in the Accumulator Model (Hayden, 1990), the Allocation Model postulates specific resource characteristics essential for the generation of territoriality. For example the resources must be relatively predictable, occur in high density and have the capacity for expansion (Rosenberg, 1990). The stands of oaks that were expanding in the Levantine hills in the late Pleistocene (Baruch and Bottema, 1991; van Zeist and Woldring, 1980) are good candidates for such resource ownership and the development of territoriality (Rosenberg, 1990). Given the habitat preference of wild cereals of the oak pistachio parkland (Harlan, 1998), the expansion of desired oak parkland resource acorns would be associated with a concomitant expansion of cereal resources in the Levant. The exploitation of cereals may have been initially adjunct to the territorialization of food resources and only later allocated (Rosenberg, 1990). The archaeological evidence of ancestor worship that developed in the early Neolithic (such as burials beneath floors, and skull caching (Hole, 1984)) is consistent with the development of territoriality (Rosenberg, 1990) and increasing cultural complexity (Kuijt, 1996, 2000) thus fitting both the Accumulator and Allocation Models.

The degree of water-intensive processing required before acorns can be used suggests to me that the wild cereals may have been the preferred oak parkland resource around which territoriality could develop rather than the acorns themselves. However, although ethnographic analysis of grain processing in modern Turkey suggests that grain processing is no less labour intensive (Hillman, 1984), early Holocene and modern methods may not be exactly comparable. Adding to the complexity of interpretation, acorns could easily be a prestige item in times of abundance leading to territoriality or a food of last resort in situations of resource stress, again leading to territoriality.

In the late Pleistocene ca. 13,000 bc at Lake Huleh (Baruch and Bottema, 1991) and ca. 9,000 at the more northerly Lake Ghab (Baruch and Bottema, 1991; van Zeist and Woldring, 1980), a wide variety of ecological niches opened (McCorriston and Hole, 1991). This may have facilitated the adaptive radiation of wild cereals that are adapted to the expanding oak-pistachio forest. In the Zagros this forest ecozone expanded much later, ca. 7,000 bc in the vicinity of Lake Urmia (Bottema, 1986) and ca. 6,000 bc at Lake Zeribar. These findings are consistent with a much later adoption of cereal cultivation in the Zagros (Hole, 1984) that has important implications for interpretation of the Ganj Dareh data.

Social models also invoke the concept of scalar stress, induced by crowding (Johnson, 1982), in their interpretations of behavioural changes at the origins of agriculture (Belfer-Cohen and Bar-Yosef, 2000; Hayden, 1990; Rosenberg, 1990). Scalar stress increases as the number of face-to-face interactions increases. It is resolved in hunter/gatherers by fissioning to maintain small group size. Factors that influence group spacing include: the population density of the region, the resource base and carrying capacity of the region, and the technological base of the population. However, the maintenance of former group spacing cannot continue indefinitely, especially when faced with increasing territoriality and constraints on mobility. Maximum group spacing will eventually be controlled by the development of territorial boundaries. As the environment's carrying capacity is reached, if migration is not an option, the alternatives are to starve or increase the intensity of resource exploitation (Rosenberg, 1990). Internal scalar stress may be alleviated through increased ceremonial feasting that is either similar to or less competitive in nature than that proposed in the Accumulator Model (Hayden, 1990).

In an alternate hypothesis, Johnson and Meiklejohn (n.d.) integrate components of both the Accumulator and Territorial Models with the concept of external scalar stress. As resource intensification develops in nuclear zones, territoriality ensues as groups in the surrounding marginal zones encroach on the nuclear zone's abundant resources. To alleviate the tension among neighbouring groups, cultural systems of ceremonial feasting and exchange emerge.

3.6 Recent Alternatives to and Extensions of Social Models

In contrast to social models, the Exorphin Model provides a biological basis for the increased expenditure of energy needed for the transition to agricultural subsistence (Wadley and Martin, 1993). Staples of an agricultural diet, cereals and milk products, have been shown to contain psychoactive substances, exorphins, which activate the reward centres of the brain. Exorphins may produce feelings of reward, motivation, reduced anxiety, and a general sense of well-being. If cereals and dairy products are not natural human foods, Wadley and Martin (1993) suggest that consumption of these products in increasing amounts may be addictive. Thus, addiction to the opioids in cereals and milk could reduce the scalar stress in developing specialized hunter/gatherer societies, and provide the rationale behind the behavioural and social changes required to effect the subsistence transition that would ensure reliable supplies of the addictive products (Wadley and Martin, 1993). The Exorphin Model is also consistent with cereals and milk products being prestige food items of the Accumulator Model (Hayden, 1990). The inferred decline in health status at the origins of agriculture (Cohen and Armelagos, 1984a, 1984b) may suggest that the relatively rapid adoption of agricultural foods was driven by pharmacological rather than nutritional motives (Wadley and Martin, 1993).

Although the Exorphin Model could partially explain the continuance of intensive agriculture that had already developed, it does not provide motivation for initiation of the behaviour in hunter/gatherers nor does it provide evidence for such early use of secondary food products such as milk. By ignoring the archaeological context of preagricultural peoples, the model would require that wild plants be the primary foods of the Epipalaeolithic inhabitants of the Levant and the Zagros. However, the vast quantities of faunal remains, in the Levant (see for example Davis, 1983; Legge, 1972; Legge and Rowley-Conwy, 2000) and in the Zagros (Hole and Flannery, 1967; and summarized in Zeder, 2000), suggest that plant foods did not comprise a sufficient proportion of the diet to induce the proposed exorphin addiction.

The Exorphin Model is also not consistent with the growing consensus among skeletal biologists that the severity and direction of health responses to the subsistence transition is varied and site-specific (Larsen, 1995, 1997; Meiklejohn and Zvelebil, 1991; Milner and Katzenberg, 1999). Evidence used by Wadley and Martin (1993) for the decline in health is based primarily on the analyses in Cohen and Armelagos (1984a). Specifically in the Zagros, decline in health was demonstrated between Epipalaeolithic and Chalcolithic populations. This compares the health of hunter/gatherers with intensive agriculturists, not incipient agriculturists or incipient pastoralists. As Waddell (1994) has shown using cortical bone growth, there appears to be little difference in health status between Epipalaeolithic and early Neolithic populations in the Zagros. In addition, although it may have contributed to the change in subsistence, taken alone, the Exorphin Model is a version of biological determinism, negating roles of human agency and culture in changes in behaviour.

In contrast to the social models discussed above wherein changes in social organization are proposed to facilitate subsistence transition (Hayden, 1990; Rosenberg, 1990), Ingold (1996a, 1996b) suggests that modern Western metanarrative drives explanations of the adoption of agriculture, and specifically pastoralism. The Western separation of humans from nature and the concomitant language that describes humans acting upon nature obscures the possibility of alternate worldviews. Ethnographic examples of human relationships with the natural world indicate that humans, herds and crops are integral reciprocal components of each other's environments. Humans do not act upon or transform nature but act within it, establishing and attempting to maintain positive relationships with the guardian spirits of cohabitants of their mutual environment (Ingold, 1996b). Ingold effectively argues that cultivation of plants and herding of animals cannot be seen as humans producing products in the sense of manufacturing. Within the context of agricultural and pastoral pursuits, although humans provide the conditions that facilitate herd and crop growth and development, all living beings participate in the same world. The rise of humans above nature, as described in Western thought, has been a relatively recent development. This has special significance when the subsistence transition is framed as a change from food collecting to food producing. We use language that does not accurately describe the relationships between early Neolithic humans and the non-human inhabitants of their mutual environment. This in turn has the potential to limit our ability to entertain theoretical formulations within which the early Neolithic subsistence transition occurred.

By extension, if worldviews in the Zagros of the early Neolithic embedded humans securely within the natural realm of the world, the development of pastoralism and agriculture may not have been as earth-shattering a revolution to the people involved as Childe (1934, 1952) proposed or as rapid as the word 'revolution' implies. In fact, a major shift in the way humans viewed the world around them may not have been a necessary development. In this scenario, local climatic fluctuations in a topographically varied region, increased seasonality and increasing snows, might have precipitated extinctions of local caprine populations (Hole, 1996). Following local extinctions, the territorial nature of goats could have prevented them from moving rapidly into recently vacated regions. Hole (1996) suggests that, rather than move, local humans may have introduced wild caprines into their local territory. People could then continue to maintain equitable relationships with the goat guardians without the necessity of major investments of time and resources involved in village relocation that would include mud-brick manufacture and new dwelling construction. This would be particularly relevant if human territoriality had begun to develop as Rosenberg (1990) suggests. This would effectively maintain the local 'natural' social balance among all inhabitants of the region, that is the social *status quo,* without necessitating migration or the exploitation of new food resources. Thus this would also maintain dietary norms. The proposed human agency would bring people into closer contact with the goats as they tried to prevent the relocated goats from returning to their former territory, in effect unconsciously changing the relationships between humans and caprines in what Hole (1996) terms Food Resource

Management. This would place incipient pastoralists within the local nuclear zones hypothesized by Braidwood (Braidwood and Howe, 1960). Thus, caprine domestication in the Zagros may have been the unexpected and unplanned outcome of concerted efforts to maintain the natural order of the world. This echoes the thesis (Zohary et al., 1998) that the process of morphological domestication of ovicaprids was due largely to unconscious selection pressures created in early pastoralist communities. In addition as this scenario does not require early Neolithic population expansion in the high Zagros it is consistent with Smith and Young's (1983) site surveys in the Ganj Dareh region suggesting that extensive population expansion only occurred in the late Neolithic well after abandonment of Ganj Dareh.

Theoretical assumptions inherent in the models and their formulation within modern Western culture can hinder analysis and interpretation of archaeological evidence. These include: the equation of permanent architecture with both sedentism and agriculture, the inevitability of the development of agriculture in areas where resources and climate allow, the dependence of pastoralism on the presence of established cereal-based plant-cultivating economies, and as discussed in the next section, the definition of domestication in both plants and animals, the criteria used to infer behaviour divergent from hunting and gathering and the development of pastoralism.

3.7 Subsistence Changes

3.7.1 Domestication

The last theoretical issue to be addressed for an integrative analysis of the Ganj Dareh human remains is domestication: its definition and its recognition in the archaeological record. Domestication is not only a state of being, that is, the end result of morphological changes, but is also a process of interactions between humans and the plants and animals (Hecker, 1982; Miller, 1992; Olsen, 1979).

Domestication can be divided into two processes: the initial cultural control of the potential domesticate, which may be difficult to recognize archaeologically, and the later acquisition by domesticates of morphological differences from their wild ancestors that are more easily recognizable archaeologically (Hecker, 1982). Cultural control includes interference with the breeding schedule of both plants and animals (Hecker, 1982), and conceptual changes in the perceived relationship between humans and animals (Ingold, 1974, 1996a). The control of plants and groups of animals, which removes them from their natural environment and breeding schedules and introduces care and provisioning, can change the structure of their population and gene pool. This increases animal accessibility and facilitates breeding of animals in captivity. Although morphological changes are an outcome of human agency (Hecker, 1982), there is a growing awareness for both plants and animals that the subsequent morphological changes associated with domestication were the unintended consequences of the changing relationships between humans and the domesticates (Hillman and Davies, 1990; Zohary et al., 1998). Ultimately changes in morphology and size of ovicaprids, wheat and barley resulted and are observed at Ali Kosh (Flannery, 1969; Zeder, 2001) that was occupied some 500 to 1000 years later than Ganj Dareh (Zeder and Hesse, 2000).

Below is a brief introduction to plant and animal domestication relevant to the Near East and specifically for the Zagros region (discussion of archaeological evidence for plant and animal domestication in the Zagros is discussed in more detail in Chapter

6). Archaeological criteria for recognition of cultural control and domestication are introduced. These include changes in population structure of protodomesticated animals and changes in seed morphology and size of plants. In addition, the recovery of remains from sites that are not within the potential domesticate's natural habitat or ecozone has been used to indicate cultural control. However, given that the climate and environment of the early Holocene differed from that of the present (COHMAP Members, 1988), discerning the natural ranges of wild species for comparison with their distribution in archaeological sites is problematic.

3.7.2 Botanical Remains:

The criteria for recognition of cultivated cereals include changes to the fruit (seed) and stalk (rachis) (Miller, 1992). Individually, seeds become larger. In addition more grains per seed stalk increase the number of grains and thus the yield of edible carbohydrate and protein per plant. When wild seeds ripen, their stalks become brittle and seed disarticulation leaves distinct, complete scars. In contrast, seed stalks in the domesticated forms of the same species are less fragile and large internode fragments are left adhering to the disarticulation scars (Kislev, 1989; Kislev et al., 1992). These changes keep grain spikelets intact during harvest. The natural process of seed dispersal is bypassed thereby increasing harvest yields (Miller, 1992; Warnock, 1998). These changes are postulated to be the unintentional result of changes in harvesting techniques (Hillman and Davies, 1990). Experimental harvesting of wild cereals suggests that the changes associated with domestication do not occur unless certain husbandry methods such as harvesting before the seeds are fully ripe are adopted. This reduces selection pressure for effective seed dispersal that maintains brittle rachis morphology at high levels in the gene pool, for example at 90% in modern wild barley (Kislev, 1989; Kislev et al., 1992). If practiced, these methods can result in changes from wild to domestic morphology in as few as 20 to 30 years so that archaeological recovery of intermediate forms is not expected (Hillman and Davies, 1990). Although early results suggest that wild and domesticated grains can be distinguished through chemical analysis of seed lipid concentrations, delineation of the process of plant domestication is not yet straightforward and may be virtually invisible in the archaeological record (Hillman et al., 1993).

The above criteria have been developed for wheat species. However, morphological distinction between wild and domesticated barley recovered from archaeological sites such as Ganj Dareh is less clear-cut (Kislev, 1989; Kislev et al., 1992). Fragmentation of the rachis, attributed to domesticated barley (Bor and Guest, cited in Kislev, 1989), occurs in up to ten percent of modern wild barley stands, diminishing its usefulness as a diagnostic criterion for domestication. In addition, in a comparison of barley recovered from early Neolithic and Chalcolithic sites in the middle Euphrates valley a clear temporal gap is observed between grain size increase and predominance of "domesticated" rachis morphology in the samples (Willcox, 2004). In samples for example at Ganj Dareh where very few rachis fragments are available for examination, the presence of "domesticated" rachis morphology in some of the remains and large seed size cannot be taken as diagnostic of the presence of domesticated barley as had previously been suggested by van Zeist and colleagues (1984).

Miller (1991, 1992, 1996) has introduced further interpretive debate into botanical analysis suggesting that archaeobotanical materials are not necessarily the remains of human food. Before widespread application of flotation methods to soil samples, most floral material was limited to macroremains clearly visible during excavation. With the use of flotation, widespread areas of sites can be examined for botanical remains, expanding the potential uses of plant material recovered, including animal dung fuel, ovicaprid bedding and provisioning materials and serendipitous local plant materials. Although remains are no longer assumed to represent human foodstuffs alone, Miller's (1991, 1992, 1996) view on the primary source of charred seeds from early Holocene archaeological contexts have been, by no means, universally accepted (Hillman et al., 1997).

3.7.3 Faunal Remains

The general criteria for the recognition of domesticated animals include: morphological and body size changes, the occurrence of morphologically wild animals outside their natural geographic range, a change in population structure such as the selective slaughter of young animals, especially males, and an increase in pathological conditions (Crabtree, 1992; Hecker, 1982; Legge, 1996; Olsen, 1979).

A decrease in bone and tooth size has been used to infer animal domestication (Crabtree, 1992; Hecker, 1982; Legge, 1996; Olsen, 1979; Payne and Bull, 1988). However, in caprines (goats and sheep) size differences between wild and domesticated counterparts are less dramatic than for other species domesticated such as cattle. Recognition of the change in status may be confounded by differences in sexual dimorphism within species before and after domestication. Large within-sex variation and/or large overlap of female and male metric ranges may limit data interpretation. In modern wild goats, latitudinal variation in size has been observed in faunal samples from the Near East (Zeder, 2001; Zeder and Hesse, 2000). Thus, size may indicate geographic or sex differences in addition to changes in human-animal economic and subsistence relationships.

If animals recovered from archaeological sites, such as Ali Kosh in the Piedmont, are thought not to be in their natural range, this may suggest domestication (Olsen, 1979). However, determination of the "natural" range for species in the past may be problematic, particularly in the Near East where rapid changes in altitude, climate and vegetation occur over very short distances (Zohary, 1973). Animal manipulation may also be observed as changes in slaughter patterns (Hesse, 1982; Payne, 1968; Zeder, 2000, 2001) that precede the genetic and morphologically observable changes that distinguish domesticated animals from their wild ancestors. If the animals are selectively hunted in the wild, a potential bias might be expected in the faunal assemblage towards the very young and the very old (Payne, 1973). In contrast, if herds are under human manipulation, herd manipulation and culling of selected animals results in distinctive mortality curves that reflect the economic goals of the herders (Hesse, 1982; Payne, 1968, 1973; Zeder, 2000, 2001). For example, from Payne's (1973) models (Fig. 3.2), mortality curves with high proportions of sub-adult males, and older females would suggest a strategy emphasizing meat production (Fig. 3.2A), whereas samples comprised mostly of infant and young juvenile males would indicate milk production (Fig. 3.2.B).

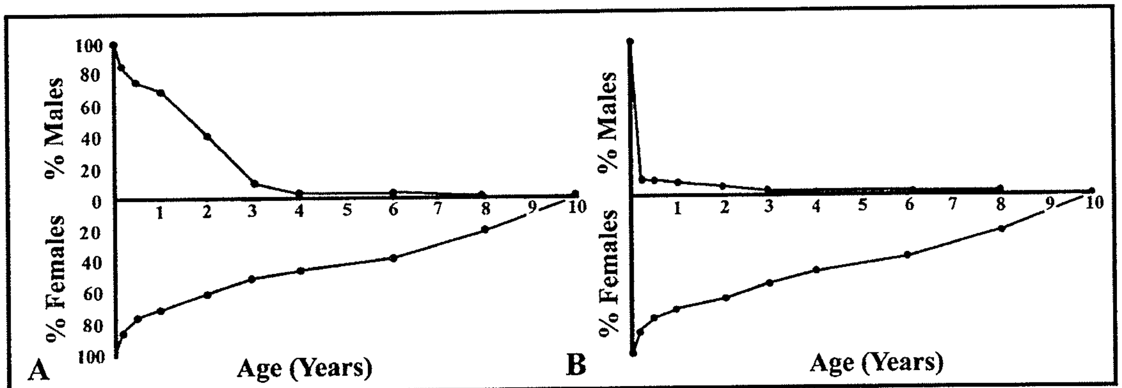

Figure 3.2. Goat mortality curves reflecting the economic goals of the herders. A. Meat production. B. Milk production. (Modified from Payne, 1973).

Change in species abundance through time has also been used to indicate domestication. At sites such as Ali Kosh ca. 6,750-6,000 bc, change through time from a predominance of goat remains to a predominance of sheep in the faunal assemblages is associated with morphological changes that also suggest domestication (Flannery, 1969). In addition, evidence of live animals within the village boundaries when the village is still occupied by humans suggests that the animals were at least comfortable with humans in close proximity. The classic example of this criterion is from Ganj Dareh, where goat hoof prints were observed in the mud bricks used in house construction (Smith, 1972). Increases in pathology due to work-related stresses, decline in sanitary conditions as herd sizes increase, and/or increased ease of transmission of disease, have also been associated with domestication (reviewed in Crabtree, 1992).

Early resource manipulation can be difficult to identify from both floral and faunal remains and is open to differing interpretations. For example, the smaller size of domesticated goats observed in the later levels at Ali Kosh could have resulted from human selection for smaller animals in controlled herds, small size of the animals in ancestral herds or as a response to adverse climatic conditions at Ali Kosh (Zeder and Hesse, 2000). However, the use of multiple lines of evidence can facilitate the interpretation of archaeological evidence and the construction of chronologies of the development of the food-producing economies of the Zagros/Piedmont region.

3.7.4 Pastoralism

The study of pastoralism can be approached from diverse perspectives: relating to human settlement patterns, uses of the animals, relationships between human and non-human animals that share an environment, and human behaviour of decision-making and risk management strategies. From a modern perspective pastoralism is a form of subsistence strategy based on the herding of domestic animals that are kept as property (Chang and Koster, 1986). Galaty and Johnson (1990) distinguish between the use of unimproved pasture and fodder provisioning, although as with other means of characterizing pastoralists, variation exists in local emphasis on these methods of feeding livestock. Wide variation occurs in terms of strategies for herd management and degree of mobility. In addition no types of social organization are found exclusively in pastoralists (Salzman, 2002; Spooner (1973) cited in Chang and Koster (1986) and Crawford and Leonard (2002)). The degree of modern variation in all aspects of life in modern pastoralist communities in the Zagros (Salzman, 2002) makes the recognition of pastoralist economies in the archaeological record problematic.

Pastoralism is thought to be an effective means of adaptation to "marginal" environments such as the steppes through its use of animals in conversion of low quality plant resources into higher quality animal based foods (Crawford and Leonard, 2002). However, Salzman (2002) does not tie pastoralism solely to marginal environments. In fact he characterizes the Zagros Mountains as being rich habitats that do not necessitate either pastoralism or nomadic settlement strategy for survival (Salzman, 202:255). This effectively reduces the persuasiveness of environmentally deterministic explanations for the development of pastoralist economies in the early Holocene. More complex models are required that include multiple factors and allow for variation in cultural and individual behavioural preferences in adaptive responses to climatic instability and changing macro- and microenvironments.

Animal domestication furnishes two fundamentally different classes of products of use to humans: those provided while the animals are alive such as dung for fuel and fertilizer, milk, blood, and wool, and those obtained only after death of the animal such as meat, sinew, bone and hides (Ingold, 1996b; Sherratt, 1981, 1983). In addition, the process of domestication causes and results in changes in relationships between animals and humans. Whereas animals in the wild belong to no one, as increasing control over animals proceeds, the animals and their offspring belong to individual humans or to social groups of varying composition. Both the living adult animals and their offspring can be utilized to establish and further social relationships among humans (Ingold, 1996b) and in this way extend the animals' value as living beings.

"Risk and uncertainty can be expected to play a particularly important role in human decision-making about subsistence" (Stein, 1989:87). For all living beings, food is necessary for survival. However, food availability is variable in most environments (Stein, 1989), and specifically in the steppe environment of the Zagros/Piedmont in the context of early Holocene climatic instability (COHMAP Members, 1988). Circumstances in a particular region and cultural context can result in unique solutions to the ever-present problems of earning a living. Minimization of risks of subsistence failure is a prevailing goal that can be attained with varying degrees of success through the adoption of multiple strategies (Salzman, 1996; Stein, 1989) including reliance on a wide variety of resources: the resource diversification of the Broad Spectrum Revolution (Flannery, 1969), mobility (development of vertical economies such as those of the Zagros and Taurus Mountains), and the development of strategies of resource storage. These strategies parallel the behavioural responses proposed by Redding (1988) to increasing population that ultimately resulted in the adoption of agriculture emphasizing that, while exhibiting substantial inter-site variability, the archaeological evidence is consistent with multiple hypotheses of agricultural origins.

The issue of pastoralism in the Zagros has been indirectly addressed archaeologically in terms of early animal domestication through search for the presence of animal manipulation, morphology of domestication, settlement patterns, and changes in social organization and ideology that might reflect changing relationships between humans and proto-domesticates. Much early work explicitly on pastoralism (Gilbert, 1982; Henrickson, 1985) explores the later development of specialized transhumant pastoralism that assumes prior establishment of agricultural economies and an inherent dependence of pastoralists on agriculture. However, pastoralism as demonstrated in modern Iranian pastoralist subsistence strategies (Salzman, 1996, 2002) is a flexible and variable adaptation to diverse environments existing in close proximity to each other. This is consistent with Waddell's (1994) extensive synthesis of subsistence in the Zagros, finding there is scant evidence for plant cultivation in the Zagros until the Chalcolithic. The bioarchaeological assessment of human health of inhabitants of the early Holocene Zagros environment can be compared with the published human biology of modern pastoral populations (for example in Leonard and Crawford, 2002) to provide insight into the development of pastoralist subsistence strategies (discussed in Chapter 7).

3.8 Summary of Theoretical Modelling

From the wide diversity of theoretical stances developed to explain the origins of agriculture, it can be seen that many variables such as resource availability, climatic and environmental fluctuations, degree of sedentism and relationships between human and non-human inhabitants, contributed to the early Neolithic changes in human behaviour in the Near East. As will be demonstrated in Chapter 6, evidence from each site fits to varying degrees with each of the models. This observed inter-site variability calls for a multifactorial model similar to the Biocultural Model of Health that is used to model health in past populations. Indeed, use of a bioarchaeological approach is well-suited to exploration of subsistence transition in the Near East, a region of rapid changes in topography and ecological diversity over relatively short distances (see Chapter 4 for discussion of geography and present and palaeo-climate of the Near East).

One conceptual disadvantage of models of the transition to agriculture is their development within a world in which agricultural subsistence is known and on which most of the world's present human population is dependent. It is difficult to envision a world without plant and animal domestication and without the accompanying knowledge and cumulative expertise. This is exacerbated by the academic Western world view of archaeologists that, as Ingold (1996a, 1996b) proposes, is embedded in a conceptual world of Cartesian dichotomies. Of particular importance to this discussion is the very modern view that places humans above and separate from the remainder of the natural world. Archaeologists make their living "writing archaeology". This is analogous to the situation of cultural anthropologists "writing culture", where the text effectively reflects the writer's world view rather than that of the text subjects (Clifford, 1986).

In an ideal world the task would be to create testable hypotheses that effectively eliminate knowledge of the modern world around us, specifically the reality of agriculture and pastoralism. Since scientific method and the testing of hypotheses are products of Western world view, separation of archaeological thought from the knowledge of the existence of agriculture is not entirely possible. However, there are strategies for archaeologists that can minimize the effects of "writing archaeology". Acknowledgement of the problem is of primary importance, with follow-up to include new terminology for the subsistence transition and close examination of modern non-Western views of the relationships between human and non-human inhabitants of mutual environments.

In "writing" the archaeology of subsistence transitions, wording is of critical importance to minimize the insertion of inherent assumptions. For example, the "adoption" of agriculture implies that the outcome is known and that the people involved in the transition have visible choices of "agriculture" and "not agriculture".

Examination of ethnographic accounts of the relationship between modern non-Western agriculturalists and their environment, both cultivated and natural, suggests that in most other cultures this division does not exist. Thus the world was probably not perceived as such in the early Neolithic (Ingold, 1996a, 1996b). The challenge is to construct and test viable models for plant and animal domestication while acknowledging differences in world view between the "studiers" and the "studied" and taking into account that the Neolithic people were going about their daily activities without the foreknowledge of agriculture and pastoralism. This does not negate the role that human agency played in the subsistence transition, but rather posits that the perception of early Neolithic inhabitants of the Near East was that they were merely taking advantage of local opportunities to maintain what in their world view was "normality". It is within this context that the bioarchaeological analysis of the Ganj Dareh skeletal sample is conducted.

At present there is still no single generally acceptable model that adequately explains the origins of agriculture. Although there is agreement that the climatic conditions of the Near East were unstable (COHMAP Members, 1988; Wright, 1993), and that hunter/gatherer populations of the Near East were becoming increasingly sedentary (Flannery, 1972; Henry, 1985; Redding, 1988; Tchernov, 1991), there is no consensus on the nature of population size changes, the factors motivating human behavioural changes or the resource availability in the populations that were adopting agricultural subsistence. Over the last 20 years, the pace of archaeological excavation in the Levant has overshadowed that in the Zagros, such that much of the work on the origins of agriculture has been done in the Levant. The apparent paucity of sites in the Zagros may have been taken in part as evidence that the Levant was the centre of domestication, whereas the Zagros/Piedmont region was peripheral to the Neolithic Revolution. Discovery of three sites within a 7 km radius of Ganj Dareh (Smith and Mortensen, 1980) and recent excavations at Hallan Çemi, Qermez Dere and Nemrik (Watkins, 1998) suggest that the Zagros/Piedmont was more highly populated in the Epipalaeolithic/early Neolithic than had been previously thought (Smith and Mortensen, 1980; Watkins, 1998) and invites renewed analysis, such as the present study, of the role that populations in the Zagros/Piedmont played in the transition to pastoralist and agricultural subsistence.

CHAPTER 4. THE FERTILE CRESCENT: THE PHYSICAL ENVIRONMENT

4.1 Introduction

The transition from food-acquiring to food-producing occurred many times throughout the world. Archaeological evidence for its occurrence has been recovered from sites in the Near East that date to the Pleistocene – Holocene boundary[1]. This chapter provides the geographic context for the transition to agricultural subsistence in southwest Asia, an upland to mountainous region that has long been known as the Fertile Crescent. Discussion of the geography is necessary for understanding the regional ecology and its influences on past human behaviour (Meiklejohn, 1993).

A unique suite of physical, environmental and cultural factors combined in the Fertile Crescent to facilitate the adoption of agriculture. The Fertile Crescent is a large area of contiguous landforms that are topographically very diverse. However, the close proximity of the component regions and exposure to the same atmospheric circulation patterns dictate that the climate and environment of each region cannot be understood in isolation. In addition, evidence for palaeoclimate reconstruction (presented in Chapter 5) comes in large part from pollen profiles of sediment cores, most of which are located around the periphery of the Fertile Crescent. Interactions of climatic variables among the areas of the Near East and their influences on the climate of the Zagros are essential for reconstruction of the palaeo-climate and environment of the Ganj Dareh region in the early Holocene.

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[1] The issue of other separate geographic origins near the Pleistocene – Holocene boundary is not significant for this thesis.

4.2 Geography of the Fertile Crescent

4.2.1 Introduction

The Fertile Crescent, at the eastern end of the Mediterranean Sea, is defined by a long arc of mountains with their associated foothills and surrounding lowlands (Bar-Yosef, 1996). It extends between the latitude of 30°N to 38°N. In longitude, the region encompasses from 35°E in the west, the southern Mediterranean coast of Israel, to 50°E,

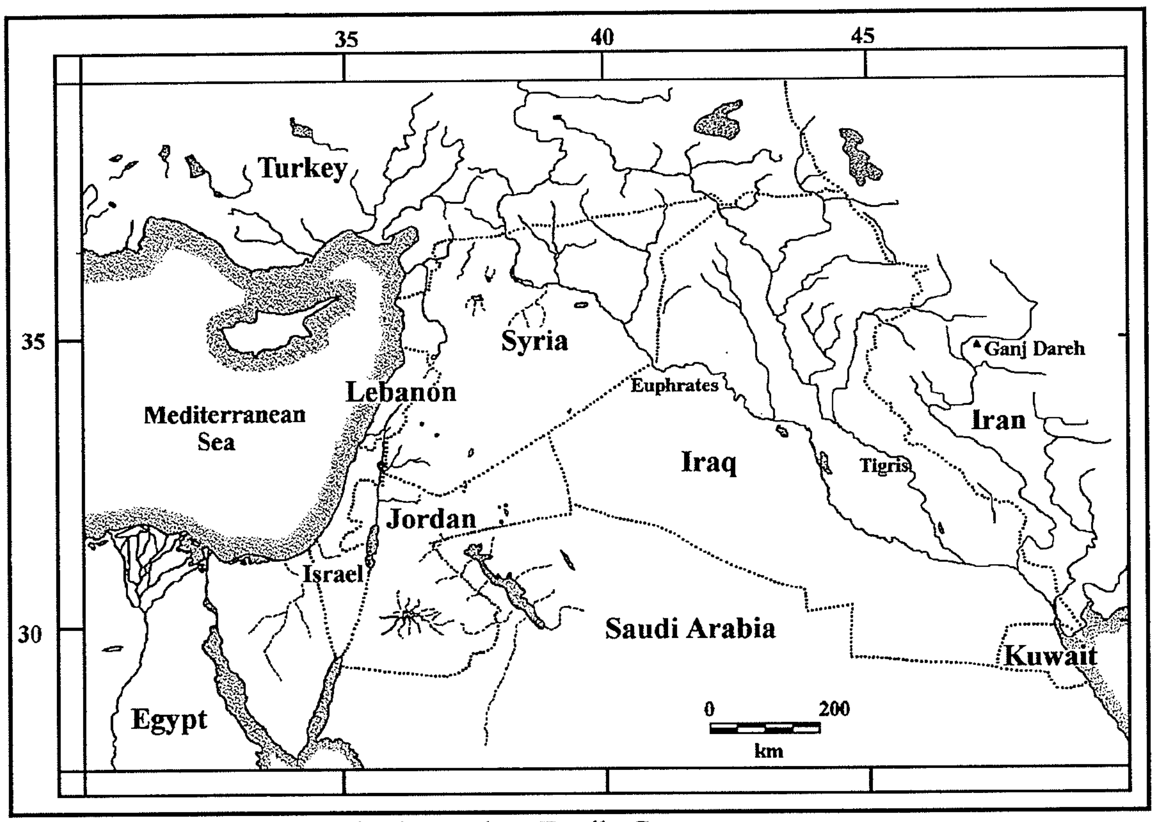

Figure 4.1. Political states in the modern Fertile Crescent.

the western end of the Persian Gulf. It is divided in the modern world into a number of political entities (Fig. 4.1).

The landforms of the Fertile Crescent are complex (Zohary, 1973), and reflect its geological past. Topographically the region includes high mountains of elevations to 5,000 meters, as well as the Dead Sea depression, 400 meters below sea level. The transition between these two extremes includes high plateaus, alluvial lowlands, fresh and salt-water lakes, and desertic regions with sand dunes. Soil salinity increases in regions with high rates of transpiro-evaporation (Zohary, 1973) limiting agricultural potential. The flow of the major river systems is directed by the local topography of the mountain systems. Thus local areas within the Fertile Crescent are characterized by highland – lowland dichotomies (MacNeish, 1991).

Southwest Asia is divided into three structural zones: the more northerly Irano-Anatolian folded zone, the southern Nubo-Arabian crystalline block and an intermediate

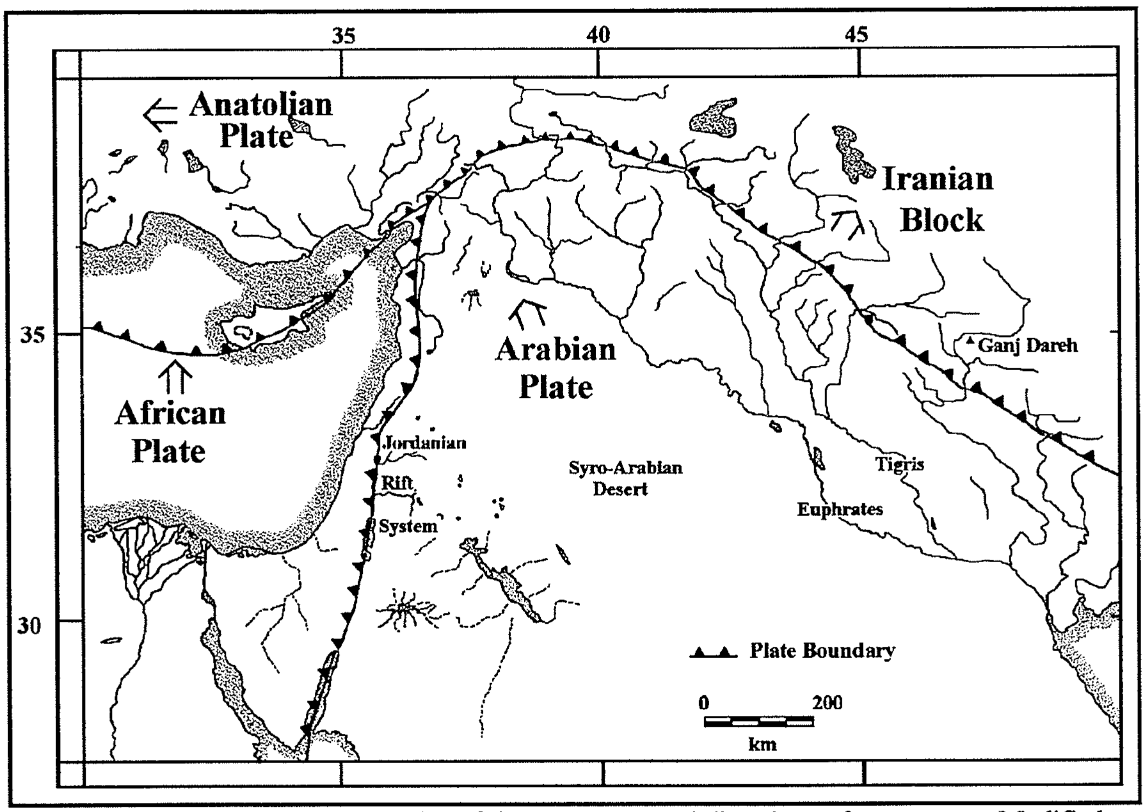

Figure 4.2. Tectonic plate boundaries of the Near East and directions of movement. Modified from Hamblin and Christiansen (1995).

zone. The region is at the juncture of four continental plates: the Anatolian, African, Eurasian and Arabian (Fig. 4.2). Movement of these geological plates is integral to the formation and topography of the area. The resulting tectonic activity is reflected in regions of volcanic cones, lava flows and the Jordanian rift system and resources such as basalt and obsidian (Zohary, 1973).

The Irano-Anatolian folded zone, the Iranian block, is composed of sedimentary strata from the bed of the ancient Tethys Sea that extended between the ancient continents of Gondwana, remnants of which remain as the African and Arabian plates, and Angara, the Anatolian Plate. Through the process of uplifting and folding, a long series of mountain ranges were formed, extending from the Pyrenees to the Himalayas, including the two northerly sections of the Fertile Crescent, the Taurus and Zagros Mountains. The Taurus Range of southern Turkey comprises poorly ordered mountains, the alignment of which has been extensively disturbed by faulting and the movement of landmasses. The Zagros Mountains extend southeastward from the Taurus range as a series of orderly folds of parallel ridges and intermountain valleys.

The Nubo-Arabian crystalline block makes up the southern regions of the Fertile Crescent. Within this geological structure are a series of mountains of much lower elevation than the higher more northerly Zagros and Taurus Mountains, the Syro-Palestinian Highlands. These mountains parallel the eastern coast of the Mediterranean Sea and define the western boundary of the Jordanian Rift System.

The final structural region, the Intermediate Zone, spans the region between the Nubo-Arabian crystalline block and the Irano-Anatolian folded zone. This forms a transitional zone of undulating alluvial plains and other relatively flat regions drained by the Euphrates and Tigris Rivers (Zohary, 1973).

Within each of these broad regions are a series of landforms that include lava flows, tuffs, boulders and plains of basalt, folded zones of mountains, stream valleys and depressions. Regions of calcareous plateaus, characterized as either hard limestone or soft chalks and marls, influence the local soil types and their formation rates. The Nubian sandstone uplands predominate in the southern Fertile Crescent, and are the source of sand in southern Israel, Jordan and Iraq. Coastal plains are not well developed within the region and do not figure prominently in the reconstruction of the regional prehistory (Zohary, 1973:6-7).

In addition to being categorized by geological structures, the Fertile Crescent is divided into three primary geographic regions: the Levant, Anatolia and the Zagros Mountains (Fig. 4.3). The Levant is bounded on the west by the Mediterranean Sea, to

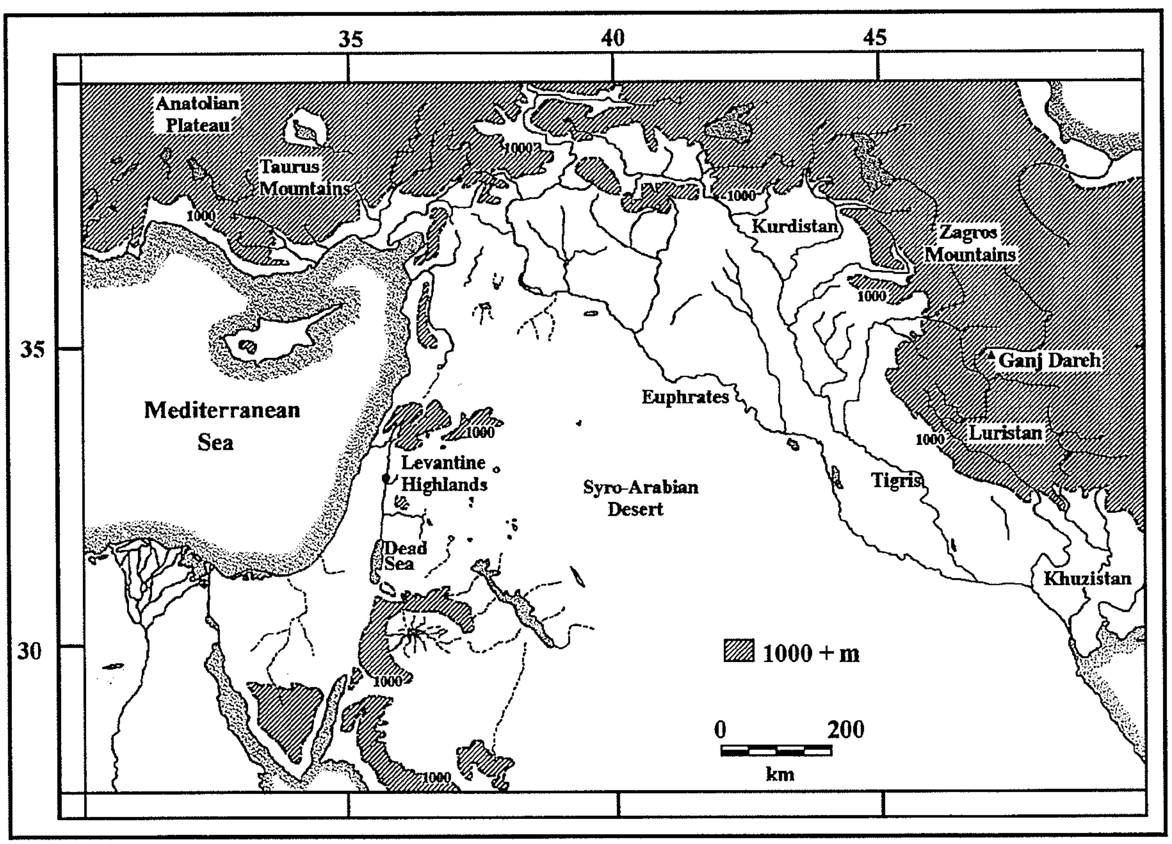

Figure 4.3. Geographic regions of the Fertile Crescent.

the south by the Gulf of Suez and the Gulf of Aqaba, to the east by the Syro-Arabian Desert and to the north by the Taurus Mountains. Anatolia encompasses the southern half of the modern country of Turkey. The Zagros is the easternmost region. It extends from the Taurus Mountains in the Northwest to the Persian Gulf in the southeast. To the northeast, the Zagros is bounded by the central Iranian plateau and to the southwest by the southern alluvium of the Euphrates and Tigris Rivers (Zohary, 1973).

The geographic and topographical diversity of each of the three primary regions of the Near East: the Levant, Anatolia and the Zagros, provide for a wide variety of local microenvironments within which the earliest transition to agricultural subsistence occurred. The rapid changes in altitude and microclimate over short distances makes the Near East well suited to the development of diverse vertical economies (Redman, 1978).

4.2.2 The Levant

The Levant is divided into four geographic zones that run parallel to the Mediterranean coastline: coastal plain, hill zone, rift valley and the Jordanian Plateau. This creates substantial east-west diversity of environment and climate. However, there is considerable uniformity along the north-south axis of the Levant (Henry, 1989) allowing characterization of east-west altitude-precipitation relationships (Fig. 4.4). The coastal plain varies in width, soil types and amount of annual precipitation from north to south (Henry, 1989). Although precipitation on the northern coast, 500-1000 mm annually, is suitable for the growth of cereal grasses in the high carbonate soils, frequent cliffs limit areas suitable for agricultural use in prehistory (Henry, 1989). The wider more arid southern coastal plain is primarily silicaceous sands, indicating the region's

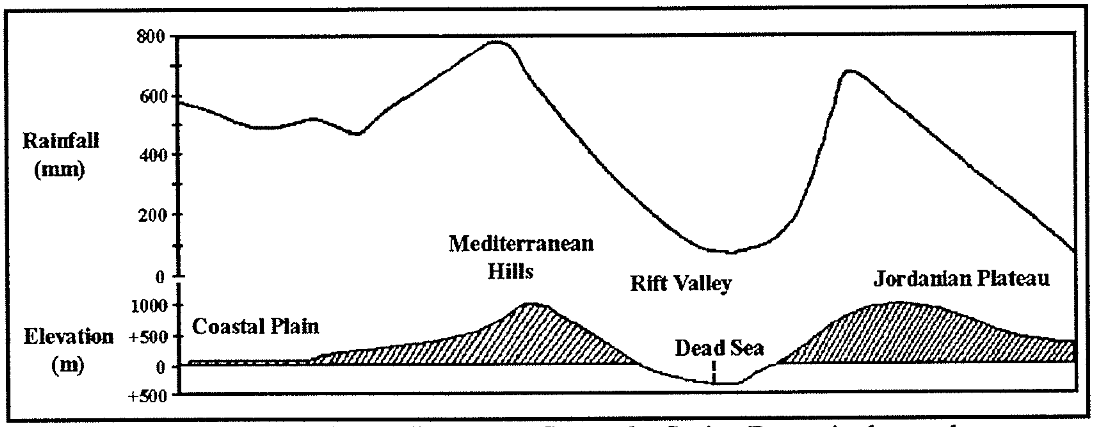

Figure 4.4. Transect from the Mediterranean Sea to the Syrian Desert in the southern Levant showing the changes in elevation and the associated changes in precipitation. (modified from Zohary, 1973:25).

origins in the Nubo-Arabian geological zone. Sandstone ridges that parallel the coast separate coastal dunes from a series of swamps (Henry, 1989) so that although there are regions of fertile alluvial soil (Zohary, 1973), the southern coastal Levant was also of limited agricultural potential.

Inland are the Mediterranean Hills created when the African and Arabian landmasses collided (Henry, 1989). This ridge of mountains extends from southern Turkey in the north to the central Negev in southern Israel. The Mediterranean Hills average 1300 meters in altitude, with peaks to 3,000 m (MacNeish, 1991:126). Soils are derived from Cretaceous limestone and dolomite, sources of high quality flint for tool manufacture. Interspersed among the regions of calcareous soils are basalt outcrops that indicate the volcanic history of the region (Henry, 1989).

The Levantine Rift System divides the hill zone in the west from the Jordanian plateau (Henry, 1989:60). The southern rift valley extends from the Gulf of Aqaba to the Huleh basin, the site of pollen cores that have been integral to our understanding of past Near Eastern climate (Baruch and Bottema, 1991). Within the central basin of the rift system, the soils are highly saline, reflecting the high rates of evapo-transpiration and the elevation below sea level. The northern region is bisected by a series of rivers that arise in the Anti-Lebanon Mountains (Jebel esh Sharqi) including the Orontes, Litani and Jordan (Fig. 4.5). The rift system, in the rain-shadow created by the Mediterranean Hills, is an environmental mosaic of desert, oases and lakes (MacNeish, 1991:126).

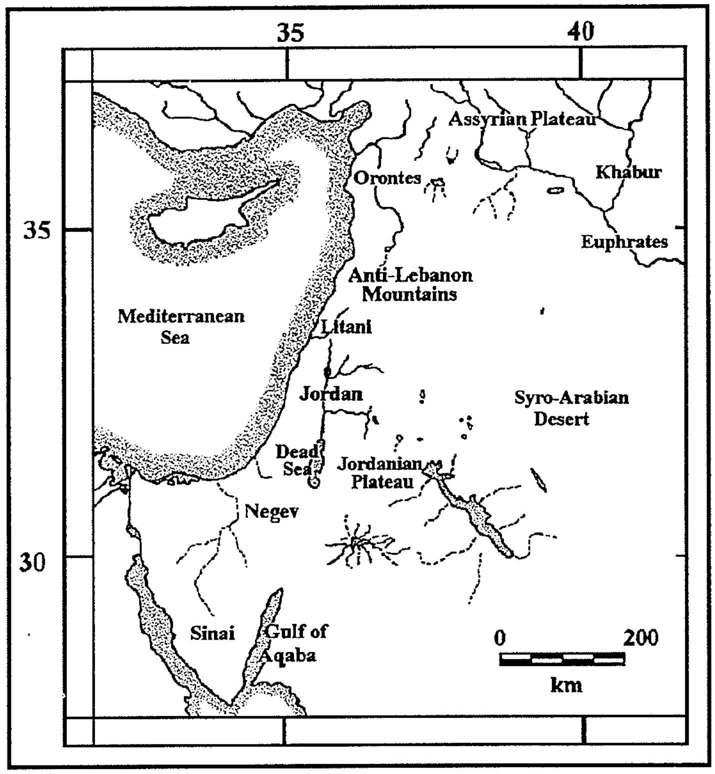

Figure 4.5. Landforms of the Levant.

East of the rift valley is the Jordanian Plateau, produced by uplifting during the Oligocene and Miocene. Limestone, dolomites and sandstone predominate, with some regions of basalt (Henry, 1989). The steep western slopes have a Mediterranean climate, while the plateau slopes towards the east to form a transitional zone between the Mediterranean Hills and the Syro-Arabian Desert (MacNeish, 1991). The undulating northern expanse of the plateau, with an elevation of 300-450 m, forms a ecological and cultural bridge connecting the southern to the northeastern Levant (Moore, 1988) and thus to Anatolia and the Zagros. This transitional region, the Assyrian Plateau, is drained by the middle and upper reaches of the Euphrates River and the extreme upper Tigris River. This plateau, cut by wadis and perennial tributaries such as the Khabur River, is composed of moderately alkaline soils that tend to accumulate calcium carbonate and gypsum concretions. Cracks that open to a depth of 70-100 cm in the dry season fill in during the wet season, enhancing soil fertility (Wilkinson, 1989). Across the Assyrian Plateau, the rivers meander creating areas suitable for agriculture, interspersed with saline basins that mark the ancient river course (Miller, 1980).

4.2.3 Anatolia

As in the Levant and the Zagros, Anatolia (Fig. 4.6) is characterized by a highland-lowland dichotomy (MacNeish, 1991). Rapid changes in altitude result in

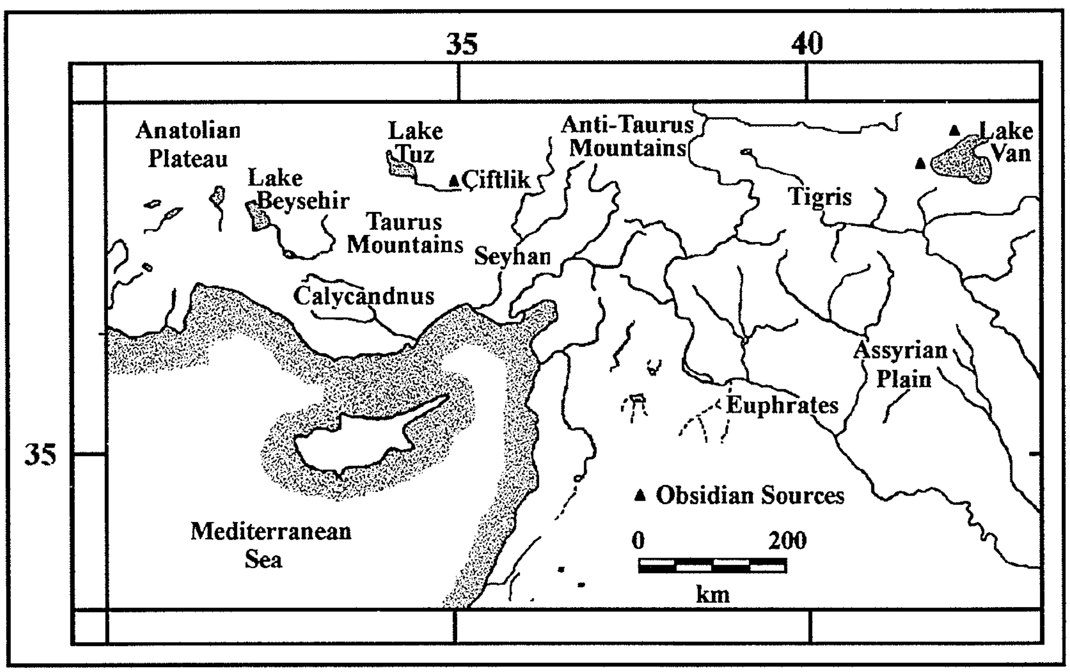

Figure 4.6. Landforms of Anatolia. The obsidian sources of Çiftlik and Lake Van reflect the tectonic activity of the region.

ecological diversity and seasonal variation. The Anatolian mountains, north of the eastern end of the Mediterranean Sea, are part of the Irano-Turanian folded system.

Irregularly-oriented ridges are interspersed with a complex arrangement of deep valleys and high and medium altitude plateaus. To the north of the mountain systems in Central Anatolia is a rolling plateau, 900-1200 m in elevation, with undrained basins that form salt flats and saline lakes such as Tuz (Zohary, 1973). Farther south in the Taurus Mountains, freshwater lakes such as Beysehir occur (van Zeist et al., 1975).

