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The maize from Black Dog Cave: Testing the concept of races of maize in the American Southwest

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THE MAIZE FROM BLACK DOG CAVE:

TESTING THE CONCEPT OF RACES

OF MAIZE IN THE AMERICAN

SOUTHWEST

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ABSTRACT

The Maize From Black Dog Cave: Testing the Concept of Races of Maize in the American Southwest

by

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Maize cobs from Black Dog Cave, a Virgin Anasazi Cave site near modern Moapa, Nevada, were measured for twelve morphological characters. Plants, ears, and tassels from living maize plants grown for this study at Las Vegas, Nevada were measured and compared quantitatively to four sets of data: the maize from the cave, a mathematical synthesis of archaeological maize from sites all over the American Southwest, quantifications defining living maize races of the Southwest, and statistics from isozyme studies. Comparisons of all data indicate: the Virgin Anasazi raised the flinty Onaveno variant of Basketmaker maize; maize grows differently and environmental selection is extremely strong in the hot, lowland Southwest; new descriptive measurements presented here define the Southwest maize races Pueblo and Pima-Papago for the first time; a Basketmaker II Anasazi presence is established in the desert lowlands; and the maize race Pepitilla is the probable ancestor of Fremont Dent maize.

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CHAPTER 1

PROBLEMS, METHODS, QUESTIONS, AND HYPOTHESES

INTRODUCTION

This thesis is the first attempt to analyze archaeological maize from a Virgin Anasazi site. Until this study, very little has been known about maize from the Pueblo or pre-Puebloan occupations of the Virgin Anasazi cultural area. The goals of this thesis are extensive and involve the testing of a significant amount of data compiled by myself and by others. The purposes of this research are as follows: to discover what type or types of maize the Virgin Anasazi (of the Basketmaker II through Pueblo period) raised in their fields; to investigate the probability of a Basketmaker II presence at Black Dog Cave; to test the validity of the concept of races of maize through the comparison of morphological studies of maize with isozyme studies; to test the numerically descriptive definitions of the races of maize of the Southwest; and to investigate the factors of environmental and human selection acting on maize grown in the lowland, desert climate of the Southwest. Given the vast amount of data generated and the test results, the conclusions of this research project increase our knowledge of Virgin Anasazi maize and our understanding of the maize of the prehistoric and contemporary Southwest: comparisons of isozyme studies with morphological studies conducted on living samples of maize reinforce the validity of the concept of races of maize; the Virgin Anasazi raised maize of the races Onaveno and Basketmaker (both variants of the race Pima-Papago); a Baskemaker II

presence is established at Black Dog Cave through radiocarbon dating and morphological studies; new numerical calculations presented here define for the first time the indigenous Southwest maize races Pueblo and Pima-Papago; factors of environmental selection affecting maize are extremely strong in the lowland, desert Southwest, perhaps stronger than human selective factors; and comparisons of isozyme studies with morphological studies and archaeological data indicate that maize belonging to the race Pepitilla was the probable ancestor of Fremont Dent maize.

The Virgin Anasazi people were the westernmost residents of the prehistoric Anasazi who inhabited much of the northern Southwest in pre-contact times. The Anasazi were known to have been agriculturists, who cultivated domesticated maize, beans, and squash, and supplemented their diet with diverse native flora and fauna that varied through time and space (Harrington 1930, 1942; Lyneis 1995; Schroeder 1953; Shutler 1961). This thesis concentrates on one of these food resources: maize, excavated at Black Dog Cave, a site located in the lowlands of the Moapa Valley on the Muddy River, Clark County, Nevada. The cave was excavated in 1942 by Bradley Stuart, Mark Harrington, and S. M. Wheeler (Lyneis 1997; Wheeler 1942). The cultural remains, including maize, are currently housed at the Southwest Museum in Los Angeles, and the Nevada State Museum in Carson City. The Nevada State Museum holds by far the greater amount of maize collected from the site, and all the maize samples analyzed in this project are from that collection.

Black Dog Cave is an interesting site, and it is difficult to understand why its collections have been ignored by researchers for so long. Preservation of cultural materials was excellent because of the extremely dry climate, and because of protection from the weather afforded by the cave. Perishable materials (including yucca fibers, maize remains, squash parts and seeds, beans, cotton fragments) wooden articles, sandals and basketry were recovered during the excavation.

This thesis concerns the maize from Black Dog Cave: What kinds of maize did the Virgin Anasazi raise? How old is the maize, and did it change over time? Was Virgin Anasazi maize more similar to maize raised by the contemporary Anasazi at higher altitudes on the Colorado Plateaus of Arizona and New Mexico, or was it more like that of the contemporary Hohokam living in desert lowlands? What evolutionary mechanisms selected more strongly for change in Virgin Anasazi maize, cultural selection or environmental selection? Does maize behave differently in hot, lowland environments than it does in cool highland locations? Does some of the maize from Black Dog Cave support a Basketmaker II presence there?

The methods used in this thesis to answer these questions fall into two separate studies, the results of which, when taken together, should explain more about the Black Dog maize than could be gained by a simple morphological analysis. First, a morphological analysis of fifty-five maize cobs and several individual kernels from the site was conducted. Each piece was described, photographed, and measured for twelve morphological characters. The function of the measurements of the twelve characters is to identify individual samples of maize mathemetically; the resulting data is used comparatively in this study of maize. Second, an experimental study was conducted to study 23 varieties of maize genetically related to prehistoric Southwest maize. Plants of these varieties of maize were grown in an experimental plot a few miles from Black Dog Cave, at Las Vegas, Nevada. This was undertaken in a very similar climate and altitude, and under conditions as close as possible, to the conditions under which prehistoric agriculture once took place at the site. The maize cobs from the experimental crop were measured for the same twelve morphological characters as the archaeological material from the cave. Also, the leafy parts of the plants were measured for 28 vegetative characters, and compared to analogous data taken in the 1950s, at high altitudes in Mexico (Wellhausen et al. 1952) that were used to define the concept of "races" of maize. Photographs were taken of both cobs and plants grown for the experiment. The aim of

this part of the study was to see if climate, altitude, photoperiod, evapotranspiration, heat and drought influence the growth of maize plants causing noticeable differences in measurements that vary from the widely-used, prescribed concepts of races of maize formulated from the Mexican data.

Traditionally, studies of Southwest archaeological maize have been based upon the study of morphology of cobs and kernels, which are usually the best-preserved and most frequently recovered maize remains. This study aims to expand the general body of knowledge of Southwest maize to incorporate an understanding of how the plants themselves behave (and behaved in prehistoric times) under local environmental conditions of the American Southwest.

“RACES” OF MAIZE

The concept of races of maize was established in the 1940s by Edgar Anderson and Hugh Cutler (1942:71) who considered it thus: "...we shall define the word race as loosely as possible, and say that a race is a group of related individuals with enough characteristics in common to permit their recognition as a group." Anderson and Cutler intended to assign maize samples or varieties to race based upon their having several genes or clusters of genes in common. Races of maize were meant to be thought of as peaks or groupings of genes in the massive sea of variability and mutability that is present in maize. They defined four races of maize existing in the contemporary Southwest: "Pueblo," with large, straight-rowed cobs, big shanks and a variety of colors; “Intermediate Pueblo”; “Intermediate Pima-Papago” with some affinities to the intermediate Pueblo type; and "Pima-Papago,” with slightly tapering cobs, a variation in seed-shape, and kernels usually colored white or yellow. The geographic center of variation of Pueblo types was thought to be in the eastern Southwest, and the center of variation for Pima-Papago types was thought to be located in the western Southwest (Anderson and Cutler 1942:84-85).

The concept of race was further developed in the 1950s by Wellhausen et al. (1952), who carefully measured and described living maize in Mexico and defined several races, some of which were thought to be ancestral to races grown in the American Southwest. Since then, researchers of archaeological maize have elaborated on these racial designations of prehistoric maize in the region, so that today, over fifteen races of maize have been described for various locations and time periods in the prehistoric Southwest.

Winter (1983) has criticized the use of the concept of race in application to prehistoric maize in the Southwest, and prefers to work with row number, which he states is a genetically determined condition in maize (Winter 1983:429). He does not recognize the fact, proven by many studies, that moisture stress and photoperiod can also reduce row numbers (Mackey 1983:212-213; Toll et al. 1985:112-115; Sundberg et al. 1995). The problem of row numbers and moisture stress as it applies to both modern, or living, maize, and to archaeological maize, will be examined through the comparison of previously gathered data with data I personally gathered from the experimental crop of maize grown for this study, under the difficult environmental conditions here in the western Southwest. These problems are discussed in Chapters 7 and 9 of this volume.

BLACK DOG CAVE

Black Dog cave was discovered in 1936 by members of the Civilian Conservation Corps. One of the excavators of the cave, S. M. Wheeler, accompanied the men on a return visit to the cave in the spring of 1936. Wheeler returned to find the cave in 1939, but could not find the entrance. The cave was rediscovered in 1942 by Bradley Stuart, who informed S. M. Wheeler, and in 1942 a joint expedition to excavate the site was formed by the State of Nevada and the Southwest Museum of Los Angeles, California.