From west to east, the mountain ranges of Anatolia are the Taurus, Anti-Taurus, and Zagroso-Kurdistan Mountains. Some peaks in the Taurus range are snow-capped year-round. Short rivers such as the Calycandnus and Seyhan drain the Taurus of southern Anatolia to the Mediterranean Sea. The Seyhan River flows between the Taurus and Anti-Taurus Mountains, separating the western from the eastern sources of obsidian (Fig. 4.6). To the east, the Anti-Taurus range merges with the Kurdish Alpines and the Zagros mountain system. The Kurdistan Mountains are drained by the Euphrates and Tigris rivers that flow south then east across the Assyrian Plain and the Mesopotamian Lowlands to the Persian Gulf. The upper reaches of the Euphrates and Tigris were well populated in the late Epipalaeolithic and early Neolithic. Sites such as Mureybet, Abu Hureyra, and Jerf el Ahmar on the Euphrates and Çayönü, Hallan Çemi, Nemrik 9 and Qermez Dere in the Tigris watershed provide substantial evidence of transitional subsistence activities that supply contextual backdrop for analysis of the Ganj Dareh site and skeletal sample.

4.2.4 The Zagros

As in the Levant, the Zagros region consists of a series of long narrow geographical zones: a low plateau, foothills, and highlands resulting in a lowland-highland dichotomy of environment and climate (similar to that illustrated in Fig 4.4). This transition occurs over a distance similar to those in the Levant and Anatolia, creating similar potential for the development of vertical economies and adaptations. In the Zagros, at each elevation there is little geographic variability from NW to SE, that is, there are long narrow ecozones. However, following a SW to NE trajectory, there is wide ecological variation, with a series of western slopes with high precipitation and eastern rainshadows. The distance from the Mediterranean Sea and proximity to the large central Asian land mass create distinctly continental versions of the Levantine ecozones (Zohary, 1973).

The low plateau, a southeastern extension of the Assyrian Plain of the northeastern Levant, is a flat plain 35 - 300 m in elevation, through which the Euphrates and Tigris flow towards the Persian Gulf. The eastern-most region is the Khuzistan plain: a series of alluvial fans deposited by the Karkheh, Karun and Diz rivers. These rivers grade into marshes. To the southwest beyond the Euphrates and Tigris, the marshes give way to desert sand dunes (MacNeish, 1991). Further to the northwest are the Luristan and Kermanshah Plains. Ganj Dareh is in the upper reaches of the Kharkeh River valley at the eastern extreme of the Kermanshah Plain. The Kurdistan piedmont and highlands (Fig. 4.7) are drained by a series of rivers including the Diyala, the Lesser Zab and the Greater Zab.

The Zagros foothills form ridges with a northwest to southeast orientation that generally parallel the Tigris and Euphrates. The elevation of the foothills ranges from 500 to 1500 m. The ridges increase in altitude with increasing distance to the northeast of the Tigris, where they eventually grade into mountains of 800-2500 m, altitude with peaks to 5,000 m beyond this. These mountains, barriers to the storm tracks from the west, create rain-shadows in the intervening fertile valleys, deep gorges and intermountain plains. On the windward side of the ridges, the precipitation increases

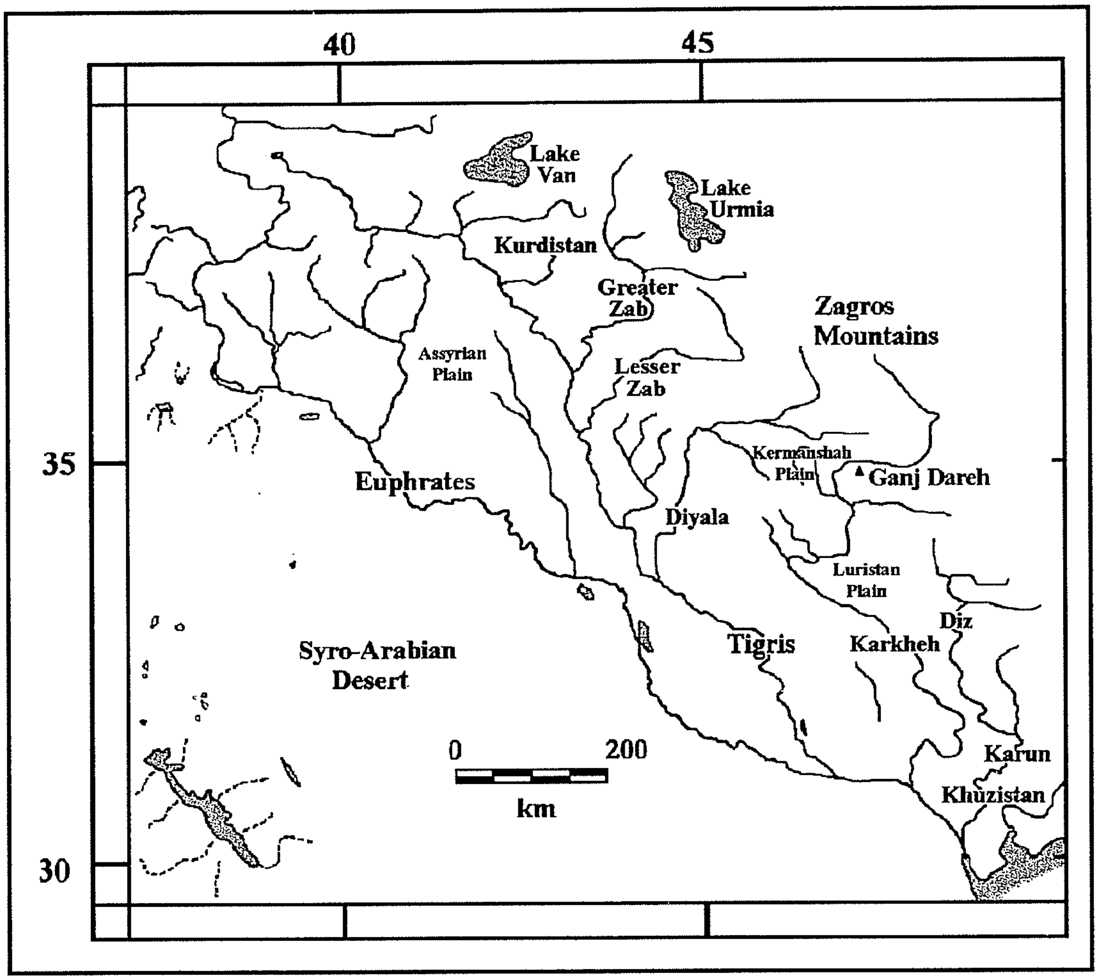

Figure 4.7. Landforms of the Zagros.

with elevation. Annual precipitation ranges between 500 and 1000 mm (MacNeish, 1991; van Zeist and Bottema, 1977), equivalent to that of the Levantine Coast.

CHAPTER 5. PALAEOCLIMATE RECONSTRUCTION

5.1 Introduction

In bioarchaeological perspective, environmental conditions together with the geographic characteristics of a region (provided for the Zagros/Piedmont in Chapter 4) provide the physical setting within which people live. Reconstruction of the climate and environment of the Near East, specifically the Zagros/Piedmont region, situates the archaeologically detectable changes in human behaviour that occurred in the early Holocene in physical context and facilitates approximation of the potential physical variables that influenced the lives and health of the Ganj Dareh inhabitants.

Climate of a region has a substantial impact on its human inhabitants including their health. It comprises an important component of the physical environment, influencing the flora and fauna of the region, the types, quantity and quality of food and shelter resources available and consequently the types of adaptations that are possible and successful. Specifically in the high central Zagros, rate and extent of change of climate and vegetation following the last pleniglacial have important consequences for the inhabitants of Ganj Dareh and the theoretical modelling of the subsistence changes.

Establishment of the palaeoclimate and palaeoenvironment at the time of occupation of Ganj Dareh contextualizes the human skeletal remains, facilitating analysis of early Neolithic human behaviour. This provides a means of assessing if the Ganj Dareh hinterland ca. 7,000 bc were nuclear or marginal, eliminating some models of agricultural origins from further consideration. Multiple interpretations of the frequencies of non-specific indicators of stress can be reduced to a few if it is known whether the Ganj Dareh people were experiencing periods of resource abundance or stress. If oak parkland had been established by ca. 7,000 bc, then the presence of acorns and grains would be expected, generating expectations for the potential development of territoriality and cereal cultivation. In addition, knowledge of the climatic and vegetation conditions, in combination with topography, geographic location, are necessary for assessment of the range of potential floral and faunal domesticates inhabiting the Ganj Dareh region ca. 7,000 bc.

This chapter introduces the global and local factors that can affect climate and explores their roles in the generation of climatic conditions and ecological systems of the Near East. The lines of evidence used in palaeoclimate reconstruction are introduced with reference to global climate modelling and the climate of southwest Asia. Climate of the Zagros/Piedmont region will then be reconstructed for the early Holocene and specifically for the early eighth millennium bc (uncalibrated) when Ganj Dareh was occupied. The unique geographic and climatic characteristics of the Near East are assessed for their potential as the physical components of liminal spaces wherein changes in human behaviour ultimately facilitated the adoption of agriculture.

5.2 Factors Influencing Climate

Many global, regional and local factors interact to affect the climate of a given region (Zohary, 1973:Vol 1). Global influences include the extent of world glacial coverage, orbital factors that govern the Milankovitch cycles, and global atmospheric and oceanic circulation patterns. At the regional level in the Near East, latitude, distance from the Mediterranean coast, and altitude are the major determinants of climate. Local microenvironments are also created by rain-shadow effects, wadi location, local moisture and water table levels, and year-to-year variation in precipitation (Zohary, 1973:Vol 1).

The global determinants of climate are a function of both external and internal factors regulating the amount of radiant energy reaching the earth (COHMAP Members, 1988). Solar radiation output of the sun and the details of the earth's orbit are the primary external variables. The periodicity of the Milankovitch cycles of solar energy reaching earth are produced by interactions between shorter cycles of the earth's tilt, in the range of 41,000 years, and eccentricity of the earth's orbit, 100,000 years. The earth's tilt on its axis relative to the plane of orbit around the sun creates latitudinal differences in solar radiation levels (insolation) and influences seasonality. The degree of seasonality and relative lengths of seasons also vary with earth-sun distance that is governed by orbit eccentricity. Conditions on earth (internal variables) including the amount of land ice and snow cover, sea-ice limits, global mean annual sea surface temperature, cloud cover, air-borne volcanic ash and atmospheric CO_2 concentrations influence the amount of solar radiation reaching the earth. Interactions among the myriad external and internal climatic variables affect the circulation patterns of the oceans and atmosphere, ultimately resulting in the locally and regionally unique climates observed (COHMAP Members, 1988).

Patterns of sea circulation influence climate at the global and regional level (Bond, 1995:385). Ocean circulation upwind from a region can affect distant climates. Ocean water movement as far away as the North Atlantic (that is, the Atlantic conveyor) has an important influence on climate in the Near East. Warm surface water of the Gulf Stream flows north, warming the west coast of Europe, while cold denser water returns south, far below the surface of the North Atlantic. Changes in water density, for example, caused by an influx of fresh water into the North Atlantic from melting glaciers during periods of global warming, can stop the conveyor initiating a return to glacial conditions (Bond, 1995) in Europe and the Near East. Changing sea circulation patterns, in conjunction with insolation and degree of glaciation, can thus shift the paths of the atmospheric circulation systems and storm tracks in distant locales and result in local climate changes.

Through the formulation of models incorporating these variables, both modern and past climatic conditions can be predicted (COHMAP Members, 1988) and compared with archaeological, geological and biological evidence of past climates. For example, the climate of the Near East is characterized as mediterranean, with hot dry summers and cool to cold moist winters. It's geographic location at the boundary of three landmasses: Europe, Africa and Asia, and the predominant mediterranean climate reflect the transitional zone between the prevailing westerly winds and the subtropical dry atmospheric circulation system. Global climate trends, which precipitate a north-south movement of circulation system boundaries, are predicted to have profound effects on the climatic conditions of boundary regions such as the Near East. The COHMAP models predict that a global shift toward glacial conditions, as was thought to have occurred during the Younger Dryas global cooling event at the end of the Pleistocene, would increase the strength of the polar front causing a southerly shift of the westerlies in winter. A concomitant northward shift of the summer subtropical dry circulation would decrease the amount of summer precipitation accentuating the "mediterranean"-ness of the climate of Southwest Asia and resulting in increased seasonality, summer aridity and generalized climate instability (COHMAP Members, 1988).

Although these models are good predictors on a widely regional basis, they have insufficient resolution for reconstruction of local past climates (Bamforth, 1990). Other evidence such as present climate (Chapter 5.3) must be used to supplement global models in site-associated palaeoclimate reconstruction (reviewed in Chapter 5.5 for the Near East and the Zagros/Piedmont).

5.3 Present Climate

Although there are many local climates within SW Asia: mediterranean, continental, desert, and alpine, they are all variations on a mediterranean theme (Zohary, 1973). Mediterranean climate exhibits a marked seasonality of temperature and precipitation with winter rain and summer drought (Henry, 1989:61). During the winter, the cyclonic weather system prevails. Most of the total precipitation, 70-80%, falls between November and February (Bar-Yosef, 1996) so that most plant growth occurs during the cold season (Bar-Yosef, 1987). On the northern Mediterranean coast near the boundary of modern Turkey and Syria, a break in the north-south chain of Levantine hills allows the winter precipitation and the mediterranean climatic zone to extend inland through the Assyrian Plateau to the Zagros foothills and mountains (Wright, 1976) so that winter temperatures vary with distance to the Mediterranean coast and the altitude (Bar-Yosef, 1987:221).

During the summer drought, air from the dry subtropical belt moves northward (Wright, 1976) resulting in summers that are hot and dry, and of longer duration than the winters (Bar-Yosef, 1987:221). Barometric low pressures that develop over the Persian Gulf direct air flow from the eastern Mediterranean to the Gulf. Although the daytime temperature is too high for the development of precipitation, the temperature drop at night can produce significant dew (Bar-Yosef, 1996). In addition, the interactions between seasonal atmospheric circulation tracks and topography create a precipitation gradient from west to east in both the Levant and the Zagros. As a result, many microclimates exist in relatively close proximity throughout the region (Henry, 1989; Maisels, 1990). Relative duration of summer and winter seasons affects water resource availability, reliability, and accessibility. If season duration and/or seasonal moisture distribution were different in the past, the conditions affecting patterns of mobility, settlement and resource exploitation of past human inhabitants in the Near East could have been very different from those suggested from modern conditions (Bar-Yosef, 1987).

The Assyrian plateau with 350 - 500 mm of precipitation annually is a moist steppic zone that grades into the foothills of the Zagros Mountains. Summers are hot and dry while winters are cool and wet. Most precipitation occurs between October and April and during the winter months some frost and snow can be expected (Wilkinson, 1989). To the east, the inner plateau of the Hilly Flanks of the Zagros (Braidwood et al., 1983) has a more continental climate with a cool moist winter and hot dry summer that supports steppe vegetation and the steppe-forest ecotone. At lower altitudes, small changes in temperature and moisture can greatly affect the boundary between the forest and steppe, which has fluctuated over time (Moore, 1988:4). This thesis is specifically concerned with climate changes during the early Holocene. At higher altitudes in the Zagros, rain shadow effects and direction of slope face predominate as factors affecting localized forest sustainability.

In winter, the drop in temperature is sufficient to cause precipitation in the form of either rain or snow. The length and intensity of winter precipitation is influenced by the path of storm fronts from eastern Europe (Henry, 1989:62) and thus on global climatic variation in atmospheric and oceanic circulation patterns. In addition, the lines of mountain ridges, from northwest to southeast in the Zagros, create a series of barriers to the prevailing Westerlies. The western slopes experience upwards of 500 mm of precipitation per year (van Zeist, 1967), 1.5 to 2 times more than the eastern rain shadow slopes (Freitag, 1977). The reduced insolation and reduced evaporation on northern slopes permits growth of trees such as oaks that would otherwise require substantially more precipitation to flourish. A vegetational mosaic is thus superimposed on the topographically diverse region. Although this was advantageous in providing a wide spectrum of resources for human exploitation over relatively short distances in the past, the same characteristics hinder the development of broad generalized predictions of past environmental conditions in which those same humans lived (Freitag, 1977). Consequently site- and region-specific topography is extremely important for estimating past climatic conditions.

5.4 Present Vegetation and Ecozones

The main factor affecting vegetation in a mediterranean climate is moisture availability (Zohary 1973, Vol 1:16). The amount of moisture is affected by temperature, air humidity, soil quality, effectiveness and seasonality of rainfall, and topography of the landscape, with more moisture retention in depressions, wadis and ephemeral water courses. Disruptions in global atmospheric circulation patterns influence the regularity of rainfall in successive years, as well as rainfall seasonality. In a mediterranean climate, variation of as little as 50 mm annual precipitation can have profound effects on the presence/ absence of key plant species, for example oak and pistachio, and on species density. Temperature variation, superimposed on variation of moisture availability can compound potential inter-ecosystem variability. Climate instability in mediterranean climatic zones when combined with highly varied topography increases the potential for the existence of many highly localized microenvironments and high inter-regional species diversity (Zohary, 1973, Vol 1:18).

The Fertile Crescent, at the boundary between major air circulation belts, encompasses three phytogeographic zones: Mediterranean (southern European), Irano-Turanian (western Asian) and Saharo-Sindian (African) (Henry, 1989). Within each zone are different patterns of temperature and precipitation fluctuation resulting in differences in seasonality. When seasonality preferences of plants are combined with high topographical variation over a relatively small region, differences in temperature, precipitation and seasonality contribute to the high species and environmental diversity of the region as a whole. In addition, although the ecozones are described below as geographically separate entities, many localized regions of transition among the three phytogeographic zones occur (Henry, 1989).

Within the Levantine mediterranean environmental zone the climax vegetation consists of evergreen forest and maquis (Henry, 1989; Olszewski, 1993). Present vegetation includes coniferous forest, sclerophyllous oak forest (leathery leafed), deciduous oak forest, evergreen park maquis, deciduous steppe-maquis and steppe forest (Baruch and Bottema, 1991; Zohary, 1962:67-68). The region's topographical diversity creates an upland – lowland dichotomy of species predominance. At greater than 300 m elevation, evergreen Palestinian oak (*Quercus calliprinos*), and Palestinian terebinth (*Pistacia palaestina*) predominate. Other species include juniper, Jerusalem pine, laurel, Judas tree, Syrian maple, Aleppo pine and cedar (Henry, 1989). In contrast, deciduous Tabor oak (*Quercus ithaburensis*) inhabits well-watered regions of the lowland forests. In more arid lowland regions where chalky bedrock predominates, the predominant tree species is carob (*Ceratonia siliqua*) (Henry, 1989). At higher elevations in the Levant, the higher precipitation allows growth of an oak-pistachio forest parkland (Baruch and Bottema, 1991; van Zeist and Bottema, 1977).

The inner Anatolian and Zagros regions of the Mediterranean environmental zone experience colder winters and hotter summers than those at lower altitudes closer to the Mediterranean coast, that is they exhibit a more continental variation on a mediterranean theme (Zohary, 1973). As an example, the region surrounding the Neolithic site of Çatal Hüyük receives a mean annual precipitation of 336 mm, some of which falls in summer. This summer precipitation allows the growth of steppe-forests that includes Austrian pine (*Pinus nigr*a) and Turkey oak (*Quercus cerris*) (Zohary, 1973). In contrast, further east in the mountains of Kurdestan, where there is less summer rain, forests of more sclerophyllic species such as Brant's oak (*Quercus brantii*) and pistachio (*Pistachia atlantica*) predominate at altitudes above 800 m while the same two prevail in park-forests above 1200 m elevation. Other components of the arboreal community include maple (*Acer cinerascens*), and hackberry (*Celtis causasica*). In the Zagros, transitional zones between Mediterranean parkland and Irano-Turanian steppe are marked by the gradation of oak-pistachio parkland to a more open maquis of *Pistacia atlantica* and almond (*Amygdalus* spp.). Below 300 m altitude, well-watered regions support lotus shrub (*Zizyphus lotus*) (Henry, 1989). Riverine environments at all altitudes support substantial willow (*Salix* spp.), poplar (*Populus* spp.), and tamarisk scrub (*Tamarix* spp.), while wild cereals and legumes prefer regions of open oak and steppe forest (Miller, 1992). In the modern central Zagros, presence of willow and poplar are markers of permanent water sources whereas tamarisk thrives in wadis with only intermittent water (Willcox, 1990).

In the Irano-Turanian Environment, most of the 200-350 mm annual precipitation falls in the cold winter. The precipitation may be in the form of heavy snowfalls, which may limit the over-wintering potential of certain plant species such as oak and pistachio (El-Moslimany, 1986, 1987). Clumps of plants including woody shrubs such as sagebrush (*Artemisia herbae-alba*) and members of the goosefoot family (Chenopodiaceae) are interspersed with areas of exposed ground (Henry, 1989). In the steppe, for example in the region between the alluvial plain of the Tigris and Euphrates and the foothills of the Zagros, at elevations of 150-300 m, the high fertility and winter rainfall support a winter grassland. Regional variation in steppic environments is primarily a function of the amount of summer rainfall. In some regions such as the plains of the upper Khabur and the Mosul Rivers, and the Khuzistan plain, low present summer rainfall and high transpiro-evaporation rates create soils too saline to support the growth of either wild or domesticated cereals (Flannery, 1965).

The Saharo-Sindian Environment receives less than 200 mm precipitation annually. In regions above the 21°C isotherm, there are high rates of transpiro-evaporation. Dwarf bushes survive between large expanses of exposed ground that do not support plant growth. Wadi beds, with higher water table, have denser plant cover and higher species diversity than the regional average. Plants include the low shrubs: bean caper (*Zygophyllum dumosi*), tarteer (*Anabasis articulata*), and Gnada trees (*Haloxylum persicum*). In wadis, Acacia trees (*Acacia albida, A. tortulis,* and *A. laeta*), can be found. At lower elevations, less than 150 m in the alluvial plain of the Euphrates-Tigris River system, annual precipitation does not exceed 250 mm annually, creating two possible biotypes: the alluvial desert with sand dunes of the Syro-Arabian Desert and reed-bordered swamps such as those at the confluence of the Tigris and Euphrates Rivers (Flannery, 1965).

The present vegetation of the Near East creates a starting point for estimation of the composition of plant communities and ecozones that could have existed in the past (Henry, 1989; Miller, 1998). However, the human propensity to environment altering behaviours such as deforestation and overgrazing (Henry, 1989; Miller, 1998; Olszewski, 1993) can potentially confound application of this uniformitarian assumption. As a consequence, the baseline for past climate reconstruction is not the present ecosystem distribution *per se* but that estimated to be the "natural" present vegetation had humans not altered their environment (Fig. 5.1). Palynological data from lake sediment cores also requires consideration. Regions of "natural" present vegetation are determined through topographic and geologic information supplemented by species composition of regions thought to be remnants of ancient plant communities (Miller, 1998). Modern plant communities however are not solely a function of the geographic and climatic conditions of a region. They result from the processes of local species extinctions and refugium

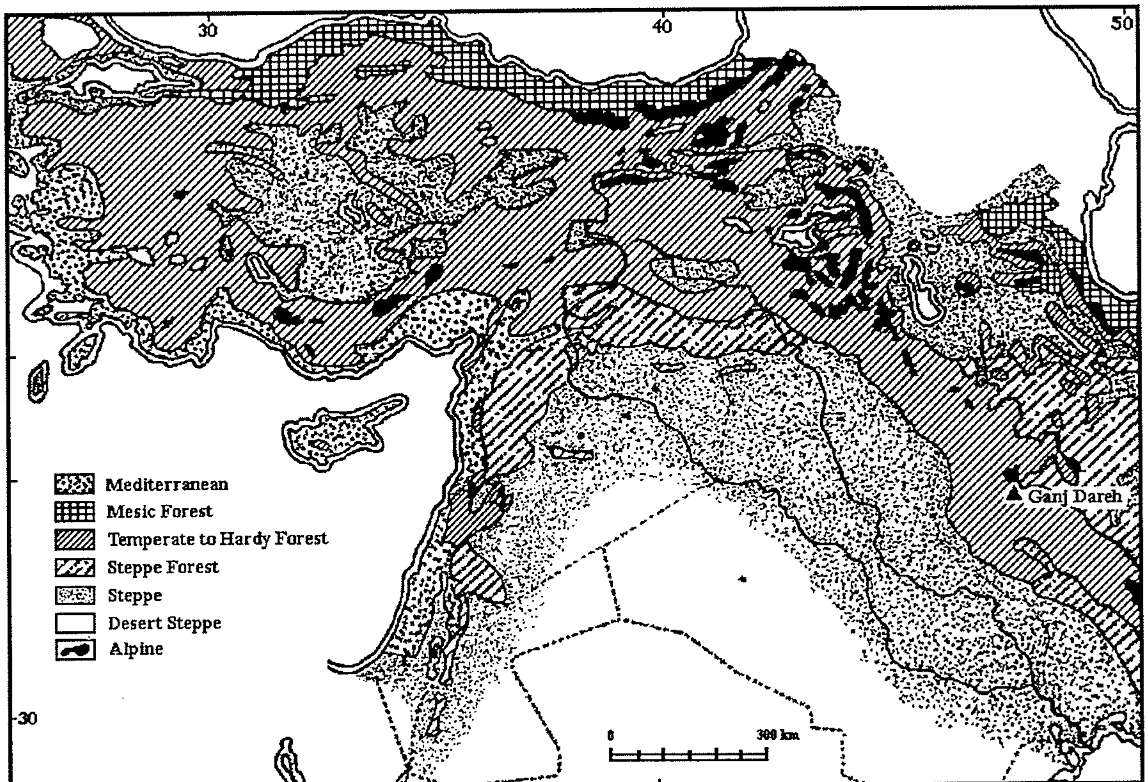

Figure 5.1. Map of the present estimated "natural" vegetation in relation to the location of Ganj Dareh. Modified from Maisels (1990:52).

formation during periods of glaciation and the progression of ecosystem regeneration following climate amelioration for example in the Holocene. This has contributed greatly to the development of both past and modern highly localized microenvironments and high regional species diversity (Zohary, 1973, Vol 1:18). This facilitated past human reliance on a wide variety of resources in the late Pleistocene and early Holocene, as suggested by Flannery's (1969) Broad Spectrum Revolution and the development of vertical economies that utilized adjacent ecozones at differing elevations (Redman, 1978). Widespread sedentism that developed during this time could have been an unintentional consequence of this ecological diversity.

The marked seasonality of a mediterranean climate accentuates the influence that soil moisture has on local variation in vegetation (Sherratt, 1980). Areas of rainfall storage such as silts and gravels of outwash fans from surrounding highlands (Miller, 1980) become local foci of flora and fauna. As a result the location of many archaeological sites on alluvial riverine soils and near springs is predicted and observed (Sherratt, 1980).

5.5 Palaeoclimate of the Near East

5.5.1 Introduction

In addition to the modelling of complex modern climates of this highly diverse region (COHMAP Members, 1988) and the estimation of modern relict vegetation systems (Miller, 1998) discussed in the previous two sections, palaeoclimate reconstruction of the Near East is based on knowledge about present climate and vegetation, ecosystem composition and uniformitarian assumptions of constancy of geological, biological (for example, floral climate preferences and dynamics) and climatological processes through time (Lowe and Walker, 1997). They include oxygen isotope levels as proxies for global and regional mean temperatures (COHMAP Members, 1988), microbotanical pollen profiles generated from lake sediment cores (Baruch and Bottema, 1991; Bottema and van Zeist, 1982; van Zeist and Bottema, 1977), macrobotanical remains recovered such as charcoal and seeds from archaeological sites (Hillman, Colledge and Harris, 1989; Miller, 1992, 1998), and geophysical evidence such as lake levels and snowlines (Wright, 1983).

The analysis of pollen isolated from sediment cores from lakes in the Near East provides the primary line of evidence for the reconstruction of past ecological communities (reviewed in Wright, 1993). In addition, stable oxygen isotope ratios and marine plankton are thought to reflect the temperature of past climates. Oxygen isotope levels from ice cores, for example in Greenland, and marine plankton from deep sea cores have provided the basis for climate modelling of the interactions between global atmospheric and oceanic circulation systems (COHMAP Members, 1988). Estimated global trends in climate change are then compared with the evidence from the region under study, for example, pollen diagrams constructed from sediment cores from lakes in the Near East.

5.5.2 Palynological Data

At the local level, disturbance of climatic variables, such as the amount and seasonality of precipitation, temperature and the relative duration of the seasons, lead to change in the conditions for the local climax vegetation. These changes initiate the process of ecological succession to a new climax community with different community composition and/or differing proportions of existing species (McCorriston and Hole, 1991; Pianka, 1983). Processes of plant community succession are observable as changes in relative species proportions of pollen incorporated into lake sediments, recovered in sediment cores and presented as pollen profiles.

All flowering plants produce pollen as part of the cycle of sexual reproduction. In a sediment core the presence of pollen from a given species suggests that at the time of sediment deposition, the species was present and flowering nearby. However, pollen from wind-pollinated plant species may travel long distances from its source of production prior to incorporation into lake sediments (Birks and Birks, 1980). In regions such as the Near East, where there are many local microenvironments and many boundaries among vegetation zones, rapid changes in vegetation occur over short distances (Henry, 1989). Thus, the presence and proportions of wind-borne pollen in sediments must be interpreted with caution (Birks and Birks, 1980).

The amount of pollen produced per plant also varies among species (Birks and Birks, 1980). Relative numbers of pollen grains per unit sediment must be adjusted for the differential production prior to inter-species comparisons of pollen frequencies. In addition, year-to-year variation in pollen production occurs. Observations of modern plant ecosystems suggest that, if high pollen production occurs in a specific year, lower production will occur in the succeeding year. Thus, in any given sediment sample thought to represent yearly deposition, the relative abundance of plants in the local environment may not be accurately represented. However, seasonal mixing of the surface sediments can reduce the effects of inter-year variation in pollen production (Birks and Birks, 1980). With these caveats on interpretation, lake sediment pollen analysis provides a means of estimation of plants in the natural environment at the time of sediment deposition. The location of most sediment cores for pollen analysis is on the periphery of the Near East (Fig.5.2), and not directly associated with the archaeological evidence of human occupation. Although pollen analysis has the advantage, over macrobotanical analysis from archaeological sites, of separating natural and human sources of pollen, lack of pollen cores in close proximity to archaeological sites in this environmentally diverse region increases the need for extrapolation of the pollen data to

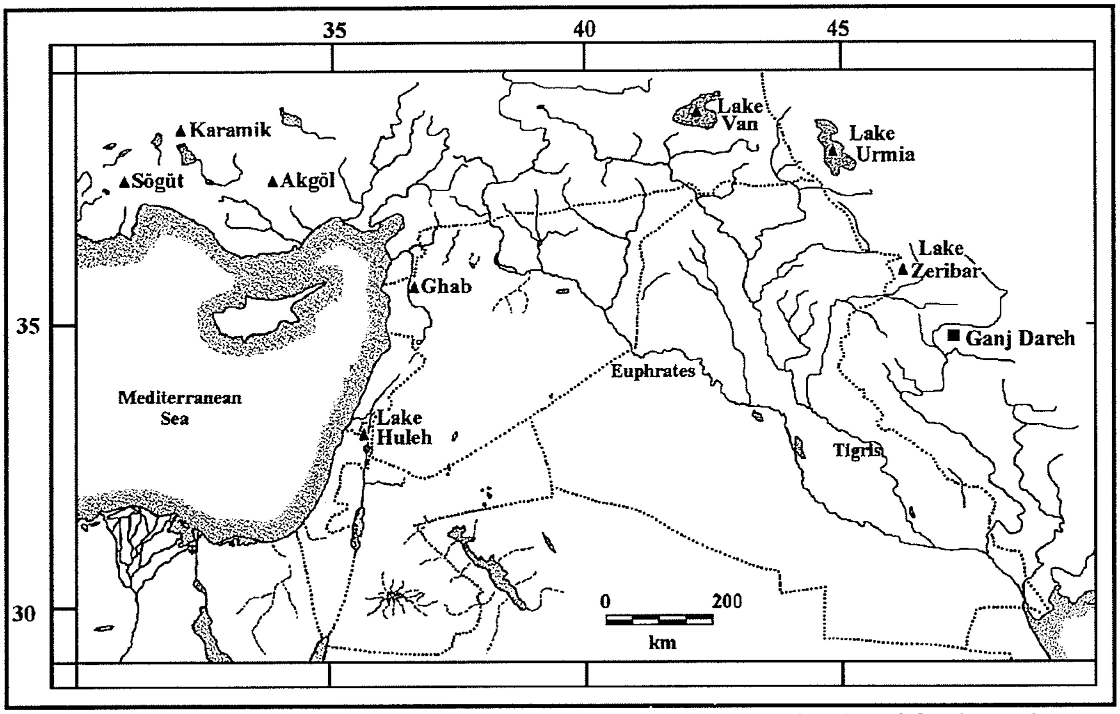

Figure 5.2. Location of pollen cores in the Near East in relation to the site of Ganj Dareh.

the environments in which humans were living.

In the Levant, pollen cores have been analyzed from two areas within the Jordanian Rift System: the Ghab Valley (northern) and Lake Huleh (central). Both sites are thought to have received increased monsoonal oceanic moisture in the late Pleistocene (COHMAP Members, 1988). However, before 8,600 bc when oak forests expanded in both regions, reciprocal climatic trends (see below) in the northern and central Levant have been observed (Baruch and Bottema, 1991). Thus care must be exercised in extrapolation of environmental conditions even within small regions such as the Jordanian Rift System that presently exhibit environmental and climatic homogeneity.

Sediment cores analyzed from the Ghab Valley indicate the presence of oak pollen in northwest Syria during most of the last glacial, suggesting that there was sufficient moisture in the northern Levant for the continued viability of oak forests

(Niklevski and van Zeist (1970), cited in Wright (1993)). This is consistent with the postulated location of refugia in the Levantine Mountains (Harlan, 1998) and palaeoclimatic modelling of postglacial climate (COHMAP Members, 1988).

An early core taken from Lake Huleh in the Jordan Valley suggests that there was relatively high summer precipitation between 18,000 and 12,000 bc, as indicated by the high levels of oak pollen, a precipitation proxy species. Between 12,000 and 9,000 bc, the decline in oak pollen was thought to reflect drier summers and a return to mediterranean climate (Bottema and van Zeist, 1982). A new core, from a different location in the Huleh basin, has recently been analyzed (Baruch and Bottema, 1991). Radiocarbon dates have been obtained from different strata than those of the first core. The resulting differences in interpolation between the radiocarbon-dated levels have placed the decline in the proportion of oak pollen between 9,500 and 8,600 bc, much later than previously thought. Although this may coincide with the dry cold episode of the Younger Dryas (Baruch and Bottema, 1991), Wright (1993) suggests that the decline in oak pollen can be explained by the interaction between the late Pleistocene atmospheric circulation patterns and an increase in insolation due to changes in the Milankovitch cycles. After 8,500 bc, the proportion of evergreen, more drought resistant oaks increases at the expense of more temperate deciduous oak species (Baruch and Bottema, 1991). The resulting increase in seasonality of precipitation and changes in oak species proportions are consistent with drier summers and the return to hyper-mediterranean climate proposed by McCorriston and Hole (1991).

In both the Zagros and Anatolia, the predominant pleniglacial vegetation is *Artemisia* and Chenopodiaceae (van Zeist and Bottema, 1977) suggesting that the winters were colder than at present, and the summers warmer. In the central Zagros at Lake Zeribar, an increase in herbaceous plants and a decline in the proportion of chenopods and *Artemisia* suggest an increase in moisture during the winter growing season. This trend reversed briefly ca. 9,500 - 9,000 bc (van Zeist and Bottema, 1977). Following 8,500 bc, the increase in proportion of oak pollen indicates that the oak-pistachio forest was expanding in the central Zagros. This suggests that there was an increase in overall moisture (Freitag, 1977; van Zeist and Bottema, 1977), or alternately, that there was an increase in summer precipitation (El-Moslimany, 1987).

Further northwest at Lake Urmia, although forest expansion was initiated several thousand years later than at Lake Zeribar, the rate of expansion was more rapid (Bottema, 1986). Modern levels of arboreal pollen were attained by 5,000 bc, more than 1000 years prior to those at Lake Zeribar. In the Lake Van region of eastern Anatolia, forest expansion extended over 3,000 years, at a rate intermediate between Urmia and Zeribar (Bottema, 1986) indicating substantial regional differences in conditions conducive to forest expansion.

The paucity of radiocarbon dates within each sediment core limits estimation of palaeoclimate from pollen diagrams (Wright, 1993). Linear interpolation assuming constant sedimentation rates is required to estimate the times of deposition of the intervening sediments. However differences in precipitation can cause variation in run-off and erosion of the land surrounding lakes sampled. The assumption of constant sedimentation rates may not be applicable to all sediment cores or even to all levels within one core. These differences due to interpolation are compounded by the flatness of the ^{14}C curve at the Pleistocene-Holocene boundary so that one ^{14}C value corresponds to several possible dates (Wright, 1993). Thus inter-site correlations of environmental change are approximate.

Interpretation of pollen profiles utilizes a number of derived data. The first and most obvious is the species prevalence relative to the total pollen recovered from each level. However, insect-pollinated species such as *Pistacia* spp. are poorly represented in pollen rain, so that *Pistacia* pollen prevalence underestimates plant prevalence in the environment. In contrast, wind pollinated species such as *Quercus* spp. can over-estimate prevalence in the local environment if atmospheric conditions at the time of pollen production allowed for long-distance transport of the pollen bloom. Thus recovery of oak charcoal from archaeological sites is used to confirm local presence of oak forest inferred from distant pollen cores.

Proxy species are often used as indicators of single environmental factors. For example, increased levels of oak pollen are interpreted as evidence of overall increasing moisture (van Zeist and Bottema, 1977; van Zeist and Woldring, 1980; Wright, 1993). However, rather than overall low precipitation levels preventing oak forest expansion, El-Moslimany (1986) suggests that the primary limiting factor is diminished summer rainfall that prevents the over-summering of young oak seedlings. These limiting conditions are reflected in the ratio of the predominant steppe species Chenopodiaceae (C) and *Artemisia* sp. (A). High C:A ratios throughout the late Pleistocene and early Holocene confirm low summer moisture levels in the Zagros during the period before proportions of oak pollen began to increase (El-Moslimany, 1987).

Much of the interpretation of palaeoclimate in the Near East has utilized the ratios of arboreal pollen (AP) to non-arboreal pollen (NAP) to facilitate inter-site comparisons and estimate the timing and extent of forest expansion following the last pleniglacial (Wright, 1993). Both latitudinal and continental effects have been observed. Reforestation of steppe environments following the pleniglacial is observed at later dates in eastern Anatolia at Lakes Urmia and Van than at the more southerly sites of Ghab and Huleh. Maximum arboreal pollen peaks occur later farther inland in the Zagros at Lake Zeribar than at Ghab near the Mediterranean coast (Wright, 1993). In addition, cold temperature, declining humidity, and changes in snowfall influence pollen proportions used in palaeoclimate reconstruction.

5.5.3 Macrobotanical Evidence

Analysis of macrobotanical remains from archaeological sites complements the environmental palynological evidence and permits the evaluation of the degree of human agency involved in their presence at the site with preservation of plant remains usually limited to wood and seeds that have been charred (Miller, 1998). Recovery of botanical remains from a site suggests that those plants were available nearby, whereas meaning of their absence is less conclusive. A wide range of botanical material has been recovered from Near Eastern Pleistocene-Holocene boundary archaeological sites including wood charcoal from both hearths and dwelling construction, seeds from the burning of dung, seed caches burned in house fires, and seeds burned during grain parching to loosen seed husks (Miller, 1998).

Comparison of modern estimated climax vegetation to macrobotanical remains found at archaeological sites facilitates assessment of the degree of similarity between the modern environment and that at the time of site occupation through the use of uniformitarian assumptions. For example, charcoal and seed hulls of almond and pistachio have been recovered from the sites of Ganj Dareh (van Zeist et al., 1984) and Abdul Hossein (Willcox, 1990), both dated to ca. 7,000 bc and located in the Zagros to the southeast of Lake Zeribar. Both are near the modern estimated boundary between more moist oak-pistachio parkland and the more arid pistachio-almond steppe forest. If palaeoclimate ca. 7,000 bc were the same as modern climate, recovery of oak charcoal and acorns would be expected at sites such as Ganj Dareh. The presence of charcoal and nuts of almond and pistachio and the absence of those of oak are consistent with the Lake Zeribar pollen record of pistachio and almond expansion following 8,500 bc and the delayed expansion of oak to its modern distribution until ca. 3,500 bc (van Zeist and Bottema, 1977). This suggests that Ganj Dareh in the central Zagros was located in a region of expanding pistachio-almond steppe forest that was devoid of the climax oak forest that is estimated to be the modern "natural" vegetation.

5.5.4 Interpretations of Palaeoclimate

Global climate change such as onset of a glacial period influences atmospheric circulation patterns, locations of developing high and low pressures and direction of storm tracks and circulation systems that influence the weather in a given season (COHMAP Members, 1988). Latitudinal shifts in weather patterns are to be expected with polar ice sheet expansion. Under glacial conditions however, the mediterranean climatic zone may not have been just displaced to the south. In many regions it may have completely disappeared (di Castri (1981), cited in Wright (1993)). However, some mediterranean plants survived in isolated refugia in the Levantine and Zagros Mountains, providing sources of mediterranean adapted plants for the recolonisation when glacial climatic conditions ameliorated (Harlan, 1998). Within each refugium the community composition varied as a result of the region's unique combination of climate, topography, vegetation and fauna at the last glacial maximum. At the end of the Pleistocene as the mediterranean ecozone shifted northward, inter-refugium species variation contributed to both past and modern regional and local microenvironmental species diversity. This diversity produced the locally unique conditions that facilitated regional diversity in subsistence trajectories in the early Holocene (McCorriston and Hole, 1991).

Seasonality of rainfall in the Near East varies with the distance from the Mediterranean Sea and the Indian Ocean as global climate responds to the recession of polar glaciers (COHMAP Members, 1988) creating what appears to separate climatic trends operating in the Levant and the Zagros from the last pleniglacial to the present (Fig. 5.3). In the Levant, forest expansion occurred during the moist conditions from 11,000 to 8,000 BC (Henry, 1989) whereas in the Zagros, summer aridity inhibited forest

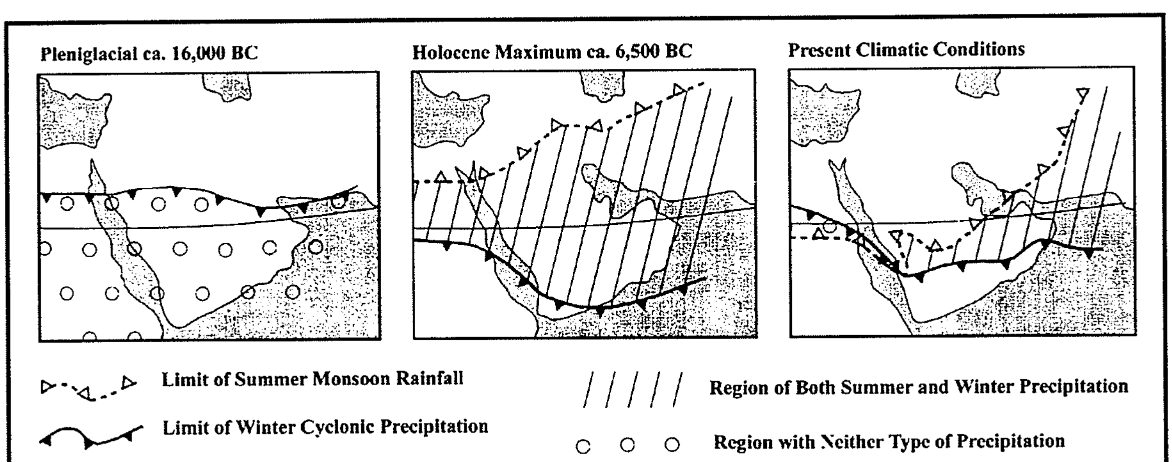

Figure 5.3. Change in rainfall systems from pleniglacial to present in the Near East. Modified from Blanchet et al. (1998).

expansion, then a return to drier conditions. Following 8,000 bc, summer aridity increased in the Levant (see change from Fig. 5.3A to 5.3B) resulting in forest contraction because the summer monsoon systems failed to extend their influence across the entire Arabian Peninsula. In contrast, the Zagros experienced some summer moisture (Fig. 5.3B) facilitating forest expansion (Blanchet et al., 1998). This palaeoclimate reconstruction is consistent with the hypothesis that summer aridity in the Zagros inhibited the survival of tree seedlings, thereby delaying the advance of forest vegetation (El-Moslimany, 1986, 1987). However it proposes a more northerly extension of the summer monsoons into the central Zagros ca. 9,000 bc than the palaeoclimate estimation of Wright (1993). Other factors contributing to the later reforestation of the Zagros relative to the Levant are the higher latitude, more continental climate, absence of trees at the pleniglacial and greater distance from refugia of the last pleniglacial (Miller, 1998). In the Levant changes in AP:NAP ratio closely reflect changes in climate, whereas in the Zagros changes approximate the distance from refugia and the time required for long-distance forest recolonisation from refugia (Miller, 1998) as well as differences in moisture seasonality (Blanchet et al., 1998).

Despite the difficulties in interpretation of palaeoclimatic data, a number of consistent trends have been observed. Climatic modelling (COHMAP Members, 1988) suggests that the pleniglacial climate ca. 16,000 bc in the Near East was primarily an Irano-Turanian steppe vegetation. After 16,000 bc, the northern hemisphere gradually warmed. Between 10,000 and 4,000 bc, increases in the proportion of arboreal pollen (AP) relative to non-arboreal pollen (NAP) indicate that forest expansion was occurring (see Table 5.1 and references therein) and that the Zagros experienced higher effective moisture than at present. However, the peaks of arboreal pollen do not appear synchronously across Southwest Asia. Forest expansion that began about 13,000 years bc. in the central Levant at Lake Huleh did not commence at the more northerly Ghab Valley until at least several thousand years later. In the Zagros, the continental effect of distance from the Mediterranean Sea and more northerly latitude maintained dominance of the glacial Artemisia-Chenopod steppe vegetation for 2,000 to 3,000 years beyond that in the Levant. Evidence for increase in the AP:NAP ratio and climate amelioration appeared in the western Zagros at Lake Urmia by 7,000 bc. In the more continental

	Location and Elevation	Start of Forest Expansion	Present Pollen Levels Attained	Present Forest Composition
Lake Urmia [1]	W. Zagros 1,300 m	7,000 bc	5,500 bc	Deciduous Oak and Pistachio
Lake Zeribar [2, 3, 4]	C. Zagros 1,300 m	6,100 bc	After 4,000 bc	Deciduous Oak and Pistachio Savannah
Ghab Valley [5, 6]	N. Levant 190 m	9,000 bc	2,000 bc	Deciduous Oak, Pistachio, Cedar
Lake Huleh [6]	C. Levant 300 m	13,000 bc Rapid after 11,000 bc	----	Evergreen Oak

Table 5.1. Arboreal pollen trends in the Near East. Dates are expressed in uncalibrated ^{14}C years bc.

[1] Bottema (1986).
[2] van Zeist (1967).
[3] van Zeist and Woldring (1978).
[4] zan Zeist and Bottema (1977).
[5] van Zeist and Woldring (1980).
[6] Baruch and Bottema (1991).

climate of the central Zagros at Lake Zeribar, initiation of forest expansion occurred almost a millenium after the occupation of Ganj Dareh (Table 5.1).

Environmental conditions, as estimated by the presence of pollen, are in large part a function of the specific regional climatic history, the variation in species composition and the distance from local pleniglacial refugia, as well as local pollen preservation conditions (van Zeist and Woldring, 1978). Comparison of macrobotanical remains such as charcoal from archaeological sites with the general environmental trends inferred from pollen cores facilitates the recognition of variation in past climatic and environmental conditions such as the presence of refugia, for example at the late Pleistocene site of Hallan Çemi in the Kurdish Zagros near Lake Urmia (Rosenberg et al., 1998). The presence of oak charcoal at Hallan Çemi (Rosenberg et al., 1998) taken together with the pollen evidence from Lake Urmia (Bottema, 1986) suggests that the forests to the western Zagros/Piedmont expanded earlier and more rapidly than they did further east in the central Zagros (van Zeist, 1967; zan Zeist and Bottema, 1977; van Zeist and Woldring, 1978). If there were oak forests at Hallan Çemi at the end of the Pleistocene, conditions would have been present for the adaptive radiation of cereals and their domestication once the climate had ameliorated sufficiently. This is consistent with the observed differences in botanical remains where oak charcoal recovered from Hallan Çemi in the western Zagros was absent at Ganj Dareh to the east, emphasizing the climatic, topographical, and environmental variation even within one of the regions of the Near East: the Zagros Mountains.

The slow increase in arboreal pollen during the early Holocene in the central Zagros suggests that the environment did not favour early adaptive radiation of wild cereals such as wheat, as has been postulated for the Levant (McCorriston and Hole, 1991). The steppe vegetation that continued well into the Holocene at, for example, Lake Zeribar (van Zeist, 1967; van Zeist and Woldring, 1978) and the mountainous terrain of the region appear to have been more conducive to the elaboration of an economy based on ovicaprid exploitation (Henry, 1989; Hole, 1996; McCorriston and Hole, 1991; Wright, 1993). This is consistent with the absence of wheat in the macrobotanical remains from sites such as Ganj Dareh ca. 7,000 bc. In contrast food-producing economies based on cereals developed in the Levant. The differences in climate and environment in the Levant and the Zagros have important consequences for interpretation of health of populations of the Near East.

The recognition that differences in the environmental settings of the Levant and the Zagros existed in the early Holocene, and that even within each of these sub-regions of the Near East uniformity was not the norm suggests that the regions must be considered on their own terms. Health consequences of subsistence strategies in the early Holocene cannot be assumed to be the same in the Levant and the Zagros, although in the literature discussions of health at the origins of agriculture are in fact assessments of health in early plant cultivating communities (Larsen, 1995, 1997). This places examination of the occupants of Ganj Dareh in a unique position to elaborate the health and subsistence of early Neolithic human populations in the central Zagros Mountains and to assess the impact of incipient pastoralism on human health.

Environmental changes in the Near East at the Pleistocene-Holocene boundary are intimately tied to the complex human-environment interactions that facilitated the subsistence change from hunting and gathering to the adoption of agriculture. These behavioural changes are embedded in the complex interactions among a series of intersecting boundaries within an unstable and shifting environment. Late Pleistocene – early Holocene humans of the Near East were living in the borderlands among atmospheric circulation systems (COHMAP Members, 1988), geostructural plates, forest-steppe ecotones (Zohary, 1973), sub-mediterranean – hyper-mediterranean climate fluctuations (McCorriston and Hole, 1991) and topographical landforms that vary extensively over short distances (Zohary, 1973). As a result inter-site and inter-region variability in the trajectory of subsistence transitions are observed in the archaeological record of Near Eastern sites. This variation is reviewed in Chapter 6: Culture History of the Near East at the Pleistocene – Holocene Boundary.

CHAPTER 6. CULTURE HISTORY OF THE NEAR EAST

6.1 Introduction

The cultures in the regions of the Near East during the Epipalaeolithic, Neolithic 1 and Neolithic 2, from ca. 17,000 bc to 6,000 bc are presented, indicating the long sequence of human occupation of the region. The cultural stages[1] within each time period are recognized on the basis of architecture, lithics, settlement patterns and mortuary practices (Moore, 1982). In addition, the major evidence for subsistence strategy is discussed. The transition from simple to complex hunter/gatherers, that is the shift toward sedentism, occurred in the Epipalaeolithic, the terminal Pleistocene. At the Pleistocene-Holocene boundary, the first evidence appears in the archaeological record of the manipulation of plants and animals. Sedentism, seen as increases in population size and dramatic changes in architecture, mark the transition from Neolithic 1 to Neolithic 2 ca. 7,600 bc.

The Levantine and Anatolian sequences are presented in very brief overview to establish the context within which plant and animal domestication is situated. This also links palaeoclimatic reconstruction (reviewed in Chapter 5, and required by all models of agricultural origins for understanding of cultural change) with changes in human behaviour that occurred in all three regions of the Near East. The Levant and Anatolia are used as a baseline for comparison of settlement patterns, subsistence and domestication, and burial practices with those of the Zagros/Piedmont, the Near Eastern region central to this research on the human skeletal remains from Ganj Dareh.

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[1] This chapter chronologically summarizes the observed trends in the archaeological record. It is not meant to suggest that the author has taken a progressive theoretical stance or that changes observed could not be reversible.

6.2 Epipalaeolithic

6.2.1 Introduction

Epipalaeolithic sites date to the terminal Pleistocene (Henry, 1985). In the Levant, three cultural traditions are recognized. The first two are Geometric Kebaran and Mushabian, with sites dating to ca. 15,000 to 9,000 bc. The later Natufian sites are dated to ca. 10,500 to 8,500 bc. In Anatolia, little is known of the Epipalaeolithic culture (Moore, 1985), with the exception of several unnamed sites in the Antalya region of the south coast of Turkey (Mellaart, 1972). In the Zagros, the Epipalaeolithic culture is named for the site of Zarzi and dates from 17,000 to ca. 9,000 bc. Location of Epipalaeolithic sites, including those mentioned in the text, are shown in Figure 6.1.

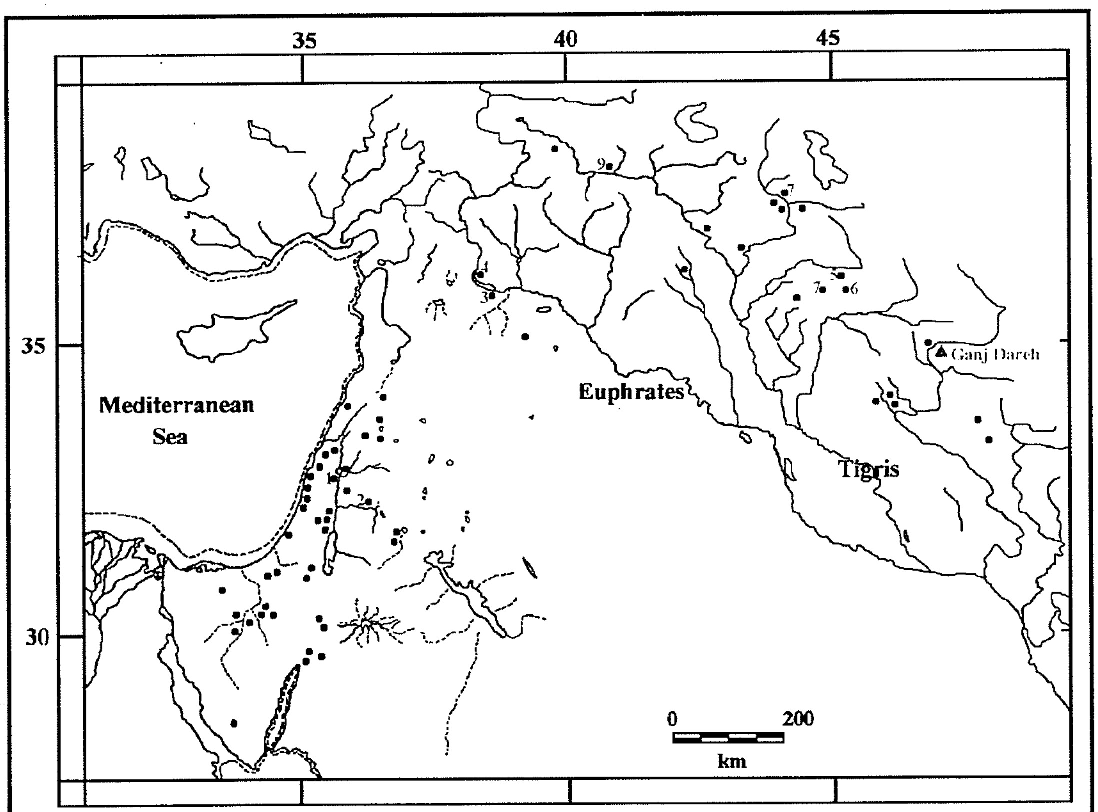

Figure 6.1. Distribution of Epipalaeolithic sites and locations relative to Ganj Dareh.

1 Ohalo II	4 Mureybet	7 Shanidar/Zawi Chemi
2 Wadi el-Jilat	5 Zarzi	8 Karim Shahir
3 Abu Hureyra	6 Pelegawra	9 Hallan Çemi

6.2.2 Epipalaeolithic in the Levant

Geometric Kebaran sites are widespread in the Levant: on the coast, in both upland and lowland terrain and in steppic and woodland environments (Bar-Yosef and Belfer-Cohen, 1992; Moore, 1985). In contrast, the Mushabian sites are limited to the Sinai and Negev regions of the southern Levant and are located in steppe and desert environments. In most respects, Geometric Kebaran and Mushabian sites are extremely similar, covering an average of 200 m^2, with very thin cultural horizons, low artifact densities, tent ring stone circles, and few hearths (Henry, 1985) suggesting a circular round of settlement with a high degree of mobility, Stage I in Mortensen's (1972) model of settlement patterns. In both traditions sickle sheen on microliths that would suggest use in grain harvesting has not been reported (Bar-Yosef and Belfer-Cohen, 1992; Moore, 1985). The few grindstones recovered are stained with ochre, inferring that they were not used in food preparation. All plant and animal remains are morphologically wild (Henry, 1985) including grains, fruits, ibex, and gazelle. With some exceptions discussed below, early Levantine Epipalaeolithic subsistence appears to be primarily simple hunting and gathering of a broad spectrum of resources (Bar-Yosef, 1990).

Several Early Epipalaeolithic sites, for example Ohalo II ca. 17,000 bc (Kislev et al., 1992; Nadel et al., 1991) and Wadi el-Jilat ca. 13,000 (Garrard and Byrd, 1992), are larger than most Geometric Kebaran sites with evidence of resource-rich habitats, repeated occupations and increased sedentism. Both sites were occupied during periods of increased moisture and oak parkland expansion as inferred from the Pleniglacial levels of the Ghab pollen profile (used as a proxy for Ohalo II palaeoclimate) and the Late Glacial levels from the Lake Hula pollen core (for Wadi el-Jilat) (Baruch and Bottema, 1991). The moister climate may have been a suitable environmental context permitting an increase in sedentism. Their early presence, followed by, and interspersed with, increased settlement mobility of most other Epipalaeolithic sites, supports the non-progressivist view that subsistence changes are indeed reversible.

The Late Epipalaeolithic of the Levant is divided into Early and Late Natufian culture: 10,500 to 9,000 bc, and 9,000 to 8,500 bc, respectively (Henry, 1985). Circa 10,500 bc, increasing aridity restricted the occupation of the Levant to the foothills and mountains of the Mediterranean forest zone (Bar-Yosef and Belfer-Cohen, 1992; Moore, 1985). The sites are located at ecotones at the base of upland slopes, with access to a wide range of steppe and forest environments and resources including gazelles, deer and stands of wild cereals, oak, pistachio and almond (Henry, 1985). Early Natufians are thought to be complex hunter/gatherers (Belfer-Cohen and Bar-Yosef, 2000; Henry, 1985).

Late Natufian coincides with a period of increased aridity as suggested by the pollen profile from Lake Huleh (Bottema and van Zeist, 1982) and is characterized by withdrawal of settlements from steppic regions into the Mediterranean forest zone (Belfer-Cohen and Bar-Yosef, 2000; Henry, 1985). Late Natufian peoples 9,000 to 8,500 bc continued their collection of wild cereals, acorns and lentils, that is, a broad spectrum of resources (Henry, 1985). Gazelle bones predominate the Natufian faunal assemblages. Although all age categories are represented, the proportion of juveniles is higher than that from earlier Levantine time periods (Davis, 1983; Legge, 1972) suggesting a shift in settlement pattern from seasonal nomadism to sedentism (Davis, 1983). Nevertheless, the gazelle behavioural pattern of seasonal territoriality diminishes its suitability for domestication, supporting the contention that, despite their age profiles, gazelles exploited by Natufians were hunted in the wild (Garrard, 1984). In addition, all other animal species recovered from late Natufian sites including cattle, goat, onager, sheep, fallow and roe deer are morphologically wild (Henry, 1985). During the late Natufian period, a northward expansion to the middle Euphrates valley saw the establishment of the earliest levels of Abu Hureyra and Mureybet. At the beginning of the Late Epipalaeolithic in the middle Euphrates, all cereals and lentils are morphologically wild (Harlan, 1998; Hillman et al., 1989; Miller, 1992). However, approaching the end of the Epipalaeolithic increasing seed frequencies of weeds of cultivation coincide with the earliest appearance of domesticated rye (Hillman, 2000).

6.2.3 Epipalaeolithic in Anatolia and the Zagros

As in the Levant, the Epipalaeolithic may be divided into two time spans. In the earlier Zarzian, ca. 17,000 to 9,000 bc, environmental conditions were cold and dry with steppic vegetation. The later period has not been named, since earlier research (Mellaart, 1972; Moore, 1985) suggested that the region was uninhabited during the late terminal Pleistocene. Occupation was not thought to be possible prior to the forest recolonisation from their glacial period refugia. Botanical evidence from the Lake Zeribar pollen core suggests that the forests did not begin expansion in the Zagros until ca. 8,500 bc (van Zeist and Bottema, 1977). However, the presence of oak, tamarisk and poplar charcoal at the site of Zarzi (Braidwood and Howe, 1960) suggests that sites are located in ecotones with access to a wide variety of resources (cf. similar settlement locations in the Levant) and near local refugia (Hole, 1996).

Earlier Epipalaeolithic sites in the Zagros are located both in caves such as Palegawra and Shanidar and at open-air locations such as Zawi Chemi and Karim Shahir. Seasonal camps with low density of artifacts and thin cultural deposits indicate repeated short term use (Braidwood and Howe, 1960) and a circulating settlement pattern (Mortensen, 1972) that suggests a simple hunter/gatherer economy. Microliths with sickle sheen indicate that plants were an important component of the economy (Braidwood and Howe, 1960). Faunal remains recovered from Palegawra cave, occupied between 12,000 and 11,000 bc, are wild and include equids, cervids and caprids (Turnbull and Reed, 1974). In the upper levels of Shanidar Cave dated to ca. 8,900 bc, storage pits were found as well as querns and mortars (RS Solecki, 1963). Artifacts are similar to those recovered at the nearby site of Zawi Chemi. In the lower Epipalaeolithic levels of Shanidar cave many microliths were recovered as well as ground stone tools (RL Solecki, 1983). A few pits suggest a storage function (RS Solecki, 1963).

The open-air site of Zawi Chemi, located in steppe savannah environment (van Zeist, Woldring and Stepert, 1975), is dated to between 10,000 to 9,000 bc. Faunal remains include bear, red deer, and morphologically wild sheep and wild goats (Perkins, 1964). Perkins (1964) suggests that the high proportion, 50%, of young sheep remains indicates that the sheep were domesticated. If true, the process of domestication may have begun at least 2,000 years prior to the earliest dates of any morphological evidence of domestication, for example the medially flattened goat horn cores from Jarmo ca. 6,700 bc (Flannery, 1969), and 1000 years prior to the slaughter pattern evidence of goat domestication at Ganj Dareh (Hesse, 1982; Zeder, 2001; Zeder and Hesse, 2000).

However, many researchers are sceptical of Perkins' (1964) conclusions (for example Meadow, 1989; Reed, 1983; and reviewed in detail in Zeder, 2000).

Karim Shahir ca. 10,000 bc is a small site in the piedmont of the central Zagros in close proximity to the Neolithic site of Jarmo (Braidwood and Howe, 1960; Howe, 1983). Here, thin cultural horizons and a few hearths with charcoal and fire-cracked rock suggest repeated short-term use. Tent rings were present, but no permanent dwellings were observed. A wide range of wild resources was used including wild deer, gazelle and wolf. A few microliths, similar to those of Zawi Chemi, exhibit sickle sheen. Recovery of mortars, pestles and querns is consistent with the microlithic evidence of plant use (Braidwood and Howe, 1960; Howe, 1983). In addition, the presence of storage pits, querns and mortars in the upper levels of Shanidar Cave ca. 8,900 bc, and from nearby Zawi Chemi (Solecki, 1983) suggest that plants were an important component of the Epipalaeolithic economy in the Zagros.

Many authors (for example Hole, 1984, 1996; Mellaart, 1972) suggest that there was no human occupation of Anatolia in the later Epipalaeolithic. Recent analysis of the Turkish site of Hallan Çemi (Rosenberg et al., 1995; Rosenberg and Redding, 2000) suggests, however, that human occupation was not absent during this period. Faunal and botanical evidence from this site, in combination with the presence of permanent architecture, suggests a complex hunting/gathering subsistence strategy.

The early site of Hallan Çemi in Anatolia dated to between ca. 9,000 and 8,700 bc is a small site with four identified building levels (Rosenberg et al., 1995; Rosenberg and Redding, 2000). The lowest has no evidence of permanent architecture, and thus resembles Ganj Dareh. Faunal resources include wild sheep and deer. The architectural remains of the second building level suggest a level of community organization consistent with the transition to sedentary life. The circular houses surround a central area. Their entrances, however, face away from this area (Rosenberg et al., 1995; Rosenberg and Redding, 2000).

Such structures have been observed in the !Kung during the initial adoption of pastoralism, and appears to increase privacy (Yellen, 1990). Two of the structures at Hallan Çemi, three times the size of the other buildings, may have a public function. This is supported by the presence at the site of imported obsidian, copper ore and an aurochs skull only within these larger buildings. In addition, a high concentration of animal bone and fire-cracked rock was recovered from the central activity area (Rosenberg et al., 1995; Rosenberg and Redding, 2000) that could imply competitive feasting in the sense of Hayden's (1990) Accumulator model. In contrast, a more likely scenario suggested by Rosenberg and Redding (2000) would be the development of non-competitive feasting in association with sedentism and increasing territoriality (Rosenberg, 1990). In modern sedentary groups such as the Yanomamo, such reciprocal feasting acts as a social institution to reduce hostility and promote cooperation between groups (Chagnon, 1983).

Across the Near East in the Epipalaeolithic burials are usually not associated with dwelling sites. In the Natufian Levant, the dead were buried in cemeteries distinct from dwelling sites (Belfer-Cohen, 1988). In Anatolia and the Zagros, no burials have been recovered from within habitation sites such as Hallan Çemi (Rosenberg et al., 1998) and Zawi Chemi, although skeletons recovered from the upper (Epipalaeolithic) levels of

Shanidar cave are thought to be contemporary with Zawi Chemi occupation (Solecki and Solecki, 1981; Solecki et al., 2004).

6.2.4 Epipalaeolithic Summary

The differences observed between Early and Late Epipalaeolithic sites in the Near East include: an increase in site size and artifact densities, more substantial architecture, and a broader exploitation of the environment through an increasingly wide spectrum of wild resources. This suggests that the later Epipalaeolithic cultures of the Near East were increasingly sedentary. Technological innovations such as grindstones and mortars, later used for processing of plant foods, were known by 15,000 bc (Henry, 1985). Microliths with sickle sheen were in use in the late Epipalaeolithic for cutting plant materials (Braidwood and Howe, 1960; Howe, 1983). Evidence for changes in social organization suggests that scalar stress may have been increasing (Belfer-Cohen and Bar-Yosef, 2000; Rosenberg and Redding, 2000; Watkins, 1990). Archaeological evidence clearly suggests that the major social developments associated with the adoption of agricultural subsistence were present in all regions of the Near East at least 1000 to 1500 years prior to the first evidence for the manipulation of wild resources and the morphologically domesticated plants and animals associated with the adoption of agriculture. This is consistent with Henry's (1985) assertion that the most important cultural transition in the stages leading to the development of agricultural subsistence is the transition to sedentism and that this had occurred by the beginning of the Late Epipalaeolithic ca. 9,000 bc.

6.3 Neolithic 1

6.3.1 Introduction

The assignment of a site to the Neolithic period indicates that there is archaeological evidence to suggest that the transition to agricultural subsistence had occurred, that is, there is evidence for domesticated plants and/or animals. In the near East, the transition from the Epipalaeolithic sedentary complex hunter/gatherers to the Neolithic is thought to have occurred ca. 8,500 bc. Four stages have been recognized in the archaeological record in the Levant, Neolithic 1 through 4 (Moore, 1982). These transitions occurred at ca. 8,500, 7,600, 6,000 and 5,000 bc, respectively. Each is

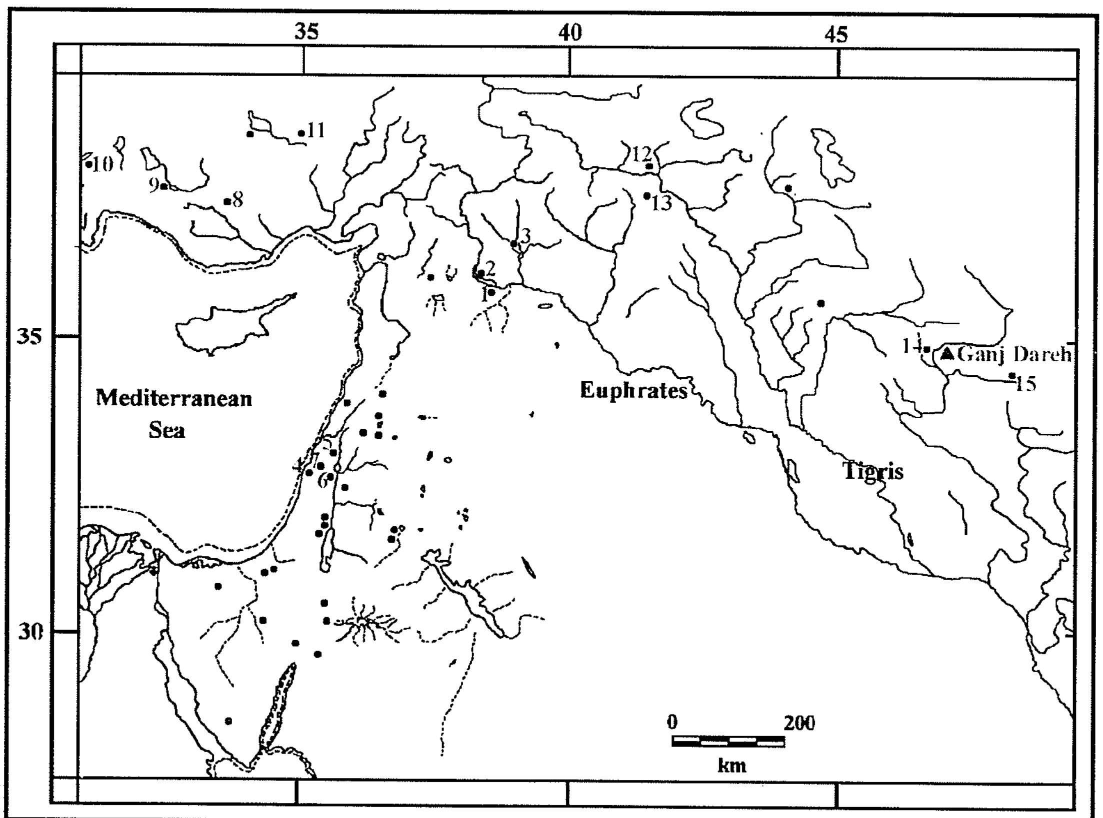

Figure 6.2. Distribution of Neolithic 1 sites and locations relative to Ganj Dareh.

1 Abu Hureyra
2 Mureybet
3 Tell Aswad
4 Nahal Oren
5 Gesher
6 Jericho
7 Hayonim Cave
8 Can Hasan
9 Suberde
10 Aşikli Hüyük
11 Haçilar
12 Nemrik 9
13 Qermez Dere
14 Asiab
15 Tepe Abdul Hosein

classified through the examination of the stratigraphic sequences at sites in the Levant that are well-dated and that have long occupational histories, such as Abu Hureyra, Mureybet and Jericho. The first two transitions ca. 8,500 bc and 7,600 bc are of relevance to the early Neolithic occupation of the Zagros and specifically the site of Ganj Dareh ca. 7,000 bc. They coincide with the beginnings of the two recognized culture periods of the Archaic Neolithic applied to archaeological sites in Anatolia and the Zagros: Neolithic 1 and Neolithic 2. Location of Neolithic 1 sites, including those mentioned in the text, are shown in Figure 6.2.

6.3.2 Neolithic 1 in the Levant

Overall, Neolithic 1 sites exhibit considerable cultural uniformity across the Levant (Moore, 1982). The increasing temperature and aridity in the Neolithic 1 has been linked with reduction in areas occupied (Henry, 1989) although at the sites of Jericho, Nahal Oren and Mureybet, the Neolithic 1 deposits are directly superimposed on the earlier Epipalaeolithic debris. The houses are round, single-roomed semi-subterranean structures (Henry, 1989; Moore, 1982).

Regional variation occurs in the proportion of the microlithic component of the chipped stone tool industry with a higher proportion in the steppic environment of the Middle Euphrates at Mureybet. However, ground stone tools such as querns and stone bowls have been recovered from all Neolithic 1 sites (Moore, 1982). Long distance trade in obsidian is an important addition to the early Neolithic economy indicating increased inter-regional interactions with populations at Çiftlik in central Anatolia (Renfrew et al., 1966; Williams-Thorpe, 1995; and see Fig. 4.6 for location). Although bone tools such as pins, awls and needles are present in Neolithic 1, the rich art and jewellery that characterize the Natufian are rare. Anthropomorphic figurines have, however, been recovered from Mureybet (Cauvin, 1977) and Nahal Oren (Stekelis and Yizraely, 1963).

The faunal and botanical remains recovered from Neolithic 1 sites suggest intensive collection and/or cultivation of cereals and legumes. A reliance on wild seeds and fruits, and the hunting of wild gazelles has been inferred (Belfer-Cohen and Bar-Yosef, 2000; Moore, 1982). Morphologically domestic emmer and barley have been recovered from sites such as Gesher and Jericho in the Jordanian Rift System, and Tell Aswad in the Damascus Basin (van Zeist and Bakker-Heeres, 1979). Although the domestic status of cereals from Neolithic 1 sites is difficult to determine from morphology alone chemical analysis of lipids extracted from the seeds using high-performance liquid chromatography (HPLC) has suggested that the grains from Neolithic 1 Mureybet are wild whereas those from Neolithic 1 Abu Hureyra are domesticated (Hillman et al., 1993).

Burials are located within the settlement rather than in separate cemeteries as in the Natufian period. In the later Neolithic 1, skulls may be buried separately from the infracranial skeleton. This mortuary tradition continues that started in the Epipalaeolithic at Hayonim Cave (Belfer-Cohen, 1988; Belfer-Cohen (1989), cited in Belfer-Cohen and Bar-Yosef, 2000). Although there are fewer sites in Neolithic 1 than in the Epipalaeolithic, the sites are larger suggesting an increase in sedentism (Moore, 1982). If the flourishing art of the Natufian period facilitated the diffusion of scalar stress (Belfer-Cohen and Bar-Yosef, 2000), its absence in the Neolithic 1, in light of possible increased sedentism, suggests that other social mechanisms such as secondary burial ritual were developing to maintain social relations on an even keel.

6.3.3 Neolithic 1 in Anatolia

Areas suitable for early Neolithic settlement in Anatolia have been subject to high rates of alluvial deposition. As a consequence, sites of short occupation may not be recognized in surface surveys (Özdoğan, 1998) and early Neolithic sites in Anatolia are not well characterized. However, sites dating to earlier than 7,500 bc have been reported at Can Hasan, Suberde, Aşíklí Hüyük, and Haçílar (Mellaart, 1972). These sites are located on good agricultural land, by today's standards, with good water availability. The mountainous topography of Anatolia and the transhumance of modern pastoralists in the region suggest that transhumance may have also been an important settlement pattern in the past (Mellaart, 1972).

Recent excavation of sites dating to Neolithic 2 and 3 to greater depths has expanded the number of sites identified as having been occupied during the early Neolithic. The extent of occupation of Anatolia during the early Neolithic is becoming more comparable to the Levant and the Zagros than was previously thought (Özdoğan, 1998). Thus Anatolia was probably not the cultural backwater portrayed in earlier analyses of the Neolithic Revolution in the Near East.

6.3.4 Neolithic 1 in the Zagros

During the Neolithic 1 in the Zagros, climate amelioration was much slower than in the Levant with open steppe predominating in the piedmont region (Henry, 1989). The rapid changes in altitude in the mountains, with more precipitation at higher elevations, create ecotones that present the opportunity for exploitation of many habitats, and facilitate the use of a broad range of resources, continuing the Broad Spectrum Revolution. Sites in the piedmont such as Qermez Dere and Nemrik 9 are postulated to be winter-occupied sites based on their locations near local upland areas (Watkins, 1989, 1990). Similarly small sites at higher altitudes in the high Zagros such as Ganj Dareh (Level E), originally dated to ca. 8,400 bc, were thought to be occupied with movement to higher pastures in summer (Smith, 1978). Thus evidence from both piedmont and high Zagros sites was consistent with the transhumance of pastoralism that continues to the present (Kramer, 1982). However, Ganj Dareh is now dated to 7,000 bc (uncalibrated) with the entire occupation spanning 100 to 200 years at most (Zeder and Hesse, 2000). This suggests that Ganj Dareh is either very late in Neolithic 1 or entirely within Neolithic 2 and is discussed in more detail in Chapter 6.4.3. The differences in dates for Ganj Dareh calls into question the dating of other Neolithic sites in the Zagros. The radiocarbon dates, both conventional and AMS, are presented in Appendix E.

Rings of stones suggesting the use of tents and fire pits are present in the earliest level of Ganj Dareh. However, there is no evidence of permanent architecture (Smith, 1974, 1978). Goats are morphologically wild with slaughter patterns that suggest the exploitation of wild nursery herds (Hesse, 1982). The barley is reported to be domesticated (van Zeist et al., 1984). However, Kislev (1989) suggests that the barley may be morphologically indistinguishable from wild barley suggesting that the application of HPLC (see Hillman et al., 1993) may facilitate resolution of this discrepancy (see also above).

The small site of Asiab in the piedmont, dated to 9,000 to 7,000 bc, contains round, semi-subterranean buildings (Braidwood et al., 1961). Evidence of wild fauna suggests a continuing reliance of wild resources in the early Neolithic (Hole, 1984). The lithics from the site of Tepe Abdul Hosein are similar to those recovered from the lower levels of Ganj Dareh and from Asiab. No geometric microliths or obsidian were recovered (Goff and Pullar, 1970) suggesting that trade networks did not yet include populations in the central Zagros. No wheat remains have been recovered from these sites suggesting that the preferred forest-steppe habitat of wheat had not yet expanded into the region.

During a brief regional survey in 1977, three additional sites were found within a 7 km radius of Ganj Dareh (Smith and Mortensen, 1980) suggesting that the high Zagros was not as sparsely settled as had been previously thought. The slow climate amelioration in the early Holocene may have influenced the preferred subsistence strategy in the region, with the development of pastoralism rather than horticulture, but did not preclude widespread settlement in the small valleys of the high Zagros (Smith and Mortensen, 1980). If reforestation in the Zagros in the early Holocene were limited primarily by lack of summer moisture, as suggested by El-Moslimany (1986), rather than by low temperature, riverine forest cover might have adequately supplied fuel needs for seasonal and initial year-round occupation villages such as of Ganj Dareh. As fuel supplies declined with length of site occupation, supplementation of wood fuel by goat dung (as per Miller (1991, 1992, 1996)) could facilitate adaptation to the mountain environment. This would provide incentive for human control of local goat populations.

Qermez Dere ca. 8,000 bc is located at an ecotone in the Piedmont (Watkins, 1989, 1990) where wild resources such as cattle, equids, gazelle, sheep, goats, hare and birds were exploited. Sites located in this region are smaller at higher elevations suggesting possible transhumance and the movement to higher elevations in summer. At both Qermez Dere and Nemrik 9 houses are semi-subterranean. Evidence from burnt daub suggests that the dwellings had heavy roofs. The lack of hearths within the houses at Nemrik 9 (Koslowski and Kempisty, 1990) might suggest summer occupation (but see contrasting interpretation of Smith, 1978, and the fact that recognizable hearths were also not found at Ganj Dareh). Occupation of multicomponent Nemrik 9 extends from ca. 8,000 bc to 6,000 bc (Kozlowski, 1989). Remains of wild ungulates and wild grains and legumes have been recovered, although no cereals have been identified. Throughout the site's occupation, clay and stone figures were manufactured, parallelling cult development at other Neolithic 1 sites such as Mureybet and Cafer Hüyük (Kozlowski, 1989).

With the exception of Nemrik 9 where a separate cemetery was identified (Kozlowski, 1989) Neolithic 1 burials are primarily within habitation sites. Burials have been recovered from beneath house floors and in sealed niches at Ganj Dareh (Smith, 1974) and at Asiab two individuals, stained with red ochre, were buried beneath house floors (Braidwood et al., 1961). Burials also been occurred within house fill at Qermez Dere (Watkins, 1989, 1990) and Nemrik 9 (Kozlowski, 1989). These examples from the Zagros are consistent with widespread development of the specialized mortuary practices that are thought to be an important component in behaviour designed to alleviate increases in scalar stress associated with developing sedentism (Kuijt, 1996, 2000).

6.3.5 Neolithic 1 Summary

Neolithic 1 elaborates the trends that developed in the Late Epipalaeolithic. The sites of the Near East that were inhabited during Neolithic 1 are distributed throughout the Fertile Crescent (Fig. 6.2). Variation in site size with elevation suggests a circulating settlement pattern with base camps at lower elevations (Mortensen, 1972). Houses are round with no interior partitioning.

Wild plant and animal resources continue to be an important component of the Neolithic 1 subsistence economy (Henry, 1985). At some sites in the Levant such as Abu Hureyra, Gesher, Jericho and Tell Aswad there is evidence for cereal domestication (Bar-Yosef and Belfer-Cohen, 1992; Harlan, 1998; Hillman et al., 1993; van Zeist and Bakker-Heeres, 1979).

Burials within villages beneath floors or between buildings are the norm (cf. Natufian cemeteries). Limited evidence (Belfer-Cohen (1989), cited in Belfer-Cohen and Bar-Yosef, 2000; Watkins, 1990) suggests a continuation of the preferential mortuary treatment of skulls that was first seen in the Epipalaeolithic.

6.4 Neolithic 2

6.4.1 Introduction

Neolithic 2 spans 7,600 bc to 6,000 bc. Location of Neolithic 2 sites, including those mentioned in the text, are shown in Figure 6.3.

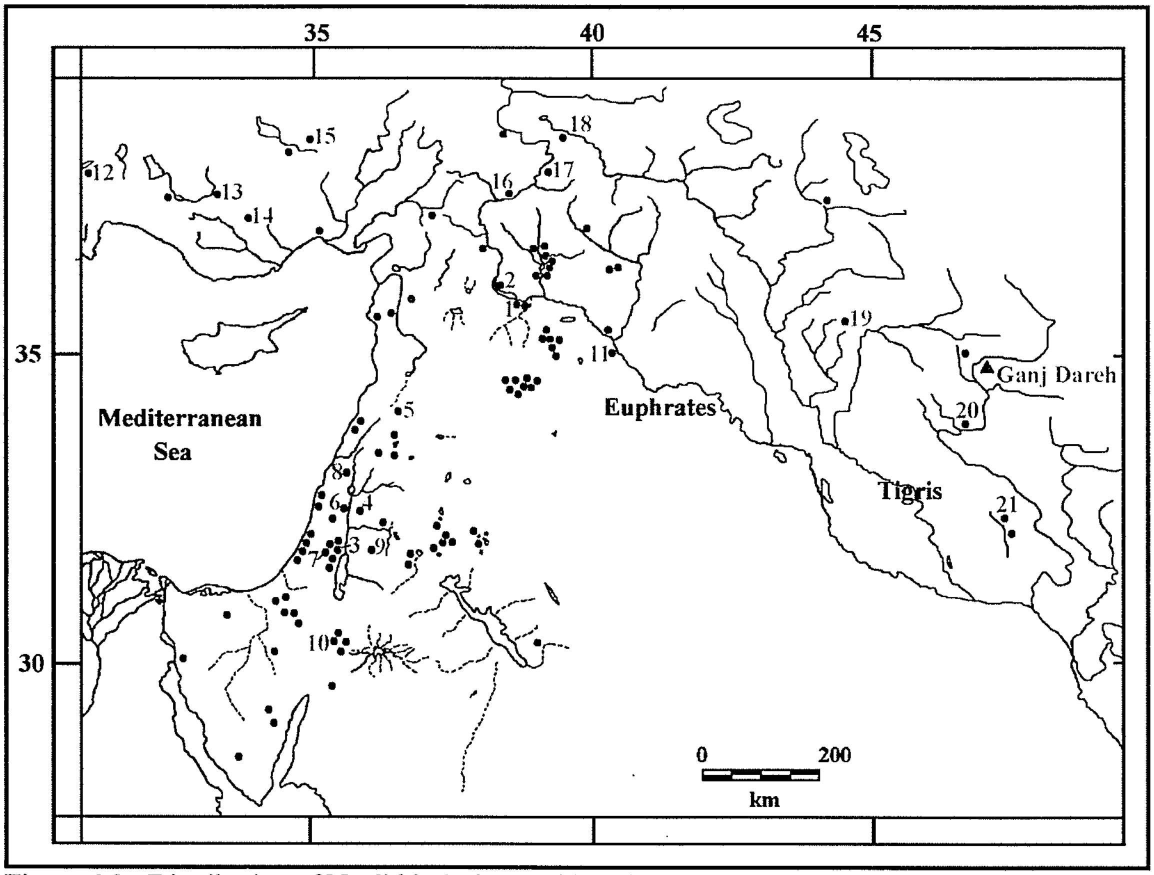

Figure 6.3. Distribution of Neolithic 2 sites and locations relative to Ganj Dareh.

1 Abu Hureyra	8 Beisamoun	15 Aşíklí
2 Mureybet	9 'Ain Ghazal	16 Gritille
3 Jericho	10 Beidha	17 Cafer Höyük
4 Tell Ramad	11 Bouqras	18 Çayönü
5 Labweh	12 Haçilar	19 Jarmo
6 Munhatta	13 Çatal Hüyük	20 Tepe Guran
7 Abu-Ghosh	14 Can Hasan III	21 Ali Kosh

6.4.2 Neolithic 2 in the Levant

By Neolithic 2, 7,600 to 6,000 bc, both site number and size have increased (Moore, 1982). Houses are rectilinear rather than circular, with interior partitioning into several rooms. However, the transition from round to rectangular houses varies temporally occurring at both Mureybet and in Palestine at the beginning of Neolithic 2 (Moore, 1982) while not occurring at Beidha in the southern Transjordan region until the middle of Neolithic 2 (Kirkbride, 1966). It is not clear whether this indicates that the other transitions associated with Neolithic 2 occurred later at Beidha, or that the changes in house shape in the Transjordan are not diagnostic of Neolithic 2 culture.

Obsidian recovered from Neolithic 2 sites was obtained from eastern Lake Van sources rather than the Neolithic 1 source at Çiftlik in central Anatolia (Moore, 1982; Pernicka et al., 1997). Expanding trade networks also connected Abu Hureyra in the Middle Euphrates with steatite sources in the Zagros, reducing regional isolation. Local short distance trade of bitumen, basalt, coloured limestone and gypsum is also evident (Moore, 1982).

Many more ground stone tools have been recovered from Neolithic 2 than Neolithic 1 sites (Moore, 1982). Regional distribution of axes appears to be dependent on the estimated local timber availability. Although axes are rare at Abu Hureyra in the middle Euphrates, they occur in relatively higher frequency at sites in the Mediterranean forest zone such as Tell Ramad, Labweh, Munhatta and Abu-Ghosh (Moore, 1982). Technology for the manufacture of plaster from gypsum developed. Lime plaster on walls and the construction of plaster vessels, recovered from the Syrian sites of Abu Hureyra, Bouqras, Tell Ramad and Labweh (Akkermans et al., 1983; Kafafi, 1986; Rollefson, 1990), suggest craft specialization and increasing social complexity (Moore, 1982).

Domesticated sheep, goats, pigs and cattle were present in the Levant, replacing wild gazelles in archaeological assemblages by late Neolithic 2 (Rollefson, 1989). The economy was dominated by the cultivation of cereals and pulses including domesticated einkorn and emmer wheat, barley, chickpeas and lentils (Miller, 1992). Thus by the end of Neolithic 2, the subsistence of Levantine communities is distinctly based on agriculture.

Burials are located under house floors or between buildings as single primary burials or as secondary collective burials. Frequently a skull was removed from the infracranial skeleton and given special treatment such as painting with red ochre (Moore, 1982). At Jericho, Tell Ramad and Beisamoun skull treatment included modelling with plaster before reburial in a new location (Ferembach and LeChevalier, 1973; Rollefson, 1983; Strouhal, 1973) suggesting intensification of social mechanisms for diffusion of scalar stress (Kuijt, 1996, 2000).

6.4.3 Neolithic 2 in Anatolia

In contrast to the paucity of Neolithic 1 sites in Anatolia, there are numerous sites dating to Neolithic 2, such as Çayönü, Çatal Hüyük, Can Hasan III and Haçílar. As in other regions of the Near East, the houses are rectilinear in form. However, internal dwelling complexity is evident at Çayönü on the upper Euphrates (Braidwood et al, 1971, 1974) and at Çatal Hüyük houses are tightly packed (Mellaart, 1975). The presence of burnt lime in the lowest levels ca. 7,500 bc indicates that plaster making technology had been perfected (cf. plaster use at the contemporary Levantine sites of Jericho, 'Ain Ghazal, and Bouqras). In later Neolithic 2, the replacement of gypsum plaster with clay suggests that firewood sources were depleted by intensive lime plaster production (Matthews, cited in Balter, 1999). At Çayönü evidence for the development of technology for cold-hammered working of copper has been recovered (Braidwood et al, 1971, 1974).

At most Anatolian sites gazelles are gradually replaced by domesticated sheep and goats. The increasing proportion of sheep to goats, in combination with the decline in faunal remains through time, suggests an increasing importance of secondary animal products such as milk and wool. The presence of spindle whorls (Mellaart, 1975), wool fabric and carpets in the upper levels of Çatal Hüyük (Burnham, 1965) also supports this interpretation. However, inter-site variation in caprine exploitation strategies is observed. For example, morphologically wild caprines have been recovered from early levels of Cafer Höyük and Aşíklí, ca, 7,200 bc, whereas domesticated caprines are present by between 6,400 to 5,800 bc at Gritille on the upper Euphrates (Harlan, 1998). The presence of domesticated cereals such as barley and wheat and lentils and peas (Hole, 1984), and the overall declining proportion of faunal remains at most Anatolian Neolithic sites, has been interpreted as an increased reliance on cereal production (Braidwood et al, 1971, 1974).

The mortuary tradition of burial beneath house floors was continued during Neolithic 2 (Mellaart, 1975). Children of Çatal Hüyük were buried in baskets (Balter, 1999; Mellaart, 1975). These practices appear to be similar to the burials of children in pottery vessels at Byblos in the Levant during the Neolithic 3 period (Moore, 1982). Two isolated skulls, with frontal bones touching were recovered during the 1999 field season at Çatal Hüyük (Balter, 1999). This indicates a possible continuation of the separate treatment of skulls and burial practices observed at the Epipalaeolithic site of Hallan Çemi, on a tributary of the Tigris (Rosenberg and Redding, 2000). However, there is also evidence to suggest that mortuary practices in the Near East were becoming regionally differentiated. For example at Çayönü, 90 skulls and the remains of at least 400 individuals were recovered from within one building (Schirmer, 1990).

6.4.4 Neolithic 2 in the Zagros

Neolithic 2 sites have been found in both the piedmont: Jarmo, Tepe Guran and Ali Kosh, and the high Zagros: Ganj Dareh (Flannery, 1969), continuing the settlement pattern established in Neolithic 1. Early interpretations suggest a pattern of transhumance, with winter base camps at lower elevations and summer sites at higher elevations (Flannery, 1969; Mortensen, 1972). However, there is substantial evidence from the presence of the commensal *Mus musculus*, house mouse, that some high elevation sites such as Ganj Dareh were occupied year-round (Hesse, 1978). Year-round occupation of villages does not preclude transhumance by certain segments of the population, as documented ethnographically in many regions of the world (reviewed in Salzman, 1996). Houses are multi-roomed, rectilinear mudbrick dwellings. During the early Neolithic 2, houses increased in size. The proportion of seeds represented by wild small-seeded wild legumes declines, possibly indicating decreased reliance on wild plant resources. By end of Neolithic 2 goats, for example in the upper levels of Ali Kosh, are clearly morphologically domesticated as indicated by medially-flattened horn cores (Flannery, 1969).

Jarmo is a multicomponent site spanning 300 to 500 years of the early to mid seventh century bc. It is situated in the Chemchemal Valley, an intermontane plain at an altitude of 800 m with numerous perennial streams and springs. Oak charcoal has been identified suggesting that the oak forest was in close proximity to the site (Braidwood, 1983). Both wild and domesticated forms of emmer and einkorn wheat were recovered (Watson, 1983). The large size of caprine horn cores and the low proportion of juvenile caprine remains suggest that the caprines may have been wild (Stampfli, 1983). Overall the Jarmo inhabitants exploited both wild and domesticated resources.

Mortensen (1972) used Tepe Guran, located at an elevation of 950 m and dated from ca. 6,300 bc to 5,900 bc, for the development of his model of settlement patterns. Domesticated goats were recovered from all levels of this site suggesting that the inhabitants may have been pastoralists. The appearance of mud-walled houses, mortars, grindstones and sickle-blades in the upper levels suggests a shift from a seasonal round with base camps in Neolithic 1 to a radiating settlement pattern in early Neolithic 2 (Mortensen, 1972). By 6,200 bc, both 2-row barley and pistachios had been added to the diet as had domestic pigs. The wide spectrum of exploited resources included both wild and domesticated forms of emmer, einkorn, barley, as well as field peas, lentils and vetch. The economy that had developed encompassed both the exploitation of local wild and agricultural resources (Mortensen, 1972).

Ali Kosh, at the boundary between the piedmont and the southern Mesopotamian alluvium, was occupied between ca. 8,000 and 5,900 bc (Flannery, 1969). Food resources include emmer wheat and 2-row hulled barley, chickpeas, and wild cereals (Miller, 1992), as well as domesticated sheep and goats. The hunting of wild fauna such as onager, boar and ox remained important through all levels of Ali Kosh, as it had at Tepe Guran. Throughout the site occupation the only change observed in the faunal assemblages is an increase through time of the proportion of sheep relative to goats (Flannery, 1969). This is consistent with studies of overall trends in the sheep:goat ratios in southwestern Iran (Redding, 1985). Over this same period, Ali Kosh more than doubled in area suggesting that a gradual increase in population size had occurred during Neolithic 2. From its establishment ca. 8,000 bc, the mudbrick buildings were multi-roomed and rectilinear (cf. the shift to rectilinear buildings in the Levant following 7,600 bc).

In the Zagros, many sites such as Jarmo and Ali Kosh were radiocarbon dated prior to the development of accelerator mass spectrometry (AMS) dating techniques. The much larger samples required increased the risk of sample contamination. In addition, bitumen, a carbon-based local resource at some sites in the piedmont, was used on basketry and as an adhesive (Braidwood and Howe, 1960). Its presence can systematically skew the radiocarbon dates resulting in radiometric dates that are older than the actual chronological dates (Bowman, 1990). In contrast, at more recent excavations in the Levant, AMS methods have been employed. Thus, the temporal change in radiocarbon methodology and/or the contamination of sites with ancient hydrocarbons may increase the inter-site variability in the inferred timing and pace of observed cultural changes.

In the high Zagros an important Neolithic 2 site is Ganj Dareh. The site is dated to 7,000 bc (Zeder and Hesse, 2000). Pollen analysis suggests that the vegetation of the region was pistachio-almond forest-steppe. Wild and some possibly domesticated barley were the only cereals recovered from the site (van Zeist et al., 1984). Almonds and pistachios were abundant. Their presence is consistent with the delayed expansion of the oak forest zone relative to that in the Levant (van Zeist and Bottema, 1977). Goats were under human control although still morphologically wild. This assessment is based on slaughter patterns (Hesse, 1982, 1984) and the presence of goat hoof prints in the mudbricks of some buildings. In Level D, honeycomb subterranean structures, possibly for storage, were observed. The presence of large ceramic vessels may suggest incipient pottery. However, these may have been sun-dried vessels that were fired *in situ* during an extensive village fire that preserved much of Level D (Smith, 1978).

Human skeletal remains were recovered from beneath house floors. Cranial deformation has been observed in the intact skulls possibly indicating the beginnings of social stratification (Meiklejohn et al., 1992). In addition, although a few human figurines were recovered from Level E of Ganj Dareh, large numbers of animal and human figurines were recovered in Level D (Smith, 1978). This may indicate increasing scalar stress (Belfer-Cohen and Bar-Yosef, 2000) at Ganj Dareh with the establishment of permanent architecture.

6.4.5 Neolithic 2 Summary

Neolithic 2 is generally identified in the archaeological record by a transition from round houses found in Neolithic 1 to rectilinear dwellings. Growth in site size occurs through time. In Anatolia, there is evidence to support the development of building specialization (Braidwood et al, 1971, 1974; Schirmer, 1990). There is inter-site variation in the proportion of lithics made from obsidian suggesting regional variation in trading networks and the amount of long distance trade.

The relative importance of wild fauna varies across the Near East reflecting regional differences in adaptive strategies. In the central Zagros, there is continued reliance on a substantial proportion of wild fauna throughout Neolithic 2 (Flannery, 1969;

Hesse, 1978), while further west at Çayönü in Anatolia, the proportion of gazelles declines as does the overall faunal assemblage. In the Levant, as in Anatolia, there is a dramatic decrease in the proportion of wild fauna in the bone assemblages (Rollefson, 1989).

At sites dating to the end of Neolithic 2, evidence of domesticated plants has been recovered in all three regions of the Near East (Moore, 1985). In contrast, domesticated goats are present by the beginning of Neolithic 2 in the Zagros, and by the end of Neolithic 2 in the Levant (Hole, 1984, 1996). This places the process of ovicaprid domestication and the development of an economic system that was in part focussed on pastoralism squarely in the Archaic Neolithic (Neolithic 1 and 2).

Burials continue to be within settlements. The separate treatment of skulls increases in frequency. During Neolithic 2 the skulls of cattle are embedding in walls at Çatal Hüyük (Mellaart, 1975), ovicaprid skulls in walls of Ganj Dareh (Smith, 1972), whereas at Bouqras one human skull was plastered into a wall (Akkermans et al., 1983). In addition, some skulls recovered from sites in the Levant were modelled with plaster faces prior to secondary burial (Ferembach and LeChevalier, 1973; Rollefson, 1983; Strouhal, 1973).

6.5 Summary: Culture History and Subsistence Transition

Key to the understanding of human health is the contribution of both the physical and cultural environments, including plants and animals inhabiting the region under consideration. The balance between plant and animal resources utilized, and between sedentary and nomadic settlement patterns greatly affects the health and well-being of human societies (this will be discussed in greater depth in Chapter 7).

Across the Pleistocene-Holocene boundary, examination of the culture history of the Near East reveals three predominant inter-related trends: increase in sedentism, in population size and density, and shifts in diet and subsistence activity. The development of Epipalaeolithic cultures in the Near East is presently thought to have facilitated the adoption of agricultural subsistence through a series of major cultural changes prior to 8,500 bc (Henry, 1985; Hayden, 1990; Rosenberg, 1990; Rosenberg and Redding, 2000) reflecting changes in social organization and a transition from simple to complex hunter/gatherer subsistence strategies. Of primary importance is the development of sedentism in the Epipalaeolithic. Over the period of the Epipalaeolithic, Neolithic 1 and Neolithic 2, site number and size increased. While early sites are within caves, open air sites with permanent architecture rapidly become the norm. Correlation of settlement patterns with changes in subsistence activities however is not straightforward.

The appearance of permanent architecture, initially as round houses in Neolithic 1, and then as rectilinear houses in Neolithic 2 has been interpreted as an indicator of agriculture (Moore, 1985) and thus sedentism. However, villages with stone or mud brick dwellings may not necessarily indicate a completely sedentary lifestyle. In modern northern Mexico, permanent architecture coexists with transhumant pastoralism, agriculture and living in caves in winter (Hard and Merrill, 1992). Other archaeological evidence such as the presence of commensals is necessary in establishing year-round site occupation.

The change in habitation from caves to open-air sites in the Epipalaeolithic and to permanent architecture occurred during the proposed period of early human-caprine interactions (Hole, 1996). Modern ethnographic analogy from the Shanidar cave in western Iran (Solecki, 1963) and from northern Mexico (Hard and Merrill, 1992) suggests that, at least for already domesticated caprines, cave dwelling facilitates herd protection, especially during the winter. If this were also the case at the end of the Pleistocene, and if movement to open-air sites were necessary for as yet unidentified reasons, unique solutions, such as the development of permanent architecture, would have been required for herd protection from predators. For example in modern Iran (Kramer, 1982), stables are located underground, and directly beneath village houses. I suggest that early permanent dwellings could have afforded the herds and their herders with adequate protection and additional residential flexibility not offered by caves. Thus, in the Zagros where evidence of domesticated cereals in the early Holocene is lacking (Hole, 1984, 1996; but see van Zeist et al. (1984) for an alternate view), the transition to sedentism and permanent architecture could have been at least in part a response to incipient pastoralism.

The pattern of intensive exploitation of a broad spectrum of resources, established in the Epipalaeolithic (Flannery, 1969), continued through both stages of the Archaic Neolithic, with increasing interactions between humans and the plants and animals in their environment (Miller, 1992; Redding, 1988). Within each ecological niche and its associated ecotones and ecozones, unique optimal adaptive strategies could develop, contributing to the inter-site and inter-regional variation in archaeological assemblages and inferred adaptations. The transition cannot be expected to be a unilinear irreversible process, nor to proceed at uniform rates in all regions. For example, domesticated cereals appeared 2,000 years earlier in the Levant than the central Zagros. In contrast, there is evidence of human-caprine interactions in the Zagros 1,000 years earlier than evidence of the domestication of cereals (Hole, 1984, 1996).

The archaeological evidence, such as the recovery of wild macrobotanical remains, querns, mortars and microliths with sickle sheen, suggests that the exploitation of wild plant resources was a component of the subsistence economy of Epipalaeolithic humans in the Zagros/Piedmont region (cf. Hole, 1984). Thus if animal domestication preceded plant domestication in this region (archaeological evidence summarized in Table 6.1), the presence of appropriate technology is not a sufficient condition to initiate the early development of a plant-based agricultural economy. Local circumstances including overall climate, climate stability, local availability plant and animal resources, social organization, ideology, and human behavioural concerns all influence individual and group subsistence choices.

Site	Date (Years bc)	Faunal Remains	Botanical Remains
Zawi Chemi [2,4]	10,000-9,000	Possibly domesticated sheep (slaughter pattern)	Wild plants
Hallan Çemi [3]	9,000-8,700	Possibly domesticated pigs (tooth size, slaughter pattern)	Wild pulses, pistachio No cereals recovered
Ganj Dareh [1,5]	7,000-6,800	Goat domestication (slaughter pattern, hoof prints in bricks)	Barley (wild and/or domesticated) No wheat recovered

Table 6.1. Balance between plant and animal exploitation at selected Epipalaeolithic and Neolithic 1 sites in the Zagros and eastern Anatolia.

[1] Hesse (1982).
[2] Perkins (1964), but see Zeder (2000) for an alternate and the presently accepted view.
[3] Rosenberg et al (1998).
[4] Solecki (1983).
[5] van Zeist et al. (1984).

The increase in site size does not always have to indicate an increase in population size. Uninhabited houses in disrepair and with slumped walls are interspersed among inhabited dwellings in agricultural villages in modern Iran, so that increased village size could be at least partly a function of the length of site occupation. During archaeological excavations houses are represented by wall stubs so that contemporaneity of dwelling occupation is difficult to discern (Kramer, 1982). Thus, the increase in site size is not necessarily indicative of increasing population although it has been used to support Population Pressure Models of agricultural origins (for example Smith and Young, 1972) and is an important contributing factor to declining sanitary conditions associated with sedentism.

The social models of the origins of agriculture (reviewed in Chapter 3) suggest that resource competition occurred. Competition for prestige items is postulated to have occurred in a climate of resource abundance in Hayden's (1990) Accumulator Model. In this scenario, good overall population health is predicted. In contrast, if agricultural lifeways were driven by times of resource stress, as suggested in the Allocation Model (Rosenberg, 1990), poor population health status as estimated from skeletal remains would be expected. If within group competition is framed initially in resource abundance, only to be gradually replaced by competition with neighbouring groups as resource stress develops with increasing population size (Johnson and Meiklejohn, n.d.), a diachronic decline in population health would be observed. This concurs with my hypothesis that the situation in the Near East at the Pleistocene-Holocene boundary is not as clear-cut as any of the published models suggest.

The transition to agricultural subsistence is a complex multifactorial process that occurred in a region of topographical extremes and of climatic and ecological diversity. Within the physical and environmental context of the Zagros, local variation in adaptive strategies is expected that has important implications for human health. Although generalizations can be made concerning the effects of subsistence and settlement patterns on population health (the subject of Chapter 7), consideration of local and regional cultural adaptations at sites such as Ganj Dareh is imperative for interpretation of the skeletal evidence for health of local human populations.

CHAPTER 7. HUMAN HEALTH AT THE ORIGINS OF AGRICULTURE

7.1 Introduction

Many factors, including topographic, climatic and environmental parameters of a region, resource availability, population size and density, and social organization, contribute to human health as modelled by the Biocultural Model of Health (reviewed in Chapter 2). These same factors have also been implicated in models of agricultural origins as causes and/or driving forces of subsistence shifts to plant cultivation and animal herding (reviewed in Chapter 3). As the adage "you are what you eat" implies, it appears that health and subsistence are inextricably linked. Thus, elucidation of health of the Ganj Dareh inhabitants through examination of their skeletal remains can inform on issues of archaeological importance such as subsistence activities in the central Zagros in the early Holocene.