The cave is situated inside a terrace above the floodplain of the perennial, spring-fed Muddy River. Several pithouses were located on the surface of the terrace, and

one of them has been excavated and dated to Basketmaker II times (Larson 1978). Other pithouses at the site are thought to date to Basketmaker III (Schroeder 1953). The soils of the mesa containing Black Dog Cave are composed of sandstone and clay, overlaid with a layer of cemented gravels (Lyneis 1997:2; Wheeler 1942:3). The cave has four rooms, but only rooms 1 and 2 have been excavated.

During the excavation in the summer of 1942 the excavators found stratigraphy mixed in the south half of room 1, but Wheeler was more confident of the stratigraphy in the north half of room 1 and in room 2 (Wheeler 1942:11). Cultural remains appearing to date from Basketmaker II through Pueblo times and even to the historic period were found in several pits (or cists) in the floor of the cave. Wheeler thought that room 2 contained the earliest pits, and thought that pit #31 (a pit existing under another, presumably later pit) was the oldest one uncovered at the site. Well-preserved maize remains were found in many of the pits, and two samples of maize from pit #31 have recently been radiocarbon dated to Late Basketmaker II times (see pages 164-165 and Figure 25 of this volume).

Wheeler (1942), Harrington (1942:174), and Schroeder (1953:64) believed that objects found at Black Dog Cave indicated the strong possibility of a Basketmaker II presence at the cave. Since the cave was not well-known, and since a Basketmaker II presence at the cave had not been firmly established, Black Dog Cave was not generally considered to have been a part of the area of Anasazi Basketmaker II occupation in archaeological literature of the Southwest. Basketmaker II populations were thought to have existed only in the relatively high altitude Colorado Plateaus of Arizona. Cave Dupont (Nusbaum 1922), and White Dog Cave (Guernsey and Kidder 1921) are diagnostic Basketmaker II sites, and their inhabitants practiced floodwater and dryland maize agriculture, (Matson 1991).

Previous to this thesis, the agricultureof Basketmaker II period Anasazi groups had been solely associated with floodwater or dryland farming on the Colorado Plateaus

(Matson 1991). In the lowland desert climate of the Virgin Anasazi the only method of growing maize was by diversion of flowing water, or in other words, through irrigation. Thus, a Basketmaker II presence here in the lowlands indicates both early Anasazi presence in the Virgin and Muddy Rivers area and a different way of growing crops (through water diversion and irrigation) than has been previously associated with Basketmaker II populations.

To test the hypothesis of a Basketmaker II presence at Black Dog cave, Dr. Margaret Lyneis analyzed a great number of the cultural remains collected from the site. Among the objects she studied that appeared to be of Basketmaker II date were basketry, S-shaped sticks, sandals, and dart points. The actual dates of cultural remains found in Black Dog Cave had been unknown until the samples of maize from Black Dog cave were sent for radiocarbon analysis by Dr. Lyneis during 1997. These early dates (A.D. 258-A.D.294 from sample one at one Sigma, sample number AA 25317 BDC-31-1; and A.D. 248-A.D. 390 for sample two at one Sigma, sample number AA25318 BDC-31-2) firmly establish a Basketmaker II presence at Black Dog Cave.

RESEARCH QUESTIONS

Several questions will be asked of the data collected in the study of both archaeological and living maize. Do maize races behave differently with longer photoperiods (as here in the Southwest), and at lower altitudes, higher temperatures, and higher rates of pan evaporation than they do with shorter photoperiods (as in Mexico), and at high altitudes , moderate temperatures, and lower levels of pan evaporation? How has the original data on maize races affected our perception of the races recognized today? Do maize races behave differently here in the American Southwest than they do in highland Mexico? How valid is the concept of race when applied to archaeological maize? Do isozyme studies reveal much information on prehistoric maize that can be applied to the large database gathered over this century on the archaeological maize of the

Southwest? What race, or suite of races of maize did the Virgin Anasazi grow, and for what characteristics were they artificially selecting? How does Virgin Anasazi maize compare to other Anasazi and Hohokam maize elsewhere in the Southwest? How does Virgin Anasazi maize compare to prehistoric Southwest maize in general?. Does some of the maize found at Black Dog Cave represent Basketmaker II Anasazi?

HYPOTHESES

Several hypotheses were tested by the data collected for this thesis, and were conceived at the inception of this study. First, maize should grow and flower differently in the desert lowland climate of the Virgin Anasazi area than in the highland climates of the Colorado Plateaus and Mexico. Second, Virgin Anasazi maize should be more similar to highland Anasazi maize through time than to lowland Hohokam maize because of cultural rather than environmental selection factors. Third, Virgin Anasazi maize should show a similar level of diversity to the maize raised by other Anasazi living in the highlands, due to cultural reasons. Last, some of the maize from Black Dog Cave should be representative of Basketmaker II Anasazi maize, thus strengthening the case for a Basketmaker II presence in the western lowlands.

ORGANIZATION OF THIS THESIS

The following is a brief summary of the main points of each chapter. Chapter 2 reviews the theoretical frameworks that have been applied to the domestication of plants, the co-evolution of humans and cultivated plants, and the domestication of maize. Theories of the adoption of cultivated plants and the beginnings of agriculture in the Southwest also are discussed. Chapter 3 discusses the development of agriculture in the Greater Southwest, and examines environment, demography, and behavior as it is currently viewed for the prehistoric periods. Chapter 4 looks at the environment, demography, behavior, and archaeology of the lowland Virgin Anasazi, with an emphasis

given to the local climate, patterns of storage and reciprocity, trade, and agricultural tools and technology. Chapter 5 is a summary of general Virgin Anasazi subsistence, including diet, possible agricultural and resource scheduling, maize diets and health, and an examination of maize cultivation and selection behaviors in the ethnographic Southwest. Chapter 6 presents the data taken from the maize excavated at Black Dog Cave, with numerical quantifications and photographs, and a discussion of the site. Chapter 7 presents the data from the growing and testing of samples of modern, living races of maize that either have descendance from prehistoric Southwest maize, or are thought to be closely related to prehistoric races. Comparisons are made between the data taken from the experimental crop grown in Las Vegas, Nevada, and data taken from maize grown in high altitude conditions in Mexico in the 1950s that were used to define the races of maize. Chapter 8 is a synthesis of prehistoric Southwest maize, with measurement and classification information taken from archaeological maize excavated all over the Southwest, gathered from data taken by a large number of researchers over most of the Twentieth Century. Chapter 9 is a discussion of the comparison of the maize excavated at Black Dog Cave, and the results of the experimental plots of maize; a discussion of the validity of the concept of races of maize; and a comparison of the Black Dog maize with other Anasazi maize and prehistoric Southwest maize in general. Finally, the hypotheses presented in Chapter 1 are addressed, and questions are presented that address future research.

CHAPTER 2

AGRICULTURE AND THE AMERICAN SOUTHWEST

The development of agriculture in the prehistoric Southwest is a complex and extensively studied phenomenon. Anthropological theory has been an important component in the explanation of agriculture in Southwest prehistory, and has addressed intriguing problems such as the human manipulation and domestication of plants (Darwin 1875; Rindos 1989), co-evolution of plants and humans (Rindos 1989), human practices of selection (Harris and Hillman 1989), and ecological interaction between humans and plants Harris 1989).

Darwinian evolutionary theory is directed toward explaining biological changes in plants, and cultural evolutionary theory attempts to explain changes in human social and economic structures due to the domestication of, or adoption of, previously domesticated plants. Both of these theoretical bases have been applied to the Southwest by various scholars. The large body of theory combined with extensive archaeological data have been used to construct several models explaining the introduction of cultivated plants, including maize, into Southwest cultures, and to explain the evolution of agricultural adaptations in the region. Using empirical information available concerning demography, environment, cultural and behavioral factors, and the remains of cultivated plants, with the employment of theoretical positions, we can formulate multifaceted views of prehistoric Southwest agriculture that explain the probabilities of the past as fully as possible.

AGRICULTURAL THEORY, CO-EVOLUTION AND DOMESTICATION

In the broadest sense agriculture can be defined as an interaction between humans and plants in which the forces of human plant selection combine with evolutionary forces of natural selection to result in an ongoing "co-evolution" of plants and animals (Darwin 1875; Rindos 1989). In this view, the processes of human culture are looked upon as a part of nature, with "cultural selection" acting upon human populations as an evolutionary force working in conjunction with the over-arching evolutionary processes of Darwinian natural selection, which act upon both humans and plants. This combined theory applies to human interaction with animal species as well as plant species. Human selection of plants and animals is viewed as a cultural act that affects the evolution of the species being selected, and in turn, and over time, affects the humans themselves, as they further adapt to the domesticated products of their selective practices.

The beginnings of this theory originated with Darwin. His theory of natural selection holds that "...those...individuals which are best fitted for the complex, and in the course of ages changing conditions to which they are exposed, generally survive to procreate their kind" (Darwin 1875). Darwin described three types of selection: methodical selection, which is "...selection to a model of a predetermined standard;" unconscious selection, "...man's naturally preserving the most valued and destroying the least valued without intending to alter the breed;" and natural selection, which is described above.

Selection of plants by humans is a process as old as the human species, and is embedded in feeding behavior (Harris 1989). It is the degree to which selection affects the environment and plants themselves that has changed over time, and this has intensified significantly with the explosion of human populations and the emergence of sedentary cultures practicing food production over the last 10,000 years. The intensified selection that has created domesticated plants (and animals) has changed the evolution of those

species over time, and has affected the evolution of humans as well. Harris and Hillman (1989) have described the cultural process of selection of domesticated plants in evolutionary terms: "We regard human exploitation of plant resources as a global evolutionary process which, in different regions at varying times in the past, incorporated the beginnings of cultivation and crop domestication" (Harris and Hillman 1989:2). This process of the evolutionary change of both humans and the plants they grow, and selection of certain traits over time has been termed "co-evolution" (Rindos 1989:37).

In a broad sense, the adoption of maize by the peoples of the Southwest in the Late Archaic period, and the subsequent changes in human culture and maize itself over the next three millennia, can be viewed as an example of the co-evolution of humans and plants. Though human populations in the Southwest remained mobile for at least a thousand years after the introduction of maize, there was a great deal of change and acceleration in culture and in the evolution of maize after populations became more sedentary in the Southwest. This aspect of the study of maize in the prehistoric American Southwest is addressed in chapters 3, 8 and 9 of this volume.

THE ORIGINS OF AGRICULTURE

The term "food production" is used as synonymous with "agriculture" by many authors (Binford 1968; Braidwood 1960; Flannery 1969; Harris 1989). Webster's New Dictionary (1975) defines agriculture as "field + cultivation," and horticulture as "garden + culture." The term horticulture has been used in literature to refer to small-scale gardening, especially when discussing root crops, and the use of wild and cultivated plants in combination in gardens. The term "agriculture" is most frequently used to refer to field cultivation of domesticated crops, and is the term usually used to refer to the food production practiced in the prehistoric Southwest. Throughout this thesis, the term "agriculture" refers to food production practices that were undertaken in the prehistoric

Southwest in general, and in the vicinity of Black Dog Cave, by the Virgin Anasazi who occupied the site.

Early twentieth century models of the origins of agriculture are now viewed as too simplistic to fully explain the variation and complexity now known to be possible in the development of agriculture. Simplistic "prime-mover" models include population pressure (Boserup 1965; Cohen 1977), sedentism (Binford 1969), resource stress and broad spectrum foraging (Flannery 1969), and expansion of plant populations (Henry 1989). Today it is recognized that the development of food production resulted multicausally through all of the above factors to varying degrees.

Multicausal theories of the development of food production often used ethnography as a basis for explanation. Braidwood (1960) thought that agriculture began where plants were extensively collected by hunter-gatherers, and Flannery (1969) believed that a disruption in the human-plant ecological system of seasonal resource scheduling caused one resource to be favored over others through direct manipulation, eventually leading to economic dependency on that resource, and to the domestication of that resource. Ford (1985) pointed out that a population need not be sedentary in order for agriculture to develop, and that "...no complex form of social organization was necessary for the advancement of food production or its diffusion from one culture to another (Ford 1985:14).

Harris (1989) has devised an explanatory model of human and plant interaction that illustrates the increasing output of human energy for a given plot of land in relation to various cultural practices that involve varying degrees of labor output in relation to their respective intensity. The least intensive outlay of labor includes the practices of gathering, collecting, burning, and protective tending of wild plants by hunter-gatherers. More intensive investments of labor in the human manipulation of plants include the replacement of plants through tilling, transplanting, sowing, weeding, harvesting, storage, drainage, and irrigation. The greatest investment of energy involves land clearance, systematic soil

tillage, propagation of genotypic and phenotypic variants (domestication), followed by cultivation of the domesticated crops (Harris 1989:17). This recent theory is a detailed, multicausal explanation of the beginnings of agriculture, based in studies of human behavior. It is a broad evolutionary model in which steps vary according to time, place, and ordering, in which specific activities could potentially overlap.

THE DOMESTICATION OF MAIZE

Certain characteristics in wild plant species have pre-adapted them to cultivation. These include the tendency to be "weedy" and to colonize bare or disturbed soils, the possession of large seeds containing food reserves, and the adaptation to long periods of dormancy between rains, lessening chances of competition with other plants and pre-adapting them to dry storage (Hawkes 1969). These characters are evident in the early domesticated plants of the Near East (wheat, barley, and lentils) and of North America (squash, beans, and maize). Most of the early cultivated crops are also self-pollinating, especially those in the grass family (Zohary and Hopf 1993:16).

The gathering of ripened seeds at a specific time, replanting them, and harvesting them all at once over and over again, in successive generations, is a form of selection that causes changes in the rachis (the part of the plant that the seeds are attached to) of domesticated plants. Because the seeds that are picked are those that are replanted by humans, selection takes place upon the plants that causes the seeds to tend to remain attached to the rachis. This is opposed to the condition (selected for in nature) of having the seeds loosen from the rachis and being spread through the action of shattering, as would occur, and be selected for, in the wild. Cultivation of plants by humans is known to select for a tougher rachis, which causes the seeds to remain on the rachis until harvesting, thus creating a condition of uniform ripening (Zohary and Hopf 1993:17).

Maize, being a type of grass that has been domesticated, is adapted to disturbed soils, and to long periods between rains in its seed form. It has large seeds which possess

significant food reserves, and exhibits a uniform ripening of seeds that are firmly attached to a tough rachis.

THE EVOLUTION OF MAIZE AS A DOMESTICATE

The evolution and origin of maize as a cultivated plant is quite complex and controversial. Researchers, in looking for the ancestors of a domesticated plant, usually search for populations of supposed wild progenitors of the plant in question. Scientists use data from morphology, cytology, and molecular biology, and examine the distribution of wild forms of a plant to determine its geographic zone of domestication. Maize has changed so much from its original wild form that there is disagreement among researchers over its ancestry. One group of researchers (Adams 1977; Dobzhansky 1955; Mangelsdorf and Reeves 1939; Weaver 1972; Willey 1966) follow a theory that maize was descended from an extinct ancestor, a "wild maize." Another opposing view, held by another group of scholars (Beadle 1939, 1972; Galinat 1971, Iltis 1970), believes that maize was descended from a species of annual teosinte, which is found in Mexico.

Recent theories propose that maize originated as a transmutation (a radical change) of distichous (two-ranked) male teosinte spikes into female polystichous (many-ranked) ears (Allen and Iltis 1980; Doebley and Iltis 1984; Iltis 1983, 1987; Sundberg, LaFargue and Orr 1995). Isozyme studies of teosinte and maize have also shown a close relationship between maize (*Zea mays ssp. mays*) and species of wild teosinte from Mexico (*Zea mays ssp. parviglumis*) (Doebley, Goodman and Stuber 1987). In any case, domesticated maize is a much-changed plant from its original ancestor, and if it did evolve from teosinte, domesticated maize represents the most radical sequence of physiological changes known in any plant.

Taxonomically, maize is assigned to the order *Gramineae*, the tribe *Maydeae*, and the genus *Zea* (Sturtevant 1899:7). Doebley and Iltis (1980) have formulated the most

recent classification of the genus *Zea*, with Mexican wild teosinte (*Zea mays ssp. mexicana Schrader)* considered to be the ancestor of cultivated maize (*Zea mays ssp. mays*) (Doebley and Iltis 1980:982).

As maize is classified as a member of the grass family (*Gramineae*) it can be considered as analogous agriculturally and economically to cereal grains of early sedentary populations of the Near East. Maize became a staple in the diets of major prehistoric civilizations of North America, and is extremely important in the diet and economies of civilizations of the Western Hemisphere today (Mangelsdorf 1974:2).

Zohary and Hopf (1992) list the properties exhibited by maize and other cereal grasses that made them attractive and advantageous to domestication by humans. All of these grasses thrive in disturbed soils, all complete their life-cycle in less than a year, most tend to have high nutrient value, their seed can be stored for long periods, their kernels contain starches and proteins, and their yields are usually high (Zohary and Hopf 1992:15). These factors isolate the domesticated grasses from their wild forms, though teosinte pollen is readily accepted by maize (Mangelsdorf 1974:37). This receptiveness to the pollen of a (reasonably) distant ancestor or relative indicates that maize is more subject to the hybridizing influence of its (possible) wild ancestors than are other domesticated grasses.