To provide the context for the results of the current research, the literature concerning the relationships between human health and subsistence are reviewed. Before continuing, however, it is important to note that in published discussions of the relationship between health and agriculture, agriculture is defined, at least implicitly, as cultivation of plants for use as human food. This is the case in Cohen and Armelagos, 1984) and is made explicitly in Hassan (1981) and Larsen (1995). The relationship between human health and plant cultivation provides the backdrop for comparison with the health and subsistence of the Ganj Dareh inhabitants.

Early estimations of health in the past were primarily based on the assumption that the Neolithic Revolution, that is the adoption of agriculture, was the inevitable outcome of human evolution and adaptation (Childe, 1934, 1952). Such a teleological view from the early and mid twentieth century posited that agriculture was the natural and ideal solution to the cycles of resource abundance and stress considered to be part of the hunter/gatherer human condition. The model of population pressure as the primary cause of economic change, for example agricultural intensification (Boserup, 1965), was rapidly incorporated into models of the origins of agriculture (Binford, 1968; Flannery, 1969; Smith and Young, 1972) and of past health (Cohen, 1977, 1989).

The first synthesis of the relationship between health and agricultural subsistence that was based on skeletal evidence emerged from the 1982 symposium on palaeopathology at the origins of agriculture (Cohen and Armelagos, 1984). This formed part of a growing trend in skeletal biology to address problem-based research questions through the grouping of lesions of similar morphology and their quantification at the population level (Katzenberg, 1992). The relationship between health and subsistence transition was addressed explicitly. For each geographic region of the world, data of many researchers were synthesized. Although the data, taken using different methods and of varying degrees of completeness, were often difficult to compare (Rathbun, 1984; Meiklejohn et al, 1984), clear trends across the transition were identified, albeit with regional variation (reviewed in Cohen and Armelagos, 1984:Chapter 23). Agricultural populations exhibit higher prevalences of infections and of evidence of malnutrition, changes in types of evidence for episodic stress, and lower severity of peak physical stress and of trauma than do their hunter/gatherer counterparts. A more recent survey of the published literature (Larsen, 1995) documents the biological changes (health consequences) associated with the transition from hunting and foraging to plant-based farming, that is, from food collection to food production in many different ecological and topographical regions of the world, confirming that the broad trends in health status are frequently modified by site- and region-specific context.

Clearly identified in these reviews (Cohen and Armelagos, 1984; Larsen, 1995) are variables associated with agricultural subsistence that affect population health, including increases in sedentism and population size, the introduction of new foods and/or changing proportions of existing foods, and changes in habitual activities (reviewed in the subsequent sections of this chapter). However, for populations in the Fertile Crescent of the Near East, a substantial body of evidence (reviewed in Chapter 6) indicates that sedentary communities were well established by the late Epipalaeolithic. Thus, some of the identified variables such as sedentism could very well exact their effects on health independently of subsistence change suggesting that populations must have begun to adapt to declining sanitary conditions and increasing scalar stress well in advance of archaeological evidence of plant and animal domestication (reviewed in Chapter 6). Health consequences are also a function of the degree to which changes in social organization buffered the negative effects of sedentary settlement patterns. It may be difficult, however, to isolate a single cause for health changes observed in past populations, making multifactorial explanations within a post-"Osteological Paradox" theoretical framework mandatory for bioarchaeological interpretation.

The remainder of this chapter summarizes health trends observed in sedentary and food-producing communities. A review then follows of the presently available data of health in the Zagros/Piedmont at the end of the Pleistocene and the early Holocene. The expected health outcomes of subsistence transition vary with conditions and assumptions inherent in the different models of agricultural origins. For each model, data for the Ganj Dareh inhabitants are predicted.

7.2 Health in Sedentary Communities

The change from mobile to sedentary settlement patterns affects human biology of village inhabitants and sanitary conditions of the immediate surroundings of habitation sites. As discussed in Chapter 3.4 the critical fat hypothesis, originally developed to explain amennorhea and late menarche in athletes (Frisch and Revelle, 1970; Frisch and McArthur, 1974), has been invoked to explain late Pleistocene - early Holocene increases in population size in regions of the Fertile Crescent through a reduction in birth spacing. Critiques of the Critical Fatness Hypothesis emphasize the complexity of reproductive physiology and of the relationship among age of menarche, birth spacing and diet concluding that other contributing factors such as psychological stress (Scott and Johnson, 1982) and increased availability of plant-based weaning foods (Hassan, 1981) require consideration. In modern peoples, higher fertility rates are observed in intensive agriculturalist than in non-agricultural communities. However, the great degree of variation in fertility rates and overlap of the two groups leads some authors to the conclusion that it is "impossible to predict fertility on the basis of subsistence alone" (Bentley, Jasieńska and Goldberg, 1993:779).

An alternate explanatory model of fertility and family size, developed in a modern Mayan population, correlates fertility with the balance between food production contributed and food consumed by each additional child in a household. Only with the intensification of agriculture does children's contribution to family food production adequately compensate the cost of their consumption of additional food. As a result, fertility rates observed in intensive agricultural populations are higher than those in the non-agricultural and horticultural groups surveyed (Kramer and Boone, 2002). Thus at Ganj Dareh where evidence for intensive agricultural subsistence strategy is lacking (Waddell, 1994) fertility rates approaching those of non-agriculturalists are predicted.

If fertility rates and population size are increasing, the age profile of a skeletal sample is predicted to exhibit an increased proportion of infants and young children, low estimated life expectancy at birth, and reduced mean age-at-death (Jackes, 1994; Paine and Harpending, 1998; Sattenspiel and Harpending, 1983; Wood et al., 1992). In contrast, Cohen (1989) interprets these same changes in demographic parameters as evidence for decline in health and increase in mortality rates in agricultural populations.

For populations at the Pleistocene/Holocene boundary, infectious diseases are primarily zoonotic and/or environmental in origin (Cockburn, 1971; Cohen, 1989; Inhorn and Brown, 1990). Based on ethnographic evidence in modern hunter/gatherer communities, population sizes are thought to have been too small to sustain a chain of transmission for acute diseases such as measles and smallpox (Black, 1975). Diseases that are chronic and/or have substantial portions of their life cycle in the environment, for example in water and soil, or in non-human vectors, such as ungulates and invertebrates, predominated and were capable of being maintained in small populations (Cockburn, 1971; Cohen, 1989; Inhorn and Brown, 1990).

With increased sedentism and population density, sanitary conditions in close proximity to and within villages declines, facilitating pathogen exposure through the fecal-oral route. The aggregation of hosts and pathogens in close proximity also promotes the human-to-human transmission of air-borne organisms increasing rates of infection. From the pathogen's perspective, human sedentism provides a continual supply of newly susceptible individuals, perpetuating disease in the community (Brothwell, 1991; McGrath, 1992). Human susceptibility to disease is exacerbated by the scalar stress that accompanies life in sedentary settlements (Johnson, 1982), by contributing to psychological stress and compromising immune function (Tsigos and Chrousos, 1996). Increased susceptibility contributes to increased rates of infection following exposure and to conversion from a state of infection to active disease (Brothwell, 1991; McGrath, 1992). In times of rapid climatic fluctuations, resource stress and its counterpart malnutrition could compound adverse health effects associated with sedentism.

7.3 Health and Food-Producing Economies

In addition to the effects of increasing sedentism, the subsistence transition from hunting and gathering to plant-based farming (reviewed in Larsen, 1995) affects diet composition, the types and duration of exposure to pathogens and toxins, and repetitive habitual activities. These changes affect rates of oral health status, dental attrition, bone growth and development, inflammatory processes and patterns of bone injury and bone robustness (reviewed in Larsen, 1995, 1997). The specific skeletal indicators used in this study to assess health in the Ganj Dareh people are discussed in Chapter 8.

Increased reliance on plant foods as the primary source of calories is accompanied by reduced intake of essential amino acids, altered vitamin and trace minerals composition of the diet, and increased ingestion of chelators such as phytates that reduce trace metal bioavailability. The transition to plant-based agriculture has been associated with increased rates of caries and ante-mortem tooth loss (AMTL) in South America (Kelley et al., 1991) and in south-central Asia (Lukacs, 1989, 1992). Associated changes in dental attrition (BH Smith, 1984) and trauma, related to the hardness of food sources and changes in food preparation, and observed as changes in tooth macro-and micro-wear and in prevalence of tooth chipping, can also contribute to the observed changes in caries and AMTL rates (Larsen, 1995). However, the extent of changes is also dependent on the specific carbohydrate source. For example, the transition from hunting and foraging to rice agriculture in southeast Asia is not associated with increased rates of caries and AMTL (Tayles et al., 2000). In addition, pre-agricultural caries rates can be influenced by readily available sources of dried fruits such as figs, dates and raisins. Continued consumption of these cariogenic foods across the Epipalaeolithic (Mesolithic)-Neolithic boundary can obscure dental evidence that characterizes the adoption of plant-based agriculture in many populations so that caries rates can remain constant across the subsistence transition or even be reduced (Lubell et al., 1994; Meiklejohn et al., 1988). These observations are consistent with post-paradox interpretative frameworks that suggest that site-specific context is essential for interpretation of health status. This also suggests that in certain regions many of the changes previously associated with the transition to agriculture had already occurred in the Epipalaeolithic (Henry, 1985). These influences on dental health should not be expected in the early Neolithic of the Zagros if first food production were animal-based, and relative consumption of wild plant resources unchanged across the transition.

In times of climatic fluctuations, as suggested for the late Pleistocene and early Holocene (COHMAP Members, 1988), the types of wild plants exploited can influence human health. The use of pulses but not grains in the Epipalaeolithic at Hallan Çemi suggests that some populations of the Zagros may have been at risk in times of resource stress for the development of lathyrism, a progressive paraplegia caused by a neurotoxin in some species of *Lathyrus* (reviewed in Hansen (1999) and tentatively identified in an individual from Bouqras ca. 6,000 bc (Merrett and Meiklejohn, 2001)). Thus, diseases that are associated with plant-based economies such as Bouqras may also be present in incipient pastoralist populations in the Zagros/Piedmont region.

Changes in subsistence strategy can result in changes in patterns of pathogen exposure (Larsen, 1995, 1997; McGrath, 1992). With the domestication of animals, increased exposure to zoonotic pathogens, transmitted from the normal reservoirs in non-human animals to humans, can be expected on a daily basis and possibly within villages (as indicated by goat hoof prints in the mud bricks at Ganj Dareh; Smith, 1978), rather than on more isolated occasions at the time of the hunt. At Hallan Çemi, the possible domestication of pigs suggests that increased exposure to trichinosis may be expected. An increased prevalence of diseases that are transmitted from caprines to humans such as tuberculosis at Zawi Chemi (Agelarakis, 1989; Ferembach, 1970) and brucellosis, tentatively identified in one Ganj Dareh individual (Merrett, 2001), are to be expected.

In regions of plant cultivation, tilling the soil increases exposure to soil pathogens (St. Hoyme, 1969). If early Neolithic villagers in the Zagros were pastoralists, increases in infections due to exposure to soil fungi might not be expected. However, since the dwellings in sedentary communities are constructed of mud-bricks in this region, the presence of soil-borne fungal diseases is possible, particularly in individuals with compromised immune systems (Ortner, 2003). These changes are expected at the beginning of sedentism and permanent dwelling construction rather than at the beginning of plant cultivation. Mud-brick houses also decrease air circulation relative to less permanent structures. Increased prevalence of diseases transmitted *via* the air-borne route such as maxillary sinusitis (Merrett, 2003; Merrett and Pfeiffer, 2000) and certain intestinal parasites (Araújo et al., 1998) is predicted.

Subsistence strategy affects the types, duration and intensities of daily physical activities (Larsen, 1995, 1997). Examination of the condition, severity and skeletal distribution of articular surface lesions, and muscle and ligament insertions, provides insight into the nature of workloads and the severity of repetitive injuries experienced by past peoples. Changes in subsistence activities can alter the age of onset of development of activity related diseases such as osteoarthritis. For example, evidence of repetitive habitual activities such as the grinding of grains has been observed in the agricultural community of Abu Hureyra (Molleson, 1989, 1994, 2000). In modern communities in the Near East where refrigeration is not available, grinding of grains for daily consumption occupies many hours during which high levels of mechanical stress are exerted on hyper-flexed knees and toes. The high prevalence of osteoarthritis of the knee and first metatarsal-phalangeal joints and of vertebral osteophytes in young women of Abu Hureyra is attributed to similar subsistence-related activities (Molleson, 1989, 1994, 2000). The presence of technology for the exploitation of wild cereals in Epipalaeolithic of the Zagros/Piedmont region, that is grind stones, suggests that repetitive activities in the early Neolithic may have changed only in frequency and duration, and not in kind.

7.4 Health in the Zagros/Piedmont Region

A wide range of factors contributes to health status of the individual and the population including climate and environment of a region, and the local flora and fauna to which the human inhabitants are exposed. The wide topographic and climatic variation in the Zagros (Zohary, 1973) and the resulting local adaptations to resources and terrain exert substantial influences on human health, for example on the age of onset and severity of osteoarthritis. Since particular diseases experienced are predicted to vary with the local species domesticated (Groube, 1996), ovicaprid zoonotic diseases such as tuberculosis and brucellosis are expected to be present in populations where early goat herding has been archaeologically documented. To provide a background for estimation of health of the inhabitants of Ganj Dareh, current knowledge of health in the Zagros is reviewed.

In his review of the palaeopathology of Iran and Iraq, Rathbun (1984) remarks on the paucity of analyses of human health at the origins of agriculture in the eastern portion of the Fertile Crescent. Those that do exist have not followed identical research strategies, so that inter-site comparisons are problematic. In addition, the small sample sizes and the fragmentary nature of the remains hinder interpretation and identification of temporal trends. The Epipalaeolithic remains from Zawi Chemi Shanidar suggest high prevalence of degenerative joint disease (DJD), dental attrition and AMTL with few caries and no Harris' Lines. Neolithic health status, based primarily on later Neolithic sites (Deh Luran, Choga Sefid and Tepe Guran), is assessed as poorer than that of the Epipalaeolithic, with similar prevalence of DJD, but with higher rates of trauma, dental attrition and caries.

A temporal trend of increased prevalence of Harris' Lines is observed (Rathbun, 1984) suggesting that later Neolithic juveniles experienced more frequent episodes of stress and were thus overall less healthy than their Epipalaeolithic counterparts, or alternately that they, at minimum, recovered from multiple illnesses or bouts of malnutrition before succumbing (Wood et al., 1992). This trend contrasts with some North American populations where frequency of Harris' Lines declines with the adoption of maize horticulture (Cassidy, 1984; Perzigian et al., 1984) where by inference the juveniles were healthier in horticultural societies or died before recovering sufficiently for long bone growth to resume (as *per* Wood et al., 1992). This illustrates the variability in health indicator trends with subsistence transition, emphasizing the importance of site-specific context for data interpretation.

Mean age-at-death is reported to have remained constant from the Epipalaeolithic to the metal ages in the Zagros, possibly suggesting that fertility rates did not change throughout this period. However, the number of sites increased dramatically in the Kermanshah Valley during the Chalcolithic period (Smith and Young, 1983) implying that there should be demographic evidence of population growth, that is reduction of mean age-at-death. Small sample sizes and sampling bias against younger individuals for the sites surveyed by Rathbun (1984) skews estimation of fertility rates, so that those reported are at best minimum fertility estimates (Paine and Harpending, 1998).

Growth studies in modern populations reveal that those who experience growth suppression in childhood generally attain reduced terminal height although catch-up growth can occur following exposure to stressors (Bogin, 1988; Larsen, 1997). Thus, following uniformitarian assumptions, estimates of mean adult stature have been used as indicators of overall population health in past populations. In the Zagros, mean stature of women is relatively constant from the Epipalaeolithic through the metal ages. However, mean height for men is much more variable, as is the degree of sexual dimorphism in stature (Rathbun, 1984). As with estimates of fertility, small sample sizes and the paucity of sites representing each time period limit the usefulness and validity of these comparisons.

Bone as a living tissue is in a state of flux throughout life, incorporating stable isotopes and trace elements from the environment, including the diet, into its molecular structure. Through chemical analysis of bone, consumption profiles obtained can be related to past dietary patterns although interpretation of elemental signals is complex (Sandford and Weaver, 2000). The estimation of the proportions of plant and animal resources in the diet of populations in the Fertile Crescent has been estimated by the ratio of strontium to calcium (Sr/Ca) in human skeletal samples (Schoeninger, 1981; Sillen and Lee-Thorp, 1992; Smith et al., 1984). The Sr/Ca ratio varies inversely with the trophic level such that herbivore bone contains more strontium than that of carnivores, with humans intermediate between the two (Schoeninger, 1981, 1985).

In a comparison of Sr/Ca ratios of generalized and specialized hunter/gatherers from the Fertile Crescent, the Ganj Dareh samples were most similar to those of the generalized hunter/gatherers from Kebara C suggesting that both have substantially higher proportions of meat in their diet than the specialized Natufian hunter/gatherers (Schoeninger, 1981). Further analysis of the Levantine hunter/gatherers suggests that the dietary composition of the specialized and generalized hunter/gatherers were more similar than previously thought (Sillen and Lee-Thorp, 1991), despite differences in food-processing technologies that are observed in the archaeological record (Henry, 1985; Sillen and Lee-Thorp, 1991). In the Zagros/Piedmont, where the archaeological differences are less pronounced, a continuing high proportion of meat resources in the diet could be consistent with the early development of an animal-based food-producing economy. These interpretations are not straight however. Within and between sites, strontium:calcium ratios vary among species analyzed. In addition, at sites in the Zagros, bone strontium levels are an order of magnitude greater than those in the Levant. To facilitate comparisons among sites standardization of human to faunal values is required, placing some doubt on the conclusions that diets at Ganj Dareh contained higher proportions of meat than at Natufian sites in the Levant (Schoeninger, 1981).

Otitis media has been observed in the skeletal remains recovered from Dinkha Tepe, a Bronze and Iron Age site (Rathbun, 1984; Rathbun and Mallin, 1977). However, middle ear disease also occurred at Shanidar (Agelarakis, 1989). Although the Dinkha Tepe sample size is small, the higher prevalence at the metal age sites than at the late Epipalaeolithic site of Shanidar is consistent with changes from temporary to permanent architecture and increased settlement size that had occurred.

Increases in the duration and intensity of exposure to zoonotic pathogens, such as tuberculosis and brucellosis that can be transmitted from caprines to humans, may result in increased prevalence of skeletal indicators of these diseases in pastoralist populations. Evidence of skeletal lesions consistent with caprine-associated diseases has been recovered from Zawi Chemi (tuberculosis)(Agelarakis, 1989; Ferembach, 1970), and Ganj Dareh (brucellosis)(Merrett, 2001). These results suggest that the food-producing economies of these two sites in the Zagros could have been similar and primarily based on caprine pastoralism. Evidence of possibly domesticated caprines at Zawi Chemi (Perkins, 1964; but see Zeder (2000) for current thought on this issue) suggests that zoonotic respiratory infections such as tuberculosis have a long history in the Zagros/Piedmont region.

Comparisons of the Epipalaeolithic skeletal material from Zawi Chemi Shanidar and the early Neolithic site of Ganj Dareh reveal that individuals at both sites experienced significant dental attrition but with few caries (Agelarakis, 1989). This is consistent with both populations practicing caprine pastoralism, and relying on similar types and proportions of plant resources. The increased prevalence of degenerative joint disease in the Ganj Dareh skeletal sample could be associated with the site's location at higher altitude in the high Zagros and the ruggedness of the terrain.

In a comparison of skeletal remains of infants and children from the early Neolithic site of Ganj Dareh and the later Chalcolithic site of Seh Gabi in Iran, Waddell (1994) observed a higher prevalence of non-specific indicators of stress in the Seh Gabi skeletal remains. Growth stunting (Skinner, 1980; Waddell, 1994), lower cortical bone thickness, higher prevalence of enamel hypoplasia and Harris' Lines in the Seh Gabi infants is consistent with chronic protein-calorie malnutrition during fetal and post-natal life. The poorer health status of the Seh Gabi infants and children has been interpreted to reflect the change from a diversified economy at Ganj Dareh to one of reduced diet breadth at the later site of Seh Gabi. The poor health status at Seh Gabi may have been compounded by reliance on intensive agriculture, a stressed resource base, and high population density (Waddell, 1994). However in keeping with the post-paradox paradigm, it also suggests that conditions at Seh Gabi were sufficient for infant and child survival beyond the illness episodes that initiated the growth arrest. At Ganj Dareh, the lower prevalence of non-specific indicators of stress in those who died young can be interpreted in several ways, all of which are possible but not distinguishable. They had either not experienced illness episodes prior to death, had experienced illness from which they had not recovered before death (Wood et al., 1992), or had experienced illnesses during periods of growth stasis (Lampl et al., 1992). The absence of adults in the Seh Gabi sample precludes the assessment of adolescent and adult health status and demographic comparisons between the two samples.

This review of the literature on the health status of inhabitants of the Zagros/Piedmont region of the Near East suggests that, with the presently available data and the degree of inter-site variability observed, it may not be possible to extract meta-trends in health status for the region at the Pleistocene-Holocene boundary. An increased number of samples from the early and late Epipalaeolithic for comparative analysis is needed. Because many of the changes in social organization, required for the adoption of agriculture, were in place prior to the end of the Epipalaeolithic (for example, Henry, 1985; Kuijt 1996, 2000), changes in health status would have begun during the Epipalaeolithic. However, some of the trends that occurred in the Levant are not expected in the Zagros/Piedmont region if the first food-producing economy there were animal- and not plant-based.

The small sample sizes, the lack of comparable data from many sites in the region, and the fragmentary nature of the skeletal samples (Rathbun, 1984) identify a research strategy requiring systematic re-examination of the skeletal materials available in light of the interpretive and multidisciplinary framework of the bioarchaeological investigation. The present research contributes to this reanalysis through examination of the largest known sample from the Zagros/Piedmont that dates to the early Neolithic period, underscoring its importance for our understanding of health in the Zagros Mountains in the early Holocene.

7.5 Predictions from the Models of Agricultural Origins

Each of the competing models of the origins of agriculture sets forth a different series of conditions such as resource stress or abundance and temporal sequences of behavioural changes such as sedentism, population increase, plant cultivation and animal domestication. The theoretical stance of each model thus predicts a suite of conditions that influence health of a population for each stage of the behavioural transition.

To reduce the number of models tested, the degree of resource abundance for Ganj Dareh ca. 7,000 bc is assessed. For example, if Ganj Dareh were inhabited during a period of relative abundance, models that invoke resource stress as a driving factor in subsistence change can be eliminated from further examination. For each of the remaining models (reviewed in Chapter 3) an expected profile of skeletal indicators is developed, within the archaeological context of the Zagros region and specifically of the site of Ganj Dareh. This provides the framework for developing and testing hypotheses concerning the relationship between human behaviour and health. The health consequences of sedentism, scalar stress, dietary composition and availability, and pathogen exposure are predicted.

From the botanical and faunal remains recovered during Ganj Dareh excavations (described in more detail in Chapter 9.2 and 9.3, respectively), it is evident that the high central Zagros was a region of resource abundance in late Neolithic 1 and early Neolithic 2. Although the botanical remains recovered are scant, wild barley was available through all levels of occupation as were almond and pistachio (van Zeist et al., 1984). Similarly, proportions of small ungulates, hares, fox and chukar partridge remained fairly constant during the site occupation (Hesse, 1978). This is consistent with Flannery's (1969) Broad Spectrum exploitation within the context of resource abundance.

In the Nuclear Zone Hypothesis (Braidwood and Howe, 1960) resource abundance is postulated in restricted zones in the late Epipalaeolithic. As people developed the appropriate technology, they experimented with agricultural methods. Only after agriculture had developed did they settle in sedentary villages. For this model, increases in prevalence of diet-related pathology such as caries and AMTL and declines in dental attrition are predicted at sites with evidence of agriculture but without evidence of sedentism and scalar stress. Osteoarthritis due to agriculture-related activities such as grain grinding (Molleson, 1994) would be expected at sites with archaeological evidence of intensive reliance on plant-based foods.

For population pressure models population growth is a natural and continuous phenomenon so that populations with a given level of technology tend to grow beyond the carrying capacity of a region. Smith and Young (1972) proposed that population growth occurred in the Zagros due to resource abundance of the early Holocene period of climate amelioration. Sedentism and concomitant increase in population were possible as the intensity of food production increased to expand the regional carrying capacity. Increases in fertility and thus population size are expected throughout the temporal sequence. If the hunter/gatherers are sedentary before agricultural lifeways are adopted, changes in health due to sedentism such as increases in periostitis, and in evidence of increased pathogen load in the local environment would be expected to be present in the population before agriculture- and diet-related pathology. Thus the predicted sequence of pathology development in a population would be the reverse of that expected by the Nuclear Zone Hypothesis. Cohen's (1977) version of the population pressure model predicts that once subsistence intensification begins, periodic resource failures would result in increased prevalence of indicators of growth disruption.

The models of Binford (1968), Flannery (1969) and Redding (1988) postulate resource abundance occurs first in the sequence, facilitating sedentism and increases in population size in the nuclear zone. Diseases of sedentism and evidence of increasing fertility are expected in sites exhibiting year-round occupation in the nuclear zone. Once population expansion is initiated, a portion of the population relocates to regions of marginal carrying capacity. To replicate diet and lifestyle of the nuclear zone and to minimize resource stress, experimentation with agricultural methods is required. Thus in the marginal zone, archaeological evidence of incipient agriculture should be accompanied by health-related effects of growth disruption, diet change and agriculture-related activities. However, in this scenario, health status indicators predicted are contingent on site- and region-specific environmental assessment to determine the carrying capacity and marginality of the site hinterland. In the resource rich central Zagros at the time of Ganj Dareh occupation, the Marginal Zone hypothesis would not apply.

The Accumulator Model (Hayden, 1990) suggests that agriculture developed in sedentary communities that were established in regions of resource abundance.

Manipulation of non-food-staple resources for ritual feasting formed the basis for the subsistence transition. Since population pressure is not required in this model, indicators of increased fertility in demographic analyses would not be expected nor would evidence of growth disruption. However, diseases associated with sedentism are predicted. In contrast, the Territoriality and Allocation Model (Rosenberg, 1990) proposes that resource stress in a growing population precipitated a situation of population pressure. Evidence of both increased fertility and growth disruption are expected. If animosity accompanied the development of territoriality, some evidence of interpersonal violence might also be expected. As territoriality emerged to control limiting resources such as the oak forest, resource stress would require an increase in diet breadth to include cereals native to the oak forest habitat. Diseases associated with both sedentism and diet change would be expected at sites dated to late in this temporal sequence. However, as with the Marginal Zone model, the Territoriality and Allocation Model does not apply to Ganj Dareh.

As with the population pressure models other social models such as that proposed by Kuijt (1996, 2000) require sedentism before the adoption of agriculture, allowing for the early development of social methods for coping with scalar stress. Although sedentism alone would predict a high prevalence of sedentism-associated conditions, the presence of evolving cultural buffers might reduce the prevalence expected for non-specific infections in non-agricultural sedentary villages. Health consequences are thus predicted to be a function of the degree to which changes in social organization may have been capable of buffering the negative effects of sedentary settlement patterns. Low prevalence of stress-related indicators observed in people living in year-round occupied villages would support the social organization models of agricultural origins.

At Ganj Dareh there is archaeological evidence of sedentism, manipulation of morphologically wild ovicaprids, exploitation of barley (probably wild), and social

Factor	**Evidence at Ganj Dareh**	**Predicted Health Outcomes**
Diet	Wild Barley Wild Ovicaprids Wild Fauna from Many Ecological Niches	Low Prevalence of Caries, AMTL
Subsistence Activities	Ovicaprid Management	Zoonotic Diseases • Brucellosis • Tuberculosis
Sedentism	Permanent Architecture House Mouse (Commensal)	Non-Specific Periostitis High Pathogen Load Respiratory Infections Scalar Stress-Related Conditions
Social Organization	Niches Containing: • Human Burials • Sheep Horns	Reduction of Scalar Stress-Related Conditions Associated with Sedentism

Table 7.1. Predicted health outcomes of the Ganj Dareh inhabitants based on the archaeological evidence for factors affecting health.

buffering systems (ritual and burial niches). Within this archaeological context a series of predictions can be made concerning health consequences of their diet, subsistence activities, sedentism and social organization (Table 7.1).

If the first food-producing economies of the Zagros/Piedmont region, for example Ganj Dareh, were based on animal production, the general trends of declining health observed in regions where Neolithic subsistence was plant-based agriculture would not be predicted. The present analysis of health status of the Ganj Dareh inhabitants, within the framework of bioarchaeological method and theory, facilitates the integration of skeletal and archaeological evidence to infer subsistence behaviour. A low prevalence of non-specific indicators of stress in human skeletal remains would be consistent with food abundance, and/or absence of nutritional stress during the early stages of subsistence transition in conjunction with the presence of social mechanisms for effectively dealing with the scalar stress generated in sedentary villages.

CHAPTER 8. HEALTH ASSESSMENT FROM HUMAN SKELETAL REMAINS

8.1 Introduction

This study of the skeletal remains of the Ganj Dareh People addresses issues of health-related life history, infectious disease exposure, oral health, and activity and subsistence patterns in the community. The relationships between subsistence strategy and these health issues are explored through macroscopic and radiographic examination of non-specific indicators of stress, bone resorption and deposition, dental health and degenerative bone changes associated with habitual repetitive activities.

Health history during growth and development is recorded in the skeleton as non-specific indicators of growth disruption (see Chapter 2.3 for skeletal evidence of exposure to stressors). These disruptions result from varied causes, including periods of malnutrition possibly indicating resource stress, and/or exposure to infectious diseases. The macroscopic skeletal indicators used to estimate health status in past populations include Harris Lines seen in long bone radiographs (Harris, 1931a, 1931b), enamel hypoplasia (Goodman and Armelagos, 1985; Goodman and Rose, 1991; Hughes et al., 1996; Skinner and Goodman, 1992) and stature-for-age (Hoppa, 1992; Saunders and Hoppa, 1993; Sciulli, 1994). These indicators record in skeletal tissues episodes of growth disturbance following exposure to stressors (presented in detail in Chapter 8.2).

Most of the changes in bone morphology that occur as a result of infectious disease are non-specific, that is, the changes observed in dry bone are not pathognomic for specific pathogens (Goodman and Rose, 1990, 1991; Lewis et al., 1997; Miller et al., 1996). These non-specific indicators of health such as periostitis, maxillary sinusitis, and porotic hyperostosis of the cranial vault are used primarily as general measures of the levels of health and environmental sanitary conditions in a community, reflecting the pathogen load to which the people were exposed. They provide insight into the daily activities of village inhabitants (reviewed in Larsen, 1995, 1997, and described in more detail in Chapter 8.3). Also of specific interest to the present study are two specific diseases that can be distinguished in dry bone specimens: tuberculosis and brucellosis.

Caries location and prevalence, inflammatory processes of alveolar bone (abscessing), and ante-mortem tooth loss (AMTL) provide details of oral health (Beckett and Lovell, 1994; Hillson, 2000; Hodges, 1987; Lillie, 1996; Lubell et al., 1994; Lukacs, 1996; Meiklejohn et al., 1984). In conjunction with dental attrition, examination of oral health can provide insight into the amount of processed carbohydrates in diet and the extent of reliance on plant materials such as grains (Chapter 8.4). In addition, trauma and repetitive activity patterns (for example, Molleson, 1989, 1994, 2000), measured by the prevalence of osteoarthritis, enthesopathy and osteophytosis, round out the assessment of subsistence. Interpretation of these skeletal indicators and the trends observed in subsistence transitions are reviewed in the subsequent sections of this chapter. This provides a framework for analysis of the health of the Ganj Dareh inhabitants as a study of patterns of morbidity throughout the people's lives rather than an explicitly of mortality *per se*.

8.2 Growth Disruption

8.2.1 Harris' Lines

Growth in long bone length at the epiphyseal plates occurs prior to the attainment of adult stature. Differential rates of chondroblastic and osteoblastic activity during the recovery phase following exposure to a stressor can lead to a brief period of excess bone matrix deposition at the epiphyseal plate and result in lines of increased bone density, seen in radiographs as Harris' Lines (HL) (Hughes et al., 1996). The presence of Harris' Lines indicates that the individual was exposed to and survived beyond a stress episode, at least long enough for growth to resume (Goodman, 1991b).

The relationship between radiopaque transverse lines and illness episodes has been explored by many researchers (Garn et al., 1968; Harris, 1931a, 1931b; Hughes et al., 1996; Hummert and van Gerven, 1985; Mays, 1985; McHenry, 1968; Pfeiffer et al., 1986; Wells, 1967). In the non-adults from a maize-horticulturist precontact Iroquoian sample from southern Ontario, Harris' Lines have been associated with reduced cortical area, both indicators of stress suggesting that the children died after intermittent illness episodes rather following single event trauma or acute disease (Pfeiffer et al., 1986). In other regions of North America, the adoption of maize horticulture presents conflicting patterns of association. At Dickson Mounds (Goodman and Clark, 1981) and in the Ohio Valley (Cassidy, 1984; Perzigian et al., 1984) decreases in Harris' Line prevalence were observed. In these same skeletal samples, however, other non-specific indicators of stress increased in prevalence. As discussed in the context of stress exposure (Chapter 2.3) and below (Chapter 8.2.3), Harris' Lines are not always present in individuals who experience illness episodes (Gindhart, 1969; Hummert and van Gerven, 1985). The bone must be in a period of growth for growth arrest and subsequent recovery to be recorded.

In contrast to the enamel of teeth that does not remodel after initial formation, bone undergoes remodelling throughout life. Harris' Lines may, thus, be partially or totally obliterated with age (Garn et al., 1968). This can result in an under-representation of Harris' Lines in a skeletal sample, confounding their interpretation. In a skeletal sample from southern France, dating to the 10th to the 13th centuries (Grolleau-Raoux et al., 1997), the presence of Harris' lines is demonstrated to be age-dependent in adults. Thus for intersite comparisons, Harris' line frequencies must be standardized for any differences in age profiles (Grolleau-Raoux et al., 1997). Indeed, Larsen (1997) suggests that HL data from non-adults is more representative of stress history than similar data from adults.

8.2.2 Enamel Hypoplasia

Growth disturbances such as trabecular irregularities and enamel hypoplasias were first recognized by Harris (1931a, 1931b) and Kronfeld and Schour (1939), respectively. Enamel hypoplasia has been widely used as an indicator of stress in past populations (Brook et al., 1997; Duray, 1996; Ensor and Irish, 1995; Goodman and Armelagos, 1985; Goodman et al., 1980; Skinner and Goodman, 1992; Wood, 1996) as well as in modern populations (Goodman et al., 1987; Goodman et al., 1991; Skinner et al., 1994; Sweeney et al., 1971). The horizontal bands of thinner enamel on the tooth crown reflect the temporary cessation of enamel matrix production by ameloblasts (Suckling, 1989). In addition, circular defects of the deciduous dentition, primarily of the canine, have also been associated with growth disturbances (Skinner, 1980; Skinner and Hung, 1989), and deficient growth of labial alveolar bone (Skinner and Newell, 2003). However, the lower bilateral than unilateral expression of circular defects in modern Pakistani children suggests that, unlike linear enamel defects, they are not indicators of systemic stress (Lucacs, 1991).

Enamel hypoplasias indicate that the individual was exposed to and survived beyond a stress episode, at least long enough for growth to resume (Goodman, 1991b). Because tooth enamel is not remodelled during life, the growth disturbances recorded in teeth are subject to loss only through attrition and ante-mortem tooth loss (AMTL). Factors that influence the appearance of enamel defects include the timing of the illness episode relative to the molecular events occurring at the stage of tooth crown development, the severity and the duration of the insult, the type of stressor, and individual variability and susceptibility (Brook et al., 1997). In a modern rural population in Mexico, increased prevalence of enamel defects has been associated with decreased socioeconomic scores and decreased height-for-age, as well as with endemic mild-to-moderate malnutrition (Goodman, 1991b). In past populations, increased prevalence of enamel hypoplasia has been associated with decreased mean age-at-death. Individuals who survive to adulthood have fewer enamel defects than those who die young (Duray, 1996; Goodman, 1991b).

8.2.3 Stature-for-Age

As with enamel defects and Harris' Lines, the use of stature as a measure of growth disturbance requires understanding of the relationships among timing and duration of the exposure to stress, and the environmental factors that can influence growth. Growth patterns have been used to draw inferences concerning nutritional status and the effects of infection (King and Ulijaszek, 1999; Meiklejohn et al., 1984). However, the inter-relationships between undernutrition and infection make them difficult to separate (Hoffman-Goetz, 1988). King and Ulijaszek (1999) suggest that only individuals that experienced growth faltering prior to age 2 years will exhibit growth stunting. Thus, individuals of normal stature that die young have increased probability of death due to other causes (King and Ulijaszek, 1999). However, similar to the inverse relationship between enamel hypoplasia and age (Duray, 1996; Goodman, 1991b), studies in a variety of vertebrates suggest that growth compensation following nutritional deficit and episodes of stress exposure can negatively influence later life trajectory and health status (Metcalfe and Monaghan, 2001).

In situations where there are repeated exposures to pathogens and activation of the acute phase immunological response, the demand for amino acids for antibody production is increased. If protein intake is low, repeated infection may contribute to an impaired nutritional state. An elevated immune response may also occur in the absence of clinical symptoms (King and Ulijaszek, 1999). This mechanism may account for the presence of Harris' Lines and enamel hypoplasia in modern individuals with no recorded illness episodes (Gindhart, 1969; Sarnat and Schour, 1941, 1942).

In a study of modern infant growth, the accepted concept of continuous growth is suggested to be an artifact of the methodology of measurement (Lampl et al., 1992). Growth has been traditionally measured throughout infancy on a three-month basis. If growth is measured weekly, biweekly and/or daily in infants, the patterns of growth observed are saltational, with periods of growth and stasis suggesting that growth is not a continuous process (Lampl et al., 1992). The timing of illness episodes, relative to the periods of stasis and growth, influences the presence/absence indicators of growth arrest and recovery such as Harris' Lines and enamel hypoplasias. If illness occurs during a period of stasis, the skeletal remains will not exhibit a record of stress exposure, at least partly accounting for observed declines in Harris' Line prevalence when other indicators suggest that a population is highly stressed.

8.3 Inflammatory Processes

8.3.1 Non-Specific Inflammation

Macroscopic changes to the surface of bone, such as periostitis on long bones (Larsen, 1995; Mensforth et al., 1978) and in the maxillary sinuses (Merrett and Pfeiffer, 2000), have been used to estimate general health status and respiratory health status, respectively. These indicators are used in this study to estimate the pathogen load in the environment to which the Ganj Dareh inhabitants were routinely exposed and air quality in the mud-brick dwellings in the village.

The inner layer of the periosteum remains potentially osteoblastic throughout life (Ortner and Putschar, 1985; Ortner, 2003). Inflammatory responses to a wide variety of tissue injuries activate osteoblast differentiation and result in periostitis, the deposition of a layer of woven bone (Larsen, 1995; Mensforth et al., 1978). Regions of periostitis, such as those on the anterior face of the tibia in response to localized trauma, are characterized by an irregular surface, uneven hypervascularity, and variability in the degree to which the new woven bone is remodelled and incorporated into the underlying cortical bone (Ortner and Putschar, 1985; Ortner, 2003). Although periostitis is highly variable in macroscopic morphology, it has been extensively used as a non-specific indicator of health. In many populations increasing sedentism, and secondarily subsistence transition, has been associated with increased prevalence of periostitis (Cohen and Armelagos, 1984a and papers therein, 1984b; Pfeiffer and Fairgrieve, 1994). However, timing and intensity of the transition also affect rates of periostitis. In the Valley of Oaxaca in Mexico, where agricultural intensification occurred over several thousand years without increasing sedentism or population growth, changes in the prevalence of periostitis were not observed (Hodges, 1987).

Periostitis of the maxillary sinuses has also been used to assess upper respiratory health. In modern populations a variety of risk factors for development of sinusitis have been identified, including chronic exposure to wood smoke (for example, Albalak, 1997; D'Souza, 1997), crowded dwellings (Chen, 1988; D'Souza, 1997), poor sanitary conditions (D'Souza, 1997) and dental pathology (Mélen, et al., 1986). Poor air quality, as measured by particulate concentrations, has been proposed to account for the higher prevalence of maxillary sinusitis in urban mediaeval populations than in those from rural settings (Lewis et al., 1995) and the high prevalence in Iroquoian populations from southern Ontario (Merrett, 2003; Merrett and Pfeiffer, 2000). In the high Zagros at Ganj Dareh, the absence of hearths in dwellings and the presence within the village of only one structure with a fire-box at its base (PEL Smith, pers. comm., 2004) indicate that the inhabitants might not be exposed to substantial air quality factors that facilitate the development of maxillary sinusitis.

Porotic hyperostosis is a multifactorial condition that reflects iron deficiency resulting from high intestinal and blood-borne parasite loads and low iron levels in the diet. Synergistic interactions among nutritional status, immune competence and exposure to infectious disease greatly affect the pathogenesis of porotic hyperostosis (Mensforth et al., 1978). The lesions on the superior surface of the orbit and on the superior ecto-cranial surfaces of the cranial vault are characterized by sieve-like porosity, a widening of the diplöe and a thinning of the outer table. Hair-on-end spicules of bone that are perpendicular to the inner table are observed macroscopically and/or radiographically (Józsa and Pap, 1991; Mensforth et al., 1978; Steinbock, 1976). Porotic hyperostosis has been associated with increased erythropoiesis, and iron deficiency (Mensforth et al., 1978; Steinbock, 1976), adaptation to high pathogen load (Stuart-Macadam and Kent, 1992) and anaemia caused by malaria and thalassaemia (Angel, 1966). In contrast, Rothschild (1998) suggests that reduced iron levels would result in a reduction rather than an increase of the diplöic spaces.

Bioarchaeological analysis of late Holocene Nubian sites indicates a high prevalence of porotic hyperostosis. These intensive agriculturists relied heavily on milled grains that are low in iron and high in phytates that chelate iron, thus reducing its bioavailability (Carlson et al., 1974). Farther south at Kulubnarti, the presence of porotic hyperostosis in 50% of a mediaeval population has been associated with low levels of dietary iron, sedentism and poor sanitary conditions. In contrast, a regional survey of health at the Mesolithic-Neolithic transition in Europe reveals no association between porotic hyperostosis and subsistence transition. Although the etiology and pathogenesis of porotic hyperostosis remain unclear, Goodman (1994) views it as an adjustment to stress rather than adaptation because of its negative effects on work capacity, cognition and immune competence.

8.3.2 Specific Infections: Zoonotic Diseases

Although most bacterial infections cannot be diagnosed from dry bone lesions alone (Rothschild and Martin, 1993), two are of particular relevance to the Ganj Dareh population: the ovicaprid zoonoses brucellosis and tuberculosis. In earlier hunter/gatherer populations in the Zagros, contact with ovicaprid pathogens would be limited. Intensification of the interactions between humans and live goats during the process of domestication would bring the two into daily contact, changing the timing, intensity and duration of exposure to these pathogens. Increased prevalence of ovicaprid diseases is thus expected in humans who are beginning to practice pastoralism, relative to their hunter/gatherer predecessors.

Brucellosis, caused by the bacterium *Brucella melitensis*, is transmitted from non-human natural hosts to humans through skin contact with or ingestion of infected milk and meat products (Gotuzzo and Carrillo, 1998), and through inhalation of infected aerosols (Ortner and Putschar, 1985) as well as by contact with the placenta when assisting during kidding (Hendricks and Meyer, 1975). Although this last mode of transmission would be rare if animals were in the wild, it becomes an occupational hazard of pastoralism (Capasso, 1999; Gotuzzo and Carrillo, 1998). Since human-to-human transmission does not occur (Gotuzzo and Carrillo, 1998), its presence in past populations indicates intensive contact with the disease reservoirs. The high prevalence of brucellosis among modern goat herders (al-Rawi et al., 1989; El-Amin et al., 2001), and its presence at the Bronze Age site of Bab edh-Dhra, Jordan (Ortner, 2003; Rashidi et al., 2001), supports the suggestion that transmission of ungulate diseases to humans would also occur at Ganj Dareh if a pastoral economy were developing.

Symptoms of brucellosis in humans include fever and back pain in the acute form. Although rarely fatal (Aufderheide and Rodrígez-Martín, 1998), the chronic form is characterized by recurring fever and complications including anaemia, clotting abnormalities, arthritis, spondylitis, inflammation of the uvea of the eye, and neurological symptoms such as depression and chronic fatigue (Gotuzzo and Carrillo, 1998). Brucellosis infection thus has important consequences for individual and community health and well being.. Bone involvement occurs in ten percent of cases, although prevalences up to seventy-five percent are possible (Aufderheide and Rodrígez-Martín, 1998). Brucellosis is characterized by resorption of the superior anterior surface of the vertebral bodies immediately below the *anulus fibrosis* and by periosteal new bone formation on anterior surfaces of vertebral bodies. During healing, sclerotic new bone forms as beak osteophytes within the anterior longitudinal ligament, often resulting in fusion of vertebrae (Aufderheide and Rodrígez-Martín, 1998; Capasso, 1999; Ortner, 2003).

Zoonotic tuberculosis, caused by the bacterium *Mycobacterium bovis*, can be transmitted to humans by the air-borne route in respiratory aerosols from animals. In contrast to brucellosis, bovine tuberculosis can also be transmitted from humans to other humans (Aufderheide and Rodrígez-Martín, 1998). Patients with pulmonary tuberculosis exhibit coughing, prolonged fevers and wasting (Des Pres and Heim, 1990). With the ingestion of contaminated meat and milk products, cervical lymph nodes and the gastrointestinal tract are the primary targets of infection although pulmonary tuberculosis can also develop. Both acute and chronic forms of the disease are possible. Often mycobacteria are isolated through granuloma formation in the lungs, resulting in bacterial sequestration and dormancy. Subsequent reduction of immune competence can result in disease activation, often many years after initial infection (Aufderheide and Rodrígez-Martín, 1998; Des Prez and Heim, 1990; Ortner, 2003). Thus tuberculosis can be maintained in low density populations, and is less indicative of intensification of relationships with ovicaprid herds than is brucellosis.

Skeletal manifestations of tuberculosis are resorptive lesions on the surfaces of the vertebral bodies with little new bone formation. Only when spine stability is compromised, for example due to compression fracture of the vertebral body is there evidence of bone deposition and ankylosis. Joint involvement is also common, for example in the knee, hip and elbow (Aufderheide and Rodrígez-Martín, 1998; Ortner, 2003). Development of tuberculosis can lead to substantial disability burdening community health.

Increases in the prevalence of tuberculosis have been observed in eastern North America with the introduction of maize horticulture (for example, Cook, 1984; Perzigian et al., 1984). Other researchers (Rathbun, 1984; Rose et al., 1984) emphasize that sedentism and related changes in living conditions are instrumental in increasing the rate of transmission from person to person and thus contribute more to increased prevalence than does subsistence transition *per se*. The tentative diagnosis of tuberculosis in one individual from Zawi Chemi (Agelarakis, 1989; Ferembach, 1970) illustrates that the potential for exposure to tuberculosis was present in the Zagros region at least several thousand years before the site of Ganj Dareh was occupied.

8.4 Oral Health

Structures of the oral cavity are directly related to health and survival of the individual. Being at the site of ingestion of food and water, teeth and alveolar bone can reflect overall health of the individual, changes in diet composition and food processing techniques, and extra-masticatory uses of the teeth (Hillson, 2000; Larsen, 1995, 1997; Lucacs, 1992). As with other aspects of bioarchaeology, interpretation of oral health is contingent on a thorough knowledge of the site- and region-specific context and understanding of the complex interactions among etiologies and pathogenesis of the lesions observed (Fig. 8.1). Reflecting diet composition and the extent of reliance on plant materials, oral health has important implications for assessing subsistence and the proportion of grains in the diets of the Ganj Dareh inhabitants. The primary conditions assessed in the present study are caries, alveolar inflammation (abscessing and remodelling of alveolar bone), ante-mortem tooth loss (AMTL), and dental attrition (tooth wear).

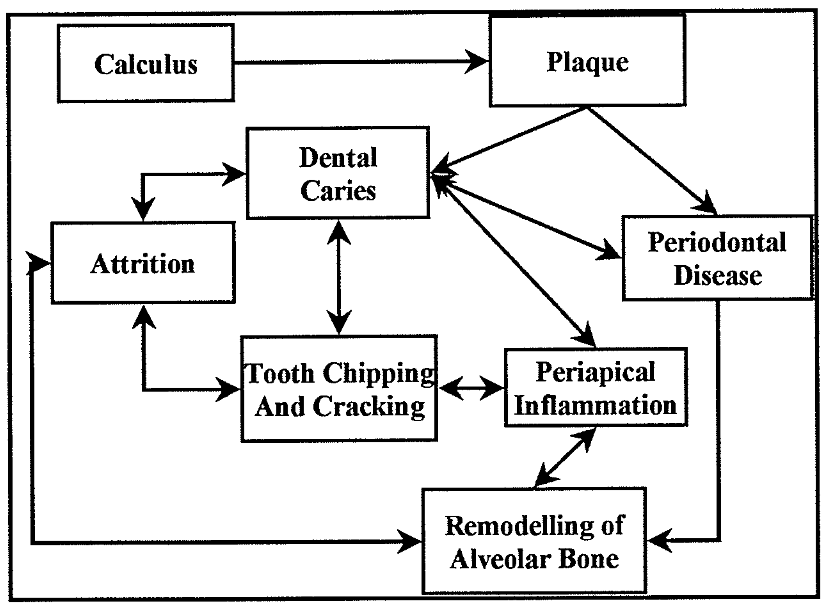

Figure 8.1. Interactions among dental conditions, all of which are affected by diet, overall health status and human behaviour. Modified from Hillson (2000:250).

Central to decline in oral health is the development of calculus, mineralized plaque, a mixture of oral bacteria, inorganic salts and salivary glycoproteins (Hillson, 2000; Larsen, 1997; Lucacs, 1992). Dental caries is a process of focal progressive demineralization of tooth enamel by acids that are produced by plaque bacteria in the fermentation of carbohydrates). The development of tooth-related inflammation in alveolar bone can result from exposure of tooth pulp chambers to pathogens through rapid attrition, tooth cracking and/or caries (Dias and Tayles, 1997; Hillson, 2000; Larsen, 1997; Lucacs, 1992). Periapical inflammation elicits resorption of alveolar bone surrounding the tooth, creating smooth-walled small granulomata, larger radicular cysts or draining fistulae (Dias and Tayles, 1997). In the maxillary premolars and molars, pyogenic processes in periapical inflammation can contribute to the development of maxillary sinusitis (Merrett and Pfeiffer, 2000).

Ante-mortem tooth loss (AMTL) can result from a variety of causes that reduce the effectiveness of the periodontal ligament attachment from the cementum to the surrounding bone. These include periodontal disease, attrition, and human intervention to extract painful diseased teeth (Hillson, 2000; Larsen, 1997; Lucacs, 1992). On all continents higher AMTL has been associated with agricultural subsistence rather than that of their respective hunter/gatherer predecessors (for example, Lucacs, 1992; Patterson, 1984; Rose et al., 1993). However, the complexity of the relationships among the potential causes of oral conditions suggests that different mechanisms may have been in operation in the populations surveyed.

The degree of dental wear (attrition) and the wear angles have been observed to vary with subsistence strategy (BH Smith, 1984). However, specific dietary composition before and following the transition also play an important role in tooth wear.

Although high rates of carious lesions, abscessing of the alveolar bone and dental attrition have been associated with agricultural subsistence, for example in maize horticulturists in southern Ontario Iroquoians (Patterson, 1984), site- and region-specific context influences the patterns of dental health observed (Larsen, 1995, 1997; Lillie and Richards, 2000; Lubell et al., 1994; Meiklejohn et al., 1988; Tayles et al., 2000). For example, while a negative relationship between caries and attrition has been noted in a Dutch whaling station sample from the 17th and 18th centuries (Maat and van der Velde (1987), a positive correlation between these variables is observed in two Portuguese Mesolithic skeletal samples, suggesting that the two variables are independently affected by diet (Meiklejohn, Wyman and Schentag, 1992). Factors such as grit in the diet from grindstones (Beckett and Lovell, 1994; Molleson and Jones, 1991) and proximity to sandy deserts (Cook, 1994) can influence attrition rates as well as the prevalence of tooth chipping. If ground grain, with many grit inclusions, were a large component of the diet at Ganj Dareh, caries would be expected and in combination with high attrition rates.

8.5 Habitual Repetitive Activities

Bone, as a living tissue, reacts morphologically to repeated stress from muscles and ligaments (Niepel and Sit'al, 1979; Resnick and Niwayama, 1983) stimulating bone deposition, osteophyte production, and degenerative joint disease (DJD). Bone, thus, provides a record of habitual repetitive activity. In addition, traumatic injury can elicit extensive changes in bone integrity and morphology, including fractures and injury to entheses, the interfaces between ligaments/tendons and bone.