Zea mays ssp. mays is a highly mutable species. Mutation is a characteristic typical of many domesticated plants, but it is especially pronounced in maize, which displays a great degree of genetic plasticity and variation (Darwin 1875:348; Sturtevant 1899:9; Weatherwax 1954:182). Temperature, altitude, soil moisture and fertility, and photoperiod (day length) all affect maize in various ways, and these genetic factors of plasticity, combined with human selection practices, have caused significant changes in maize over time

Morphologically, the evolutionary changes in maize under domestication, as compared with teosinte, are really quite major. A reduction in the branching of the plants

has occurred, from a many-stemmed plant with scores of tassels and ears (as in teosinte) to a usually single-stemmed plant with one or several ears, and one terminating tassel (Weatherwax 1954:185). The ears have become monstrous, and almost completely non-shattering (though some of the more primitive varieties of maize do expose their seeds when dried on the plant, and easily shatter, as noted from personal experience with some of the living races of maize of the Southwest). The seeds, stems, leaves, ears, and tassels of domesticated maize have all become much larger than they were in teosinte. Both the ear and tassel have spikelets that are more condensed (in the extreme) than teosinte (Doebley and Iltis 1980:982).

Figure 1 is an illustration of both a teosinte plant and maize plant. Shown are evolutionary changes in the shape of the plants from teosinte, on the left, to maize, on the right. The tessellated branches of teosinte have become greatly shortened, as if one teosinte branch has become a complete maize plant with only one tassel, with a reduced number of ears, but an increase in the size of the ears. On the surface, it appears as if selection by humans was strong for larger cobs with more seeds, and a reduced number of stems and leaves.

Figure 2 is an illustration of the changes in the inflorescence of teosinte into maize through selection based on personal observation, and information in Beadle (1980) and Mangelsdorf (1974).

Modern maize was first classified according to its type of kernel, or endosperm, by Sturtevant (1899). He divided maize into six types: pod, pop, flint, flour, dent and sweet (Sturtevant 1899:85). Virtually all of these forms of maize had been developed by Native Americans during the prehistoric period. The vast development of domesticated maize out of teosinte was due to selective practices of Native Americans who, over time, selected for characters in the maize that varied with the time, place, and intended use of the maize that they raised.

Today there are over 300 recognized races, or varietal types, of maize as defined

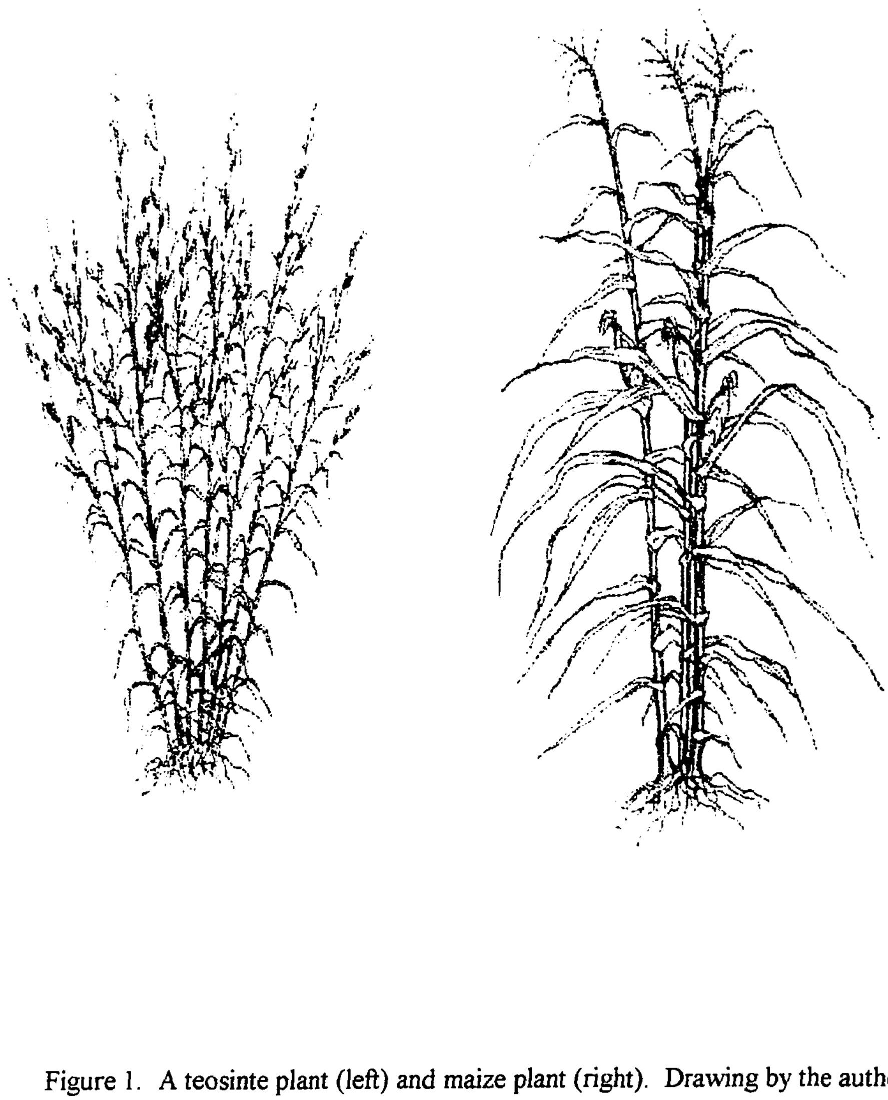

Figure 1. A teosinte plant (left) and maize plant (right). Drawing by the author after personal observation.

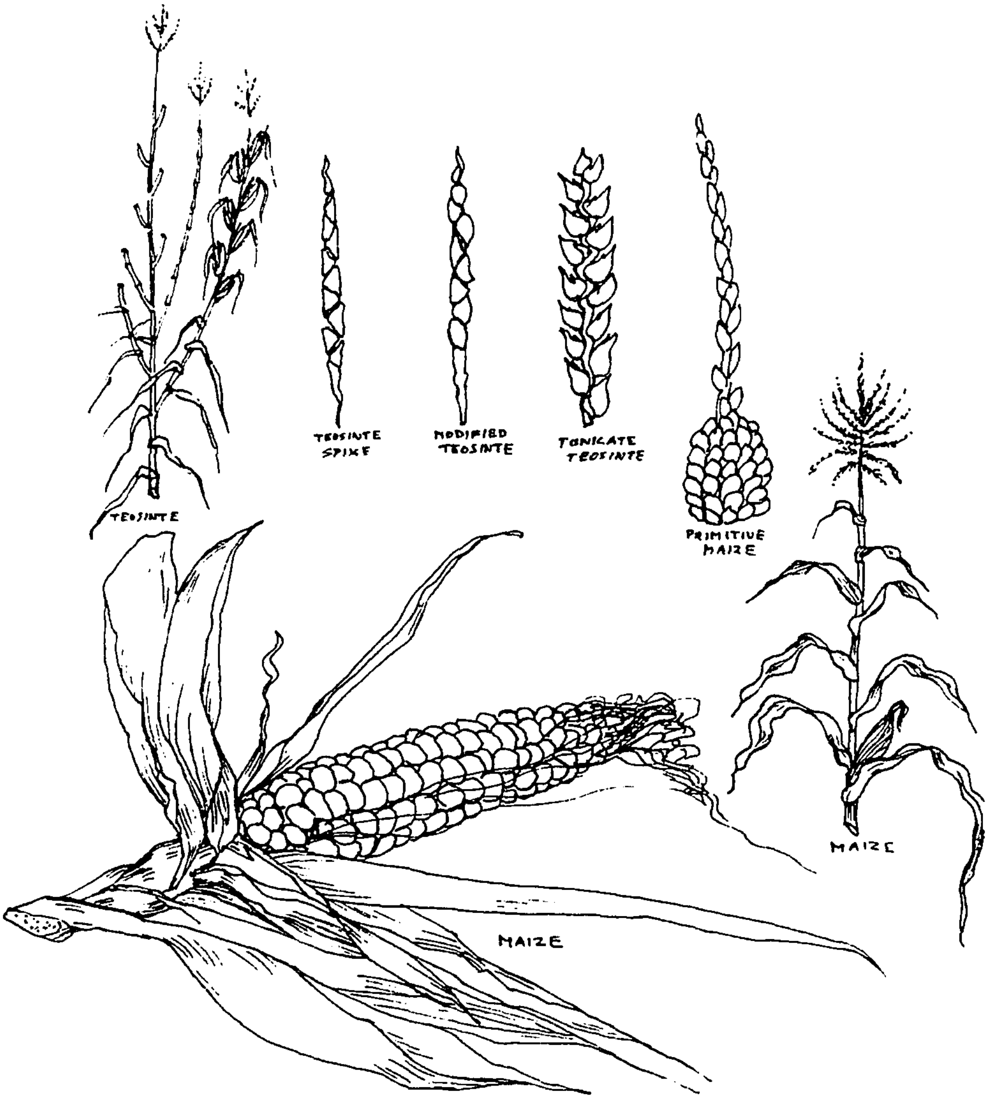

Figure 2. The progressive changes in the inflorescence of annual *Zea*, through human selection, from that of teosinte into that of maize. Based on personal observation, and information in Beadle (1980) and Mangelsdorf (1974).

through research in the 1950s and 1960s (Mangelsdorf 1974:2). In Chapter 7, 8, and 9 an attempt will be made to numerically describe and define the races of maize of both the prehistoric Southwest, and the living races of maize of the Southwest.