During normal repetitive or habitual activity, muscle contraction stimulates the deposition of new bone to strengthen the enthesis, resulting in larger and more prominent muscle attachment sites (Kennedy, 1989; Niepel and Sit'al, 1979; Resnick and Niwayama, 1983). Connective tissues, for example the *ligamenta flava* and the anterior longitudinal ligament of the spine, gradually ossify. Horizontal osteophytes, produced on margins of vertebral bodies in response to intervertebral disk degeneration, are both age and activity related (Rogers et al., 1987). Specific activities can be inferred when ossified ligaments are observed in young adults (see below).

Degenerative joint disease (DJD) is characterized by progressive destruction of cartilage in synovial joints, pitting of articular facets and subchondral bone resorption. In advanced cases, with the complete absence of articular cartilage, eburnation of the joint surface occurs as articulating bones come into direct contact (Ortner, 2003; Rogers et al., 1987). At the early Neolithic site of Abu Hureyra in the middle Euphrates Valley both ossification of *ligamenta flava* and degenerative joint disease of the knee and metatarsal-phalangeal joint of digit 1, usually seen in older individuals, have been observed in young women. In this early agricultural population, this suite of skeletal lesions is consistent with many hours per day grinding grain (Molleson 1989, 1994, 2000). If the Ganj Dareh inhabitants were as intensively exploiting grain resources, similar evidence of osteophytosis and osteoarthritis in young individuals would be expected.

World wide, there is a great variation in the patterns of osteoarthritis through time and within populations (reviewed in Larsen, 1997). Although specific lesions may be associated with specific activities (Kennedy, 1989; Molleson, 1989, 1994, 2000), often inferences are limited to confirmation that changes in activity and workloads occurred. In general, the shift to agriculture in southeastern North America (Bridges, 1989, 1991), Europe (Meiklejohn et al., 1984) and south Asia (Kennedy, 1984) has been associated with reduction in prevalence of osteoarthritis. However, these changes can be accompanied by increased bone robusticity (Bridges, 1989, 1991). Knüsel (1993) has interpreted these observations with reference to clinical literature on the relationship between work load and the age of commencement of strenuous adult activities. The early assumption of adult roles in agricultural communities results in increased bone mass, conditioning of the joints and robustness that protect the individual from later development of osteoarthritis. In response, Bridges (1993) suggests that multiple local factors contribute to the variable reactions of the skeleton to subsistence change.

Ankylosing spondylitis and diffuse idiopathic hyperostosis (DISH), both conditions of unknown etiology, result in the fusion of adjacent vertebral bodies without disk space reduction (Arriaza, 1993; Ortner, 2003; Rogers et al., 1987). Individuals with ankylosing spondylitis rarely exhibit ossified anterior longitudinal ligament. Bony bridges between vertebral bodies result from ossification of the *anulus fibrosis* as well as bilateral involvement and eventual fusion of the sacroiliac joints. In contrast to ankylosing spondylitis, DISH is characterized by the flowing appearance of the anterior longitudinal ligament, primarily on the right side, and an absence of ossification of the *anulus fibrosis* (Arriaza, 1993; Ortner, 2003; Rogers et al., 1987). A higher prevalence of DISH has been observed in skeletal samples from east Asia that are identified as agro-pastoralist than in populations practicing a hunter-gatherer subsistence strategy (Hukuda et al., 2000). If DISH were exhibited by any of the Ganj Dareh inhabitants, it could be consistent with the development of a Proto-Agro-Pastoralist Economy.

Spondylolysis, separation of the neural arch from the vertebral body between the superior and inferior articular facets, results from high mechanical loading of the lumbar spine. In populations in southeastern North America, a higher prevalence has been observed, in conjunction with increased levels of osteoarthritis, in agricultural than in hunter/gatherer populations (Bridges, 1989). However, high prevalence in arctic populations (for example, Merbs, 1983) suggests that activity-related mechanical explanations assume priority over ones based solely on subsistence.

Where excessive force applied to the skeleton exceeds the strength of the tendon and/or bone, acute injury can occur. In children and adolescents, bone is less well ossified and is weaker than that in adults. Forces that result in soft tissue (tendon or ligament) injury in adults cause bone damage in the immature skeleton (Niepel and Sit'aj, 1979; Ogden, 1981, 1982; Resnick and Niwayama, 1983). Excessive stress exerted on the enthesis may elicit a resorptive response realigning the bone contour during healing (Donnelly et al., 1999; Resnick and Niwayama, 1983) or an avulsion (separation) of the enthesis from the bone (Niepel and Sit'aj, 1979; Resnick and Niwayama, 1983). In the present study, the distribution of inter-and intra-individual variation in enthesial morphology provides insight into the muscle groups intensively and habitually used during daily life in the high Zagros Mountains.

As with enthesis injury, examination of patterns of bone fractures can inform on hazards of life in the Neolithic. A high prevalence of injuries suggesting inter-personal violence in the Ganj Dareh sample would support the population pressure and territoriality models.

CHAPTER 9. MATERIALS AND METHODS

9.1 Ganj Dareh

9.1.1 The Site

Excavation of the site of Ganj Dareh, located in the Gamas-Ab River valley of western Iran, was carried out in conjunction with a broad archaeological survey of the northeastern regions of the Fertile Crescent of the Near East. Human occupation of the Zagros Mountains, documented from the Middle Palaeolithic to the Bronze Age, was the object of archaeological study in the middle decades of the twentieth century between 1930 and 1979 (Braidwood, Howe and Reed, 1961; Mortensen, 1962, 1963; Solecki and Solecki, 1983; R.S. Solecki, 1963; Young and Smith, 1966). However since the Islamic Revolution in 1979 archaeological excavations in this region have effectively ceased. Evidence of human settlement has been recovered from caves, rock shelters and open air mounds or 'tepes' (Young and Smith, 1966). Ganj Dareh is one such mound.

The initial typological analysis of lithics and absence of pottery suggested a date of between 10,000 and 8,000 BC. Preliminary examination of test pit stratigraphy suggested that the site was occupied over a few centuries. Erosion between occupational levels appeared inconsequential, indicating that long periods of site abandonment had not occurred (Young and Smith, 1966).

Ganj Dareh is a conical mound, 40 metres in diameter. Excavations of about 20 per cent of the mound (Fig. 9.1) were carried out in the 1967, 1969, 1971 and 1974 field seasons. The seven to eight metres of the debris from mud brick dwellings are divided into five occupation levels, E to A (Smith, 1974, 1978, 1990). In the earliest level (E), no evidence of permanent architecture was observed. All subsequent levels exhibited mud brick architecture. Radiocarbon dates obtained indicated that, in contrast to the initial

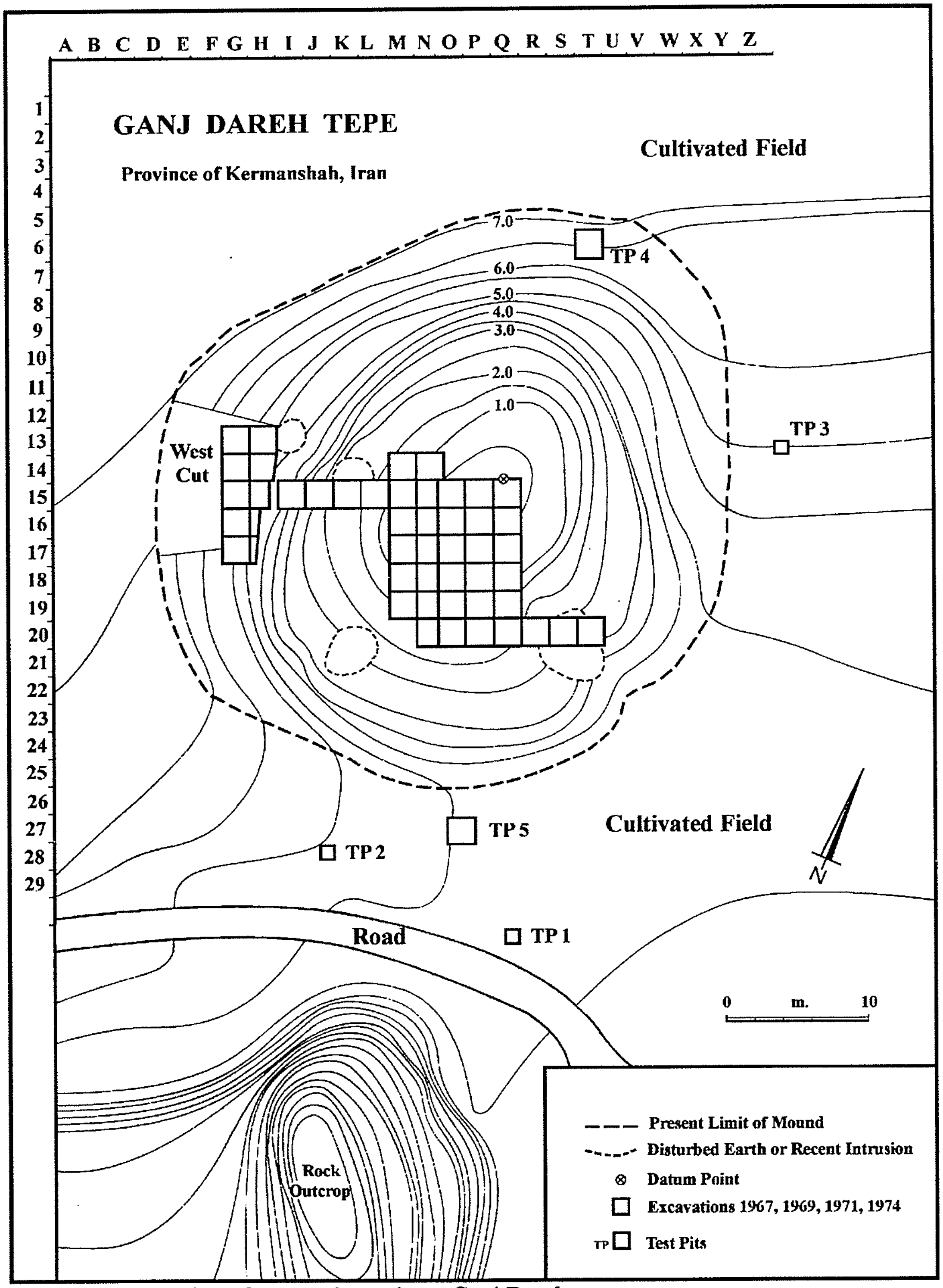

Figure 9.1. Location of excavation units at Ganj Dareh.

stratigraphic conclusions, the site was first inhabited ca. 8,500 years bc (Level E), abandoned for some five hundred to one thousand years, then reoccupied from 7,300 to 7,000 bc (Smith, 1978). However, recent dating of animal bone from the site by Accelerator Mass Spectrometry radiocarbon dating supports the initial assessment that the entire occupation of Ganj Dareh, Levels E through A, lasted only a few hundred years. The new radiocarbon assessments centred around 7,000 radiocarbon years bc (Zeder and Hesse, 2000) are presented in Appendix E.

Much of what is known about Ganj Dareh spatial organization and architecture (Fig. 9.2) and building methods derives from the analysis of level D where a village-wide fire enhanced dwelling preservation. No streets, courtyards (Smith, 1990), hearths (pers. comm. PEL Smith, 2004) or obvious doors were observed. Storage bins and mortars indicate that normal daily activities occurred here. The presence of baked clay impressions of horizontal beams, small support posts and plastered floors above cubicles suggests that some of the houses were 2-storied. Many of the walls in Level D were perforated by portholes ranging in diameter from 20 to 40 cm, of unknown function, and often sealed with clay plugs (Smith, 1990). The architectural details observed in Level D appear to be continued through the later occupation levels although preservation is variable.

Niches, cubicles and sealed burial cubicles, reflective of functions beyond the purely utilitarian, are regular features preserved in the burnt remains of Level D. In one subfloor niche two wild sheep skulls were plastered into walls (Smith, 1972) in a manner similar to that of cattle skulls in more extensive shrines at Çatal Hüyük (Mellaart, 1975). Six subfloor burials, two adults and four children, were located in the room adjacent to the sheep-skull cubicle (Smith, 1990). Although the functional relationship of the two rooms is not evident, they were connected through a small porthole, inviting speculation

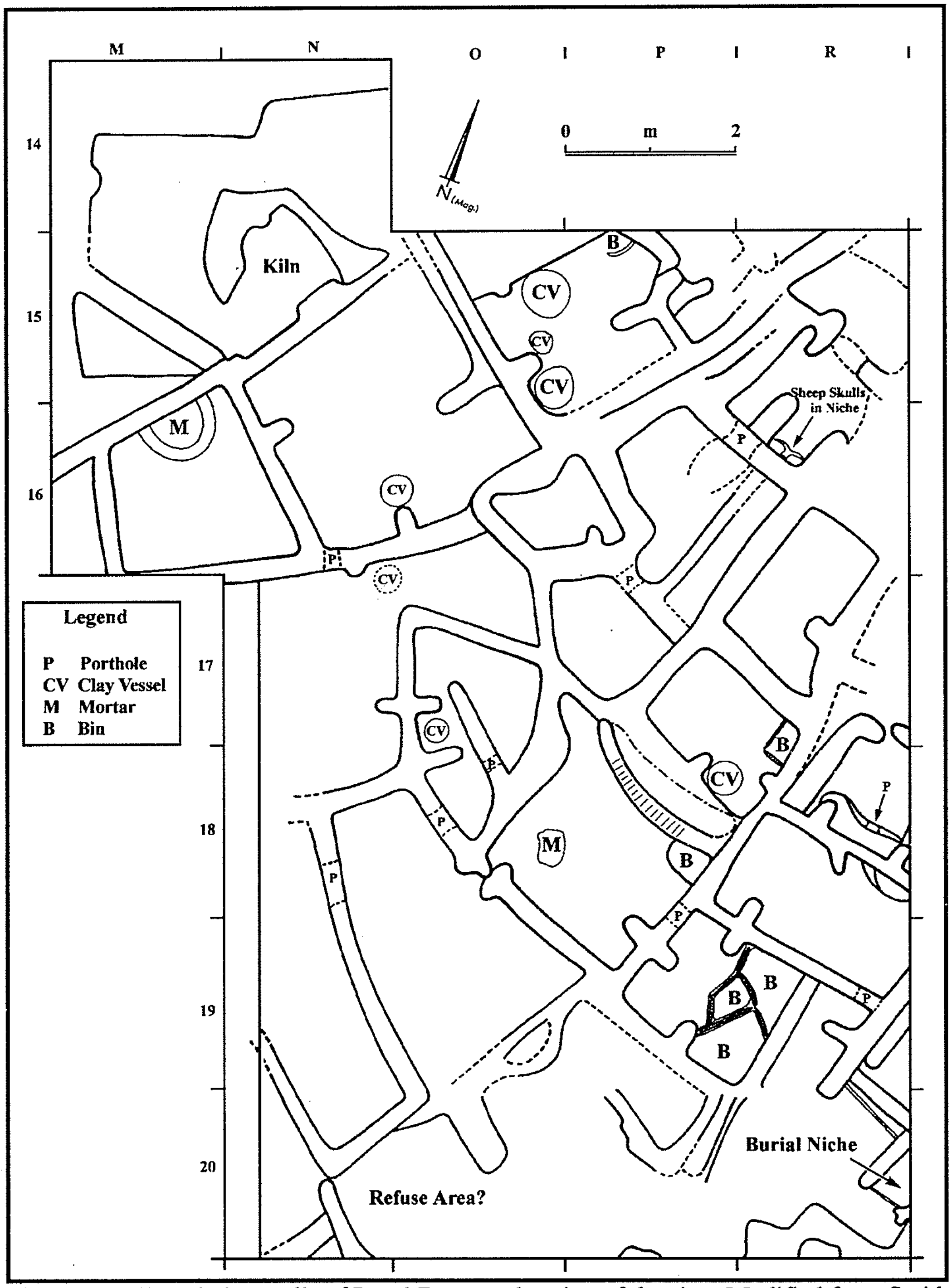

Figure 9.2. Foundation walls of Level D, central region of the site. Modified from Smith (1990:327).

concerning their close spatial association. As with the architecture there is continuity of burial practices in later levels of the site. For example, skeletons #15, #16 and #17 from Level C were recovered from with a sealed mud brick sarcophagus within a larger brick structure, thought to be an abandoned house or special mortuary chamber (Smith, 1972).

9.2 Archaeobotanical Analysis

Archaeobotanical analyses were conducted on the carbonized macrobotanical remains recovered from Ganj Dareh by van Zeist and colleagues (van Zeist et al., 1984). Data are from three primary sources: remains observed and isolated during excavation, remains isolated from soil samples through flotation and those identified from impressions made in burnt brick and clay. Of importance for the interpretation of subsistence is the recovery in all levels of two-row hulled barley and the absence of other cereal types, wheat and rye, commonly isolated at Near Eastern Neolithic sites.

Much of the interpretation of the botanical remains at Ganj Dareh rests on the assumption that it is located in what is presently considered to be the Zagros oak forest belt, before human intervention and overgrazing. This ecozone, absent during the last pleniglacial, was not replaced by "modern" vegetation until after ca. 6,000 bc (van Zeist, 1967; van Zeist and Bottema, 1977; van Zeist and Woldring, 1978), based on the pollen cores from Lakes Zeribar and Mirabad (see Chapter 5 for a detailed discussion of palaeoclimate reconstruction and implications for Ganj Dareh climate ca. 7,000 bc). What appears clear from the palynological analysis and macrobotanical analysis at Ganj Dareh is that the oak forest had not reached its modern extent at the time of site occupation and that local vegetation was primarily almond/pistachio steppe-forest.

Of primary concern for interpretation is the density of forest cover in the region of the site in the high Zagros Mountains and the intervening valleys. The relatively high frequency of legumes suggests scattered tree cover in a steppe environment rather than denser forest (Miller, 1992). In addition, more maple and oak would be expected if substantial forest existed locally. A riparian environment, consistent with the site's location in a high mountain valley, is supported by the extensive use of willow for roof construction, as seen in the charcoal fragments associated with the burnt Level D dwelling remains (van Zeist et al., 1984) and the impressions preserved in the mud roof coverings (Smith, 1990). Charcoal analysis suggests the close proximity of hackberry, pistachio, willow, poplar, cherry and buckthorn to the site for use as firewood (van Zeist et al., 1984). The macrobotanical evidence presented above suggests that Ganj Dareh was not located in a marginal environment. As such, only models of agricultural origins that invoke subsistence change during periods of resource abundance are relevant for application to the Ganj Dareh data.

Of more immediate interest for the reconstruction of subsistence strategy is van Zeist's interpretation of the barley (*Hordeum* sp.). Large stands of wild barley frequent modern primary habitats of the Zagros Mountains and would presumably have done so in the past (Harlan and Zohary, 1966; Zohary, 1973). However, barley at Ganj Dareh underwent much distortion during carbonization and preservation is less than ideal, compromising inferences made for barley use at this site. Most of the barley fragments did not exhibit the regions diagnostic for domestication. Only six internode fragments were complete enough for determination of shattering or non-shattering behaviour and, of those, four appear to exhibit tough rachis morphology (van Zeist et al., 1984). At the time of publication, 1984, origins of agriculture research was looking to establish the "earliest" evidence of domestication and hints at non-shattering rachis morphology in barley from Ganj Dareh appeared promising in establishing earliest barley domestication in the Zagros.

Willcox (2004) has recently examined well-preserved barley from several sites on the upper Middle Euphrates, including Jerf el Ahmar and Dja'de that were occupied in the late 8th Millennium bc, a few hundred years before Ganj Dareh. At these sites 90% of the rachis fragments exhibited intact articulation scars indicative of shattering, that is, 10% were non-shattering. In modern stands of wild barley in the Near East, Kislev (1989) has demonstrated that up to 10% of internodes show non-shattering morphology. Thus, both modern and Neolithic wild barley are consistent with biological populations in which variation is present, and on which selection pressures can be exerted.

The temporal separation of size increases and acquisition of domestication-associated morphology has been recently established for these same sites in the upper Middle Euphrates (Willcox, 2004). Increases in grain size occurred between the early, ca. 7,800 to 7,700 bc, and later, ca. 7,300 to 7,200 bc, levels of Jerf el Ahmar and Dja'de. However, large-grained barley exhibiting domesticated morphology has not been recovered from this region until ca. 4,000 bc at Kosak Shamali (Willcox, 2004). The Ganj Dareh barley grain breadths, ranging from 2.5 to 3.5 mm (van Zeist et al., 1984), are similar in size to those recovered from the Neolithic upper Middle Euphrates sites. The size similarity and possible contemporaneity of occupation with Ganj Dareh suggests that the Ganj Dareh barley were of the large-seeded wild variety.

Because of the generally poor preservation of botanical remains at Ganj Dareh and the presence of only six internode fragments for which shattering behaviour could be assessed, the presence of tough rachis morphology in four grains could equally be interpreted as the result of better preservation potential of non-shattering rachises under non-ideal preservation conditions or as evidence for domestication. Although the use of wild barley by Ganj Dareh inhabitants is incontrovertible, the interpretation that barley was cultivated and domesticated should be viewed with caution.

9.3 Zooarchaeological Analysis

The faunal remains recovered from Ganj Dareh have been extensively studied (Hesse, 1978, 1982; Zeder, 2001; Zeder and Hesse, 2000). Hesse' (1978) dissertation included the identification and analysis of 500,000 bone fragments, of which 57,675 could be identified to skeletal element. A subset of these, 34,492 fragments, could be assigned to one of forty-nine taxonomic groups, indicating that the Ganj Dareh inhabitants exploited a broad spectrum of fauna. The species proportions did not vary among the levels, suggesting that major shifts in subsistence had not occurred at the site. The primary taxa recovered were goat, sheep, hare, fox and chukar partridge.

Two of the taxa, house mouse (*Mus musculus*) and bezoar goat (*Capra hircus aegagrus*) are particularly relevant to the present study. Mouse remains, most often femora, were recovered from all levels of the site (Hesse, 1978). The mouse mandible and the third molar exhibit features that allow species differentiation. Although house mouse remains were identified in Levels D to A, the absence of mouse mandibles in Level E precludes identification of the mouse remains recovered to the species level. The presence of house mouse at Ganj Dareh has been interpreted as indicating year-round occupation of the site (Hesse, 1978).

Of the 29,995 specimens of mammalian bone, 26,967 (89.9 %) were ovicaprid (Hesse, 1978). Just less than one-fifth (17.4%) were identified as *Capra hircus aegagrus*, whereas only 2% were identified as *Ovis orientalis*, that is, goat remains outnumber sheep nine to one. This ratio is similar to those observed at other early sites before intensification of agriculture has occurred and herd composition shifts to a predominance of sheep (Flannery, 1969; Köhler-Rollefson et al., 1988; Redding, 1985).

For the entire sample of ovicaprid remains, age-at-death estimates were made from patterns of tooth eruption and wear (Hesse, 1978, 1982). Slaughter profiles of the ovicaprids in relation to possible herd type and site location provide insight into the types of subsistence strategy practiced and time of year of site occupation (Table 9.1). For

Herd Type	Age Profile	Site
Bachelor	Mature Males	Asiab
Nursery	Females, Foetal and Young Kids	Ganj Dareh Level E
Managed (Proto-Domesticated)	Young Males and Adult Females	Ganj Dareh Levels D to A

Table 9.1. Relationship between herd type and expected age profile. Modified from Hesse (1982).

example, the faunal assemblage from the Neolithic 1 site of Asiab, located in an open valley, implies spring hunting of goat bachelor herds as they descend from the mountains. Similarly, the Level E assemblage from Ganj Dareh, located in the preferred narrow valley habitat of nursery herds just before and during kidding, also suggests spring occupation (Hesse, 1982). These age profiles contrast greatly with the profiles obtained for the upper levels of Ganj Dareh, where a sharp decline in fetal and very young kid remains was observed. The predominance of juvenile bucks and adult does in these same levels would not be possible to select for in hunting, strongly suggesting that herd management was being practiced (Hesse, 1978, 1982, 1984).

Reduction in body size of goats, used as an indicator of domestication (Crabtree, 1992; Hecker, 1982; Legge, 1996; Olsen, 1979; Uerpmann, 1978) is suggested to follow human control of ovicaprid breeding schedules (Hecker, 1982). In earlier reports the Ganj Dareh goats were thought to be reduced in size from their wild counterparts (Helmer, 1989; Uerpmann, 1979, cited in Zeder, 2000, 2001). However, the small size of the animals is a function of the age and sex profiles of the animals, that is, those that survive to adulthood are female. Measurements were also taken following the methods of von den Dreisch (1976), whereby only bones with fused epiphyses are measured. Recent comparison of Ganj Dareh goat metrics with those of modern goats from Iran and Iraq places the Ganj Dareh ovicaprids squarely within the size range of modern wild goats. Further, comparisons with goat assemblages from Asiab ca. 8,000 bc and Ali Kosh ca. 6,400 to 6,000 bc demonstrate that size reduction occurred some time between the Ganj Dareh and Ali Kosh occupations (Zeder and Hesse, 2000).

Evidence of size and morphology of the Ganj Dareh goats suggests: First control of the animals e.g. at Ganj Dareh (Hesse, 1978, 1982), then centuries later, e.g. at Ali Kosh, decrease in ovicaprid size and change in horn core morphology (Zeder, 2001; Zeder and Hesse, 2000). This contrasts with plant domestication where the initial change was an increase in seed size, followed much later by a change in morphology (Willcox, 2004).

9.4 Human Skeletal Remains

Human skeletal remains, recovered in all but the first field season (Table 9.2), were encountered within the village in a variety of contexts including subfloor burials and sealed burial niches. They were also recovered from test pits (for their locations see Fig. 9.1) beyond the present boundary of the mound (Smith, 1974). However, it is possible that reduction of the extent of the mound has occurred as a result of modern agricultural activities. Thus the test pit burials may have originally been within the village boundaries (Young and Smith, 1966).

Field Season	Human Remains Excavated (Cumulative Total)
1967	0[1]
1969	7[1]
1971	26[2]
1974	41[3]

Table 9.2. Chronology of the recovery of human remains at Ganj Dareh.
[1] Date notation on field notes for each skeleton.
[2] Smith (1972).
[3] Smith (1974).

Grave goods, although not abundant, are associated with children's remains (Smith, 1974). Often what were thought to be single burials, at the time of excavation, have been recognized through ongoing laboratory analysis to be, in fact, multiple interments. The minimum number of individuals (MNI) has been reported as forty-nine (Meiklejohn et al., 1980) and as sixty-nine (Meiklejohn et al., 1992), the latter augmented through the addition of human skeletal elements from faunal samples. The present study has carefully reconsidered all of the remains to integrate the numbers of more-or-less complete skeletons with the numbers of those individuals represented by isolated elements (see Chapter 10 for details).

Human skeletal remains were recovered from all levels of the site. Of the one hundred sixteen individuals identified in the sample by this study, only five could be identified as deriving from Level E. A further ten individuals could be assigned only to Level D/E. No differences in pathology could be discerned between the Level E individuals with their hunting economy and those from the upper pastoralist levels of the site.

Previous studies on the collection have been conducted by a number of researchers (Agelarakis, 1989; Carmichael, n.d.; Lambert, 1979, 1980; Meiklejohn et al., 1980, 1992; Schoeninger, 1980, 1981; Waddell, 1994; Wang, 1994) and incorporated in a summary of Iranian health at the origins of agriculture (Rathbun, 1984). Overall, from a variety of indicators, the Ganj Dareh inhabitants appear to be generally healthy, with low caries rates and minimal number of Harris' Lines per individual (Meiklejohn et al., 1980). Further comparisons of morphology with the Epipalaeolithic inhabitants of Zawi Chemi (Agelarakis, 1989) and of non-adult cortical bone mass with the Chalcolithic people of Seh Gabi (Waddell, 1994) confirm the initial findings of Meiklejohn and colleagues (1980). Consistent with these results are the calcium to strontium ratios obtained by Schoeninger (1980, 1981), suggesting that the Ganj Dareh diet contained similar proportions of meat to Levantine Epipalaeolithic generalized hunter/gatherers, and much more meat than the specialized Natufian hunter/gatherers.

Two observations are of particular interest. The first is the initial recognition by Lambert (1979, 1980) and the later detailed comparative analysis by Meiklejohn and colleagues (1992) that some of the Ganj Dareh crania were intentionally deformed[1]. The early presence of intentional cranial deformation in the Zagros region suggests that cultural mechanisms, including social stratification, were developing to cope with the

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[1] All crania reconstructed at the time of this study (1992) were deformed. This observation does not extend to further crania reconstructed during the work of this thesis.

scalar stress of sedentism, possibly as a result of both internal scalar stress as suggested by GA Johnson (1982) and external by AL Johnson and Meiklejohn (n.d.). This is consistent with the social models of agricultural origins and the development of territoriality (see Chapter 3 for detailed discussion).

The second observation, the presence of porotic hyperostosis, was reported in adults by Meiklejohn and coworkers (1980) and will be discussed in the present study. The porotic hyperostosis observed in infants was interpreted by Agelarakis (1989) in the context of Angel's (1966) malaria hypothesis. However, the possibility that the bone morphology observed may be due to new woven bone deposition in rapidly growing infants, a subject neglected in the literature, places the interpretations beyond the scope of this thesis. It is, however, discussed in Chapter 12, directions for future research.

9.5 Methods

From the skeletal elements present in each burial, the minimum number of individuals in the sample was estimated. Inventory and data collection followed the methods of Meiklejohn (Schentag and Meiklejohn, 1985, 1987) and Buikstra and Ubelaker (1994). Data collection forms used for skeletal inventory of the cranial and infracranial skeleton, the maxilla and mandible, and the dentition are presented in Appendix A.

Methods of age-at-death estimation for non-adults included the assessment of developmental processes such as tooth formation and eruption from macroscopic and radiographic data (Moorees et al., 1963a, 1963b), enamel prism cross-striation counts (FitzGerald, 1998) from thin (50 to 60 μm thick) sections, patterns of development of the occipital, temporal, vertebrae, sacrum and innominates (Scheuer and Black, 2000), bone length (Fazekas and Kósa, 1978; Gindhart, 1973; Maresh, 1970; Merchant and Ubelaker, 1980; Scheuer and Black, 2000; Sundick, 1978) and patterns of epiphyseal fusion (Buikstra and Ubelaker, 1994; Scheuer and Black, 2000; McKern and Stewart, 1957). Data collection forms used for non-adult age estimation are presented in Appendix B.1. Detailed methods for preparation of thin sections are given in Appendix B.2. Age categories utilized are presented in Table 9.3.

Code	Age Range (Years)
1	0-0.9
2	1-3
3	4-7
4	8-11
5	12-17
6	18-29
7	30-50
8	>50
9	18-50
10	>30
11	>18

Table 9.3. Age Categories.

In adults, primarily degenerative, and secondarily chronometric, processes were assessed to estimate age-at-death. Degenerative changes include dental attrition (Scott, 1979; Smith, 1984), morphological changes of the pubic symphysis (Boldsen et al., 2002; Brooks and Suchey, 1990) and the auricular surface (Lovejoy et al., 1985), and cranial and palatal suture closure (Mann et al., 1987; Meindl and Lovejoy, 1985). Adult ages were assessed for four adult teeth by the counting of cementum annulations in incisor and canine root cross-sections[2] (Wittwer-Backofen and Buba, 2002). The results for the remainder of the adult cementum annulation counts are in progress. Data collection forms and codes used for adult age estimation from suture fusion are presented in Appendix B.3 and Appendix C.2.1, respectively. All adult mandibles were seriated according to tooth wear to facilitate refinement of the age estimations.

[2] The four teeth were analyzed by Dr. Ursula Wittwer-Backofen, Max Planck Institute of Demographic Research, Rostock Germany, August, 2002. Data from an additional 20 teeth, initially planned to be included in the present study, are not yet available and thus are not included here. When available, this will refine the age estimations for a substantial proportion of the Ganj Dareh adults and will facilitate the generation of a more accurate age profile.

Sex of adults was estimated from the degree of sexual dimorphism of the skull and the pelvic bones (Acsakí and Nemeskeri, 1970; Buikstra and Ubelaker, 1994; Phenice, 1969). Metric measurements of skeletal elements were taken for age estimation in non-adults (Fazekas and Kósa, 1978; Gindhart, 1973; Maresh, 1970; Merchant and Ubelaker, 1980; Scheuer and Black, 2000; Sundick, 1978) and for stature estimation in adults (Feldesman, 1992; Trotter, 1970). Equations used for stature estimation are given in Appendix A.5.

Radiographs, taken at Department of Radiology, Winnipeg Children's Hospital, were employed for evaluation of suspected healed fractures, tooth root and crown development in intact jaws and identification and measurement of Harris' Lines. Radiographs were taken for the present study to complement the existing incomplete data set.

Each skeletal element was assessed through a Leica Zoom 2000 dissecting microscope at x 7 to 30 magnification for evidence of bone resorption and deposition. Regions of bone resorption, deposition and porosity were recorded separately for all periosteal surfaces and the entheses (codes Appendix C.2.2 and Appendix C.2.3 to C.2.5, respectively). Articular surfaces were scored for porosity and marginal lipping to estimate the prevalence of osteoarthritis (codes Appendix C.2.6).

Presence of linear enamel hypoplasias (LEH), the teeth affected and number of anomalies per tooth was recorded. Positions of LEH were measured relative to the occlusal surface and the cemento-enamel junction (CEJ) with needle-tipped Helios dial calipers to the nearest 0.05 mm. Primary canine hypoplasia and circular hypoplasia were recorded separately as to tooth type, jaw and location on the crown. Harris' Lines were scored as present if extended at least across one half of the diaphysis, following the criteria of Byers (1991). Locations and distances from the growth plate were measured to the nearest 0.05 mm.

Inflammatory lesions of the long bones (Larsen, 1995; Mensforth et al., 1978) and maxillary sinuses were recorded for each individual following the scoring system for periosteal bone deposition and resorption of Merrett and Pfeiffer (2000). Differentiation was made between new woven bone indicating lesions active perimortem and those that exhibited smooth periosteal surfaces indicating remodelling and incorporation of new bone into the existing cortical bone (Buikstra and Ubelaker, 1994; workshops at the annual meetings of the Paleopathology Association run by Don Ortner and Bruce Ragsdale). Scoring codes used for infracranial periostitis are given in Appendix C.2.7 and for sinusitis in Appendix C.2.7. Porotic hyperostosis of the orbital roof (Appendix C.2.8) and the cranial vault (Appendix C.2.9) were scored following the methods of Buikstra and Ubelaker (1994) and Stuart-Macadam (1985).

The number, location and condition of teeth were recorded for each individual (Appendix C.1.1). Hypercementosis was recorded by tooth affected, jaw and severity (Appendix C.1.2). Aspects of oral health assessed include caries, dental attrition, abscessing and ante-mortem tooth loss. The location and size of caries were recorded on the tooth diagrams (Appendix A.5 and A.6). Tooth wear was assessed according to the diagrams and stages of BH Smith (1984, 1991). Criteria used for evaluating occlusal tooth wear are summarized in Appendix B.6.

Age- and activity-related bone changes were scored separately for the axial and appendicular skeleton. In the spine the zygapothyseal joints (Appendix C.2.6) and vertebral bodies (Appendix C.2.10) were scored for estimation of osseous degenerative processes. Osteophytes indicating ossification of *ligamenta flava* were scored according to Appendix C.2.11.

The axial skeleton of each individual was examined for evidence of bone resorption and deposition, beak osteophytes and ankylosis. The location, activity and severity of lesions was recorded. Developmental anomalies were compared to those in the extensive review by Aufderheide and Rodríguez-Martín, (1997), Barnes (1994) and Ortner (2003). Bone abnormalities suggestive of healed fractures were radiographically examined. Depressions in the inner and outer tables of the cranial vault were designated as outlined in Appendix C.2.12.

The data of lesions in the subgroups of the Ganj Dareh skeletal sample are primarily frequency data. Chi Square analyses including Fisher's Exact Test (SPSS statistical software package V7.5, 1996) were used to test hypotheses and identify relationships among the categorical variables and across age categories.

The data on which the analysis in Chapter 10 is based are presented in Appendix D. Appendix E presents the ^{14}C dates for Ganj Dareh.

CHAPTER 10. ANALYSIS

10.1 Skeletal Inventory

Through the course of the initial inventory for the present study, each burial identified at the time of excavation was examined for evidence of the presence of more that one individual, for example, by evidence for age differences and element duplication. Nine additional individuals were identified (see Appendix 4.1 for skeletal inventory list).

In the field, the left maxilla of middle adult Ganj Dareh #4 (GD #4) was recatalogued as juvenile Ganj Dareh #5 (GD #5), on the basis of an unerupted left maxillary canine visible due to damage to the alveolar bone. However, examination of the surrounding alveoli revealed that all the other teeth in the quadrant were fully erupted. Considering the alveolar morphology, the bone preservation and colour, and the perfect fit with the right maxilla of GD #4, GD #5 was reunited with the remainder of its skeleton (GD 4).

All skeletal elements that had been isolated from the faunal samples, labelled by excavation unit only, were identified as to excavation area and occupational level (pers. comm., PEL Smith, 2003, 2004). Isolated elements from ten excavation units were identified as possibly recent intrusions to archaeological Level A, and were not included in the present analysis (Appendix D.1). Bones from units 1148 and 1347 were recatalogued as associated with burials GD #13a and GD #29, respectively.

In several instances groups of bones, isolated from adjacent excavation units at the same occupational level, were similar in colour, preservation, size, morphology and developmental stage. When there was insufficient evidence to consider them as separate individuals, the adjacent units were collapsed to be considered as single individuals, for example 1508/1509, 855/856, and 1483/1484.

During the inventory and analysis of the Ganj Dareh skeletal sample, the fragmentary nature of the remains necessitated reconstruction of many of the skeletal elements. This facilitated identification of individuals, as well as lesion distributions within individuals. The minimum number of individuals (MNI) is 116 (Table 10.1). This includes 56 skeletons that range from nearly complete to consisting of at least 4

	Total MNI	Skeletons	Isolated Bones	Isolated Teeth	Isolated Teeth & Bones
Non-Adults	51	28	14	9	0
Adults	65	28	26	10	1

Table 10.1. Minimum number of non-adult and adult individuals. Total MNI, those skeletons represented by > 4 skeletal elements, by isolated bones and by isolated teeth.

skeletal elements, 39 individuals represented by fewer than 3 bones, 19 individuals indicated by the presence of less than 4 teeth, and 1 individual comprised of both teeth and bones, but fewer than 4 elements in total. Each of the 116 individuals represented in the MNI of the site can be distinguished from all the others by at least one of the following criteria: age-at-death, occupation level, excavation area, and excavation unit.

Age Category	Age Range (Years)	Number of Individuals
1	0-0.9	18
2	1-3	12
3	4-7	6
4	8-11	8
5	12-17	7
6	18-29	15
7	30-50	14
8	>50	5
9	18-50	13
10	>30	15
11	>18	3

Table 10.2. Number of individuals in each age category.

10.2 Age Profile

10.2.1 Mortality and Survivorship

Age-at-death was assessed for each individual. Individuals were then assigned to one of the eleven age categories (Table 10.2). For the construction of a mortality profile (Fig. 10.1) and life table (Table 10.4), individuals in the broad adult age categories 9 to 11 were redistributed across the corresponding specific adult age categories 6 (Young Adult), 7 (Middle Adult) and 8 (Older Adult). The resulting number of individuals in each age category is given in Table 10.3.

Age Category	# Years / Age Category	Number of Individuals
1	1	18
2	3	12
3	4	6
4	4	8
5	6	7
6	12	22.5
7	20	29
8	20	13.5

Table 10.3. Number of individuals in each age category used in the mortality profile and the life table.

When the number of individuals is plotted by age category, a U-shaped mortality profile is obtained (Fig. 10.1). This is similar to modern Third World populations, for example Peru (Waldron, 1994:8), with the greatest frequencies of deaths in the young children, ages birth to three years, and adults greater than fifty years.

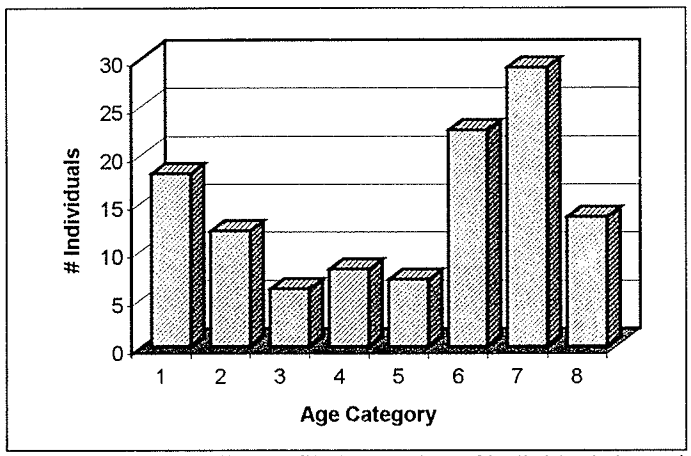

Figure 10.1. Mortality profile by number of individuals in each age category.

When age (x axis) is divided into roughly equal increments, the number in each

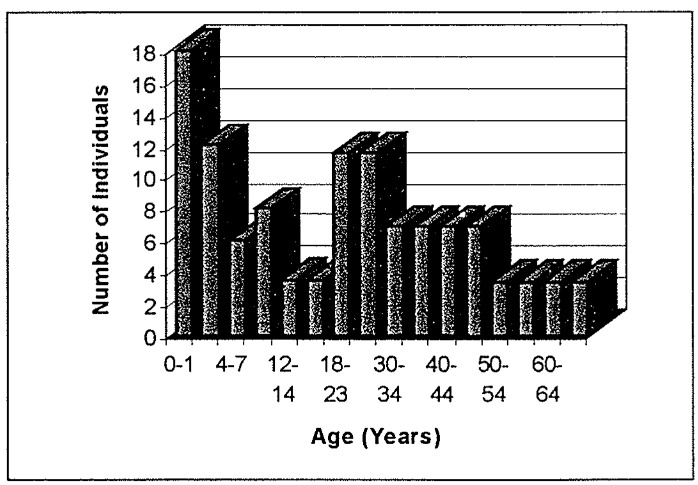

Figure 10.2. Mortality profile. Age increments illustrated are less than or equal to six years.

age interval (Fig. 10.2) is similar to the West 4 model mortality profile (cited in Jackes, 1994). This second representation emphasizes a third peak of deaths, those in early adulthood, ages eighteen to thirty years.

Traditional analysis in palaeodemography utilizes life tables for the generation of survivorship curves. Although there are many theoretical problems with their use for

Age (Years)	**Y_x (N)**	**d_x**	**l_x**	**Q_x**	**L_x**	**e_x**
0-1	18	155.2	1000.0	0.155	922.4	23.9
1-3	12	103.4	844.8	0.122	2379.3	27.2
4-7	6	51.7	741.4	0.070	2862.1	27.8
8-11	8	69.0	689.7	0.100	2620.7	25.7
12-14	3.5	30.2	620.7	0.049	1816.8	24.3
15-17	3.5	30.2	590.5	0.051	1726.3	22.5
18-23	11.25	97.0	560.3	0.173	3071.1	20.6
24-29	11.25	97.0	463.4	0.209	2489.2	18.3
30-34	7.25	62.5	366.4	0.171	1675.6	16.4
35-39	7.25	62.5	303.9	0.206	1363.1	14.2
40-44	7.25	62.5	241.4	0.259	1050.6	12.2
45-49	7.25	62.5	178.9	0.349	738.1	10.6
50-54	3.375	29.1	116.4	0.250	509.2	10.0
55-59	3.375	29.1	87.3	0.333	363.7	7.5
60-64	3.375	29.1	58.2	0.500	218.2	5.0
65-69	3.375	29.1	29.1	1.000	72.7	2.5

Table 10.4. Ganj Dareh life table. Equations used for calculation of the life table (Boddington, 1987; Jackes, 1988).

x = age category
xn = last age category
$d_x = (Y_x / \sum Y_x) * 1000$
Survivorship: If x = o, $l_x = 1000$
If $x \geq 1$, $l_x = l_{x-1} - d_{x-1}$

$Q_x = d_x / l_x$
$L_x = [l_x - (d_x / 2)]$ * # years in age interval
$e_x = (L_x + .. L_{xn}) / l_x$

estimation of population parameters of the living population from which a skeletal sample is derived (see Chapter 2), they are still useful for visualizing the age profile of the skeletal sample for comparative purposes. The life table for Ganj Dareh (Table 10.4) provides the survivorship values (l_x) plotted for the age range of birth to 70 years (Figure 10.3).

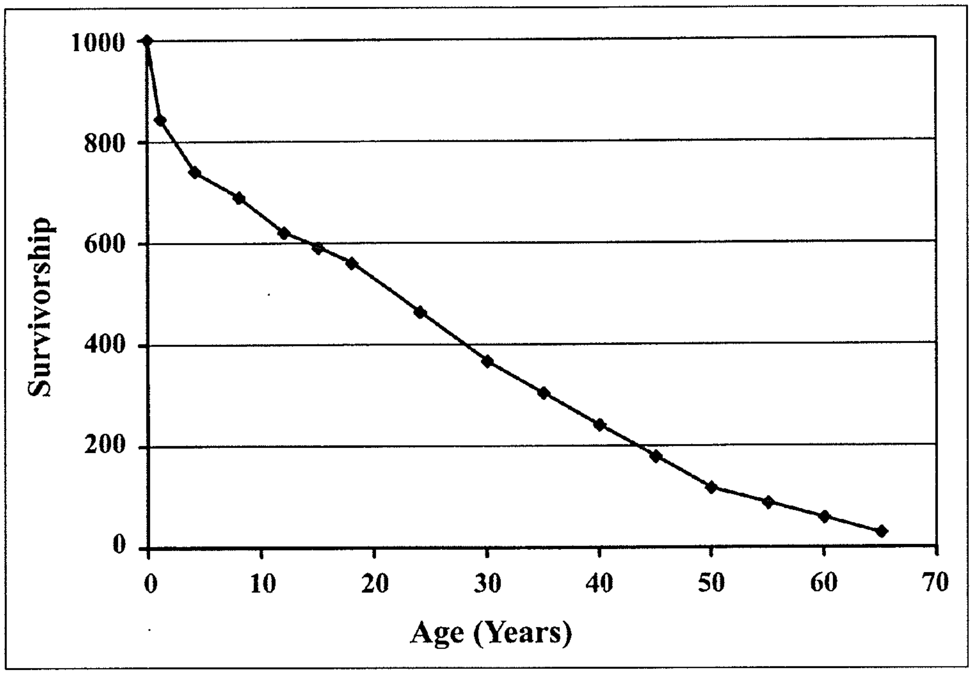

Figure 10.3. Survivorship curve.

10.2.2 Age Estimation of Infants

Age estimates from cranial and infracranial bone size for eleven infants are consistently in the late fetal – perinate range based on modern length-for-age standards (Table 10.5). Developmental ages for the four infants with cranial remains and dentitions were estimated based on the growth and fusion of the initial ossification centres of the sphenoid, temporal and occipital bones, and on tooth crown formation (Table 10.6). Cranial developmental and tooth crown formation age estimates are consistently older than ages estimated from size alone (Table 10.6). The number of enamel cross striations between the neonatal line and the enamel surface provides a refined and more accurate age-at-death, confirming that these infants lived for a substantial time after birth (Figs.

	Estimated Age		
Ganj Dareh #	Cranial Size[1] (wk[2])	Long Bone Length[3] (wk)	Long Bone Length[4] (wk)
12	f 40 – 2 wk pp	f 40	f 37- 1 wk pp
27*	f 40 – 2 wk pp	f 40 - > f 40	f 36- 40
1a*	f 40 – 2 wk pp	> f 40	f 38 – 2 wk pp
21*	f 40 – 2 wk pp	f 36-38	f 35-39
7	f 38 – 2 wk pp	f 36-38	f 32-36
1506	---	f 36-38	f 32-36
1485	---	f 36-38	f 34-38
37a	---	f 36-38	f 33-37
468b	---	f 36-38	f 37–1 wk pp
1150a	---	f 38-40	f 36-40
1153	---	f 40	f 36-40

Table 10.5. Perinate age estimation from cranial and infracranial length-for-age standards.

* Calcined bone lengths corrected for 10 % shrinkage
[1] Scheuer and Black (2000).
[2] Weeks gestation (f).
[3] Fazekas & Kósa (1978).
[4] Scheuer et al. (1980).

10.4 and 10.5). In addition, comparison of age estimates based on size with those based on development facilitates recognition of instances of slow growth.

Ganj Dareh #	Long Bone Length [1] (wk)	Cranial Development[2] (wk)	Tooth Crown Formation[3] (wk pp)	Cross Striations #	Cross Striations (wk pp)
12	f 40 - > f 40	2-24	0-16	33	4.5
27	f 40	> f 40	f 36 - 4	39	7.5
1a	> f 40	---	0-16	70	10
21	f 38-40	16-42	2-20	105	17

Table 10.6. Comparison of long bone length, cranial development, crown formation and dental microstructure age estimations.

[1] Fazekas & Kósa (1978). Lengths corrected for 10% shrinkage due to post-burial fire exposure (#1a, #21, #27).
[2] Scheuer and Black (2000).
[3] ± 2 SD. Moorees et al. (1963).

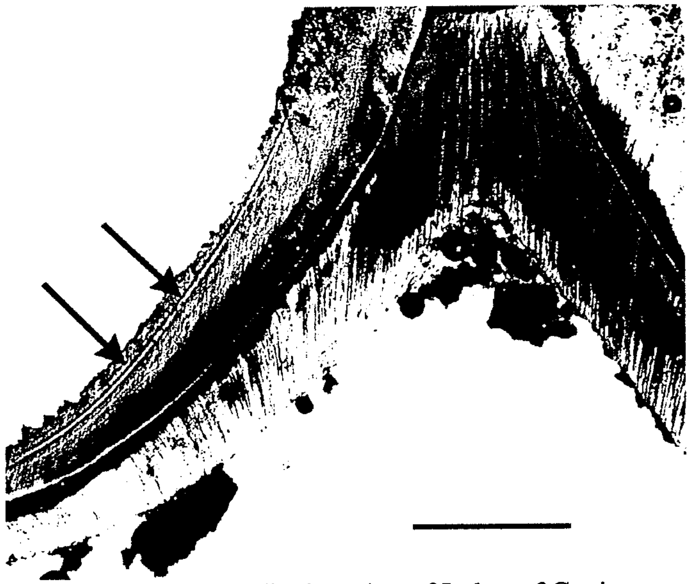

Figure 10.4. Longitudinal section of L dm_1 of Ganj Dareh #12. Low magnification showing neonatal line (arrows). Scale bar = 500 μm.

Figure 10.5. Higher magnification showing enamel prisms (arrows). Within each prism at least 39 cross striations were observed between the neonatal line and the enamel surface. Scale bar = 50 μm.

Although all four infants are perinatal in size, infant #21 is 7 weeks older than infant #1a, 9.5 weeks older than infant #12 and 12.5 weeks older than infant #27 (Table 10.6). Thus all four infants were in the post-neonatal age range (one month to one year) at the time of death. For the infants #1a, #12 and #27, the relationship between long bone length and chronometric age appears to be linear (Fig. 10.6). Femur length for infant #21 is clearly an outlier given its dental age suggesting that infant #21 had experienced growth stunting during both the pre- and postnatal periods.

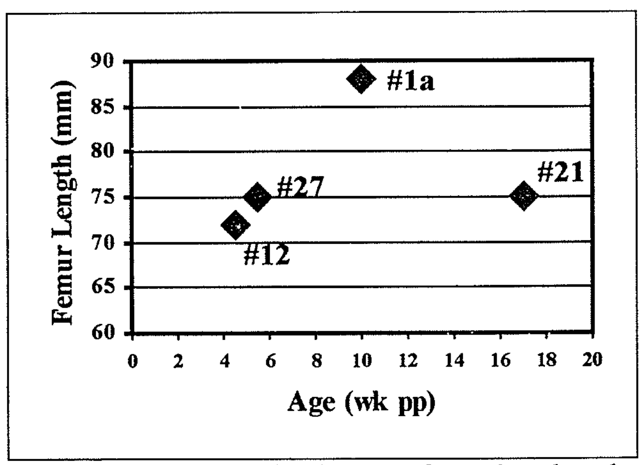

Figure 10.6. Relationship between femur length and chronometric age based on enamel prism cross striations.

Infants #7 and #1153 have similar femur lengths to #12 and #27. Based on the relationship between femur length and enamel cross striation age, this suggests that they were between four and six weeks of age placing them within the post-neonatal age range. Metric comparisons of other skeletal elements revealed two identifiable clusters among the eleven young infants: neonates: #7, #1506, #1485, #37a, and post-neonates: #12, #27, #468b, #1150a, #1153, #1a, #21.

In order to compare this data with that of modern populations, all infants in age category 1, aged birth to one year (N_{min} = 14, N_{max} = 20)[1], were analyzed. In the first year of life 71-80 % of the deaths occurred during the post-neonatal period.