In reviewing the characteristics of the maize of Native American cultures of the Southwest, we must caution ourselves not to think of maize in terms of our own contemporary American value system, which places sweet maize (which is eaten in an unripened state) as of the highest value. As far as we have been able to discover about the maize of the prehistoric Southwest, sweet maize was unknown during the pre-contact period. But, what did exist was a tremendous diversity of maize races and varieties.

EARLY MAIZE IN NORTH AMERICA

In North America the center of domestication of maize and other cultigens is thought to have been in the highlands of Mexico. Kent Flannery's excavations at Guila Naquitz rockshelter near Oaxaca reveal a slow development of agriculture in a context of hunter-gatherer populations undergoing climatic and population changes, with squashes as the earliest plants to be domesticated, by 7,000 B.P. (Flannery et al. 1986).

Richard MacNeish's excavations in the Tehuacan Valley unearthed some of the earliest maize known. Originally thought to date to 7,000 B.P., accelerated mass spectrometry studies have shown it to be probably no older than 5,500 B.P. (Fritz 1994; Smiley 1994:176). Chili peppers, avocados, and squash appear to have been used by these populations earlier than maize, and probably reflect the beginnings of the human manipulation of plants in North America. Seed planting and food storage probably began about this time in the area (8,950 B.P. to 6,950 B.P.). Later, in the Coxcatlan phase (6950 B.P. to 5,350 B.P.) maize and bean cultivation began, with seasonal groupings of bands of people at harvest time. Field agriculture is thought to have begun in the Abejas phase (5,350 B.P. to 4,250 B.P.). At the establishment of settled village life, agriculture

assumed a major importance in the diet and economy (MacNeish 1970). It is now generally accepted by scholars that maize was domesticated in Mexico and entered the American Southwest in its domesticated form.

THE ADOPTION OF CULTIGENS IN THE PREHISTORIC SOUTHWEST

As the domestication of indigenous crops and food production is known to have begun in Mesoamerica and then spread to the American Southwest, it is also acknowledged that the situation in Southwest prehistory was one of the adoption of cultivated crops, rather than the domestication of local, native plants in the region. Minnis (1985) has originated terms to describe these differing conditions. "Pristine domestication" refers to the original development of cultivated crop plants in the regions where they were first cultivated. "Primary crop acquisition" refers to the use (or adoption) of previously domesticated crop plants by peoples that did not originate their use. "Secondary domestication" applies to plants that were newly domesticated from native plants by people already practicing cultivation (Minnis 1985:309). Both of the terms "primary crop acquisition" and "secondary domestication" apply to the situation in the Late Archaic prehistoric Southwest, where hunter-gatherers are thought to have added some of the Mesoamerican domesticates to their diet of wild plants and animals through primary crop acquisition (Ford 1985; Irwin-Williams 1973; Minnis 1985; Wills 1988; Wills et al. 1994). The secondary domestication of plants is thought to have occurred later, after adopted cultivated plants had been in use for quite some time. There is a paucity of archaeological specimens indicating any changes in native plants due to domestication in archaeological sites in the Southwest.

The model of primary crop acquisition of cultivated plants by prehistoric peoples of the Southwest had its beginnings with Guernsey and Kidder through their investigation of Basketmaker caves in southern Utah and northern Arizona from 1914 through

1923. Kidder believed that maize cultivation had developed in the Southwest through the adoption of agricultural practices: "At some early time, then, the Southwestern nomads took up the practice of [maize] growing; but at first their agriculture sat lightly upon them; their crops were not of sufficient importance, nor had their methods of cultivation become extensive enough, to tie them very closely to their fields..." (Kidder 1924; reprint 1962:326). Kidder saw the Late Archaic populations of the region as developing into the Basketmaker II culture on the Colorado Plateaus.

Irwin-Williams (1973:9) interpreted the existence of a direct link from Late Archaic hunter-gatherers to the Anasazi of the Pueblo period. She believed them to be the same people, and thought that when the Anasazi of the Armijo phase (1800 B.C. to 800 B.C.) adopted maize agriculture, that food production was a "...secondary rather than a primary focus." The adoption of agriculture increased the predictability of food resources for people living in small bands who participated in larger, seasonal, group aggregations. Population aggregations probably took place at the time of the greatest annual abundance of resources (most likely September on the Colorado Plateaus) (Irwin-Williams 1973:11). The introduction of the technology of cultivation reduced the probabilities of resource stress and gave these people a selective advantage in a cultural evolutionary sense, and raised the ceiling of the human carrying capacity of the environment, and therefore enhanced the adaptiveness of their culture.

With this theoretical view in mind, one might expect immediate, obvious changes in the cultures existing in the Late Archaic Southwest due to the acceptance of cultivated plants, such as increased population growth and sedentism, but actually, the opposite appears to have been the case. Evidence points to a period of nearly 1,000 years of cultivation of maize on the Colorado Plateaus before people became economically dependent on cultivated plants (if radiocarbon dated macrobotanical remains are considered rather than the contextually less reliable pollen dates) (Minnis 1985:310; Simmons 1986:74).

Minnis (1985) sees two models of the acceptance of cultivated plants in the Late Archaic Southwest: one, a model of "necessity" in which native people were pushed by resource stress into cultivation through a need to increase food availability, and another of "opportunity" in which native people were drawn to the cultivation of plants as a means of enhancing the predictability and abundance of their food supply (Minnis 1985:333-334).

W. H. Wills (1988) states that "...the decision to accept domesticated plants by Southwest hunter-gatherers can be understood as a product of selective advantage for enhanced resource predictability" (Wills 1988:2). He points out that the timing of the acceptance of cultivated plants is important because it reveals the socioeconomic context of the adoption of domesticates (Wills 1988:6). The incorporation of cultivated plants into hunter-gatherer economies would have provided the selective advantages of control, predictability, and reduced uncertainty accompanied by greater competitive advantages (Wills 1988:36).

Irwin-Williams (1973), Minnis (1985), Simmons (1986), and Wills (1988, 1994) all share the opinion that agriculture was accepted by native peoples of the Southwest, and this model is the most generally accepted one today among scholars of the prehistoric Southwest.

FOOD PROCUREMENT AND CULTIVATION IN THE LATE ARCHAIC SOUTHWEST

Late Archaic populations in the Southwest certainly had an intimate knowledge of their environment, and a definite awareness of the seasonal availability of important economic plants. It is quite probable that these mobile human groups practiced a seasonal scheduling of movements to facilitate plant procurement in the diverse altitudinal environments of the Southwest.

Kent Flannery (1968) authored a theoretical model of early Mesoamerican

food-collecting that does have some elements in common with what is believed to have occurred among Late Archaic hunter-gatherers in the Southwest. Flannery states that "primitive peoples" usually did not adapt specifically to environmental zones as much as they tended to pursue ways to exploit certain plant and animal species that "cross-cut several environments" (Flannery 1968:66). His model was based on systems theory, with its emphasis on patterns of behavior that generate "negative feedback" and promote equilibrium in the economic system. Conversely, changes in the environment or in behavior are labeled "positive feedback." These cause deviations in the entire system, thus generating a condition of expansion in the system (Flannery 1968:68).

In the Southwest it is evident that certain species of plants and animals that were economically important and exploited over the whole Southwestern ecosystem in the Late Archaic period and later, included the following: *Agave* species; cactus fruits; legumes (such as mesquite and teparies); white-tailed deer; and cottontail rabbits. All of these were exploited generally in Mesoamerica as well (Flannery 1968:70-73). In the Greater Southwest, during the Late Archaic period, walnuts, pinyon nuts, *Chenopodium ssp.*, rice grass, sunflowers, and jackrabbits were also preferred species (Wills 1995:220, 222, 225). Flannery stressed the importance of the seasonal availability of these foods, and the cruciality of the scheduling of human procurement of resources. This involved the employment of group task forces that reported on the availability and quantity of any prospective crop (Flannery 1968:75). The "basic adaptation" was said to be based on the procurement of various foods, and was not to be interpreted as an adaptation to any particular zone. People roved through many diverse environments to gain access to their preferred foods (Flannery 1968:78).

In the ethnographic Southwest (and in Mesoamerica) procurement of famine foods tended to be undertaken by small task forces, "macrobands." This periodic group aggregation and dispersal was beneficial to the cultural acceptance of maize cultivation, because it provided a social pattern that was already in place: that of people grouping

together seasonally. Thus, it was not a great social change to enter into the kind of a seasonal group aggregation that would have been required for the planting and harvesting of cultivated maize.