10.2.3 Tooth Wear

Mandibular tooth wear was scored for sixteen individuals (adolescents and adults) following the method of BH Smith (1984, 1991). Criteria for recognition of each of the stages are given in Appendix A.8. The mandibles were then seriated to facilitate age estimation (Table 10.7), assuming similar degrees of tooth use and diet across all members of the community.

Wear Stage	Ganj Dareh #
1	#15, #17, #41
2	#20, #23, #40
3	#3, #31, #1150
4	#4, #13a, #35
5	#22, #30, #34, #37

Table 10.7. Wear stage observed in the mandibular dentitions of Ganj Dareh individuals.

10.2.4 Adult Age Estimation from Suture Fusion

Two of the late adolescents and twelve adults had cranial vault bone with identifiable segments of sutures for cranial suture fusion age estimation. An additional eight individuals had isolated cranial fragments exhibiting some of the suture margin

[1] In the life table and mortality profile analysis, age category 1 has 18 individuals.

locations required for the methods of Meindl and Lovejoy (1985) and Mann and colleagues (1987). None of the individuals were sufficiently complete for calculation of vault and lateral-anterior scores. Consequently, data presented are the maximum individual site score for each individual. Similarly, none of the palates were complete enough to estimate palatal scores. Palatal values recorded are primarily based on the degree of fusion of the incisive suture and secondarily of the anterior and posterior medial palatine sutures. Age estimates from cranial suture fusion are given in Table 10.8.

Ganj Dareh #	Cranial Suture	Palatal Suture	Tooth Wear
15	0	--	1
41	0	YA	1
3a	0	--	1
4	1	>25	4
8/9	0	--	2
11	1	--	4
13a	0	MA	4
19	2	--	--
20	3	>25	2
22	2	--	5
23	0	--	2
28	0	--	(3)
30	3	>25	5
31	2	--	3
34	1	--	5
35	0	>25	4
37	2	>25	5
40	0	--	2
1150	1	--	3
370	0	--	--
507	0	--	--
855/856	0	--	2

Table 10.8. Comparison of degrees of suture fusion and tooth wear. Suture fusion ranges from 0 (open) to 3 (completely obliterated). Criteria for the five tooth wear stages used are given in Appendix A.8. Tooth wear for GD #28 is based on observation of one mandibular incisor. YA = young adult. MA = middle adult.

10.3 Sex Estimation

The poor preservation of the pubis in all innominates present precluded assessment of the subpubic concavity and ventral arc. The sex of fifteen of the adults and the three late adolescents could be assessed (Table 10.9). Of the eighteen individuals, nine (50.0%) were estimated to be male, four (22.2%) probably male and five (27.8%) female.

Ganj Dareh #	Sex	Nuchal Area	Mastoid Process	Supra-Orbital Margin	Glabella	Mental Eminence	Ventral Arc	Ischiopubic Ramus	Greater Sciatic Notch	Preauricular Sulcus
15	M?	1	1	2	2	2-3	--	--	5	4
17	M	2	2	2-3	5	4	--	--	5	4
41	M	5	5	4	5	4	--	--	--	--
3a	F	--	--	2	2	3	--	--	--	1
4	M?	3-4	--	1	3	3	--	--	0	0
13a	M?	--	3	--	4	4	--	--	--	--
20	M	4	5	5	--	5	--	--	4	4
22	M	--	--	--	--	4	--	--	5	3
23	F	--	1	3-4	2	3	--	--	--	--
28	F	2	--	1	--	3	--	--	--	2
29	F	--	--	--	--	--	--	--	2	1
30	F	2	2-3	1	2	1	--	1	1	2
31	M	5	4	4	5	5	--	--	5	3
34	M?	4	4	2	2-3	3	--	--	3	--
35	M	4	4	5	5	5	--	--	--	--
37	M	5	5	3	5	5	--	--	--	--
40	M	--	--	3	--	5	3	--	5	3
1150	M	4	5	--	--	5	--	--	--	--

Table 10.9. Sex estimation. Scoring follows the methods outlined in Buikstra and Ubelaker (1994).

10.4 Growth Disruption

10.4.1 Harris' Lines

Of the thirty-nine individuals with metaphyses that could be radiographed, eight (20.5%) non-adults and one (2.6%) adult exhibited Harris' Lines. These proportions are not significantly different (Fisher's Exact Test: two sided p = 0.399, and one-sided p = 0.195). They were present in all age categories of non-adults. In adults, the only individual affected was younger than thirty years (Table 10.10). Harris' Lines were observed in the proximal humerus, distal femur, proximal and distal tibia and distal fibula. Of the children with more than two Harris' Lines per skeletal element, all exhibited at least four lines, with a maximum of seven in Ganj Dareh #17 distal femora.

Age Category	≤ 2 HL per Bone	>2 HL per Bone	Absent
1	#228	0	13
2	#38	#14b	5
3	0	#2, #16	0
4	0	#10	0
5	#13	#17	2
6-11	#40	0	10

Table 10.10. Harris' Lines by age category and number of lines per skeletal element affected. The Ganj Dareh # is given for those affected.

10.4.2 Enamel Hypoplasia

Observations of enamel surface texture were made on 162 deciduous and 164 permanent tooth crowns of twenty-eight non-adults, and on 228 permanent tooth crowns of thirty adults. Both linear (LEH) and circular (CEH) enamel defects

Age Category	Absent	LEH	CEH	LEH + CEH
1	6	0	1	0
2	1	1	4	1
3	2	1	0	1
4	3	0	2	1
5	0	2	0	2
6	7	4	1	2
7	5	5	0	1
8	2	3	0	0
Total	26	16	8	8

Table 10.11. Frequency of enamel hypoplasia by age category.

were observed in thirty-two of the Ganj Dareh dentitions (Table 10.11). Circular defects were observed on canines and molars in both the primary and permanent dentitions.

The frequency of all hypoplasia types is not significantly different between non-adults (≤17 years) and adults (>17 years), (Fisher's Exact Test, p=0.798). Similarly, the frequency of LEH is not significantly different for the two groups (Fisher's Exact Test, p=0.192). However, for the same age groupings, the prevalence of CEH is significantly different between the two groups (Fisher's Exact Test, p=0.018), since individuals with primary canine circular hypoplasia account for a substantial proportion (9/16 or 56.2%) of those exhibiting CEH, and they are not expected to be present in individuals older than age category 4. In the fourteen individuals younger than 12 years and with deciduous canine tooth crowns present for examination, nine (64.3%) exhibit circular defects on the labial surfaces (Table 10.12).

Of the six non-adults with localized hypoplasia of the primary canine (LHPC), five (GD #25, #26b, #38, #16 and #10) also exhibit circular enamel defects on other deciduous and/or permanent teeth. CEH of the permanent canines and LEH were also present in the dentition of the eight to ten year old child GD #10. Four individuals older than 12 years (two adolescents GD #15, #17, one young adult #40 and one middle adult #37) exhibited circular enamel defects on the labial surfaces of their permanent canines. LEH was also present in the three younger individuals.

Age Category	Absent	Present
1	3	1
2	1	3
3	0	1
4	1	1

Table 10.12. Prevalence of CEH of the primary canines (LHPC) in individuals in whom deciduous canines are expected and present.

10.4.3 Long Bone Growth

Long bone metaphyses are not well preserved in the Ganj Dareh skeletal sample. Of the thirty-five non-adults with infracranial skeletal elements present, seventeen had femora sufficiently intact for measurement of diaphysis length. Maximum length measurements were possible for only nine tibiae and eight humeri. Femoral lengths were plotted against estimated age (Fig. 10.7 and 10.8) to identify individuals exhibiting growth stunting and to facilitate comparisons of growth velocity with other populations.

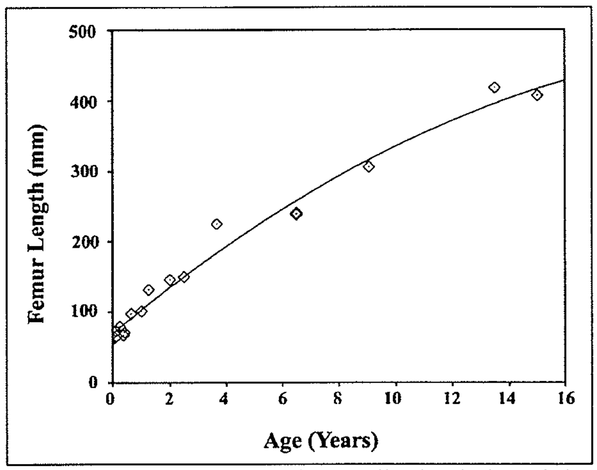

Figure 10.7. Maximum femur diaphysis length by age for non-adults. The curve indicated is fitted by quadratic regression through the scatterplot line fitting options in SPSS.

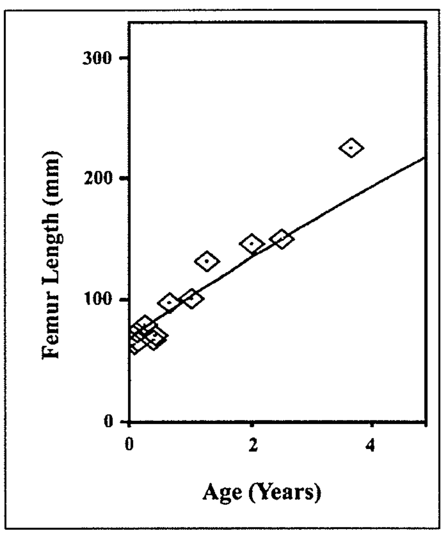

Figure10.8. Expanded view of Fig. 10.7 showing the relationship between age and femur length for infants and young children. The curve shown was generated using the entire non-adult sample.

10.4.4 Adult Stature

Stature was estimated using the regression equations of Trotter (1970) listed in Table 10.13. Feldesman and colleagues (1990) have found that femur length bears a nearly constant relationship to adult stature (Femur / Stature = 26.74 %) that does not vary between sexes or among populations. Stature for the Ganj Dareh adults was estimated using both methods (Table 10.14)

Sex	Regression Equation *	± S E **
Male	3.08 Humerus + 70.45	4.05
	3.78 Radius + 79.01	4.32
	3.70 Ulna + 74.05	4.32
	2.38 Femur + 61.41	3.27
	2.52 Tibia + 78.62	
Female	3.36 Humerus + 57.97	4.45
	4.74 Radius + 54.93	4.24
	4.27 Ulna + 57.76	4.30
	2.47 Femur + 54.10	3.72
	2.90 Tibia + 61.53	3.66

Table 10.13. Equations based on people of European ancestry that were used for stature estimation (modified from Trotter, 1970).

Ganj Dareh #	Sex	Stature from Regression Equations[1]							Stature from Femur[2]
		Hum	Rad	Ulna	Fem	Tib	Fem + Tib	Mean[1]	
4	M		165.2	165.8				165.5	
23	F	153.7	155.9	161.5	162.3			158.4	163.8
31	M	168.7	175.4	176.5	177.3	177.9	177.8	175.6	182.1
34	M?	165.0		171.0	165.2	169.6	166.9	167.5	163.1
40	M	168.7	176.2	175.4	172.3			173.2	174.3
1151-2	?			162.5				162.5	
20	M				172.1	175.6	173.8	173.8	173.9
22	M				175.1	169.9		172.5	170.5

Table 10.14. Stature of Ganj Dareh adults estimated using the methods of Trotter (1970)[1] and of Feldesman and colleagues (1990)[2].

10.5 Dental and Alveolar Pathology

10.5.1 Caries

The 366 teeth of twenty-eight non-adults and 228 teeth of thirty-two adults were examined for evidence of carious lesions[1]. Caries were not observed in the forty individuals younger than thirty years (Table 10.15). Of the twenty middle and older adults, five (25.0%) exhibited caries. Caries frequencies in the two age groups are significantly different (Fisher's Exact Test, p=0.003).

Age (Years)	Absent	Present
≤ 29	40	0
≥ 30	15	5

Table 10.15. Frequency of caries by age.

A total of seven caries were present, affecting six teeth from both the maxillary (N=2) and mandibular (N=5) dentitions (Table 10.16). Five of the caries are located at

Ganj Dareh #	# Teeth Observed	Tooth Affected	# Caries per Tooth	Caries Location
4	19	LP^4	1	Mesial inter-proximal margin of occlusal surface
30	2	LM_2	1	Entire crown absent Associated with periapical cyst
31	26	RM_3	1	Mesial inter-proximal CEJ
34	19	RC^1	2	Labial CEJ Distal inter-proximal CEJ
37	8	RP_4 LP_4	1 1	Distal inter-proximal CEJ Distal inter-proximal CEJ

Table 10.16. Caries location, teeth affected and number of caries per tooth for individuals affected.

the cemento-enamel junction (CEJ) of the tooth. One is on the occlusal surface. The caries of individual #30 has involved and destroyed the entire crown of the left

[1] A total of 594 teeth were examined for evidence of caries. A subset of these teeth (N=554) exhibited enamel surfaces sufficiently free of calculus and/or consolidant-soil mixture to be examined for enamel hypoplasia (data presented in Chapter 10.4.2).

mandibular second molar, exposing the pulp chamber. Bone resorption at the root apex resulted in formation of a smooth-walled periapical cyst.

10.5.2 Alveolar Abscessing

Alveolar abscessing was observed in only two (10.5%) of the nineteen non-adults with alveolar bone present: GD #14b (3-4 years) and GD #15 (14-16 years). Eight (57.1%) of the fourteen adults also exhibited alveolar abscessing (Table 10.17). Frequencies of abscessing in the two age groups are significantly different (Fisher's Exact Test, p=0.010).

Age	Absent	Present
0-0.9	7	0
1-3	4	1
4-7	3	0
8-11	1	0
12-17	2	1
18-29	6	2
30-50	0	2
>50	0	3
>18	0	1

Table 10.17. Number of individuals exhibiting alveolar abscessing by age range.

10.5.3 Ante-Mortem Tooth Loss

Ante-mortem tooth loss (AMTL) was observed in eight (29.6 %) of the twenty-seven individuals with alveolar bone present. The distribution of AMTL, evident only in middle and older adults, is highly significantly different across age categories (Fisher's Exact Test, p=0.003 comparing the two groups non-adults and adults). Of the one hundred fifty-three alveoli examined, 22 tooth sockets (14.3%) were filled with healed or healing bone. If any portion of the alveolus exhibited smooth walls indicating that the root stub was still present during life, the lesion was considered to be an inflammatory process and was scored as abscessing rather than AMTL. Both maxillary and mandibular teeth had been lost as well as all tooth types (Table 10.18).

Ganj Dareh #	Age Category	# Alveolae Examined	Maxilla	Mandible
4	7	20	RP^4, RP^3	
13a	7	24		LI_1, LI_2, LC_1
22	8	11	LI^1	LM_1
30	8	24	LP^4, LM^1	RM_1, RP_4, RI_1, LI_1
31	7	17	LI^1	
34	8	21		RM_3
35	7	25	LI^1	LP_3, LP_4
37	7	21	RM^1, RP^4, LP^3, LM^1	

Table 10.18. Individuals with ante-mortem tooth loss and teeth lost by dental quadrant.

10.6 Inflammatory Processes

10.6.1 Non-Specific Inflammation

10.6.1.1 Periostitis

Ganj Dareh #	Age Category	Skeletal Elements Affected
23	6	Radius, Ulna
33	9	Fibula
34	8	Scapula
507	6	Proximal foot phalanx
1483/1484	10	R MT II

Table 10.19. Individuals with periostitis by age category and skeletal elements affected.

All non-entheseal periosteal surfaces of the infracranial skeleton of seventy-one individuals were observed macroscopically using a dissecting microscope. Porosity of infant bone was assumed to be the normal condition and scored as periostitis absent for the purposes of this study[2]. Periostitis was observed in five individuals (7.0%). All were older than seventeen years (Table 10.19).

[2] Others (for example Angel (1966) and Agelarakis (1989)) have interpreted the porous appearance of infant cranial bone as indicative of disease states. However, the similarity of appearance of many periosteal surfaces of infracranial infant bone suggests to me that this may be the "normal" condition. The literature is sparse on this topic. This avenue of research is beyond the scope of the present study, but will be addressed in future research (Chapter 12).

Prevalences of periostitis in adults and non-adults are not significantly different (Fisher's Exact Test, p=0.315).

10.6.1.2 Sinusitis

The paranasal sinuses of seventeen individuals were present for examination (Table 10.20). Four exhibited bone deposition or resorption on the floor of the maxillary sinuses and one displayed new bone buildup in the form of plates and lobules of the frontal sinus. Of the two late adolescents affected, one had maxillary and the other frontal sinusitis. The three adults suffered from maxillary sinusitis.

Age Group	Absent	Present
Non-Adult	7	2
Adult	5	3

Table 10.20. Frequency of sinusitis (maxillary and frontal by age group).

10.6.1.3 Porotic Hyperostosis and *Cribra Orbitalia*

Cranial hyperostosis was observed on the ectocranial surface of the vault of a substantial proportion (82.2%) of the Ganj Dareh inhabitants (Table 10.21). In all cases the degree of vault thickening was minimal. Of the thirty-two individuals that exhibited evidence of cranial porosity only one child GD#25 and one young adult GD#20 showed indications that the lesions were active at the time of death.

Age Group	Absent	Present
Non-Adult	4	15
Adult	3	17

Table 10.21. Frequency of cranial hyperostosis by age group.

In contrast, cribra orbitalia was present in only 58.6% of those with orbital roofs present (Table 10.22).

Age Group	Absent	Porosity Only	Blood Vessel Impressions and Porosity
Non-Adult	5	11	1
Adult	5	0	7

Table 10.22. Frequency of *cribra orbitalia* by type of lesion and age group.

Minimal expressions of porous new woven bone were visible in all of non-adults scored as exhibiting *cribra orbitalia*. One non-adult showed some blood vessel impressions with the porosity. In contrast porosity with blood vessel impressions was present in all of the adults with bony changes to the morphology of the orbital roof. All cases of *cribra orbitalia* were of minimal expression. One third (34.4%) of those scored for cribra orbitalia and porotic hyperostosis (N=29) exhibited both.

10.6.2 Zoonoses

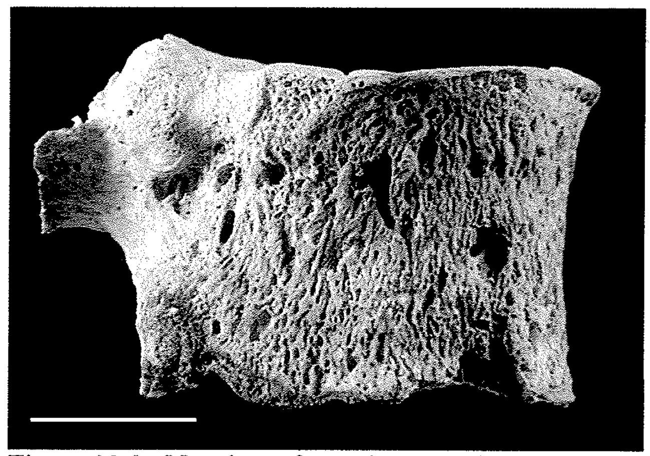

Figure 10.9. New bone formation on a thoracic vertebral body of Ganj Dareh #22. Scale Bar = 1 cm.

In the modern world, brucellosis and tuberculosis are common zoonotic diseases in populations practicing subsistence pastoralism that focuses on ovicaprids (al-Rawi et al., 1989; Collins and Grange, 1983; El-Amin et al., 2001). The bodies and arches of the vertebrae of thirty-four individuals were examined for bone deposition and resorption. Neither resorption of the anterior and lateral surfaces of the bodies nor kyphosis from vertebral body collapse were present, suggesting that the Ganj Dareh people did not suffer from tuberculosis. However, older adult GD#22 exhibited periosteal new bone formation on the anterior surface of a thoracic vertebral body (Fig. 10.9). On the anterior superior margin of a lumbar vertebra from the same individual was a region of bone resorption partially obliterating the annular ring epiphysis. Thus the lytic lesion is immediately under the *anulus fibrosis*.

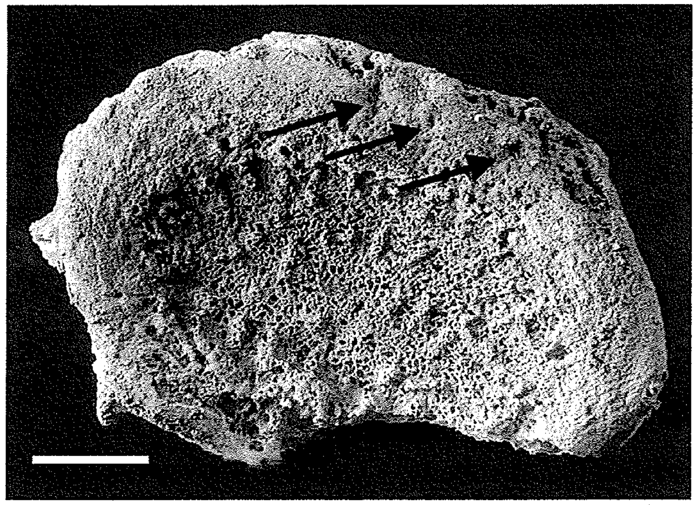

Figure 10.10. Superior surface of a lumbar vertebra of Ganj Dareh #22. Areas of resorption through the annular ring epiphysis beneath the *anulus fibrosis* are at the anterior margin (arrows). Scale bar = 1cm.

Adjacent to the area of resorption, osteophytes project from the superior margin of the vertebral body (Fig. 10.10). The locations of bone resorption and deposition suggest brucellosis infection. However, a lateral radiograph failed to show evidence of sclerosis below the lytic lesion.

10.7 Activity Related Conditions

10.7.1 Osteoarthritis of the Non-Axial Skeleton

Age Group	Absent	Present
<30 Years	11	3
≥30 Years	27	11

Table 10.23. Frequency of non-vertebral osteoarthritis by age group.

All non-vertebral articular facets were examined for each of fifty-two individual using a dissecting microscope. Criteria used for osteoarthritis assessment were condition of the subchondral bone (pitting and eburnation) and bone activity (deposition and resorption of the articular margin). One quarter (26.9%) of individuals examined exhibited at least one of the criteria of osteoarthritis (Table 10.23). There is no significant difference in the prevalence of osteoarthritis in the two age groups tested: those younger than 30 years, and those older than 30 years (Fisher's Exact Test, p=0.732). The ten degree angulation and shortening by three centimetres of the right humerus of adolescent GD#15 adversely influenced the biomechanics of his right arm, resulting in subchondral pitting of the trochlea and enthesopathies at the insertion of latissimus dorsi and pectoralis major, muscles that adduct and medially rotate the arm at the shoulder. The temporal-mandibular joint of Ganj Dareh #35 shows evidence of subchondral pitting and possible masticatory discomfort.

Eburnation of the articular surface was present in four individuals. Two had involvement of the acromio-clavicular joint, young adult GD#1150 and older adult GD#37. Individual GD#37 had also sustained injury to the right knee, indicated by the presence of eburnation of the right distal femoral condyles.

10.7.2 Enthesopathies and Activity Levels

Muscle and ligament attachment sites (entheses) were examined macroscopically using a dissecting microscope. The degree of roughening of the periosteal surface as well as bone deposition and resorption were recorded. Of the fifty-nine individuals with entheses that could be scored, thirteen (22.0%) exhibited substantial bone deposition or resorption at these locations (Table 10.24). None were observed in children younger than eight years. The prevalence in juveniles and adolescents is not significantly different from that in adults (Fisher's Exact Test, p=0.69). There is development of the origin and insertion of brachialis (flexion of the elbow) as well as of all major entheses of the lower limbs, including at linea aspera, gluteal tuberosity, soleal line and gastrocnemius origin

Age Group	Absent	Present
8-17 Years	8	3
Adult	38	10

Table 10.24. Frequency of enthesis development by age group.

and insertion. The presence of osteophyte development at entheses was also recorded (Table 10.25).

Ganj Dareh #	Age Category	Skeletal Element	Muscle/Ligament	Muscle Action
15	5	Humerus	Insertion of Pectoralis Major	Adducts and Medially Rotates Arm
20	6	Humerus	Origin of Pronator Teres	Pronates Forearm and Flexes Elbow
4	7	Ulna Femur Tibia	Origin of Supinator Insertion of Medial Femoral Muscles Origin of Soleus	Supinates Forearm Adducts Hip Plantar Flexion of Ankle
31	7	Ischium Femur	Sacrotuberous Ligament (Origin of Gluteus Maximus) Obturator Externus	Extends and Laterally Rotates Hip Laterally Rotates Thigh
22	8	Humerus	Origin of Brachialis	Flexes Elbow
34	8	Humerus	Origin of Brachioradialis	Flexes Elbow
37	8	Tibia Calcaneus	Patellar Ligament (Rectus Femoris) Achilles Tendon (Gastrocnemius and Soleus)	Extends Knee Plantar Flexion of Ankle
24	9	Tibiae	Patellar Ligament (Rectus Femoris)	Extends Knee
28	10	Ulna Calcaneus	Insertion of Brachialis Origin of Supinator Achilles Tendon (Gastrocnemius and Soleus)	Flexes Elbow Supinates Forearm Plantar Flexion of Ankle
29	10	Ulna Calcaneus	Insertion of Brachialis Achilles Tendon (Gastrocnemius and Soleus)	Flexes Elbow Plantar Flexion of Ankle
1151-2	11	Ulna	Insertion of Brachialis	Flexes Elbow

Table 10.25. Individuals with osteophytes by location, muscle/ligament involved and muscle action.

10.7.3 Spinal Degenerative Processes

10.7.3.1 Osteoarthritis

Age Group	Absent	Present
Non-Adult	19	0
Adult	6	9

Table 10.26. Frequency of osteoarthritis by age group.

Of the thirty-four individuals with vertebrae present (Table 10.26), nine (26.5%) showed evidence of vertebral osteoarthritis, that is, at least one of: lipping or erosion of articular margins, pitting or eburnation of the articular facets, and horizontal osteophytes at the inferior and/or superior margins of the vertebral bodies. All instances observed occurred in adults. Prevalences in adults and non-adults are highly significantly different (Fisher's Exact Test, p=0.0).

Eburnation had occurred on thoracic vertebral articular facets of GD#31 (Fig. 10.11) and GD#4.

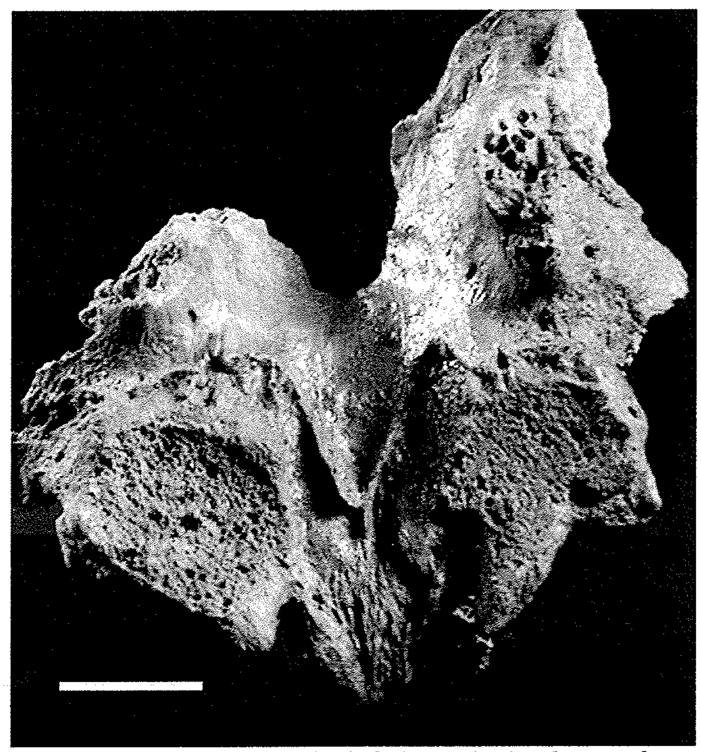

Figure 10.11. Pitting on the inferior articular facets of a thoracic vertebra of GD#31. Scale bar = 1cm.

10.7.3.2 Ankylosis

Ossification of the anterior longitudinal ligament resulted in ankylosis in the thoracic spine of older adult GD#37, involving at least four vertebral bodies (Fig. 10.12). Disk spaces are maintained (Fig. 10.13). In some regions it is possible to see a small space between the ossified ligament and the vertebral body. In one small area there is minimal ossification of the outer portion of the *anulus fibrosis*. The fragility of the bone and the resulting poor state of preservation precludes assessment of the exact location of the ossified ligament on the vertebral bodies.

Figure 10.12. Thoracic vertebral bodies of GD#37 showing ossified anterior longitudinal ligament (right) and maintained disk spaces. Scale bar = 1cm.

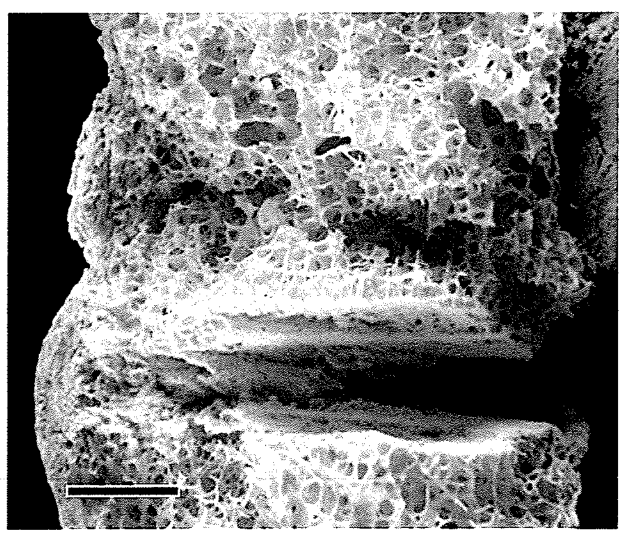

Figure 10.13. View of maintained disk space of GD#37. Scale bar = 0.5cm.

10.7.3.2 Spondylolysis

Adolescent Ganj Dareh #15 presents with unilateral spondylolysis of the thoracic vertebra 8. A stable facet is present in the inter-articular lamina of the left arch. There was no evidence that bridging of the two sides of the affected arch was occurring.

10.8 Trauma

There was very little evidence of trauma in the Ganj Dareh inhabitants. Of the 116 individuals represented in the skeletal sample, only 8 instances (6.9%) of healed or healing fractures were observed (Table 10.27). None of the features facilitated assessment of accidental or intentional cause of the fractures.

Ganj Dareh #	Age Category	Skeletal Elements Affected
15	5	Humerus
23	6	Foot phalanges
20	6	Increased femoral neck angle
1151-1	7	Foot phalanges
13a	8	Humeral head displacement distally Possible healed depression fracture of the left parietal
22	8	Healing rib fracture
30	8	Nasal bones (fused)
34	8	Coronoid process of mandible L MT IV

Table 10.27. Individuals with evidence of healed and healing fractures by age category and skeletal element affected.

10.9 Developmental Anomalies

As with trauma, there is a general lack of evidence of developmental anomalies at Ganj Dareh. Six infants and children exhibit clefting of the cranial base (Table 10.28). There is no evidence of similar basicranial clefts in any of the older individuals examined.

Ganj Dareh #	Age Category	Anomaly
7	1	Clefting in *pars basilaris* of the occipital
14b	2	
1	3	
16	3	
21	1	Clefting in pars lateralis of the occipital
25	1	

Table 10.28. Individuals exhibiting osseous clefting anomalies by age category and location of clefts.

Clefting was also observed in the enamel of the permanent incisors of Ganj Dareh #15, GD#17, and GD#10. In addition, the subchondral bone of the mandibular condyle of GD#8/9 exhibits a large furrow, dividing the articular surface sagittally into two regions.

The clavicles of infant Ganj Dareh #38 are very different in length and robustness. Radiologically there was no evidence of fracture. The size differences could indicate the presence of an additional individual in this burial feature. However, a conservative approach was taken, so as not to inflate the MNI of the sample.

Age Group	Absent	Present
<12 Years	9	1
≥12 Years	3	9

Table 10.29. Frequency of suprameatal exostosis by age group.

Of the twenty-two individuals with the auditory region of the temporal preserved, ten (45.2%) had evidence of exostosis formation immediately superior to the external auditory meatus (Table 10.29). The frequency in children younger than 12 years is significantly different than that in individuals 12 years of age or older (Fisher's Exact Test, p=0.004).

There is one example of premature sagittal suture obliteration, adolescent Ganj Dareh #17. This individual also shows evidence of intentional cranial deformation.

10.10 Other Conditions

Only one other condition is of health interest for the purposes of this study. In cortex of the midshaft of the left humerus of an older woman GD#30 is a smooth-walled lytic lesion. It extends distally from the mediodistal end of the deltoid tuberosity (seen radiologically). The lesion communicates through the periosteal surface to the medullary cavity, resulting in a region of thin cortical bone 25 mm in length and 3-5 mm in width.

Chapter 11. Discussion

11.1 Introduction

Ganj Dareh was occupied at the end of the eighth millennium bc. The large sample size, the paucity of other samples of human remains in the region and it's date of 7,000 bc illustrate the importance of the Ganj Dareh human remains in the elucidation of the biological and cultural consequences of the adoption of a proto food-producing economy and a sedentary settlement pattern in the Zagros/Piedmont region of the Near East.

The primary concern of the present study is to utilize information from the Ganj Dareh skeletal remains such as the age profile and the population health status to address the issue of subsistence behaviour in the Neolithic Iranian Zagros Mountains. Data from all segments of the population are used to get a sense of the daily life of the Ganj Dareh people.

Health status variables furnish estimates of sanitary conditions in the village, nutritional status and exposure to pathogens. Evidence obtained of episodes of growth disruption such as enamel hypoplasia in both adults and non-adults indicates that exposure to periods of malnutrition and disease was an inescapable part of Neolithic life, as it is for all biological organisms. If we as humans are as vulnerable to these stressors as other organisms, a question of primary concern to bioarchaeologists is: were people in the past recovering from their exposures to stress? The analysis of Harris' Lines for evidence of recovery, length-for-age estimates of long bones for evaluation of the effectiveness of catch-up growth on overall stature and comparative assessments of adult stature are directed towards this end.

Health can also provide details of settlement patterns, that is the degree of sedentism and the impact of human occupation of a site on the general pathogen load in the environment through assessment of levels of generalized periostitis. Maxillary sinusitis has been used, in conjunction with the archaeological context of a site, as an indicator of respiratory health as well as intra- and extra-mural air quality providing insight into the presence or absence of factors that predispose people to spread and contraction of airborne illness. Caries formation, alveolar abscessing and ante-mortem tooth loss are disease processes that affect the primary masticatory apparatus of an individual. Thus, patterns and prevalence of these afflictions provide direct evidence of diet as well as oral health.

The presence of zoonotic diseases such as brucellosis allows assessment of the degree and intensity of interaction between humans and the non-human inhabitants of the environment. Modern clinical data on disease etiology, transmission, symptoms and progression, in conjunction with similar ethnographic data, place the skeletal data into a living human behavioural context wherein daily activities can be understood in terms of their consequences on health, adaptation and well-being. In addition, daily habitual activities record the biomechanical functions of the skeleton, including age- and behaviour-related wear and tear on joints, both of the appendicular and axial skeleton. Analysis of trauma can facilitate understanding of scalar stresses associated with internal and external sedentism, providing context for the behavioural changes in subsistence that occurred during the occupation of Ganj Dareh.

11.2 Age Profile

The Ganj Dareh skeletal sample represents all levels in the site although most are from Level D. One fifth of the site was excavated (Smith, 1974, 1978). If the burials were evenly distributed throughout the site, upwards of five hundred individuals may have been buried at the site. Since site occupation has been estimated to have lasted a relatively short time, about one hundred years (Zeder and Hesse, 2000), the sample provides substantial glimpse of life in the Gamas-Ab River valley of western Iran, ca. 7,000 bc.

The U-shaped mortality profile (Fig. 10.1) is similar to those in modern developing countries (as illustrated in Waldron, 1994). However, in skeletal samples, mortality profile represents fertility rather than mortality so that similarities are tenuous and subject to the demographic concerns of Wood and colleagues (1992). In a growing population more infants are being born relative to the entire population than in a stable population. The result is such that, even though the mortality rate could be the same, more infants would enter the mortality sample of a growing population. At Ganj Dareh, infants and young children are well represented and more than one quarter (25.9%) of the sample is under the age of three years. It is difficult in archaeological situations, however, to separate the effects of selective burial practices, that is, preferential burial of specific age groups in different regions of a site, from the effects of different fertility rates. This is particularly evident when skeletons are fragmentary and when a site is only partially excavated, both of which are the case in this study.

There appears to be a substantial number of middle (25.0%) and older adults (11.6%). In the survivorship curve (Fig. 10.3), the slope of the line (the rate of deaths in each age interval) appears to remain fairly constant after age seven years. Thus, as is often the case in modern populations in the Third World, details of the mortality profile of the youngest segments of the population become increasingly informative in assessment of health status of the overall society (Moffat, 2003; Pharoah and Morris, 1979).

11.3 Neonate : Post-Neonate Ratio

Infant health and mortality rates are often used as proxies for overall health of living communities. Mortality rates in post-neonates have only recently declined in Western populations, so that Western standards are used as a benchmark by which health in developing countries can be compared. Health in a community is judged to be poor if the post-neonatal mortality rate greatly exceeds that observed in developed countries.

Of greatest utility is the dramatic decline in post-neonatal deaths in Western populations, which has been associated with improved sanitation and particularly with clean water supplies. In the developing world, a high prevalence of post-neonate deaths still occurs, primarily due to respiratory infections and high levels of dehydration due to diarrhea (Moffat, 2003; Northrup and Flanigan, 1994; Pharoah and Morris, 1979). While deaths in neonates (0-4 weeks postpartum (pp)) are primarily of genetic origin, related to maternal health or associated with birth trauma, environmental factors such as gastrointestinal and respiratory diseases become increasingly important proximate causes of death in the post-neonatal period (> 4 weeks pp to one year of age) (Pharoah and Morris, 1979). Discrimination between these two broad categories of mortality is facilitated by the use of the Neonate to Post-Neonate ratio (N:PN ratio).

In order to apply this method to skeletal samples, accurate chronological ages of very young children must be obtained. In the tooth development age assessment of Moorees and colleagues (1963a, 1963b), the age estimate for a given stage of tooth crown development can be as wide as eight to ten weeks. This is beyond the resolution required for estimations to distinguish perinates (late fetal to death at birth) from neonates (birth to one month of age) and from post-neonates (one month to one year). Factors introducing inter-individual variation in growth and developmental processes include genetic and environmental factors affecting health, and differential preservation in the archaeological record. The earliest age category for many skeletal studies is extremely broad, usually birth to one year. Thus, the N:PN ratio has not often been applied to skeletal samples.

In infants the use of the enamel prism cross-striation counts from the neonatal line to the growing enamel margin provides the required resolution for biological age assessment, reflecting diurnal changes in prism microscopic structure. This facilitated discrimination between neonates and post-neonates in the present study. Deaths in the post-neonate category account for 71-80% of all infant deaths in the Ganj Dareh sample. Similar results have been reported for the contemporary levels of Abu Hureyra (Molleson, 2000:319), for nineteenth century Upper Canada (Saunders et al., 1995) and for modern non-Western populations (Pharoah and Morris, 1979). This similarity mirrors the similarity demonstrated for the mortality profile (Fig. 10.1) discussed above in Chapter 11.2.

Correlation of known age-at-death (from enamel cross-striations) with long bone length facilitated identification of infants that had experienced growth stunting. For example, infants #21 and # 27 (of similar size, see Fig. 10.6) were recovered from the same sub-floor burial feature. Infant #21 is developmentally older than #27, and may have been severely growth stunted when compared to the other infants. However, #21 may also have experienced greater shrinkage during the wide-spread village fire that caused calcination and shrinkage of its bones. This could have resulted from differing states of decomposition (Buikstra and Swegle, 1989) or location relative to the house floor (Bennett, 1999). Although these alternate scenarios are possible, they do not fully account for the extent of discrepancy between developmental and size age estimates for infant #21, suggesting that growth stunting had occurred in this infant.

11.4 Growth Disruption

Harris' Lines (HL) were present in all age categories of non-adults (N=8) and in one young adult. Due to the small sample size, the prevalences in non-adults and adults are not significantly different. Those that exhibited only one or two HL per skeletal element were in two distinct groups: those birth to three years of age (N=2), and those twelve to twenty-nine years of age (N=2). The five children with more than two HL per bone were between ages one year and seventeen years.

There are several possible explanations for these results, following the Post-Osteological Paradox interpretive framework of bioarchaeology. The first scenarios assume that all children who developed Harris' Lines, regardless of the number per bone, experienced similar numbers of episodes of growth disruption. Infants in the youngest group may not have lived long enough to experience multiple exposures to stress before they died. They could also have been sickly or malnourished during periods of growth stasis, *sensu* Lampl and colleagues (1992). They may have been chronically exposed to stress so that for the most part, the excess bone deposition that characterizes the recovery from stress rarely occurred. In addition, rapid catch-up growth between episodes of growth arrest may have resulted in obliteration of the regions of dense bone. In the two oldest individuals some of many HL may have been obliterated through bone remodelling. However, Waddell (1994) observed a substantially higher frequency of HL in the otherwise highly stressed Seh Gabi infants. This suggests that at the population level HL prevalence in non-adults can be confidently used as a measure of overall stress.

The second major category of explanation follows the data to group the children and young adult into two groups: one with fewer HL and fewer illness/malnutrition episodes, the second with three or more HL and multiple exposures to and recovery from stress. The last scenario, one in keeping with the general term for Harris' Lines as non-specific indicators of stress, is the middle ground, a combination of the first two scenarios where it is not possible to determine exact causes of skeletal lesions or the life- and illness-histories for individuals. However, this interpretation facilitates synthesis of population health by emphasizing that people were exposed to episodes of stress and exhibit evidence of recovery. It is supported by Waddell's (1994) finding that somatic bone growth, as measured by cortical bone area, was unaffected by stress episodes at Ganj Dareh when compared to the Seh Gabi children, and by the adult stature inter-population comparisons of the present study (see Chapter 11.6).

Individuals with evidence of early childhood disruption of enamel synthesis were observed in all age categories. Survival to adulthood is not significantly associated with absence of enamel hypoplasia. However, almost half (46.0%) of the children with deciduous canines present (N=13) exhibited circular enamel defects (LHPC) on the labial surfaces. Of the six with LHPC, five have linear enamel defects on other teeth, both deciduous and/or permanent suggesting that the individuals sustained either multiple insults and/or stress severe enough to affect multiple teeth. This supports the assertion of Metcalfe and Monaghan (2001) that exposure to stressors early in life can contribute to later disease susceptibility and early age-at-death.

Although the etiology of LHPC is not well understood, it has been attributed to localized ameloblast trauma in infants with osteopenia of the alveolar bone of the canine jugum possibly induced by vitamin A deficiency (Skinner et al., 1994). It was originally thought to be restricted to the primary canines. However, it has been recently observed in the deciduous second incisors and first molars of great apes (Skinner and Newell, 2003). The appearance of circular hypoplasia in teeth other than the primary canine is corroborated in the present study. Skinner and Newell (2003) suggest that the etiology of linear enamel defects is systemic in nature, probably due to malnutrition or fevers, the presence of both linear and circular defects in five Ganj Dareh children indicates that the two conditions are not mutually exclusive. Indeed, the two may be inter-related such that the systemic stress that causes the linear defects might predispose the ameloblasts to synthetic disruption if trauma were to occur. Similarly, the cause of the osteopenia of the alveolar bone might act synergistically to exacerbate disruption of protein synthesis during episodes of illness or malnutrition.

11.5 Femoral Length-for-Age

To the plot of Ganj Dareh femoral lengths (Fig. 10.7) (all measurements are maximum lengths without epiphyses) the femoral lengths of a modern population from

Denver Colorado were added for comparison (Fig. 11.1). At birth, the Ganj Dareh infants are smaller than modern infants. Most are below the fifth centile of the modern population until about six years of age. After age six, the growth trajectory, indicated by the quadratic regression line, suggests Ganj Dareh femoral length exceeds that of the fifth centile of the modern population. In the present analysis, ideally individuals age 11 or 12 years would be included to obtain a more accurate estimate of the pre-adolescent growth trajectory and to allow exclusion of the oldest two adolescent individuals GD#15 and GD#17. However, skeletal preservation of the four Ganj Dareh children in this age range was poor and none had femora available for measurement.

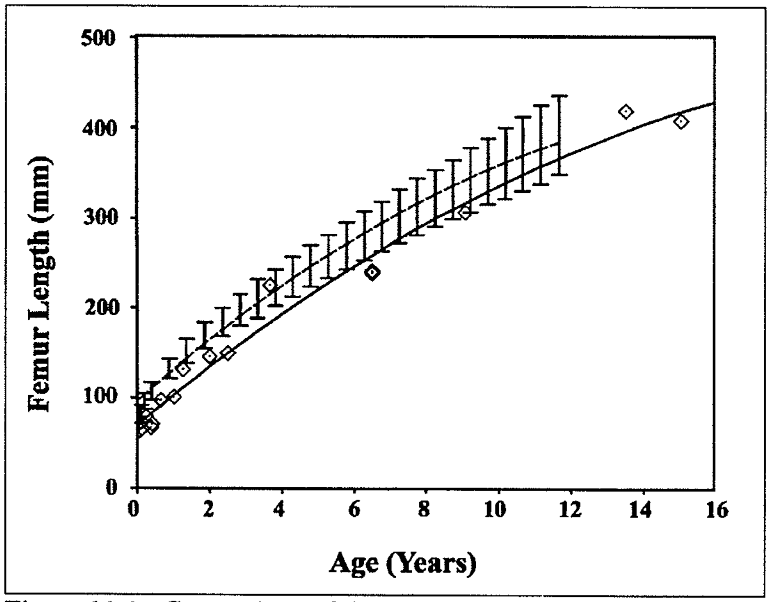

Figure 11.1. Comparison of the growth trajectory of Ganj Dareh infants and children (solid line of quadratic regression and open diamond data points) with that of a modern American population from Denver Colorado (dashed line and 95% CI). Modified from Saunders and Hoppa (1993).

Use of the quadratic regression (obtained from the graph option only in SPSS with no associated significance levels) in Fig. 10.7 and 11.1 assumes that the two oldest individuals GD#17 and GD#15 had not begun their adolescent growth spurt. GD# 17 (age 13.5 years) and GD#15 (age 15 years) are male, estimated from the shape of the greater sciatic notch, supporting this assumption. However, their femoral lengths (including epiphyses) are within the adult range. If the growth spurt were just beginning or in progress, then GD#17 was tall for his age (465 mm) relative to the adult femoral lengths observed (mean length for males is 462 mm, length for female GD#23 is 438 mm). The femur of the older individual GD#15 is shorter (448 mm). If his growth were nearing completion, as the new bone formation on the femoral epiphysis growth plate suggests, then his femur would still be within the range of other adult male femora in the sample (range 436 mm to 487 mm), albeit in the lower half of the range.

To simulate the adolescent growth spurt in Figure 10.7 and 11.1, a cubic rather than quadratic regression line was applied (Fig. 11.2). This comparison thus assumes that both GD#15 and GD#17 were well into the adolescent growth spurt at the time of death. This comparison with the modern sample (Fig. 11.2) suggests that the Ganj Dareh children's bone growth was in the low modern range after about three years of age (cf. after six years for Fig. 11.1). Similar comparisons with the tenth Century Raunds Anglo-Saxon population in England (dashed line in Fig. 10.2) indicate that in the first year of life the Ganj Dareh infants had shorter femoral lengths for age. Between one and three

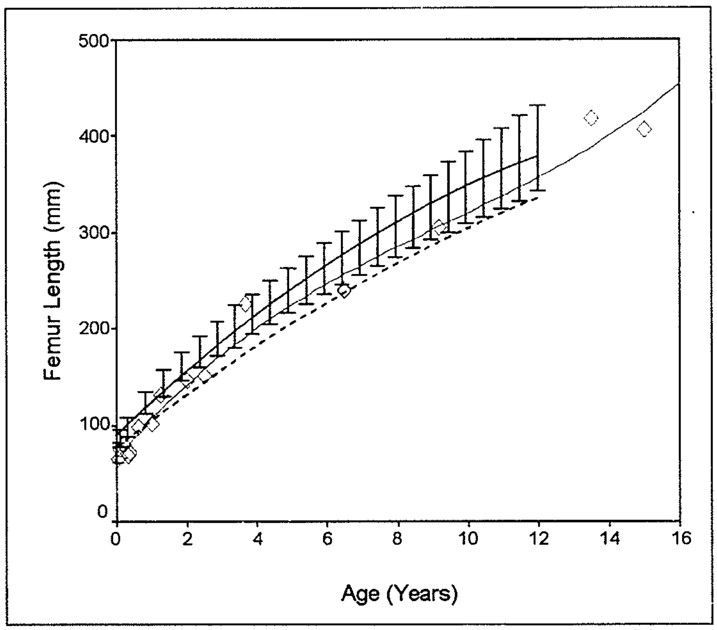

Figure 11.2. Ganj Dareh femoral length data, with cubic regression. Comparison with data from a modern sample, line with 95% CI and the tenth century Raunds Anglo-Saxon sample (dashed line). Modified from Saunders and Hoppa (1993).

years, the growth rate accelerated at Ganj Dareh, so that from age three onward, Ganj Dareh femoral lengths were consistently slightly higher than those of their Anglo-Saxon counterparts.

Comparisons with both this modern sample and the more recent past population indicate that although Ganj Dareh infants initially have shorter bone lengths for age, from age three years onward they are within the range of variation of modern children and consistently slightly larger than the tenth century AD English sample. In all cases, after three years of age the same growth trajectory is followed.

11.6 Adult Stature

The mean stature from the equations of Trotter (1970) for males is 171.4 cm (N=6) and for females 158.4 (N=2). The mean statures calculated from the formula of Feldesman and colleagues (1990) are 172.8 cm and 163.8 cm for males and females, respectively. Comparisons of mean statures with other Iranian and Iraqi samples (Rathbun, 1984), Abu Hureyra (Molleson, 2000), and southern Levantine populations (Smith et al., 1984) are presented in Table 11.1.

The stature of the Ganj Dareh people is within the range of most of the other

	Region	Site	Female Stature (cm)	Male Stature (cm)	F:M Ratio
Epipalaeolithic	Iraq	Zawi Chemi[1]	152	164	0.93
	S.Levant	Pooled Natufian[2]	158	167	0.91
Neolithic	Iran	Ganj Dareh[3]	158	171	0.92
	N.Levant	Abu Hureyra[4]	155	162	0.96
	S.Levant	Various Sites[2]	155-168	160-171	--
Bronze Age	Iran	Pooled Data[1]	159	174	0.91

Table 11.1. Comparison of mean stature estimates (cm) from selected skeletal samples from Epipalaeolithic, Neolithic and Chalcolithic sites in the Fertile Crescent, by sex and region.

[1] Rathbun (1984).
[2] Smith et al. (1984).
[3] Present study using equations from Trotter (1970).
[4] Molleson (2000).

regional populations surveyed, and taller than the limited outlier sample from Abu Hureyra. The ratio of female to male stature is very similar for all samples again except for that from Middle Euphrates site of Abu Hureyra, where the males are relatively shorter compared to the females. That the stature of the Ganj Dareh people is within the central to high end of the range of other regional samples does not support the hypothesis that the Ganj Dareh population is highly stressed. This suggests that following episodes of growth arrest, catch-up growth occurred, resulting in the resumption of the projected growth trajectory. These findings from adult stature are consistent with the length-for-age data from non-adults illustrated in Figures 10.10.7, 11.1 and 11.2 and with the cortical bone growth data from the Ganj Dareh non-adults (Waddell, 1994).

11.7 Oral Health

Of the five hundred ninety-four teeth observed, only six teeth (1.01%) were carious. Calculated by person affected, the rate is still a low 8.3%. This is well within the range of 3% to 43% reported by Rathbun (1984) for other Iranian Neolithic sites. It is also similar to the prevalence of caries at Natufian sites (2% to 7%) (Smith, 1989).

The Natufian caries data are reported to be consistent with the strontium/calcium ratio results indicating that plants comprised a substantial proportion of the diet (Schoeninger, 1980, 1981). However, the same percentage of caries is observed in the Ganj Dareh sample where the strontium/calcium ratios suggest a high proportion of meat in the diet. These inconsistencies can be in part explained by post-depositional alterations of bone chemical composition that plague trace element studies (Sandford and Weaver, 2000) and the high background strontium levels measured in bone from many archaeological sites in the Zagros (Schoeninger, 1980, 1981). The wide range of caries rates in Iranian Neolithic samples and the differences in diet composition, that is with Natufians more reliant on plant foods than the Ganj Dareh people, underscore the complex etiology of caries development. Population frequencies are often the function of site- and region-specific dietary preferences as seen in regions such as Portugal where the inclusion of figs and dates as food staples contributes to high caries rates in hunter-gatherer populations (Lubell et al., 1994; Meiklejohn et al., 1988).