Wills (1995) built on Flannery's ideas and applied them specifically to the patterns of food procurement and the acceptance of maize, and of other cultivated plants, in the Late Archaic period in the Southwest. In his most recent research, Wills presents the view that the earliest maize use in the Southwest (with dates inferred from pollen dating) occurred about 3500 B. P. (1500 years B. C.) and that economies dependent upon maize cultivation and embracing a sedentary lifestyle appeared about A. D. 500 on the Colorado Plateaus among the Basketmaker II culture (Wills 1995:217). If the inception of maize cultivation took place about 3500 B. P., then there was a period of nearly 2,000 years of the cultivation of plants in the prehistoric Southwest by mobile hunter-gatherers who supplemented their diets with cultivated plants, but who did not depend upon food production for the greater part of their sustenance. This view is in accord with the earlier views of the adoption of maize cultivation, and it appears that a significant length of time passed before peoples of the prehistoric Southwest achieved dependence on food production. Other scholars who have held this view include Kidder (1924), Irwin-Williams (1973), Minnis (1985), Ford (1985), and Simmons (1985).

Wills pointed out that the time of the acceptance of cultivated plants in the (Late Archaic) Southwest, climatically, was one of greater effective moisture. This caused an expansion of surface waters, marshlands, grasslands, and forests between 4000 and 3000 B. P. (Van Devender and Spaulding 1979; Van Devender et al. 1984; Hall 1985; Wills 1995). The abundant moisture available to the ecosystem at the time would have produced a greater abundance of resources for human collecting, and better conditions for agriculture than had before existed.

As have other researchers, Wills (1995) divided the Southwest into three large eco zones: the Southern Basin and Range, the Mogollon Highlands, and the Colorado

Plateaus. The Southern Basin and Range province is more varied and richer in year-round resources than the other two areas, chiefly because of its elevational diversity, which harbors several differing eco zones. Higher altitude areas (within the Upper Sonoran Life Zone) are very productive in autumn, while lower altitude areas (within the Lower Sonoran Life Zone) are consistently productive year-round, and from year to year (Wills 1995:222). The Colorado Plateaus and Mogollon Highlands contain resources adapted to higher altitudes. These resources are primarily available in autumn, while fewer resources are available the rest of the year (Wills 1995:223). The Mogollon Highlands do have more reliable rainfall patterns; thus agriculture would be easier in that region (Cordell 1984:25).

Hunter-gatherers in the Southern Basin and Range area during the Late Archaic seem to have had smaller ranges of resource procurement than did those living on the Colorado Plateaus, most likely due to the greater number of foods available, year round availability, and elevational diversity of the topography which places varying resources in close proximity to one another (Wills 1995:231). Presumably, people living on the Colorado Plateaus would have had to travel farther and wider for sufficient procurement of their dietary needs than the inhabitants of either the Southern Basin and Range or the Mogollon Highlands.

Through his research on the excavations and re-excavations at Bat Cave, and by comparison with other archaeological sites in the Mogollon Highlands, Wills (1994, 1995) formulated the view that the addition of domesticated plants to the economies of hunter-gatherers living in the Mogollon Highlands during the Late Archaic increased the predictability of available resources, and that cultivated plants were adopted in order to enhance and "...maintain existing subsistence strategies" (Wills et al. 1994:307; Wills 1995:242).

Maize remains have been found dating to the Late Archaic period in all three of the large eco zones of the Southwest, and all of the sites have been interpreted as areas of

either seasonal or short-term occupation (Wills 1995:223).

The area of the Southwest in which increased sedentism may have first occurred might be in the lowland valleys of the Southern Basin and Range province. Roth (1993) believed that large storage pits for maize found at the Milagro and San Augustin sites in Arizona may indicate surplus production of maize, and therefore, increased sedentism (Roth 1993:128; Wills 1995:236). Roth interprets a reduction of mobility among Late Archaic groups living along the Santa Cruz River floodplain in Arizona, and "...an emerging dependence on maize at large riverine sites" (Huckell 1990; Roth 1989, 1993:125). The sites along the river have been interpreted as representing small agricultural villages with adjacent resource-procurement areas in the nearby uplands of the mountains. Remains of cultivated plants from these Late Archaic sites have been recovered that date to the period 2800 B. P.-1678 B. P. (Roth 1993:126). Growing conditions would have been excellent for maize cultivation along the floodplains of the river, and Roth has described a trend toward focusing on the occupation of those areas during the Late Archaic period.

Wills (1995) has agreed with the early development of more intensive cultivation in the Southern Basin and Range province of the Southwest in the Late Archaic period. He presents the idea that hunting and gathering parties may have traveled from the lowlands into the highlands of the Colorado Plateaus and Mogollon region from the expanding economies of the lowlands, seeking preferred species of animals and plants (probably deer and pinyon nuts). These foraging parties may have come into competition with human populations living in the highlands at the time. Losing preferred species of plants and animals through the competition of other human groups would have diminished the fitness of human populations living in the highlands. A reduction of the highest ranked available foods would have forced upland populations to increase their consumption of second choice foods, and among those foods were cultivated plants. The increased consumption of maize and other domesticates, with their advantage of a certain degree of predictability,

would have been a prudent economic choices for peoples living in the highlands. This may explain the increasing dependence on maize in early Basketmaker II times (Wills 1995:239-242).

THE SEED ORIENTATION OF EARLY PEOPLES OF THE SOUTHWEST

A reason for the acceptance of and increasing investment of energy in the cultivation of domesticated plants in the Late Archaic Southwest may have been that the peoples living in the region already had an economic and social orientation to the use of seeds. It is generally accepted by scholars that ethnographically documented hunter-gatherers worldwide had an intimate knowledge of plant life, and exploited the dietary possibilities of seeds.

A model for the Southwest of the orientation to the economic use of seeds in the Archaic cultures of the region may be inferred from Jesse Jennings' (1964) "Desert Culture" model of Archaic subsistence in the Great Basin. His research was based on his excavations at the sites of Danger, Paisley, Humbolt, Lovelock, and Gypsum caves. The subsistence economies of these people who lived an "Archaic lifestyle" were mixed. The emphasis was on the exploitation of waterfowl, rabbits, grass seeds, tubers, pinyon nuts, and acorns, and with the employment of a grinding stone technology. Seeds were an important part of subsistence at these sites (Jennings 1964:156-159). Studies of Danger Cave and the food-processing evidence there also indicate a significant importance of seed use in their economy during the Archaic period (Berry and Berry 1986:256).

Another model for the seed orientation of people living a lifestyle analogous to that of the Late Archaic may be found in the ethnographic research of Catherine S. Fowler, who found a deep knowledge of various species of seeds among the non-sedentary Paiute and Shoshone tribes of the Great Basin. She found several "...generalized technological

complexes" for gathering and processing seeds among these peoples, including pinyon, acorn, grass, mesquite, and many other types of plant seeds (Fowler 1986:64-67).

A subsistence pattern that included the use of various kinds of seeds would indicate a degree of cultural pre-adaptation to the acceptance of new types of seeds. This may have happened in the Late Archaic Southwest. Seeds that were large, with significant food reserves would have been a desirable addition to the suite of the available native seeds of the Southwest.

It is an important fact to remember that, as well as being edible in their fruiting form, all of the cultivated plants introduced early in the prehistoric Southwest (maize, gourds, squash, and beans) were also edible in their seed form. In their seed form all of these domesticates would have been lightweight, easily transported, long-lasting in storage, and readily edible as seeds. It is highly probable that the peoples of the Late Archaic Southwest first encountered domesticated plants in their seed form.

It seems plausible that cultigens and knowledge of their use might have gradually worked their way northward from Mexico during the Late Archaic period in a sort of patchwork of hops, through introductions from one neighboring group to another, in their useful seed form. Down-the-line trade of seeds may have been a first exposure to cultivated plants received by peoples of the Southwest, who already used a wide variety of seeds in their economies. This hypothesis is in complete accord with models of the introduction of domesticated plants into the Southwest that highlight the importance to Late Archaic populations of the enhancement of existing resources and the increasing of the predictability of resources for fairly mobile populations.

The following chapter is a summary of the environment, demography, and patterns of human behavior in the prehistoric Southwest. Included are a discussion of general physiographic provinces of the Greater Southwest and information about the paleoclimate and modern climate. Patterns of precipitation, and amounts of precipitation and evaporation are presented. A discussion of demography traces the development of

population through time in the prehistoric Southwest along with the development of agriculture in the region.

CHAPTER 3

ENVIRONMENT, DEMOGRAPHY, AND AGRICULTURE IN THE GREATER SOUTHWEST

The greater Southwest is a region of elevational and geomorphological diversity, with a significant degree of variability in temperature and precipitation. The culturally defined Southwest encompasses parts of four physiographic provinces of western North America (see Figure 3). The Basin and Range province is the largest, and includes low deserts, foothills and moderately high mountain ranges (Cordell 1984:2123). This province is an area of extreme diversity. The higher altitude parts of this province are relatively arid, and lie mostly in eastern Arizona and Sonora, and western New Mexico and Chihuahua. The only relatively well-watered part of this region is a rather long and narrow area stretching from the Mogollon Mountains in southeastern New Mexico along the Mogollon Rim to the Verde River in central Arizona. This strip receives more than 50.8 cm (15 inches) of precipitation a year (Carter 1944:86) (see Figure 5). The lower altitude regions are hot desert, and include much of eastern California, southern Nevada, western Arizona, and the lower Rio Grande Valley (Steen et al. 1962:80).

The Colorado Plateaus province is a large region of altitudes higher than 1524 m, including mountains as high as 3657 m. This province is also quite dry, and most of it receives less than 25.4 cm (10 inches) of rain per year (Carter 1944:23; Cordell 1984:23).

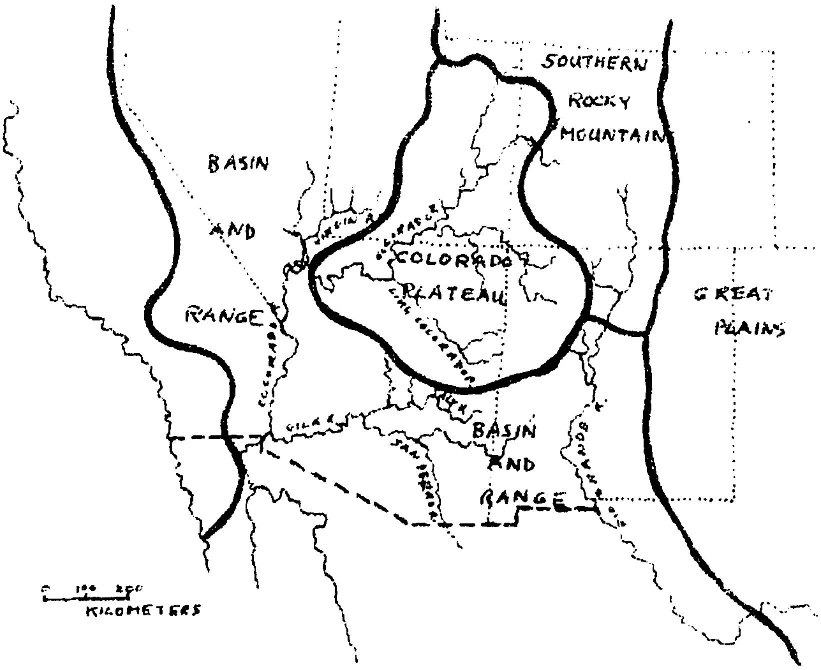

Figure 3. Physiographic Provinces of the American Southwest. Drawn by the author, based on information in Cordell (1984).

The Rocky Mountain province occurs in the Southwest only in northern New Mexico and encompasses the upper Rio Grande Valley above an altitude of 1524 m. Mountain peaks in this province reach 4207 m, and higher elevations here receive over 38.1 cm (15 inches) of rain per year (Carter 1944:86; Cordell 1984:23).

The Great Plains province touches the eastern edge of the Southwest, and ranges in elevation from 1828 to 2133 m in the north to 609 to 1524 m in the south. Topographically, this province generally slopes from the west to the east. Rainfall here is about 25.4 cm to 38.1 cm (10 to 15 inches) a year (Carter 1944:86; Cordell 1984:24).

The climate of the Greater Southwest is considered to be arid by the Koppen climate classification system, which delineates boundaries of worldwide climate types by types of vegetation and rates of evapotranspiration. The desert climates of the Southwest are created by a combination of tropical high-pressure cells (Hadley Cells) that cause descending air to heat during the summer, and by the remoteness of the region from moisture bearing winds that are blocked by the barrier created by several ranges of high mountains that reduce moisture from the Pacific Ocean. Thus, most of the Southwest is classified as low and mid-altitude desert (Gabler et al. 1993:221-222).

Desert regions are characterized by low minimum precipitation, high insolation, high temperatures, little cloud cover, and wide diurnal swings in temperature. These extremes are most pronounced at low elevations in the western Southwest, and tend to decrease with higher elevations in the eastern Southwest (Cordell 1984:24-27; Dean 1992:47).

An important factor for agriculturists in the dry climate of the Southwest is the high degree of the evaporation of moisture in the region, combined with a high rate of plant transpiration. This rate of evapotranspiration is quite high in the Southwest as a region, and is especially extreme in the western Southwest at low elevations (Gabler et al. 1993:138, 140; Harper 1986:52) (see Figure 4). Low humidity combined with high temperatures causes severe evaporative stress to growing plants (Harper 1986:51) and

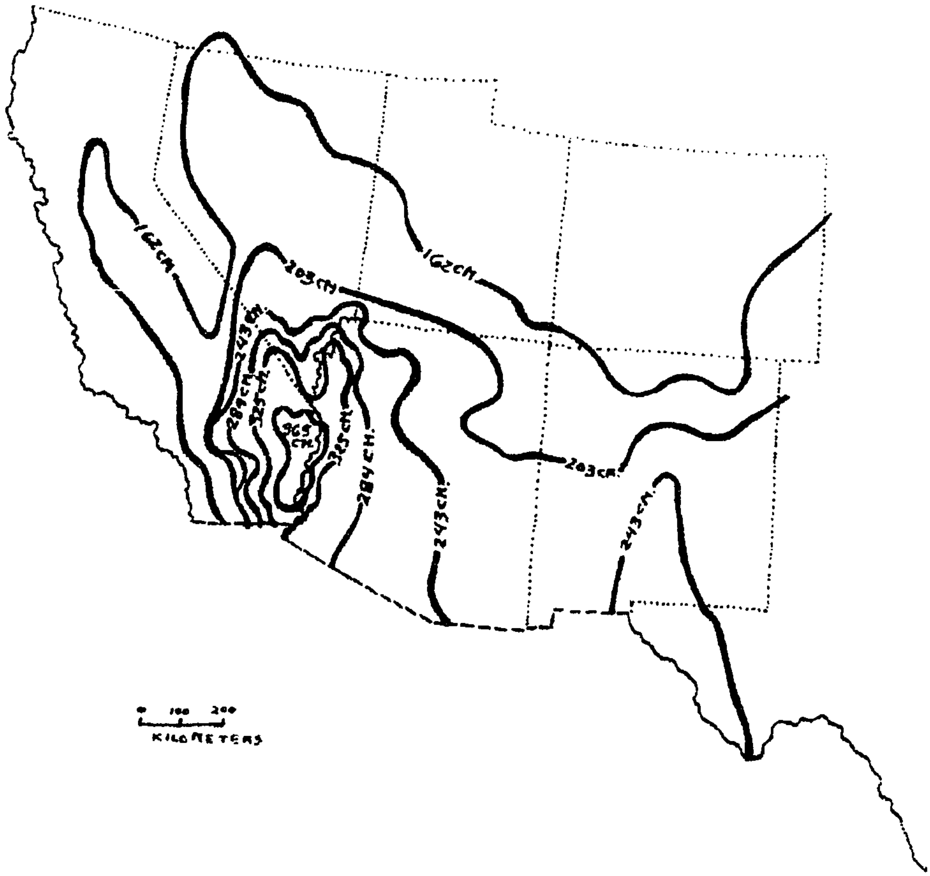

Figure 4. Rates of pan evaporation in the American Southwest. Drawn by the author, based on information in Cordell (1984), Harper (1986), and Gabler, et al. (1993).

would have had a strong selective impact on all of the introduced cultigens, which were of tropical origin, when grown in the severely hot and dry climate of the low altitudes of the western Southwest. In the eastern Southwest humidity and rainfall tend to be higher , and evapotranspiration is less severe (see Figure 4).

The timing and amount of precipitation received are very important to agriculturists, and the total available precipitation that is useful to plants is described as the effectiveness of the moisture (Gabler et al. 1993:221). If temperature is high and humidity is low, rainfall can be quite ineffective if it evaporates before it reaches the ground, or fails to sufficiently wet the ground to be of benefit to plants.

The Southwest is characterized by two patterns of distribution of seasonal moisture, and both of these vary in their degree of moisture effectiveness for the growing of crops. The northern and western Southwest have a bimodal pattern of precipitation in which moisture falls in two maxima, while the eastern and southeastern Southwest have a unimodal pattern with a single summer maximum (see Figure 5). The unimodal maximum in the east and south takes place in late June, July, and August, when the moisture comes from the Gulf of Mexico. The primary maximum in the north and west occurs in July and August, with most of the moisture coming from the Gulf of Mexico. A secondary maximum occurs here in winter, with moisture usually entering from the Pacific Ocean or the Gulf of California with a peak in February (Cordell 1984:24; Dean 1992:40).
The timing and total accumulation of summer rains are very important to the germination, growth, and maturation of agricultural crops in the Southwest. Variability in the amount of precipitation is another factor of dry climates, and rainfall is irregular and unreliable in desert regions (Gabler et al. 1993:225). Summer storms can occasionally be quite severe, and cause significant damage to crops through high winds, hail, or the flooding of fields planted in arroyo bottoms and alluvial fans. Conversely, if rains fail to arrive, a crop may die from lack of water (see Figure 6 for annual precipitation averages in the Southwest).