Most (71%) of the caries are located at the cemento-enamel junction. One of the caries had destroyed the entire crown, precluding determination of the location of the original carious lesion. Only one caries is associated with the occlusal surface, a location common in modern Western diets (Hillson, 1996).

Abscessing is evident in the Ganj Dareh sample in two forms: smooth-walled periapical cysts and rough-walled periapical abscesses. There are two examples of periapical cysts. One is a mandibular molar of GD#30. Abscessing associated with caries had destroyed the whole crown of GD#30. The second example is a maxillary second incisor of adolescent GD#15. Although there was significant destruction of periapical alveolar bone, the tooth is present in its socket and alveolar bone closest to the CEJ is intact.

Ante-mortem tooth loss (AMTL) has been associated with the adoption of agricultural subsistence from a wide variety of regions and archaeological contexts (Hillson, 2000; Larsen, 1997; Lukacs, 1992). AMTL was observed in almost thirty percent of the population, consistent with agricultural samples from southern Ontario (Patterson, 1984) and Nubia (Rose et al., 1993). All those affected are middle and older adults. All categories of teeth have been lost before death. Tooth loss is not always related to severe wear in the first molars as one might expect if the AMTL were caused by extreme dental attrition or carious lesions in the earliest erupting permanent teeth (see Table 10.18 for patterns of teeth affected). For example, middle adult GD#13a exhibits little occlusal wear on most teeth except the right mandibular first molar. However, three left anterior teeth are absent. The bone is well healed with very little loss of alveolar bone height, suggesting injury early in life.

11.8 Inflammatory Processes

Generalized periostitis has been associated with sedentism and declining sanitary conditions (Larsen, 1995; Mensforth et al., 1978). However, only five of seventy-one Ganj Dareh individuals exhibit periostitis and none of the lesions affect the tibia, the most common skeletal element reported (Ortner and Putschar, 1985; Ortner, 2003). The low prevalence of periostitis (7%) in the Ganj Dareh sample suggests that sanitary conditions in the village had not declined substantially relative to hunter/gatherer settlements, despite the presence of permanent architecture and year-round site occupation. Due to the fragmentary nature of the collection, the low prevalence may in part be a function of the non-preservation of affected elements. Even if only the fifty-six more complete skeletons are considered, periostitis is present in only 8.9% of individuals

Only one quarter of the sinuses observed in the present study showed evidence of inflammatory processes. This represents half the prevalence observed in British (Boocock et al., 1995; Lewis et al., 1995), Dutch (Coenen et al., 1996) and Iroquoian (Merrett, 2003; Merrett and Pfeiffer, 2000) skeletal samples. One primary difference in the more recent samples is the high rate of caries and subsequent maxillary sinusitis of dental origin. If only sinusitis of respiratory origin is considered, the Iroquoian (Uxbridge site) prevalence drops to 28%, basically the same as observed in the Ganj Dareh sample. However, the small sample size of the present study, only sixteen maxillary sinuses and two frontal sinuses present, may skew the observed Ganj Dareh prevalence. The first comparison suggests that the Ganj Dareh people experienced relatively good upper respiratory health and might not have been chronically exposed to wood smoke. It would be consistent with the absence of recognized hearths within the village (PEL Smith, pers. comm., 2004), and the observation in modern populations that those who routinely cook outside have much less exposure to particulates and report fewer respiratory problems than those who cook inside dwellings (Albalak, 1997). However, if the site were occupied year-round, its location at 1400 m elevation suggests that some source of heat would be needed and exposure to smoke from burning fuel would be unavoidable at least a certain times of the year, contributing to the prevalence of inflammation of the sinuses.

Regions of high porosity, for example on the ectocranial surface of the *pars basilaris* of the occipital bone of Ganj Dareh infant #7, are interpreted by Agelarakis (1989) as a manifestation of malarial infection *sensu* Angel (1966). However, as Waddell (1994) aptly observed, the infant died in the neonatal period, a time of extremely rapid cranial growth to accommodate the growing brain (Scott and Dixon, 1959; Bogin, 1988; Enlow, 1993). Thus for the purposes of this study, the new woven bone and the appearance of porosity is considered as evidence of normal bone growth. Utilizing cranial growth field theory (Enlow and Hans, 1996), downward growth of the skull is achieved through bone deposition, that is, the bone surface is a positive growth field that should be accompanied by periosteal new bone formation. If the infant dies during a period of bone growth, the surface should exhibit new woven bone. Other infants in the same age category with non-porous periosteal surfaces may not have been growing as rapidly at the time of death, or alternately may have been in a period of stasis (if cranial bone exhibits similar saltational growth as that observed in long bones by Lampl and colleagues (1992), where the new woven bone has become incorporated into the compact cortical bone.

Only one infant GD#25 exhibited regions of active porosity on the ectocranial surface of the vault bones that might be attributable to anaemia-related disease process. The regions parallel the lambdoidal suture in both the occipital and parietal bones and are macroscopically similar in appearance to the sample, degree of porosity score 2, shown in Buikstra and Ubelaker (1994:152). However, the suture margins of infants, areas of rapid growth, exhibit thicker vault thickness than the surrounding bone. It is possible that the region of porosity is part of the normal growth process where localized resorption realigns the vault contour as the infant grows.

Although for the most part the Ganj Dareh adults appear relatively healthy, 85% exhibit porotic hyperostosis. However, as in the non-adults, only young adult GD#20 exhibits active lesions. He also has extensive regions of healed and healing porosity over much of the cranial vault.

Although the exact etiology of porotic hyperostosis is not known, three possible causes have been put forward in the anthropological literature. They link the lesions to expansion of the marrow cavity as a response to anaemia. The first cause is dietary, a result of deficiency of iron in the diet (Mensforth et al., 1978; Steinbock, 1976). The second expands on the iron deficiency model, linking it to the presence of internal parasites and the body's attempt to starve the pathogens of iron necessary for their survival and reproduction (Stuart-Macadam and Kent, 1992). A third hypothesis, posited by Angel (1966) links the lesions to the anaemia caused by malaria, and has been used by Agelarakis (1989) to explain the porosity visible on the Ganj Dareh infant skulls. These hypotheses have their proponents as well as their detractors, most notably Rothschild (1998) who argues that depletion of iron supplies should reduce the volume of diplöic spaces rather than cause their expansion.

A fourth anaemia-related cause of porotic hyperostosis, not offered in the anthropological literature, is suggested here. Recent clinical literature lists anaemia as one of the primary symptoms of brucellosis (Gotuzzo and Carrillo, 1998). In addition, as is emphasized in the palaeopathology workshops run each year by Don Ortner and Bruce Ragsdale at the Annual Meetings of the Paleopathology Association, individuals may be suffering from more than one affliction at a time. In this case, skeletal manifestation of anaemia could be caused by a combination of gastrointestinal parasite-induced blood loss and brucellosis-related anaemia.

11.9 Zoonoses

Of prime importance for elucidation of the health of the Ganj Dareh population is the characterization of the relationship between the human and caprine occupants of the site. Goat remains predominate in the faunal assemblage in all levels of the site and the presence of goat hoof prints in mud-bricks indicates that goats roamed the site despite the presence of humans. Thus the presence of caprine-related disease in the human population would strengthen the case for human control of the goat population and for incipient goat domestication. To this end, each human skeleton was macroscopically examined for lesion morphology and patterning that would suggest infection by the caprine-associated diseases tuberculosis and brucellosis. Although no lytic lesions characteristic of tuberculosis were observed on any of the available axial skeletons, some evidence of early brucellosis infection is present on the vertebrae of the older adult male GD#22 (Figs. 10.9 and 10.10). The lesions are not as well-developed as those used to characterize brucellosis in skeletal remains (Capasso, 1999; Ortner, 2003; Rashidi et al., 2001). However, the argument for the presence of brucellosis in the Ganj Dareh sample is strengthened by the archaeological and faunal evidence from the site, the ethnographic and clinical evidence that brucellosis is an occupational hazard among goat herders (Capasso, 1999; Gotuzzo and Carrillo, 1998), and the presence among most (85%) of the adults of porotic hyperostosis, evidence of possible anaemia, a clinically-recognized manifestation of brucellosis (Gotuzzo and Carrillo, 1998).

11.10 Activity-Related Phenomena

One quarter of the Ganj Dareh inhabitants exhibited evidence of osteoarthritis of the appendicular skeleton: pitting of the subchondral bone, marginal lipping of the articular facets and/or eburnation of the articular surface. Development of roughness and/or shallow depressions at entheses and ossification of tendons and ligaments were common from adolescence onward, suggesting that life at Ganj Dareh was physically demanding on a routine basis. Involvement of the attachment sites of all major leg muscles is consistent with the location of the site in a small valley surrounded by rocky mountainous terrain.

Adolescent GD#15 exhibits a severe inflammatory response of the humerus at the insertion muscles involved in adduction and medial rotation of the arm at the shoulder. At adolescence muscle strength temporarily exceeds the strength of the bone-tendon interface and injury to the bone can result. The altered biomechanical relationships of the right arm and shoulder due to an earlier healed humeral fracture could have placed this enthesis at risk for injury. In addition, many of the adults had marked development of the entheses surrounding the elbow joint, also remarked on by Agelarakis (1989), specifically the origin and insertion of brachialis muscle, a major flexor of the elbow and pronator of the forelimb and the origin and insertion of pronator teres, also involved in pronation. This suggests that daily life at Ganj Dareh also required substantial upper body strength.

Middle adult GD#37 sustained knee injury that eventually caused destruction of the joint cartilage. Continued use of the joint resulted in eburnation of the articular surface. The same man also exhibited porosity and marginal lipping of the acromioclavicular (A-C) joint surfaces as well as ankylosis of a portion of the thoracic spine (see below for detailed discussion). Osteoarthritis was not restricted to the older members of the community. Young adult GD#1150 had sustained a shoulder injury severe enough to result in osteoarthritic involvement of the A-C joint.

Age- and/or activity-related diseases also affect the axial skeleton manifesting as osteoarthritis, degenerative joint disease (DJD). DJD is characterized by pitting of the articular facets of the vertebrae with marginal lipping of the facets (Fig. 10.11). Marginal horizontal lipping of the inferior and superior margins of the vertebral bodies may occur with eventual ankylosis.

One middle adult GD#37, whom we have already seen had evidence of knee and shoulder injury, also exhibited ossification of multiple tendons and osseous bridging across the intervertebral disk spaces of at least four thoracic vertebrae (Figs. 10.12 and 10.13). Analysis of the location of the intervertebral ossification suggests that this man exhibited either diffuse idiopathic skeletal hyperostosis (DISH) or ankylosing spondylitis. For a diagnosis of DISH ossification of the anterior longitudinal ligament would be expected (Aufderheide and Rodríguez-Martín, 1998) and is seen in GD#37. Involvement of the *anulus fibrosis* (minimal in GD#37) is predicted only after extensive ossification of the anterior longitudinal ligament. The poor preservation of about half of each vertebral body precludes assessment of the extent of this ligament ossification. DISH is, however, also associated with extraspinal ossification of entheses, such as those of the patella, the femoral trochanters, and the Achilles tendon insertion on the calcaneus (Aufderheide and Rodríguez-Martín, 1998). These are present in GD#37.

In contrast to DISH, ankylosing spondylitis is characterized by fusion of vertebral bodies at the site of the *anulus fibrosis*. Ossification at this location is minimal in this individual. A disease of unknown etiology, ankylosing spondylitis appears in early adulthood. Thus, by middle adulthood ankylosing spondylitis could have caused the extent of vertebral body fusion observed in GD#37. However, the anterior surfaces of the vertebral bodies appear squared in longitudinal section in individuals exhibiting characteristic ankylosing spondylitis (Ortner, 2003). The poor degree of preservation hinders this observation.

There is evidence for and against a diagnosis of both DISH and ankylosing spondylitis in this middle adult. Poor preservation of the vertebrae and the general bone fragility make a definitive diagnosis difficult. However, the presence of multiple osteophytes at tendon insertions leads me to lean tentatively toward a diagnosis of DISH. The presence of DISH has been observed to increase in a skeletal series from China that spans the origins of agro-pastoralism (Hukada et al., 2000). Its presence at Ganj Dareh would be consistent with the initiation of subsistence transition.

11.11 Other Conditions

There is very little evidence of trauma in the Ganj Dareh population. The few instances that are present cannot be directly linked to interpersonal violence. As with trauma there are few developmental anomalies evident in the Ganj Dareh population. Those present are of minimal expression and do not appear to have influenced individual survivorship.

11.12 Boning Up On the Evidence: Knitting It All Together

11.12.1 Introduction

At Ganj Dareh there is archaeological evidence of sedentism, manipulation of morphologically wild ovicaprids, exploitation of barley (probably wild), and social buffering systems (ritual and burial niches). Within this context the purposes of this research are three-fold: to estimate health outcomes of the Ganj Dareh population, to estimate subsistence strategy of the Ganj Dareh inhabitants and to test the various models of agricultural origins against the health status inferred. Integral to the exploration of the relationships between health and subsistence strategy is the synthesis of the archaeological and cultural context of the Ganj Dareh site and the Zagros Mountains with the reconstruction of palaeoclimatic and palaeoenvironmental conditions ca. 7,000 bc. Estimation of the health of the Ganj Dareh people and their subsistence activities then permits testing of the degree of fit between the health data and the various models of agricultural origins.

The location of Ganj Dareh in the eastern arm of the Fertile Crescent has important consequences for interpretation of the skeletal data. The distance from the Mediterranean Sea contributes to a much more continental climate than the more extensively studied Levantine portion of the Fertile Crescent. The continental climate, the more northerly latitude and higher altitude also contribute to a variety of other differences from the Levant including a slower rate of climate warming following the last pleniglacial, varying distances from local refugia and differences in floral and faunal composition within the refugia. Thus the rate, sequence and timing of subsistence transition and the subsequent health changes should not be expected to be the same in the Zagros as those observed the Levant.

As discussed in Chapters 7 and 8, the geography of the central Zagros in combination with the palaeoclimate reconstruction suggests that Ganj Dareh was occupied during a period of resource abundance. In addition, the local physiography and environment implies that the Ganj Dareh hinterland was a natural habitat for wild goats (see below for implications concerning the testing of models of agricultural origins). Thus, Ganj Dareh was situated in a nuclear zone for settlement by hunters relying on goats for a substantial proportion of the their diet.

11.12.2 Health Outcomes Inferred from the Skeletal Data

From the results of the present study (presented in Chapter 10, and contextualized in the preceding sections of Chapter 11), it is readily apparent that the skeletons of the Ganj Dareh people reflect some of the hazards of life in the Zagros Mountains ca. 7,000 bc. For example, the neonate to post-neonate ratio is similar to that of modern populations in developing countries as well as Western populations in the recent past. Long bone growth follows the same trajectory as that of modern American children, albeit below the fifth centile. Bone lengths may be slightly greater than those of Anglo-Saxon children. Adult stature is similar to and in the upper range of other archaeological samples from the Fertile Crescent (Rathbun, 1984 (Iran); Smith et al., 1984 (Levant)). Although daily activities exacted high biomechanical demand on the skeleton, nevertheless, many individuals survived to middle and older adulthood.

Recovery from episodes of stress is evident in many of the individuals. One quarter of the children represented in the sample experienced relatively few episodes of stress from which they recovered sufficiently that the evidence is recorded in their skeletal remains as Harris' Lines. This contrasts with the Chalcolithic Seh Gabi children who were probably chronically stressed to the point that multiple episodes of stress are evident in most individuals (Skinner, 1980; Waddell, 1994). At Ganj Dareh at least half of those who survived to adulthood had episodes of exposure to stress recorded in their teeth as enamel hypoplasia (EH), although the EH is classified as minimal to moderate. The prevalences of EH in adults and children are not significantly different, suggesting that factors other than childhood stress exposures contributed to a person's entry into the death assemblage.

Achieving adult age did not mean an end to health problems however and a substantial proportion of the people living at Ganj Dareh survived to older adulthood with 11.6% of the sample over fifty years of age at death. Dental health declined with age. At the same time degenerative processes affecting the joints of the appendicular and axial skeleton did not appear to limit older individuals. For example, in the knee of the middle adult man GD#37, the degree of eburnation and lack of joint fusion suggests that physically demanding lifestyle continued until death. Osteophytosis and ankylosis of a portion of the spine was a possible health outcome. Well-developed entheses indicating high activity levels are consistent with pastoralism in a mountainous environment.

There is mixed evidence for status of sanitary conditions in which the Ganj Dareh inhabitants lived. There is a low prevalence of periostitis, primarily in bones other than the usually affected tibia (only one tibia in the sample was affected). However, most (85%) of the adults exhibited porotic hyperostosis, a generalized indicator of iron-deficiency anaemia. In the Ganj Dareh sample, if the anaemia were caused by intestinal parasite infestation, then it would be consistent with poor sanitary conditions of sedentism (cf relatively good sanitation inferred by the low prevalence of periostitis). Because goats were in the village, anaemia could be caused by intestinal parasitic and/or brucellosis infections. Thus, the high intensity and duration of contact with ovicaprids at the site and the presence of ovicaprid zoonotic infectious disease, possibly brucellosis, in this population can skew interpretation of porotic hyperostosis, if all potential causes of anaemia are not considered. In addition, the presence of porotic hyperostosis has been used in the eastern Mediterranean (for example Angel, 1966) and at Ganj Dareh (Agelarakis, 1989) as indicative of malaria. However, the altitude of Ganj Dareh, 1400m, precludes the presence of mosquitoes, the vector of malaria. Taken together, the high prevalence of porotic hyperostosis in the Ganj Dareh adults is more consistent with the presence of brucellosis than of malaria.

11.12.3 Estimation of Subsistence Strategy

Each model of the origins of agriculture sets up an environmental and cultural scenario within which late Epipalaeolithic and Neolithic people lived. Thus, each model puts in place a series of buffers and constraints that can be directly imported into the explanatory framework of the Biocultural Model of Health. In addition, geographic location and the palaeoclimatic and environmental data provide the physical components within the model. The meshing of the archaeological and biocultural models facilitates the interpretation of the skeletal data in its archaeological, biological, cultural and human behavioural context. At the same time the interactions among the contextual variables and health outcomes for individuals and populations can provide valuable insight for the refinement of models of agricultural origins.

The skeletal evidence suggesting brucellosis supports the archaeological (Smith, 1978) and zooarchaeological data (Hesse, 1978; 1982; 1984) that the Ganj Dareh inhabitants were living in close contact with ovicaprids within the village. Diet resembling the Epipalaeolithic mixture of plant and animal foods is supported by the low caries rate (much lower than the Epipalaeolithic inhabitants of Zawi Chemi) and the high dental attrition. Daily habitual activities required high upper limb strength as seen in the extensive enthesis development at attachment sites of muscles for example of elbow flexion, brachialis, and forearm pronation, pronator teres. High lower limb strength indicated by enthesis development at the origin and insertion of the soleus and gastrocnemius muscles (important in plantar flexion) is consistent with walking/running in mountainous terrain such as that surrounding Ganj Dareh.

11.12.4 Assessment of the Models of Agricultural Origins

The final component of the bioarchaeological analysis of the Ganj Dareh human remains is testing of the health outcomes for consistency with the various models of agricultural origins (discussed in Chapter 3). As outlined in Chapters 7 and 8, archaeological evidence suggests that the central Zagros ca. 7,000 bc was a resource-rich habitat. Recovery from episodes of minimal to moderate stress and tall adult stature are consistent with this assessment. Thus models that invoke resource stress as the driving force behind subsistence transition, the Population Pressure Models (Cohen, 1977; Smith and Young, 1972), the Marginal Zone Model (Binford, 1968; Flannery, 1969) and the Territoriality and Allocation Model (Rosenberg, 1990) do not apply in the case of Ganj Dareh. In addition, the assumption of aridity in the early Holocene in the Nuclear Zone Model (Braidwood and Howe, 1960) removes it from consideration. The remaining

Model	Health Predictions	Relevant Ganj Dareh Data
Accumulator	Diseases of Sedentism	Low Non-Specific Indicators of Stress
Social Organization	Diseases of Sedentism (Lower Prevalence than for Accumulator Model)	High Porotic Hyperostosis Low Periostitis

Table 11.2. Models of agricultural origins tested for consistency with the Ganj Dareh skeletal data.

models include the Accumulator Model (Hayden, 1990) and Kuijt's (1996, 2000) model emphasizing the importance of social organization in subsistence change. Although many of the models are not tested, this does not mean that all their aspects are discounted.

Components have been used in the model proposed below, including the concepts of a nuclear zone, a marginal zone and population increase.

The absence of evidence of oak parkland in the vicinity of Ganj Dareh suggests that non-essential food items such as wheat and acorns were not available for use as prestige-creating goods, as required in the Accumulator Model (Hayden, 1990). However, this model does not require extensive population increase. Two lines of evidence from Ganj Dareh indicate that the Accumulator Model is a viable theoretical option. Population growth at Ganj Dareh is slow as inferred by the similarity of the survivorship curve to that of the Epipalaeolithic hunter/gatherer population from Zawi Chemi. In addition, the presence of barley at Ganj Dareh suggests that barley could have been used as a non-essential prestige food item. However goats, the first domesticates at Ganj Dareh, were essential food items as indicated by their abundance in the faunal assemblage. This is not consistent with their being non-essential food items as first domesticates (Accumulator Model).

The low levels at Ganj Dareh of internal and/or external scalar stress are indicated by the absence of definitive evidence of inter-personal violence inferred from the low rate of trauma 6.9% (8/116) in the population and absence of projectile points in bones. In addition, archaeological evidence of mortuary practices such as in-house niche burials, architectural features including goat skulls embedded in niche walls and skeletal evidence of intentional cranial deformation are consistent with the presence of mechanisms for diffusion of scalar stress. These lines of evidence are highly suggestive of the important changes in social organization that must have occurred at Ganj Dareh during this early phase of the subsistence transition. Further they have led to the formulation of a modified social model, described below, to explain the Ganj Dareh skeletal data.

The results of this research can now be placed into a model of subsistence transition in the Zagros region of the Fertile Crescent. Ganj Dareh is located at the entrance to a narrow valley providing access to a variety of ecozones, a broad spectrum of resources and the natural habitat of goats (Zeder and Hesse, 2000). It is suggested here that at the time of site occupation ca. 7,000 bc, Ganj Dareh was in what Binford (1968) and Flannery (1969) would call a nuclear zone of wild goat natural habitat and a nuclear zone of habitation of hunters primarily reliant on goats for a substantial proportion of their diet (Fig. 11.3). In addition to the nuclear zone of the Ganj Dareh hinterland, additional shaded regions (Fig. 11.3) indicate a few of the many areas of similar topography and habitat in the central Zagros where postulated experimentation with goat management could have occurred.

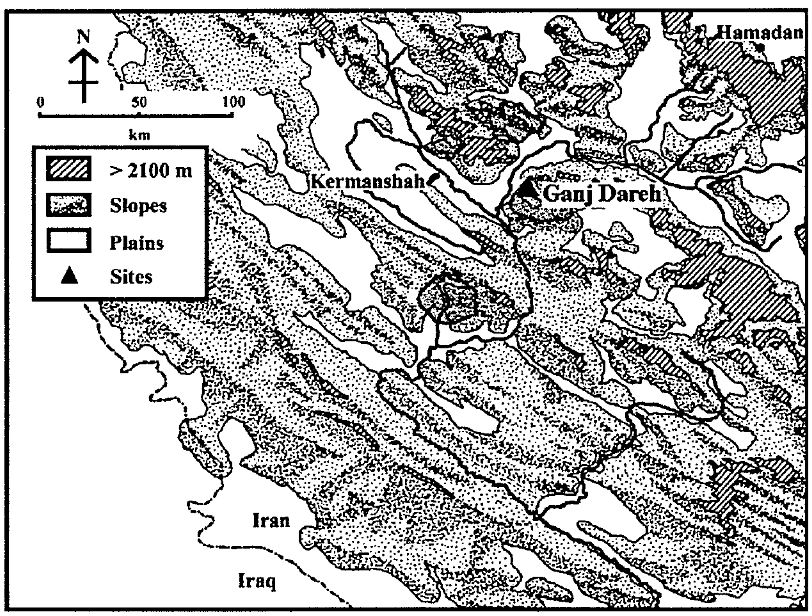

Figure 11.3. Nuclear zones of wild goat habitat in the Ganj Dareh hinterland.

The Ganj Dareh people were sedentary hunter/gatherers making a living primarily by hunting goats. In the model proposed here, I postulate that the control of goats was initiated by an extinction of the local goat population, due to local climatic fluctuation, one of many that occurred in the early Holocene (COHMAP Members, 1988; McCorriston and Hole, 1991). In order to maintain life, as they knew it, goats were imported from another area. This would initiate development of close daily human-goat contact to prevent the goats from returning to their original territory and to protect them from predators in the new unfamiliar territory. Proto-domestication thus occurred in the natural habitat of wild goats by people who were attempting to maintain their primary food source in the face of localized goat extinctions during a period that could otherwise be characterized by resource abundance.

In the scenario proposed, it could be asked why the people did not resettle in another nuclear zone of natural goat habitat. Several potential compelling reasons to remain at Ganj Dareh come to mind. Firstly, the model only proposes a localized goat extinction with temporary climatic conditions affecting the local goat population. If all other resources were unaffected, then the people would still be living in a region of general resource abundance. Introduction of a new goat population would restore the Ganj Dareh hinterland to its former state. Secondly, other human communities may have inhabited other "ideal" goat habitats nearby so that relocation was not an option. Finally, the investment in permanent architecture at Ganj Dareh suggests that, if the local environment had not changed significantly during the climatic anomaly, it would have been much easier to relocate goats in the hopes of repopulating the Ganj Dareh hinterland than to move people, build new mudbrick dwellings and create a new village in an unfamiliar locale.

In the Late Neolithic and Early Chalcolithic 6,000 to 4,500 bc, settlements of the central Zagros shift to the broad valley floors, nuclear zones of plant cultivation and sheep exploitation. One such valley is the Kermanshah Plain (Fig. 11.4). The shift in settlement concentration could have been in response to population increase and resource stress in the higher mountains, well after the initial domestication of goats and Ganj Dareh abandonment (Smith and Young, 1983). Modern ethnographic evidence indicates that even today the moisture levels and soil quality of the broad fertile Kermanshah Plain are conducive to productive mixed framing (Kramer, 1982).

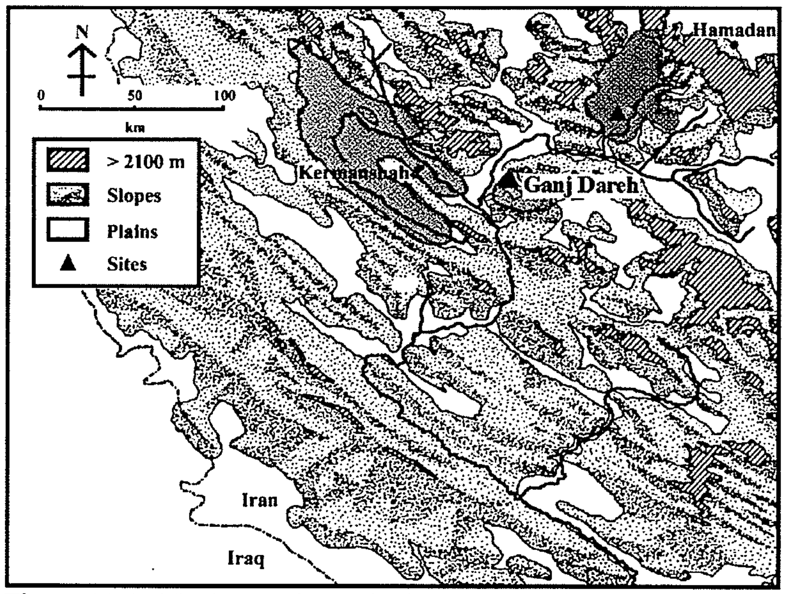

Figure 11.4. Nuclear and marginal zones occupied after abandonment of Ganj Dareh. Locations of a nuclear zone of plant cultivation and sheep exploitation (left) and a marginal zone of mixed farming (top right) relative to Ganj Dareh.

During the early Chalcolithic when people were settling in the Kermanshah Plain there is no archaeological evidence that marginal areas to the northeast were occupied (Kramer, 1982). Not until the later Chalcolithic ca. 4,100 to 3,700 bc do settlements appear in marginal areas such as those around Seh Gabi (Fig. 11.4). This suggests that population increase in the nuclear zone of mixed farming forced movement into the surrounding marginal zones. Skeletal evidence from the Seh Gabi children of low cortical bone density, high prevalence of HL and very high prevalence of LEH (Waddell, 1994) is consistent with the assessment of Seh Gabi as being in a region of marginal agricultural productivity. Even today, the region of Seh Gabi is characterized as marginal. Farmers would rather settle on the Kermanshah Plain given the chance where the higher soil fertility and lower elevation result in dramatically better crop yields and an easier life (Kramer, 1982).

Although the present model proposes population increase and resettlement from nuclear zones into marginal zones, it differs from the Marginal Zone Hypothesis (Binford, 1968; and Flannery, 1969) and Population Pressure Models (Cohen, 1977; Smith and Young, 1972) in one very important aspect. The model outlined here places habitation of marginal zones in the central Zagros following population increase occurring two to three millennia after Ganj Dareh was abandoned, that is, well after the early goat herd management observed at Ganj Dareh.

11.12.5 Summary

The Ganj Dareh people experienced relatively good health, far better than that of the children of the Chalcolithic site of Seh Gabi. Their mortality profile is similar to that of the hunter/gatherer population from the Epipalaeolithic site of Zawi Chemi. Their oral health was substantially better than that at Zawi Chemi, as indicated by the very low caries rate. As in all populations, the Ganj Dareh people experienced episodes of stress, for example disease and malnutrition. However, recovery from episodes of stress is the norm and characterization of the stress experienced is mild to moderate.

The subsistence strategy of the Ganj Dareh people is one based primarily on ovicaprid exploitation. The presence of lytic spinal lesions in one individual and porotic hyperostosis in most of the adults strongly suggests that brucellosis infections were present in the population. This is consistent with the high prevalence of brucellosis observed in many modern non-Western pastoralist populations.

The health data inferred from the Ganj Dareh skeletal remains are best explained by a modified social model of agricultural origins incorporating four major components: resource availability, levels of scalar stress, cultural mechanisms for alleviating stress and pastoralist subsistence strategy. Ganj Dareh was occupied and changes in human-goat interactions occurred during a period of resource abundance. The levels of external and internal scalar stress observed are low, due in large part to the presence of social mechanisms for diffusion of stress that develops in sedentary communities. The inhabitants of the sedentary community of Ganj Dareh practiced a pastoralist economy that developed unintentionally while they were attempting to maintain the subsistence *status quo* of ovicaprid hunting in the face of localized goat population extinctions.

CHAPTER 12. FUTURE DIRECTIONS

Throughout this research, it has become increasingly apparent that health assessment from the skeletal remains of infants and young children contain clues about the daily life of the population into which they are born and lived their short lives. Children's health can provide invaluable information as to how people made a living, what they ate and how stable the population's biological and cultural adaptations to local conditions were.

However, to facilitate this avenue of inquiry, it is necessary to explore the subject of what constitutes normality in infant skeletal remains, an area critical to decisions on defining pathology but one with hardly any literature. This paucity of documentation necessitates application of adult criteria of bone pathology to infant skeletal remains. This has the potential to drastically overestimate pathology in neonates and young children and incorrectly ascribe significant health and reproductive problems to the population. As a result, no one has used children's health, assessed through bone surface morphology, to examine one of the most important behavioural changes in human history, the adoption of agriculture.

The transition to agriculture has been viewed as a rapid irreversible transition between two dichotomous stable states: hunting-foraging and farming, with good health and poorer health, respectively (Cohen and Armelagos, 1984). However, a growing body of evidence indicates that 'transitional' economies based on herding supplanted hunting/foraging in the Zagros Mountains during the early Neolithic. In addition, Smith (2001) has suggested that 'transitional' economies form a middle ground of myriad stable adaptations to local economic and environmental conditions that did not all lead to the adoption of agriculture. The ultimate goal of future research is to develop a model whereby the stability, success and types of middle ground economies can be assessed through examination of infants' and young children's skeletal remains. This knowledge will expand the range of health data that can be utilized in elucidation of the subsistence strategy of populations in the middle ground, that is, where they are no longer hunter-foragers in the classic sense nor have they fully adopted agricultural lifeways. This research will not only contribute to our developing knowledge of the range of morphological variation of infants' and children's bone but also provide a means of modelling the relationships between subsistence and health, that will be specifically applied to the transition from hunting-foraging to agriculture.

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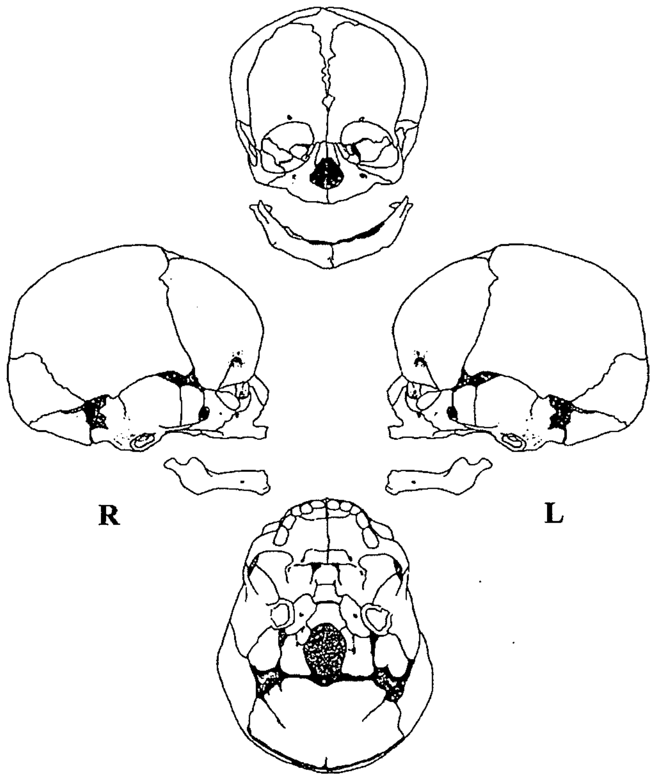
Appendix A: Skeletal Inventory

A.1 Non-Adult Cranial Inventory

Individual: ______________
Age: ______________
Status: ______________

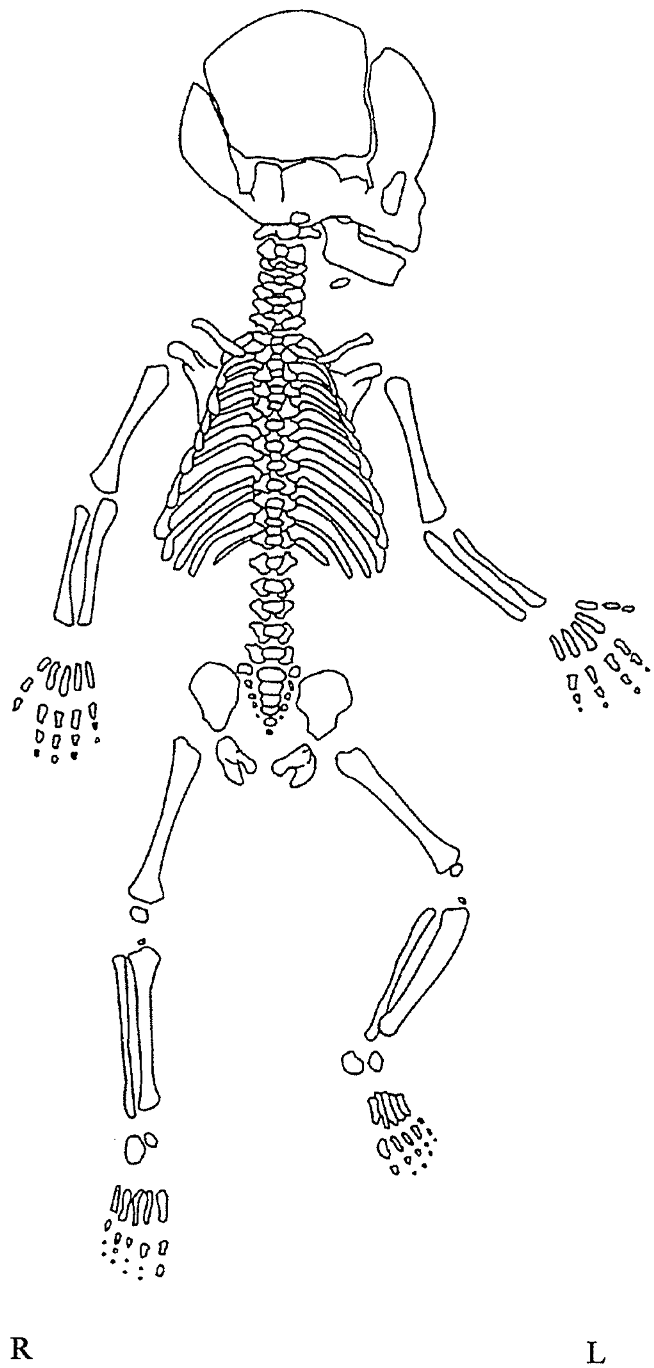


Bone	Right	Left
Frontal		
Parietal		
Temporal		
Mastoid		
Occ. Squam.		
Occip. Basilar		
Occ. Condyle		
Sphenoid		
Ethmoid		
Orbit		
Nasal		
Malar		
Maxilla		
Mand. Body		
Mand. Ramus		
Unidentifiable		

Deciduous / Mixed Dentition:

				C1	I2	I1	I1	I2	C1					
M2	M1	m2	m1	c	i2	i1	i1	i2	c	m1	m2	M1	M2	
														Maxilla
														Mandible
						R	L							

A.2 Non-Adult Infracranial Inventory Individual: ____________



Modified from Buikstra and Ubelaker (1994:5b).

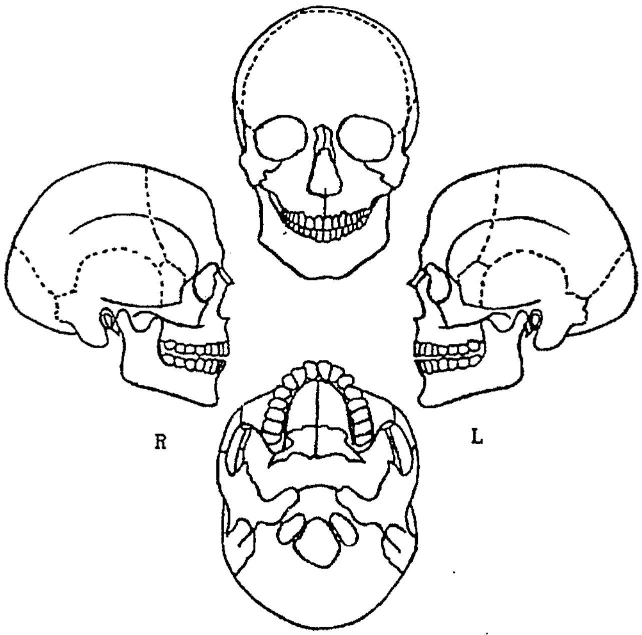
Bone	St.Rt.	St.Lt.
Clav		
Scap		
Hum		
Radius		
Ulna		
Inn		
Fem		
Pat		
Tibia		
Fibula		

Bone	St.Rt.	St.Lt.
Ribs		
H-Ph		
MC		
Car		
F-Ph		
MT		
Tar		

Vert	#	St.
Cerv		
Thor		
Lumb		
Sac		
Ster		
Manu		
Xiph		

A.3 Adult Cranial Inventory

Individual: ____________
Sex: ____________
Age: ____________
Status: ____________



Bone	Right	Left
Frontal		
Parietal		
Temporal		
Mastoid		
Occipital		
Occ. Condyle		
Sphenoid		
Ethmoid		
Orbit		
Nasal		
Malar		
Maxilla		
Mand. Body		
Mand. Ramus		
Unidentifiable		

DECIDUOUS DENTITION:

m2	m1	c	i2	i1	i1	i2	c	m1	m2	
										Maxilla
										Mandible

R L

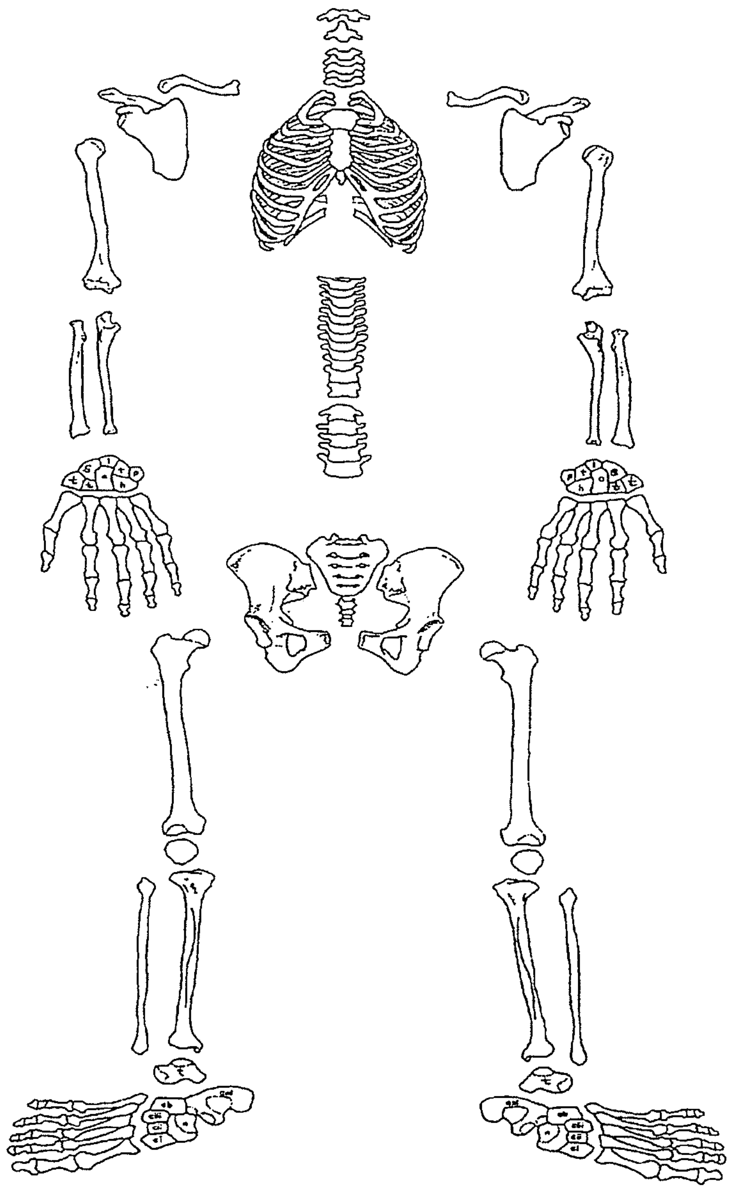
PERMANENT DENTITION:

M3	M2	M1	P4	P3	C	I2	I1	I1	I2	C	P3	P4	M1	M2	M3	
																Max
																Mand

R L

A.4 Adult Infracranial Inventory

Individual: ____________________



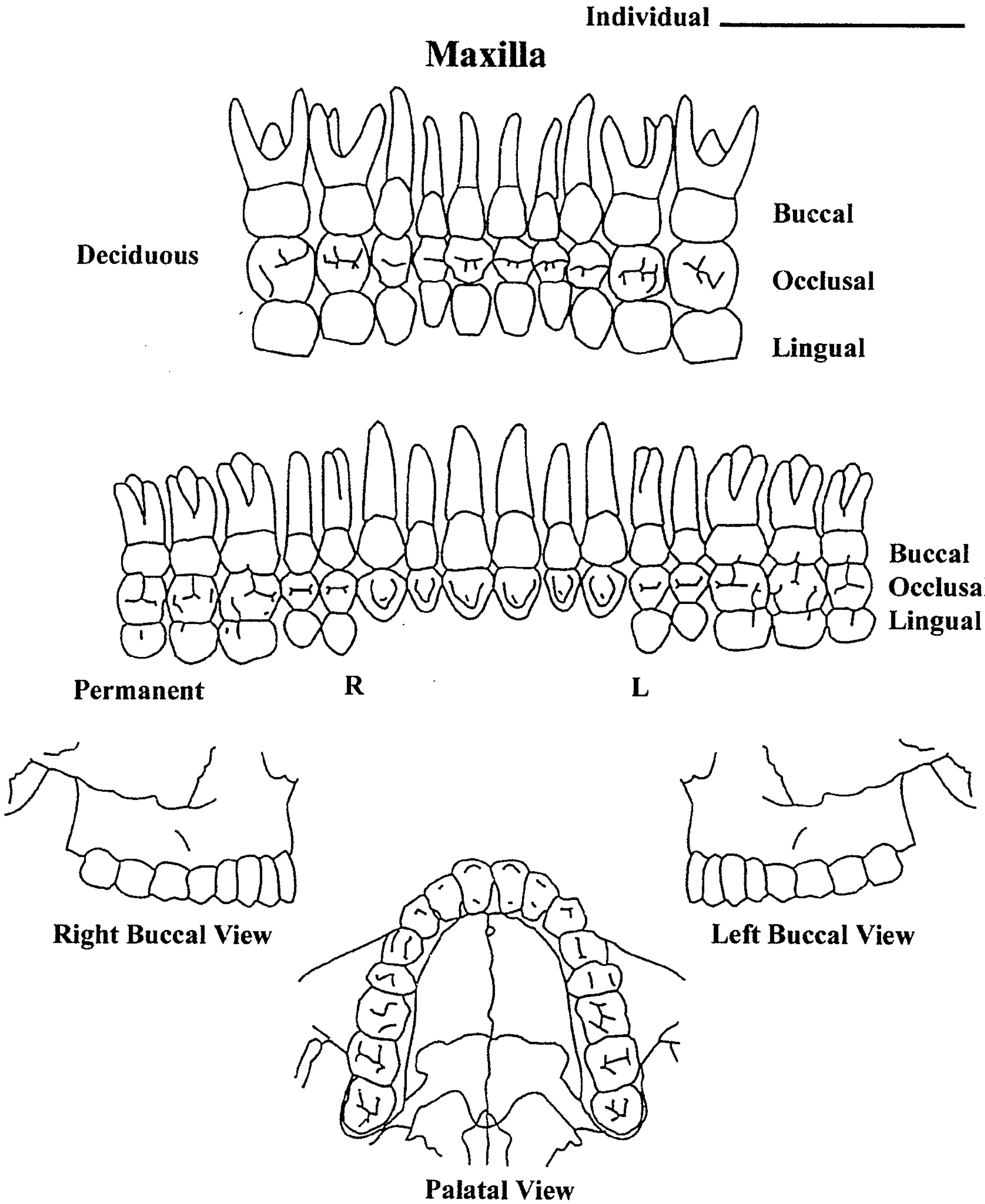
R L

Bone	St.Rt.	St.Lt.
Clav		
Scap		
Hum		
Radius		
Ulna		
Inn		
Fem		
Pat		
Tibia		
Fibula		

Bone	St.Rt.	St.Lt.
Ribs		
H-Ph		
MC		
Car		
F-Ph		
MT		
Tar		

Vert	#	St.
Cerv		
Thor		
Lumb		
Sac		
Ster		
Manu		
Xiph		

A.5 Maxillary Dentition

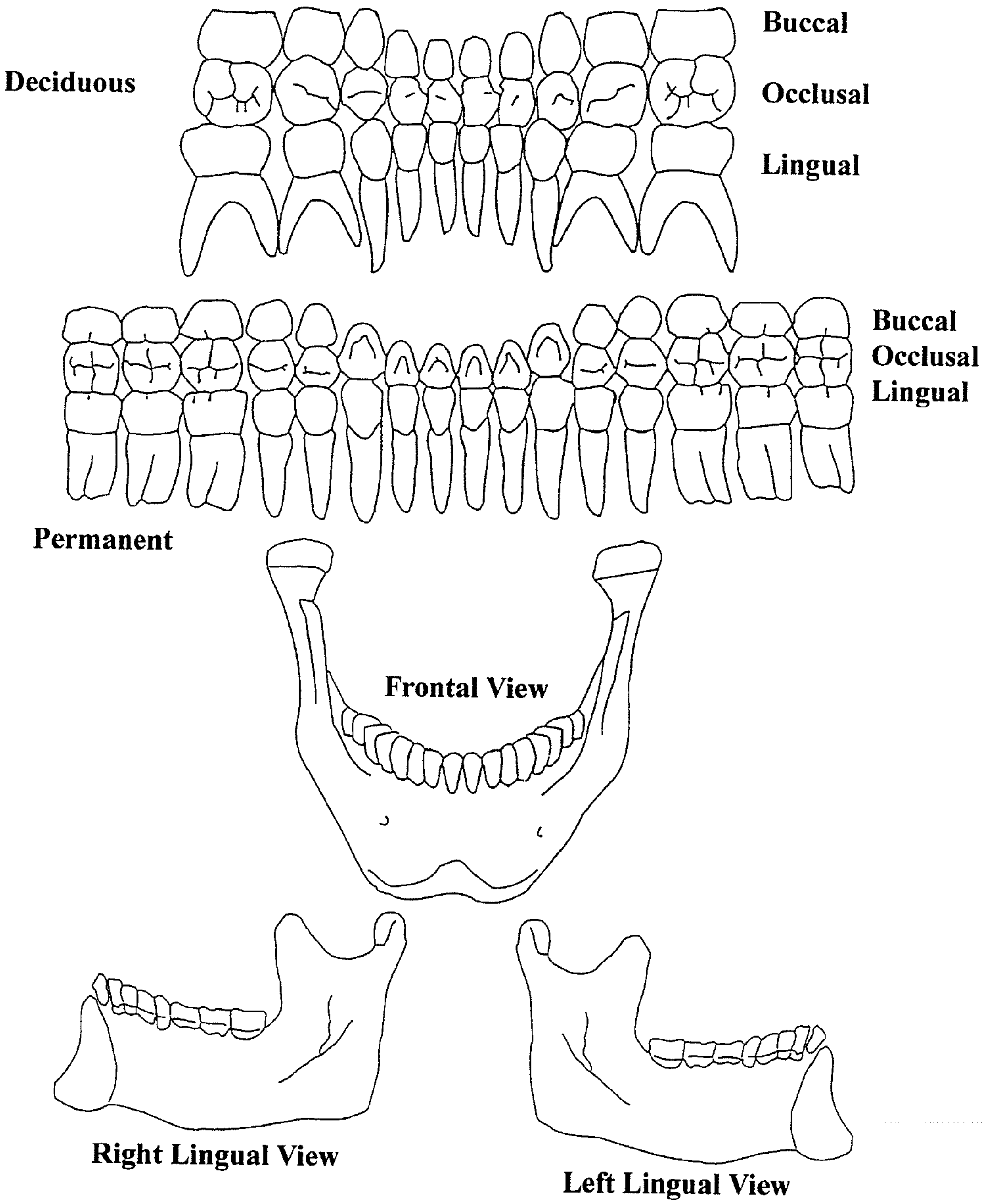


Modified from Buikstra and Ubelaker (1994:14a, 15a).

A.6 Mandibular Dentition

Individual ____________________

Mandible



Modified from Buikstra and Ubelaker (1994:14a, 15b).

A.7 Stature Estimations

Stature Estimation (Developed from Skeletons in the Terry Collection)

Population Affinity	Sex	Regression Equation *	± S E **
European	Male	3.08 Humerus + 70.45	4.05
		3.78 Radius + 79.01	4.32
		3.70 Ulna + 74.05	4.32
	Female	3.36 Humerus + 57.97	4.45
		4.74 Radius + 54.93	4.24
		4.27 Ulna + 57.76	4.30
Asian	Male	2.68 Humerus + 83.19	4.24
		3.54 Radius + 82.00	4.60
		3.48 Ulna + 77.45	4.66

* Bone measurements used are maximum lengths (cm).

* * Standard Error. Two-thirds of the estimates will fall in the range (Estimate ± SE). (Trotter, 1970)

Maximum length of each femur in centimetres. Feldesman (1992) found that femur length bears a nearly constant relationship to adult stature that does not vary between sexes or among populations. Femur / Stature = 26.74 %.

Stature (cm) = [femur length (cm)] x 3.74

A.8 Tooth Wear

Tooth wear for each tooth in the permanent dentition was assessed for occlusal attrition according to diagrams and descriptions of B.H. Smith (1984) and placed into one of 8 wear stages. On the basis of tooth wear the adult dentitions were then seriated initially according to the pattern of mandibular molar wear. For isolated teeth, the degree of wear was compared to those individuals with relatively complete dental arcades. Five broad categories were developed to describe the overall tooth wear within an individual (Table B.6.1 below).

Wear Stage	M1 Morphology	Additional Characteristics
1	0-3 small areas of dentine exposed	M3s are erupting
2	At least 3 areas of dentine exposed Buccal areas of dentine not connected to each other	M3s erupted
3	Buccal dentine regions have coalesced Mesio-lingual dentine may be joined to buccal Perimeter of enamel intact	M3s erupted
4	Exposed dentine is U-shaped Buccal rim of enamel is absent (wear into root)	M3s erupted
5	Crown completely worn, with only root stubs left OR Ante-Mortem Tooth Loss (AMTL)	Within stage 5, individuals can be seriated with respect to degree of wear on M2 and M3

Table B.6.1. Tooth wear.

Appendix B.1 Non-Adult Age Estimation

B.1.1 Cranial Development

Individual: ____________________

Bone	Elements Fused	Expected	Right	Left
Occipital[1]	Sutura Mendosa (Medial)	f 12-20 wk		
	Sutura Mendosa (Lateral)	By 1 yr		
	Superior Median Fissure	By 1 yr		
	Pars Lateralis to Squama	1-3 yr		
	Hypoglossal Canal	1-3 yr		
	Pars Lateralis to Basalis	5-7 yr		
Temporal[2]	Post Tympanic Ring to Squamous	f 35 wk		
	Tympanic Ring Lengthens	6 mo		
	Tympanic Ring to Petrous	By 1 yr		
	Petromastoid to Squamotympanic	By 1 yr		
	Foramen of Huschke and Lengthening of Tympanic Plate	1-5 yr (FH Closed by 5yr)		
Sphenoid[3]	Body to Lesser Wings	Birth		
	Greater Wings to Body	0-1 yr		
	Foramen Ovale Complete	0-1 yr		
	Foramen Spinosum Complete	By 2 yr		
	Dorsum Sellae Ossified	By 5 yr		
Frontal[4]	Anterior Fontanelle	1-2 yr		
	Metopic Suture	2-4 yr		
Mandible[5]	Mental Symphysis	0-1 yr		

[1] Scheuer and Black (2000:60,61)
[2] Scheuer and Black (2000:78,80)
[3] Scheuer and Black (2000:96)
[4] Scheuer and Black (2000:108)
[5] Scheuer and Black (2000:147)

B.1.2 Infracranial Development

Individual: ____________________

B.1.2.1 Vertebrae:

	Arch to Arch[1]		Arch to Centrum[1]		
	Exp		Exp	Right	Left
C1	3 yr		⇑		
C2	⇑		⇑		
C3	⇑		⇑		
C4	⇑		⇑		
C5	2 yr		3-4 yr		
C6	⇑		⇓		
C7	⇑		⇓		
T1	⇑		⇓		
T2	⇑		⇓		
T3	⇑		⇓		
T4	⇑		⇓		
T5	⇑		⇓		
T6	⇑		⇓		
T7	⇑		⇓		
T8	⇑		⇓		
T9	⇑		⇓		
T10	⇑		⇓		
T11	⇑		4-5 yr		
T12	1 yr		⇑		
L1	⇓		⇑		
L2	⇓		⇑		
L3	⇓		⇑		
L4	⇓		⇑		
L5	5 yr		2-4 yr		

[1] Scheuer and Black (2000:193)

Vertebra	Elements Fused	Expected	Observed	
Atlas[1]	Transverse Foramen	3-4 yr	R	L
	Arch to Arch	4-5 yr	R	L
	Ant Arch to Post Arch	5-6 yr	R	L
Axis[2]	Dens to Dens	Birth		
	Arch to Arch	3-4 yr		
	Transverse Foramen	3-4 yr	R	L
	Dens to Cent & Arch	4-6 yr	R	L
	Ossiculum Terminale	~12 yr		

[1] Scheuer and Black (2000:198)
[2] Scheuer and Black (2000:200)

B.1.2.2 Sacrum: Individual: ____________________

	Lateral to Arch (A)[1]			Arch to Centrum (B)[1]			Lateral to Centrum (C)[1]		
	Exp	Right	Left	Exp	Right	Left	Exp	Right	Left
S1	2-5yr			2-6yr			2-6yr		
S2	2-5yr			2-6yr			2-6yr		
S3	2-5yr			2-6yr			2-6yr		
S4				2-6yr			2-6yr		
S5									

Costal elements fused to arch to form ala, prior to fusion of ala to centrum
[1] Scheuer and Black (2000:207)

Score	Degree of Fusion
---	Element Not present
0	No Visible Fusion
1	Minimal
2	Moderate
3	Complete Obliteration

<20 yr: Spaces between sacral vertebrae present
<27 yr: Space between S1 and S2 only
25+ yr: All sacral bodies fused

	Fusion Ala to Next Inferior Ala[1]			Fusion to Next Inferior Centrum[1]		Annular Epiphyses[2]			Dorsal Wall of Sacral Canal[1]	
		R	L	Exp		Exp	Sup	Inf	Exp	
S1	Puberty			Early 20s		Early 20s			7-15 yr	
S2	Puberty			⇑		⇑			7-15 yr	
S3				⇑		⇑			7-15 yr	
S4				⇑		⇑			7-15 yr	
S5				Puberty		Puberty			7-15 yr	

[1] Scheuer and Black (2000:207) [2] Scheuer and Black (2000:213)

Sternum:

Element	Fusion to Next Inferior Element Expected[1]	Observed
Manubrium	Usually only in older ♀	
Sternabra 1	15-20 yr	
Sternabra 2	11-16 yr	
Sternabra 3	4-10 yr	
Sternabra 4	40+ yr	
Xiphoid		

[1] Scheuer and Black (2000:226)

B.1.3 Infracranial Size

Individual: ______________________

Element/Measurement	Observed	Expected Age
Clavicle: Max Length		[1]
Ischium: Length		[2]
Ischium: Breadth		[2]
Ilium: Length		[3]
Ilium: Breadth		[3]
Ischium: Length		[3]
Ulna: A-P at Coronoid		
Femur: Dist Epiph Width		[4]
Tibia: Prox Epiph Width		[5]

[1] Scheuer and Black (2000:60,61)
[2] Scheuer and Black (2000:356,373)
[3] Scheuer and Black (2000:373)
[4] Sundick (1978:238)
[5] Sundick (1978:240)

B.1.4 Long Bone Epiphyseal Fusion [1] Scheuer and Black (2000).

Skeletal Element	Location	Epiphysis	Right Obs.	Left Obs.	Expected Age[1] Appear	Fuse
Clavicle		Medial			12-14	b=16-21,c=29
		Lateral			19-20	19-20 yr
Humerus	Proximal	Head			2-6 mo	2-6 yr
		Greater Tubercle			1-2 yr	2-6 yr
		Lesser Tubercle			4-5 yr	2-6 yr
		Cmpd Epiphysis			2-6 yr	♀ 13-15 yr ♂ 16-20 yr
	Distal	Capitulum			1-2 yr	12-14 yr
		Trochlea			8-9 yr	12-14 yr
		Lat. Epicondyle			10-12 yr	12-14 yr
		Cmpd Epiphysis			12-14 yr	♀ 11-15 yr ♂ 12-17 yr
		Med. Epicondyle			4-6 yr	♀ 13-15 yr ♂ 14-15 yr
Radius	Proximal	Head			4.5-6 yr	♀ 11.5-13yr ♂ 14-17 yr
		Radial Tuberosity				Occasional
	Distal	Distal Epiphysis			1-2 yr	♀ 14-17 yr ♂ 16-20 yr
Ulna	Proximal	Olecranon			8-10 yr	♀ 12-14 yr ♂ 13-16 yr
	Distal	Distal Epiphysis			5.5-7 yr	♀ 15-17yr ♂ 17-20 yr
Femur	Proximal	Head			0.5-1 yr	♀ 12-16 yr ♂ 14-19 yr
		Greater Trochanter			2-5 yr	♀ 14-16 yr ♂ 16-18 yr
		Lesser Trochanter			7-12 yr	16-17 yr
	Distal	Distal Epiphysis			f 36-38 wk	♀ 14-18 yr ♂ 16-20 yr
Patella		1° Centre			3-5 yr	
Tibia	Proximal	Tibial Plateau			f 36 wk – 2 mo pp	♀ 13-17 yr ♂ 15-19 yr
		Tibial Tuberosity			♀ 8-12 yr ♂ 9-14 yr	12-14 yr
	Distal	Distal Epiphysis			3-10 mo	♀ 14-16 yr ♂ 15-18 yr
Fibula	Proximal	Head			♀ 3-4 yr ♂ 4-5 yr	♀ 12-17 yr ♂ 15-20 yr
	Distal	Distal Epiphysis			2-22 mo	♀ 12-15 yr ♂ 15-18 yr

B.1.5 Fusion of Innominate and Scapula

Innominate Individual: ____________________

Location	**Epiphysis/Cartilage**	**Right Obs.**	**Left Obs.**	**Expected Age[1] Appear**	**Fuse**
Ischium / Pubis	Ramus				5-9 yr
	Ischial Tuberosity			13-16 yr	I[2]: 16-18 yr E[3]: 19-20 yr C[4]: 20-23 yr
Acetabulum	Triradiate Cartilage			9-10 yr	♀ 11-15 yr ♂ 14-17 yr
	Anterior Epiphysis			9-10 yr	
	Posterior Epiphysis			10-11 yr	
	Superior Epiphysis			12-14 yr	16-17 yr
Ilium	AIIS Epiphysis			10-13 yr	By 20 yr
	Anterior Crest Epiph.				20-23 yr
	Posterior Crest Epiph.				20-23 yr

[1] Scheuer and Black 2000:372.
[2] I = Initiation of Fusion
[3] E = Extension Half Way Along Ramus
[4] C = Completion of Fusion

Scapula

Location	**Epiphysis/Cartilage**	**Right Observed**	**Left Observed**	**Expected Age[1] Appear**	**Fuse**
Coracoid				1 yr	16-17 yr
	Angle Epiphysis			~ 14 yr	~ 20 yr
	Apical Epiphysis			13-15 yr	~ 20 yr
Acromion				14-16 yr	18-20 yr
Glenoid Fossa	Superior Epiphysis			8-10 yr	15-20 yr
	Inferior Epiphysis			14-15 yr	17-18 yr
Blade	Medial Border & Inferior Angle			15-17 yr	19-23 yr

[1] Scheuer and Black 2000:269.

Appendix B.2 Preparation of Tooth Thin Sections

Developing deciduous molar tooth crowns were embedded in Buehler Epo-Thin epoxy resin. Crowns were oriented so that longitudinal sections were cut in a bucco-lingual direction. Infiltration was initiated under vacuum for ten minutes to remove air bubbles. Atmospheric pressure was equalized over several hours and the blocks were then allowed to harden at room temperature for 24 hours.

Sections were cut on a Buehler Isomet slow speed microtome using a diamond wafering blade. After the first cut, the exposed surface was polished using Buehler 600 and 1000 grit silicon carbide grinding paper on a Metaserv 2000 Grinder/Polisher, a water cooled and lubricated polishing wheel. The final surface was polished using 0.05 μm Gamma Micropolish Alumina No. 3 liquid on the buffing cloth of the polishing wheel. The block was mounted on a microscope slide with a small amount of epoxy resin and the epoxy cured for 24 hours. The block was remounted in the microtome chuck and cut to leave a 150 μm section of embedded tooth on the slide. The exposed section surface was ground and polished as above to a final thickness of 50 to 60 μm.

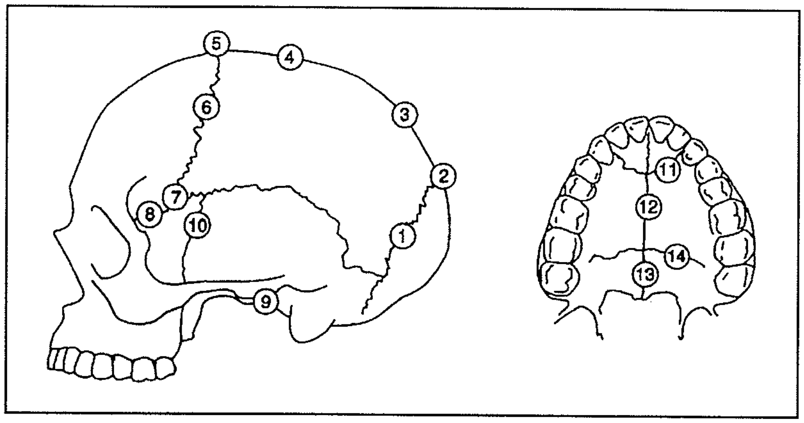
The sections were viewed under bright field illumination with x4, x10 and x20 objectives on an Olympus BX51 microscope and photographed using an Olympus MediaCybernetics CoolSNAP-Pro cf digital camera. The images were captured through Image Pro-Plus 4.5 (2001) software.

Appendix B.3 Adult Age Estimation

B.3.1 Cranial Sutures

Individual: ____________________

0 = Open
1 = Minimal Closure
2 = Significant Closure
3 = Complete Suture
Obliteration



Modified from Buikstra and Ubelaker (1994:33).

Palatal Scores:
Site 11 = Score 3: > 25 years
Site 12 or Site 13 with Score = 3: >40 years
Any 2 sites with Score = 3: > 60 years
(Mann et al., 1987)

	Site Name	Vault Score	Lateral-Anterior Score	Palatal Score
1	Midlambdoidal			
2	Lambda			
3	Obelion			
4	Anterior Sagittal			
5	Bregma			
6	Midcoronal			
7	Pterion			
8	Sphenofrontal			
9	Inferior Sphenotemporal			
10	Superior Sphenotemporal			
11	Incisive			
12	Anterior Median Palatine			
13	Posterior Median Palatine			
14	Transverse Palatine			
		Vault Total =	LatAnt Total =	
	Age Estimation			

APPENDIX C. DATA CODING

C.1 Teeth

C.1.1 Tooth Status

0	No Tooth or Alveolus
1	Tooth Intact with Alveolus
2	Tooth Intact without Alveolus
3	Tooth Lost Premortem due to Pathology/Trauma
4	Tooth Congenitally Absent
5	Tooth Absent but Alveolus Present
6	Tooth Fractured in Alveolus
7	Unerupted
8	Erupting
9	Fractured Loose, Crown or Roots Intact

C.1.2 Hypercementosis

0	Absent
1	Minimal
2	Moderate
3	Severe

C.1.3 Enamel Hypoplasia (2 Part Code)

1. Description

0	Absent
1	Linear
2	Vertical Areas (Labial or Buccal)
3	Vertical Cervical Ridges
4	1 and 2
5	1 and 3

2. Severity

0	Absent
1	Trace
2	Light
3	Moderate
4	Severe

C.1.4 Abscessing

0	Absent
1	Present

C.1.5 AMTL

0	Absent
1	Present

C.2 Bone

C.2.1 Suture/Epiphysis Fusion

0	Open
1	Minimal
2	Significant
3	Complete

C.2.2 Bone Formation and Loss (2 Part Code)

1. Bone Formation		**2. Bone Resorption**	
0	Absent	0	Absent
1	New Woven Bone	1	Rough Surface, Smooth Margins
2	Plates	2	Rough Surface, Scalloped Margins
3	Spicules (Osteophytes)	3	Smooth Surface, Smooth Margins
4	Lobules	4	Smooth Surface, Scalloped Margins
5	New Bone Remodelling	5	Porous Surface, Smooth Margins
6	1 and 2	6	Porous Surface, Scalloped Margins
7	1 and 3		
8	1 and 5		

C.2.3 Enthesis Morphology (2 Part Code)

1. Description		**2. Height**	
0	Smooth Surface	0	Not raised
1	Surface Rough, New Woven Bone	1	Slightly Raised
2	Moderate Roughness, Small Spicules	2	Moderately Raised
3	Extensive Spicule Formation	3	Extensively Raised
4	Moderate Lobules	4	Slight Fossa
5	Extensive Lobules	5	Moderate Fossa
		6	Deep Fossa

C.2.4 Enthesis Development

0	Absent
1	Minimal
2	Moderate
3	Significant
9	Not Observable

C.2.5 Enthesopathy

1	Absent
2	Present
3	Not Observable

C.2.6 Osteoarthritis (2 Part Code)

1. Marginal Lipping of Articular Facets

0	Absent
1	New Bone Formation
2	Erosion of Margin
3	1 and 2

2. Subchondral Pitting

0	Absent
1	Minimal, Through Cortex
2	Minimal, Not Through Cortex
3	Moderate
4	Severe

C.2.7 Sinusitis (2 Part Code)

1. Description

0	Absent
1	Spicules
2	Pits, Hypervascularity
3	Plaque
4	Lobules
5	1 and 2
6	1, 2, and 3

2. Severity

0	Absent
1	+
2	++
3	+++

C.2.8 Orbital Roof Morphology Re: *Cribra Orbitalia*

0	Absent
1	Plates of New Bone
2	Porosity into Diplöe and Hyperostosis

C.2.9 Ectocranial Porosity and Hyperostosis (4 Part Code)

1. Location

0	Absent
1	Orbits (Frontal) or Suprameatal Region (Temporal)
2	Adjacent to Sutures
3	Near Bosses (Frontal, Parietal) or Central Regions (Temporal, Occipital)
4	1 and 2
5	2 and 3
6	1 and 2 and 3

2. Description

0	Absent
1	Small Dense Foramina, no Coalescing
2	Small Dense Foramina, Coalescing
3	Large, Widely Spaced Foramina, no Coalescing
4	Large, Widely Spaced Foramina, Coalescing
5	Lobules of Smooth Remodelled Bone
6	Foramina and Lobules
7	Small Dense Foramina and Larger, More Widely Spaced Foramina
8	Plates and Some Associated Pores

C.2.9 Continued.

3. Table Thickness

0 No Thickening
1 Minimal Thickening
2 Moderate
3 Extensive

4. Activity

0 Absent
1 Active
2 Healed

C.2.10 Vertebral Body Margins (3 Part Code)

1. Location on Margin

0 Absent
1 Anterior
2 Lateral
3 1 and 1
4 Posterior
5 1,2 and 4
9 Not Determinable

2. Margin Affected

0 Absent
1 Superior
2 Inferior
3 Superior and Inferior
9 Fragment Orientation Not Determinable

3. Appearance

0 "Normal"
1 Horizontal Osteophytes
2 Curved "Beak" Osteophytes
3 Ankylosis

C.2.11 Ligamenta Flava Ossification

0 Absent
1 Minimal
2 Moderate
3 Extensive

C.2.12 Depressions of the Cranial Vault (2 Part Code)

1. Location

0 Absent
1 Outer Table
2 Inner Table
3 Both Tables Affected

2. Description

0 Absent
1 Shallow, Smooth Borders
2 Deep, Smooth Borders
3 Lobular Depressions
4 Finely Branching Blood Vessel Impressions
5 3 and 4
6 2 and 4

Appendix D: Tabular Summary Data

D.1 Age, Sex and Dental Data

GD#	Age	Sex	Linear Hypoplasia	Circular Hypoplasia	Caries	AMTL	Abscessing	Hypercementosis
7	0-4 wk pp	na	na	na	na	na	Abs	na
1506/1507	0-4 wk pp	na	na	na	na	na	na	na
1519	0-4 wk pp	na	na	na	na	na	na	na
1485	0-4 wk pp	na	na	na	na	na	na	na
37a	0-4 wk pp	na	na	na	na	na	na	na
187	4.5-5.5 wk pp	na	na	na	na	na	na	na
12	0-2 mo	na	Abs	Abs	Abs	na	Abs	na
27/26a	Neonate	na	Abs	Abs	Abs	na	Abs	na
1a	0-2mo	na	Abs	Abs	Abs	na	Abs	na
468b	4.5-5.5 wk pp	na	na	na	na	na	na	na
1150a	4.5-5.5 wk pp	na	na	na	na	na	na	na
1153	4.5-5.5 wk pp	na	na	na	na	na	na	na
21	3-4 mo	na	Abs	Abs	Abs	na	Abs	na
1484	1-3 mo	na	na	na	na	na	na	na
1547	2-6mo	na	Abs	Abs	Abs	na	na	na
228	~6 mo	na	na	na	na	na	na	na
32	6-9mo	na	Abs	Abs	Abs	na	Abs	Abs
25	12 mo	na	Abs	Pres	Abs	Abs	Abs	Abs
29a	12-18 mo	na	na	na	na	na	na	na
36	12-18 mo	na	Abs	Pres	Abs	na	Abs	Abs
1218	12-18 mo	na	Abs	Abs	Abs	na	na	na
486	12-18 mo	na	na	na	na	na	na	na
1527	12-18 mo	na	na	na	na	na	na	na
1b	12-18 mo	na	na	na	na	na	na	na
14a	~2 yr	na	na	na	na	na	na	na
39	1.3-2.5 yr	na	Abs	Pres	Abs	Abs	Abs	Abs
30a	2yr	na	Pres	Abs	Abs	na	na	na
26b	2-2.5 yr	na	Abs	Pres	Abs	Abs	Abs	Abs
38	2.5-3 yr	na	Abs	Pres	Abs	Abs	Abs	Abs
14b	3.2-4.1 yr	na	Pres	Pres	Abs	Abs	1	Abs
1	3.5-4.5 yr	na	Abs	Abs	Abs	Abs	Abs	Abs
31b	<5 yr	na	na	na	na	na	na	na

D.1 Age, Sex and Dental Data (cont.)

GD#	Age	Sex	Linear Hypoplasia	Circular Hypoplasia	Caries	AMTL	Abscessing	Hypercementosis
1445	5.4 yr	na	Pres	Abs	Abs	na	na	Abs
2	6-7 yr	na	Abs	Abs	Abs	Abs	Abs	Abs
16	5.5-7.5 yr	na	Pres	Pres	Abs	Abs	Abs	na
13c	5-9 yr	na	na	na	na	na	na	na
578	6-9yr	na	Abs	Abs	Abs	na	na	na
5Abs5	7-10yr	na	Abs	Abs	Abs	na	na	na
1530	8-10 yr	na	na	na	na	na	na	na
1078	8-10yr	na	Abs	Pres	Abs	na	na	na
18	8-10 yr	na	Abs	Abs	Abs	na	na	Abs
788	9-10yr	na	Abs	Pres	Abs	na	na	na
10	8.6-9.6 yr	na	Pres	Pres	Abs	Abs	Abs	Abs
23a	10.5-12 yr	na	na	na	na	na	na	na
341	>12yr	na	Pres	Abs	Abs	na	na	Abs
1151-3	<14-16yr	na	na	na	na	na	na	na
478	<14-16yr	na	na	na	na	na	na	na
13	13-18 yr	na	na	na	na	na	na	na
15	15 yr	M	Pres	Pres	Abs	Abs	Pres	Abs
17	13.5 yr	M	Pres	Pres	Abs	Abs	Abs	Abs
41	16-19 yr	M	Pres	Abs	Abs	Abs	Abs	Abs
3a	YA	F	Abs	Abs	na	Abs	Abs	Abs
4	MA	M	Pres	Abs	Pres	Pres	Pres	2
6	YA	na	Pres	Abs	Abs	na	na	Abs
#8/#9	YA	na	Pres	Abs	Abs	Abs	Abs	Abs
11	MA	na	Pres	Abs	Abs	na	na	1
13a	MA	M?	Pres	Abs	Abs	Pres	Abs	Abs
13bT	YA	na	Abs	Abs	Abs	na	na	1
19	M-O	na	na	na	na	na	na	na
20	YA	M	Pres	Abs	Abs	Abs	Abs	2
22	OA	M	Pres	Abs	Abs	Pres	Pres	2
23	YA	F	Pres	Pres	Abs	Abs	Abs	Abs
24	Y-M	na	na	na	na	na	na	na
28	M-O	F	na	na	Abs	Abs	Pres	na
29	M-O	F	na	na	na	na	na	na
30	OA	F	Abs	Abs	Pres	Pres	Pres	na
31	MA	M	Pres	Pres	Pres	Pres	Pres	1
33	Y-M	na	na	na	na	na	na	na

D.1 Age, Sex and Dental Data (cont.)

GD#	Age	Sex	Linear Hypoplasia	Circular Hypoplasia	Caries	AMTL	Abscessing	Hypercementosis
34	OA	M?	Pres	Abs	Pres	Pres	Pres	Abs
35	MA	M	na	na	Abs	Pres	Pres	Abs
36a	Y-M	na	na	na	na	na	na	na
37	MA	M	Abs	Pres	Pres	Pres	Pres	2
40	YA	M	Pres	Pres	Abs	Abs	Abs	Abs
40b	YA	na	Abs	Abs	Abs	na	na	na
42	MA	na	Pres	Abs	Abs	na	na	Abs
1150	YA	M	Pres	Abs	Abs	Abs	Abs	na
1150b	A	na	na	na	na	na	na	na
1151-1	MA	na	Abs	Abs	Abs	na	na	Abs
1151-2	A	na	na	na	na	na	na	na
U1	A	na	na	na	na	na	na	na
U38	Y-M	na	na	na	na	na	na	na
U49	Y-M	na	na	na	na	na	na	na
U59T	YA	na	Abs	Abs	Abs	na	na	na
127T	OA	na	Abs	Abs	Abs	na	na	Abs
152	Y-M	na	na	na	na	na	na	na
214	MA	na	na	na	na	na	na	na
215	M-O	na	na	na	na	na	na	na
216	M-O	na	na	na	na	na	na	na
247	Y-M	na	na	na	na	na	na	na
341a	OA	na	Pres	Abs	Abs	na	na	Abs
360	MA	na	Abs	Abs	Abs	na	na	Abs
370	YA	na	na	na	na	na	na	na
387T	MA	na	Pres	Abs	Abs	na	na	Abs
402a	M-O	na	na	na	na	na	na	na
478	M-O	na	na	na	na	na	na	na
485	M-O	na	na	na	na	na	na	na
489T	MA	na	Abs	Abs	Abs	na	na	Abs
507	YA	na	Abs	Abs	Abs	na	na	Abs
510	Y-M	na	na	na	na	na	na	na
619T	YA	na	Abs	Abs	Abs	na	na	na
662	Y-M	na	na	na	na	na	na	na
855/856	YA	na	Abs	Abs	Abs	na	na	Abs

D.1 Age, Sex and Dental Data (cont.)

GD#	Age	Sex	Linear Hypoplasia	Circular Hypoplasia	Caries	AMTL	Abscessing	Hypercementosis
864	M-O	na	na	na	na	na	na	na
876	Y-M	na	na	na	na	na	na	na
1113	M-O	na	na	na	na	na	na	na
1140	Y-M	na	na	na	na	na	na	na
1163T	MA	na	Abs	Abs	Abs	na	na	1
1213T	MA	na	na	na	Abs	na	na	2
1388	MA	na	Abs	Abs	Abs	na	na	na
1483/1484	M-O	na	na	na	na	na	na	na
1512	M-O	na	na	na	na	na	na	na
1527	Y-M	na	na	na	na	na	na	na
1534	Y-M	na	na	na	na	na	na	na
1547	M-O	na	na	na	na	na	na	na
1581	Y-M	na	na	na	na	na	na	na
1596	Y-M	na	na	na	na	na	na	na

D.2 Cranial Data

GD#	Age	RSinusitis	LSinusitis	Cribra Orbitalia	Cranial Porosity	Cranial Hyperostosis	Osteophytes at ExtAudMeatus Margin	Cranial Depression Fractures
7	0-4 wk pp	na	na	3	Abs	4.8.0.2	na	0.0
1506/1507	0-4 wk pp	na	na	na	na	na	na	na
1519	0-4 wk pp	na	na	na	na	na	na	na
1485	0-4 wk pp	na	na	na	na	na	na	na
37a	0-4 wk pp	na	na	na	na	na	na	na
187	4.5-5.5 wk pp	na	na	na	na	na	na	na
12	0-2 mo	na	na	3	Abs	4.8.0.2	na	0.0
27/26a	Neonate	0.0	0.0	3	Abs	4.8.0.2	na	0.0
1a	0-2mo	na	na	na	Abs	2.8.0.2	na	0.0
468b	4.5-5.5 wk pp	na	na	na	na	na	na	na
1150a	4.5-5.5 wk pp	na	na	na	na	na	na	na
1153	4.5-5.5 wk pp	na	na	na	na	na	na	na
21	3-4 mo	0.0	0.0	4	Abs	4.1.0.2	Abs	0.0
1484	1-3 mo	na	na	na	na	na	na	na
1547	2-6mo	na	na	na	na	na	na	na
228	~6 mo	na	na	na	na	na	na	na
32	6-9mo	0.1	na	4	Abs	0.0.0.0	Abs	0.0
25	12 mo	na	na	4	2	4.1.0.1	Abs	2.7
29a	12-18 mo	na	na	na	Abs	0.0.0.0	na	na
36	12-18 mo	na	na	Abs	Abs	1.1.0.2	Abs	0.0
1218	12-18 mo	na	na	na	na	na	na	na
486	12-18 mo	na	na	na	na	na	na	na
1527	12-18 mo	na	na	na	na	na	na	na
1b	12-18 mo	na	na	na	na	na	na	na
14a	~2 yr	na	na	na	na	na	na	na
39	1.3-2.5 yr	na	na	4	Abs	1.1.0.2	na	0.0
30a	2yr	na	na	na	na	na	na	na
26b	2-2.5 yr	na	na	4	Abs	0.0.0.0	Pres	0.0
38	2.5-3 yr	na	na	4	Abs	0.0.0.0	na	0.0
14b	3.2-4.1 yr	na	na	na	Abs	2.3.0.2	Abs	2.6
1	3.5-4.5 yr	0.0	0.0	Abs	Abs	0.0.0.0	Abs	0.0
31b	<5 yr	na	na	na	na	na	na	na

D.2 Cranial Data (cont.)

GD#	Age	RSinusitis	LSinusitis	Cribra Orbitalia	Cranial Porosity	Cranial Hyperostosis	Osteophytes at ExtAudMeatus Margin	Cranial Depression Fractures
1445	5.4 yr	na	na	na	na	na	na	na
2	6-7 yr	na	na	4	1	1.1.0.2	Abs	0.0
16	5.5-7.5 yr	0.0	0.0	4	1	1.1.0.2	Abs	2.2
13c	5-9 yr	na	na	na	na	na	na	na
578	6-9yr	na	na	na	na	na	na	na
505	7-10yr	na	na	na	na	na	na	na
1530	8-10 yr	na	na	na	na	na	na	na
1078	8-10yr	na	na	na	na	na	na	na
18	8-10 yr	na	na	na	na	na	na	na
788	9-10yr	na	na	na	na	na	na	na
10	8.6-9.6 yr	0.0	0.0	Abs	2	1.7.0.2	Abs	0.0
23a	10.5-12 yr	na	na	na	na	na	na	na
341	>12yr	na	na	na	na	na	na	na
1151-3	<14-16yr	na	na	na	na	na	na	na
478	<14-16yr	na	na	na	na	na	na	na
13	13-18 yr	na	na	na	na	na	na	na
15	15 yr	0.0	0.0	Abs	1	1.1.0.2	Pres	0.0
17	13.5 yr	Fr5.2	0.0	Abs	1	1.1.0.2	Abs	0.0
41	16-19 yr	0.0	1.2	5	1	3.3.0.2	Pres	2.2
3a	YA	na	na	Abs	1	2.3.0.2	Abs	0.0
4	MA	0.0	Fr2.1	5	0	0.0.0.0	na	0.0
6	YA	na	na	na	na	na	na	na
#8/#9	YA	na	na	na	1	2.7.0.2	na	0.0
11	MA	na	na	na	1	2.2.0.2	na	1.1
13a	MA	1.1	na	Abs	1	2.7.0.2	Pres	2.8
13bT	YA	na	na	na	na	na	na	na
19	M-O	na	na	na	1	2.7.1.2	na	0.0
20	YA	na	na	Abs	3	6.7.2.1	na	2.8
22	OA	na	na	na	1	2.1.1.2	Pres	2.3
23	YA	na	0.0	5	1	2.1.0.2	Pres	0.0
24	Y-M	na	na	na	na	na	na	na
28	M-O	na	na	Abs	1	5.1.1.2	na	0.0
29	M-O	na	na	na	1	2.3.0.2	na	2.4
30	OA	1.1	1.1	5	1	6.1.2.2	Abs	0.0
31	MA	0.0	6.2	5	1	2.3.1.2	Pres	na
33	Y-M	na	na	na	na	na	na	na

D.2 Cranial Data (cont.)

GD#	Age	RSinusitis	LSinusitis	Cribra Orbitalia	Cranial Porosity	Cranial Hyperostosis	Osteophytes at ExtAudMeatus Margin	Cranial Depression Fractures
34	OA	na	na	5	2	4.7.1.2	Pres	2.3
35	MA	5.2	6.2	Abs	1	2.1.1.2	Pres	2.3
36a	Y-M	na	na	na	na	na	na	na
37	MA	5.1	1.1	5	1	3.3.1.2	na	2.3
40	YA	na	Fr1.2	5	1	na	na	2.3
40b	YA	na	na	na	na	na	na	na
42	MA	na	na	na	na	na	na	na
1150	YA	na	1.2	na	1	1.1.0.2	Pres	2.3
1150b	A	na	na	na	na	na	na	na
1151-1	MA	na	na	na	na	na	na	na
1151-2	A	na	na	na	na	na	na	na
U1	A	na	na	na	na	na	na	na
U38	Y-M	na	na	na	na	na	na	na
U49	Y-M	na	na	na	na	na	na	na
U59T	YA	na	na	na	na	na	na	na
127T	OA	na	na	na	na	na	na	na
152	Y-M	na	na	na	na	na	na	na
214	MA	na	na	na	na	na	na	na
215	M-O	na	na	na	na	na	na	na
216	M-O	na	na	na	na	na	na	na
247	Y-M	na	na	na	na	na	na	na
341a	OA	na	na	na	na	na	na	na
360	MA	na	na	na	na	na	na	na
370	YA	na	na	na	1	2.1.0.0	na	0.0
387T	MA	na	na	na	na	na	na	na
402a	M-O	na	na	na	na	na	na	na
478	M-O	na	na	na	na	na	na	na
485	M-O	na	na	na	na	na	na	na
489T	MA	na	na	na	na	na	na	na
507	YA	na	na	na	Abs	0.0.0.0	na	0.0
510	Y-M	na	na	na	na	na	na	na
619T	YA	na	na	na	na	na	na	na
662	Y-M	na	na	na	na	na	na	na
855/856	YA	na	na	na	Abs	0.0.0.0	na	2.4

D.2 Cranial Data (cont.)

GD#	Age	RSinusitis	LSinusitis	Cribra Orbitalia	Cranial Porosity	Cranial Hyperostosis	Osteophytes at ExtAudMeatus Margin	Cranial Depression Fractures
864	M-O	na	na	na	na	na	na	na
876	Y-M	na	na	na	na	na	na	na
1113	M-O	na	na	na	na	na	na	na
1140	Y-M	na	na	na	na	na	na	na
1163T	MA	na	na	na	na	na	na	na
1213T	MA	na	na	na	na	na	na	na
1388	MA	na	na	na	na	na	na	na
1483/1484	M-O	na	na	na	na	na	na	na
1512	M-O	na	na	na	na	na	na	na
1527	Y-M	na	na	na	na	na	na	na
1534	Y-M	na	na	na	na	na	na	na
1547	M-O	na	na	na	na	na	na	na
1581	Y-M	na	na	na	na	na	na	na
1596	Y-M	na	na	na	na	na	na	na

D.3 Infracranial Changes in Bone Morphology

GD#	Age	Harris' Lines	Overall Enthesis Development	Enthesopathy	Bone Formation and Loss	Non-Spinal Osteoarthritis	Marginal Lipping	Subchondral Pitting	Eburnation
7	0-4 wk pp	Abs	Abs	Abs	Abs	na	na	na	na
1506/1507	0-4 wk pp	Abs	Abs	Abs	na	na	na	na	na
1519	0-4 wk pp	Abs	Abs	Abs	na	na	na	na	na
1485	0-4 wk pp	Abs	Abs	Abs	na	na	na	na	na
37a	0-4 wk pp	Abs	Abs	Abs	na	na	na	na	na
187	4.5-5.5 wk pp	na	na	na	na	na	na	na	na
12	0-2 mo	Abs	Abs	Abs	Abs	na	na	na	na
27/26a	Neonate	Abs	Abs	Abs	Abs	na	na	na	na
1a	0-2mo	na	na	Abs	Abs	na	na	na	na
468b	4.5-5.5 wk pp	Abs	Abs	Abs	na	na	na	na	na
1150a	4.5-5.5 wk pp	na	na	na	na	na	na	na	na
1153	4.5-5.5 wk pp	Abs	Abs	Abs	Abs	na	na	na	na
21	3-4 mo	Abs	Abs	Abs	Abs	na	na	na	na
1484	1-3 mo	Abs	Abs	Abs	na	na	na	na	na
1547	2-6mo	na	na	na	na	na	na	na	na
228	~6 mo	Pres	Abs	Abs	na	na	na	na	na
32	6-9mo	Abs	Abs	Abs	Abs	na	na	na	na
25	12 mo	Abs	Abs	Abs	Abs	na	na	na	na
29a	12-18 mo	Abs	Abs	Abs	Abs	na	na	na	na
36	12-18 mo	na	na	na	na	na	na	na	na
1218	12-18 mo	Abs	Abs	Abs	Abs	na	na	na	na
486	12-18 mo	na	na	na	na	na	na	na	na
1527	12-18 mo	na	na	Abs	na	na	na	na	na
1b	12-18 mo	na	na	Abs	na	na	na	na	na
14a	~2 yr	Abs	Abs	Abs	Abs	na	na	na	na
39	1.3-2.5 yr	Abs	Abs	Abs	Abs	na	na	na	na
30a	2yr	Abs	Abs	Abs	Abs	na	na	na	na
26b	2-2.5 yr	na	na	na	na	na	na	na	na
38	2.5-3 yr	Abs	Abs	Abs	Abs	na	na	na	na
14b	3.2-4.1 yr	Pres	Abs	Abs	Abs	na	na	na	na
1	3.5-4.5 yr	Pres	Abs	Abs	Abs	na	na	na	na
31b	<5 yr	na	na	na	Abs	na	na	na	na

D.3 Infracranial Changes in Bone Morphology **(cont.)**

GD#	Age	Harris' Lines	Overall Enthesis Development	Enthesopathy	Bone Formation and Loss	Non-Spinal Osteoarthritis	Marginal Lipping	Subchondral Pitting	Eburnation
1445	5.4 yr	na	na	na	na	na	na	na	na
2	6-7 yr	Pres	Abs	0.0	Abs	na	na	na	na
16	5.5-7.5 yr	Pres	Abs	0.0	Abs	na	na	na	na
13c	5-9 yr	na	Abs	0.0	na	na	na	na	na
578	6-9yr	na	na	na	na	na	na	na	na
505	7-10yr	na	na	na	na	na	na	na	na
1530	8-10 yr	na	na	na	na	na	na	na	na
1078	8-10yr	na	na	na	na	na	na	na	na
18	8-10 yr	na	na	na	na	na	na	na	na
788	9-10yr	na	na	na	na	na	na	na	na
10	8.6-9.6 yr	Pres	Abs	1.0	Abs	Abs	Abs	Abs	Abs
23a	10.5-12 yr	na	na	0.0	na	na	na	na	na
341	>12yr	na	na	na	na	na	na	na	na
1151-3	<14-16yr	na	Abs	0.0	na	na	na	na	na
478	<14-16yr	na	Abs	0.0	na	na	na	na	na
13	13-18 yr	Pres	Abs	1.0	na	Abs	Abs	Abs	Abs
15	15 yr	Abs	2	2.0	Abs	Abs	Abs	Abs	Abs
17	13.5 yr	Pres	Abs	0.0	Abs	Abs	Abs	Abs	Abs
41	16-19 yr	Abs	1	0.0	Abs	Abs	Abs	Abs	Abs
3a	YA	na	Abs	0.0	0.0	Abs	Abs	Abs	na
4	MA	Abs	2	1	0.0	3	1	3	Abs
6	YA	na	na	na	na	na	na	na	na
#8/#9	YA	na	na	na	0.0	Abs	Abs	Abs	Abs
11	MA	na	na	na	na	na	na	na	na
13a	MA	Abs	Abs	Abs	0.0	Abs	Abs	Abs	Abs
13bT	YA	na	na	na	na	na	na	na	na
19	M-O	na	na	na	na	na	na	na	na
20	YA	Abs	3	3	0.0	Abs	Abs	Abs	Abs
22	OA	Abs	3	2	0.0	1	1	Abs	Abs
23	YA	Abs	1	2	8.0	Abs	Abs	1	Abs
24	Y-M	na	2	2	0.0	Abs	Abs	Abs	Abs
28	M-O	na	2	Abs	0.0	1	1	Abs	Abs
29	M-O	na	2	2	0.0	3	1	3	Abs
30	OA	Abs	Abs	Abs	0.0	Abs	Abs	Abs	Abs
31	MA	Abs	3	3	0.0	3	1	3	Abs
33	Y-M	Abs	Abs	Abs	8.0	1	1	Abs	Abs

D.3 Infracranial Changes in Bone Morphology **(cont.)**

GD#	Age	Harris' Lines	Overall Enthesis Development	Enthesopathy	Bone Formation and Loss	Non-Spinal Osteoarthritis	Marginal Lipping	Subchondral Pitting	Eburnation
34	OA	Pres	2	Abs	Pres	3	3	3	Abs
35	MA	na	na	na	na	na	na	na	na
36a	Y-M	na	1	Abs	0.0	Abs	Abs	Abs	Abs
37	MA	na	3	3	0.0	3	3	na	3
40	YA	Pres	Abs	Abs	0.0	Abs	Abs	Abs	Abs
40b	YA	na	Abs	Abs	0.0	3	Abs	3	Abs
42	MA	na	na	na	na	na	na	na	na
1150	YA	na	1	Abs	0.0	3	1	3	Abs
1150b	A	na	na	na	na	na	na	na	na
1151-1	MA	na	1	1	0.0	1	1	1	Abs
1151-2	A	Abs	3	3	na	na	na	na	na
U1	A	na	Abs	Abs	0.0	na	na	na	na
U38	Y-M	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs
U49	Y-M	na	2	Abs	0.0	Abs	Abs	Abs	Abs
U59T	YA	na	na	na	na	na	na	na	na
127T	OA	na	na	na	na	na	na	na	na
152	Y-M	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs
214	MA	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs
215	M-O	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs
216	M-O	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs
247	Y-M	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs
341a	OA	na	na	na	0.0	Abs	Abs	Abs	Abs
360	MA	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs
370	YA	na	Abs	Abs	0.0	na	na	na	na
387T	MA	na	na	na	na	na	na	na	na
402a	M-O	na	Abs	Abs	0.0	Abs	Abs	Abs	na
478	M-O	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs
485	M-O	na	1	Abs	0.0	Abs	Abs	Abs	Abs
489T	MA	na	na	na	na	na	na	na	na
507	YA	na	Abs	Abs	0.3	Abs	Abs	Abs	Abs
510	Y-M	na	1	Abs	0.0	Abs	Abs	Abs	Abs
619T	YA	na	na	na	na	na	na	na	na
662	Y-M	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs
855/856	YA	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs

D.3 Infracranial Changes in Bone Morphology (cont.)

GD#	Age	Harris' Lines	Overall Enthesis Development	Enthesopathy	Bone Formation and Loss	Non-Spinal Osteoarthritis	Marginal Lipping	Subchondral Pitting	Eburnation
864	M-O	na	1	Abs	0.0	Abs	Abs	Abs	Abs
876	Y-M	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs
1113	M-O	na	Abs	Abs	0.0	Abs	Abs	2	Abs
1140	Y-M	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs
1163T	MA	na	na	na	na	na	na	na	na
1213T	MA	na	na	na	na	na	na	na	na
1388	MA	na	na	na	na	na	na	na	na
1483/1484	M-O	na	Abs	Abs	5.0	Abs	Abs	Abs	Abs
1512	M-O	na	2	Abs	0.0	Abs	Abs	Abs	Abs
1527	Y-M	na	1	Abs	0.0	1	1	1	Abs
1534	Y-M	na	1	Abs	0.0	Abs	Abs	2	Abs
1547	M-O	na	Abs	Abs	0.0	Abs	Abs	Abs	Abs
1581	Y-M	na	1	Abs	0.0	Abs	Abs	Abs	Abs
1596	Y-M	na	2	Abs	0.0	Abs	Abs	Abs	Abs

D.4 Vertebral Lesions

GD#	Age	Spinal Osteoarthritis	Vertebral Facet Lipping	Vertebral Facet Pitting	Vertebral Body Lipping	Ligamenta Flava Osteophytes	Spondyloosis	Healed Bone Fractures
7	0-4 wk pp	na	0	na	na	na	na	na
1506/1507	0-4 wk pp	na	na	na	na	na	na	na
1519	0-4 wk pp	na	na	na	na	na	na	na
1485	0-4 wk pp	na	na	na	na	na	na	na
37a	0-4 wk pp	na	na	na	na	na	na	na
187	4.5-5.5 wk pp	na	na	na	na	na	na	na
12	0-2 mo	na	0	na	na	na	na	na
27/26a	Neonate	na	0	na	na	na	na	na
1a	0-2mo	na	na	na	na	na	na	na
468b	4.5-5.5 wk pp	na	na	na	na	na	na	na
1150a	4.5-5.5 wk pp	na	na	na	na	na	na	na
1153	4.5-5.5 wk pp	na	na	na	na	na	na	na
21	3-4 mo	na	0	na	na	na	na	na
1484	1-3 mo	na	na	na	na	na	na	na
1547	2-6mo	na	na	na	na	na	na	na
228	~6 mo	na	na	na	na	na	na	na
32	6-9mo	na	0	na	na	na	na	na
25	12 mo	na	0	na	na	na	na	na
29a	12-18 mo	na	na	na	na	na	na	na
36	12-18 mo	na	0	na	na	na	na	na
1218	12-18 mo	na	na	na	na	na	na	na
486	12-18 mo	na	na	na	na	na	na	na
1527	12-18 mo	na	na	na	na	na	na	na
1b	12-18 mo	na	na	na	na	na	na	na
14a	~2 yr	na	0	na	na	na	na	na
39	1.3-2.5 yr	na	0	na	na	na	na	na
30a	2yr	na	na	na	na	na	na	na
26b	2-2.5 yr	na	0	na	na	na	na	na
38	2.5-3 yr	na	0	na	na	na	na	na
14b	3.2-4.1 yr	na	na	na	na	na	na	na
1	3.5-4.5 yr	na	0	na	na	na	na	na
31b	<5 yr	na	na	na	na	na	na	na

D.3 Vertebral Lesions (cont.)

GD#	Age	Spinal Osteoarthritis	Vertebral Facet Lipping	Vertebral Facet Pitting	Vertebral Body Lipping	Ligamenta Flava Osteophytes	Spondyloosis	Healed Bone Fractures
1445	5.4 yr	na	na	na	na	na	na	na
2	6-7 yr	na	Abs	na	na	na	na	na
16	5.5-7.5 yr	na	Abs	na	na	na	na	na
13c	5-9 yr	na	na	na	na	na	na	na
578	6-9yr	na	na	na	na	na	na	na
505	7-10yr	na	na	na	na	na	na	na
1530	8-10 yr	na	na	na	na	na	na	na
1078	8-10yr	na	na	na	na	na	na	na
18	8-10 yr	na	na	na	na	na	na	na
788	9-10yr	na	na	na	na	na	na	na
10	8.6-9.6 yr	Abs	Abs	Abs	Abs	Abs	Abs	Abs
23a	10.5-12 yr	na	na	na	na	na	na	na
341	>12yr	na	na	na	na	na	na	na
1151-3	<14-16yr	na	na	na	na	na	na	na
478	<14-16yr	na	na	na	na	na	na	na
13	13-18 yr	na	na	na	na	na	na	Abs
15	15 yr	Abs	Abs	Abs	Abs	Abs	Pres	Pres
17	13.5 yr	Abs	Abs	Abs	Abs	Abs	Abs	Abs
41	16-19 yr	Abs	Abs	Abs	Abs	Abs	Abs	Abs
3a	YA	Abs	Abs	Abs	Abs	na	na	Abs
4	MA	3	1	3	na	1	Abs	Abs
6	YA	na	na	na	na	na	na	na
#8/#9	YA	na	na	na	na	na	na	na
11	MA	na	na	na	na	na	na	na
13a	MA	2	1	2	Abs	Abs	Abs	Abs
13bT	YA	na	na	na	na	na	na	na
19	M-O	na	na	na	na	na	na	na
20	YA	1	1	Abs	Abs	2	Abs	Abs
22	OA	1	1	Abs	1.1.1	Abs	Abs	Abs
23	YA	Abs	Abs	Abs	2.1.1	2	na	Abs
24	Y-M	na	na	na	na	na	na	Abs
28	M-O	1	1	Abs	Abs	3	Abs	Abs
29	M-O	3	1	3	Abs	2	Abs	Abs
30	OA	Abs	Abs	Abs	Abs	3	Abs	Abs
31	MA	4	1	4	5.3.1	3	Abs	Abs
33	Y-M	na	na	na	9.9.1	2	na	Abs

D.3 Vertebral Lesions (cont.)

GD#	Age	Spinal Osteoarthritis	Vertebral Facet Lipping	Vertebral Facet Pitting	Vertebral Body Lipping	Ligamenta Flava Osteophytes	Spondyloosis	Healed Bone Fractures
34	OA	1	1	Abs	Abs	2	Abs	Yes
35	MA	Abs	Abs	Abs	na	na	na	na
36a	Y-M	na	na	na	na	na	na	Abs
37	MA	na	na	na	1.3.3	na	Abs	Abs
40	YA	1	Abs	1	Abs	Abs	Abs	Abs
40b	YA	na	na	na	na	na	na	Abs
42	MA	na	na	na	na	na	na	na
1150	YA	Abs	Abs	Abs	Abs	1	na	na
1150b	A	na	na	na	na	na	na	na
1151-1	MA	na	na	na	na	na	na	Abs
1151-2	A	na	na	na	na	na	na	Abs
U1	A	na	na	na	na	na	na	Abs
U38	Y-M	na	na	na	na	na	na	Abs
U49	Y-M	na	na	na	na	na	na	Abs
U59T	YA	na	na	na	na	na	na	na
127T	OA	na	na	na	na	na	na	na
152	Y-M	na	na	na	na	na	na	na
214	MA	na	na	na	na	na	na	Abs
215	M-O	na	na	na	na	na	na	Abs
216	M-O	na	na	na	na	na	na	Abs
247	Y-M	na	na	na	na	na	na	Abs
341a	OA	na	na	na	na	na	na	Abs
360	MA	na	na	na	na	na	na	Abs
370	YA	na	na	na	na	na	na	Abs
387T	MA	na	na	na	na	na	na	na
402a	M-O	na	na	na	na	na	na	Abs
478	M-O	na	na	na	na	na	na	Abs
485	M-O	na	na	na	na	na	na	Abs
489T	MA	na	na	na	na	na	na	na
507	YA	na	na	na	na	na	na	Abs
510	Y-M	na	na	na	na	na	na	Abs
619T	YA	na	na	na	na	na	na	na
662	Y-M	na	na	na	na	na	na	Abs
855/856	YA	na	na	na	na	na	na	Abs

D.3 Vertebral Lesions (cont.)

GD#	Age	Spinal Osteoarthritis	Vertebral Facet Lipping	Vertebral Facet Pitting	Vertebral Body Lipping	Ligamenta Flava Osteophytes	Spondyloosis	Healed Bone Fractures
864	M-O	na	na	na	na	na	na	Abs
876	Y-M	na	na	na	na	na	na	Pres
1113	M-O	na	na	na	na	na	na	Abs
1140	Y-M	na	na	na	na	na	na	Abs
1163T	MA	na	na	na	na	na	na	na
1213T	MA	na	na	na	na	na	na	na
1388	MA	na	na	na	na	na	na	na
1483/1484	M-O	na	na	na	na	na	na	Abs
1512	M-O	na	na	na	na	na	na	Abs
1527	Y-M	na	na	na	na	na	na	Abs
1534	Y-M	na	na	na	na	na	na	Abs
1547	M-O	na	na	na	na	na	na	Abs
1581	Y-M	na	na	na	na	na	na	Abs
1596	Y-M	na	na	na	na	na	na	Abs

Appendix E: Radiocarbon Determinations for Ganj Dareh

Level	Laboratory[3]	Age (Radiocarbon Years BP)
A[2]	B-108238	8780 ± 50
B[1]	P-1486	8890 ± 100
B[2]	B-108239	8930 ± 50
B[2]	B-108240	8780 ± 50
B[2]	B-108241	8720 ± 50
B[2]	B-108242	8940 ± 50
C[1]	P-1485	9240 ± 200
C[2]	B-108243	8920 ± 50
D[1]	P-1484	8970 ± 100
D[2]	B-108244	8840 ± 50
D[2]	B-108245	8940 ± 50
D/E	GaK-994	8910 ± 170
E[1]	SI-922	8570 ± 310
E[1]	SI-923	8630 ± 200
E[1]	SI-924	8640 ± 90
E[1]	SI-925	8340 ± 80
E[1]	GaK-807	10,400 ± 150
E[2]	B-108246	8870 ± 50
E[2]	B-108247	8830 ± 50
E[2]	B-108248	8900 ± 50
E[2]	B-108249	8840 ± 50

1 Hole (1987), Voigt and Dyson (1992). Conventional radiocarbon dates from charcoal.
2 Zeder and Hesse (2000). AMS radiocarbon dates from goat bone collagen.

3

	Radiocarbon Dating Laboratory
B	Beta Analytic
GaK	Gakushuin University
P	University of Pennsylvania
SI	Smithsonian Institution