Another factor important in the success of agriculture in the Southwest is altitude,

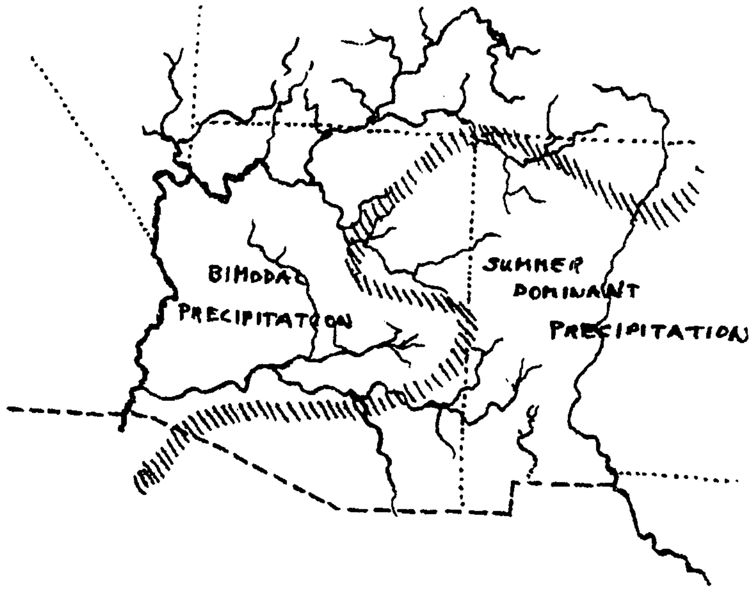

Figure 5. The pattern of seasonal precipitation in the American Southwest.

Drawn by the author, and based on information from Cordell (1984) and Dean (1992).

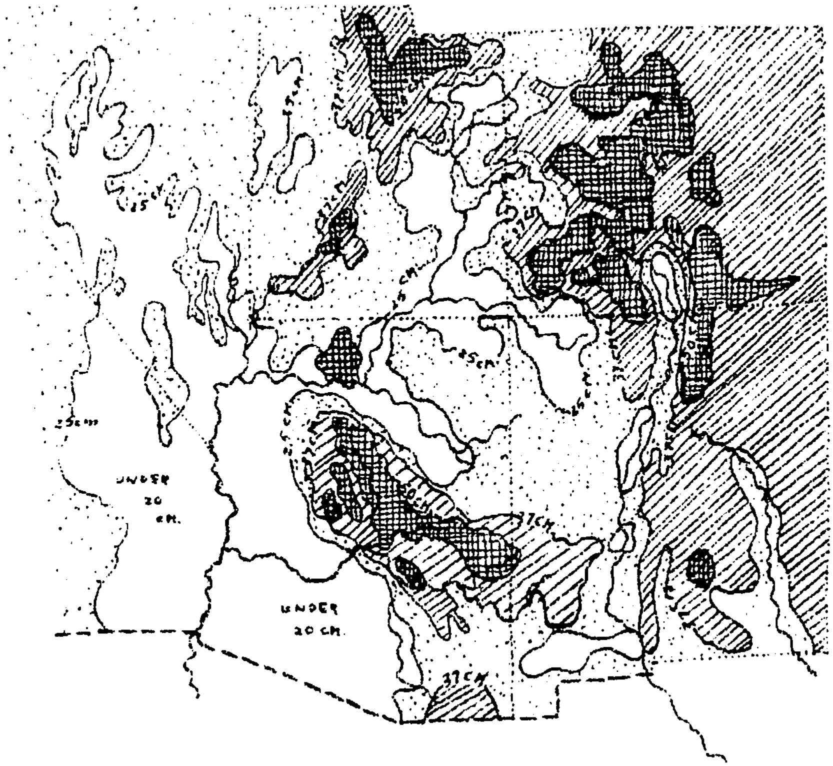

Figure 6. Annual precipitation averages in the Southwest. Drawn by the author, and based on information in Carter (1944), Dean (1992), and Harper (1986).

which has a direct link with temperature and the length of the frost-free growing season. Temperature decreases from south to north by .83 degrees C (1.5 degrees F) to 1.38 degrees C (2.5 degrees F) for every degree of latitude in the Southwest. Temperature also decreases with elevation, though this is less easily predicted (Cordell 1984:26).

All of the important prehistoric crops (maize, beans, squash, gourds, cotton and tobacco) are warm-season, frost-sensitive plants with tropical origins. Worldwide, the greatest productivity for maize takes place in areas where the warmest month ranges in temperature from a mean of 21 degrees C (70 degrees F) to 27 degrees C (80 degrees F), and the frost-free growing season is from 120 to 180 days (Shaw 1977:592). One hundred twenty frost-free days is usually accepted as the minimum number of days to mature ears of both modern hybrid maize and Southwest adapted native varieties (Adams 1979:291; Cordell 1984:26; Hack 1942:23; Lebo 1991:182), though Woosley (1980:319) states that maize requires only 110 days to mature. Placement of fields is very important at the highest altitudes in which maize agriculture is possible, because of early and late season frosts. Cooler night temperatures on high ground combined with moisture stress tend to lengthen the maturation period for maize (Cordell 1984; Hack 1942; Shaw 1977). Warm nocturnal radiation from the sides of arroyo walls, or planting in a spot in which cold air drains away, can lengthen the growing season by several days (Hack 1942:20). Conversely, planting in a low spot into which cold air drains can shorten the growing season by 10 to 30 days and increase vulnerability to early and late frosts (Adams 1979:292; Buchanan 1988:60).

The very minimum moisture requirement needed to grow maize is an annual precipitation of about 300 cm (12 inches) (Shaw 1977:593). Hack (1942:23) found that the Hopi used floodwater farming much more frequently than dryland farming, even in the zone of possible dryland farming with precipitation of 300 cm to 406 cm (12 to 16 inches), presumably because it was much less risky and more productive than dryland techniques alone. In the Southwest, dry farming is only possible at higher altitudes, usually in land

that is covered with pinyon-juniper forest and generally above 1,676 m (5,500 feet) or higher, because those highland areas are the only ones that receive enough moisture during the growing season for successful maize agriculture (Geib 1996:6). But as fields are placed on higher and higher ground, the risk of frost increases and the growing season shortens.

Crops must be grown with additional water at lower altitudes in the Southwest through such means as floodwater farming, water diversion and irrigation. Moisture and heat stress is greatly increased in the lowest altitude hot regions in the western Southwest, so great quantities of water are needed to successfully irrigate crops during the summer months.

The low altitude zones of the Southwest are located entirely within the Basin and Range province below 975 m (3,200 feet). This area is considered the Lower Sonoran Life Zone, and includes the Mojave Desert and Sonoran Desert (Cordell 1986:29; Jaeger 1957:123; Steen et al. 1962:80-81). The two deserts merge together just west of the Colorado River (Figure 3).

The site of Black Dog Cave is located within the hot desert of the Lower Sonoran Life Zone, in the extremely arid western Southwest. The local climate would have had a significant impact upon the physiological behavior of maize in the Virgin Anasazi lowlands, and this is investigated in depth in Chapter 7 of this volume.

SOUTHWEST CLIMATE IN PREHISTORY

When looking at past climate variability in the Southwest, scholars have used a system composed of three classes of factors that have had impact upon past human adaptations, and especially affected agriculture. These include stable factors, low-frequency factors, and high-frequency factors. Stable factors refer to broad, general categories such as bedrock geology, regional hydrology, gross topography, vegetation zonation, and climate type. These stable factors have not changed significantly over the

last 3,000 years (Dean 1992:29; Dean et al. 1994:54; Wills et al. 1994:305). Low-frequency factors refer to changes that can take place in time periods of more than 25 years, and include such environmental changes as the rise and fall of ground water levels, aggradation and degradation of stream beds and flood plains, erosion on slopes, and changes in vegetation in relation to elevation. High-frequency factors apply to time periods of less than 25 years, and often derive from climate changes, including temperature and precipitation variations (Dean 1992:29; Dean et al. 1994:54; Wills et al. 1994:305).

It appears that a pattern of bimodal (summer/winter) precipitation has persisted in the western and northern Southwest and a pattern of unimodal (summer dominant) precipitation has existed in the eastern and southern Southwest for at least the last 1,500 years, and probably longer (Figure 5). These important patterns of moisture have been determined by a study of tree-ring data from 27 chronologies by Dean et al 1992) and included a large region of the Southwest centering over the Four Corners region (Dean et al. 1992:38-40). The predictability of summer rains would have been of the highest importance to prehistoric farmers, and from the past record of low-and high-frequency environmental variability it can be seen that there have been wide fluctuations in the amounts of effective moisture, levels of groundwater, and cycles of stream aggradation and degradation through time (Cordell 1984:42; Dean 1992:38). This climatic record has been determined by pollen and tree-ring data.

Periods of deposition of stream sediments occurring at low-frequency intervals (over 25 years) took place during the following time frames: 200 B.C.-A.D. 250; A.D. 400-750; A.D. 925-1275; and A.D. 1475-1875. In between these periods occurred intervals of major erosion: A.D. 250-400; A.D. 750-925; A.D. 1275-1475; and A.D. 1875 to present (Wills et al. 1994:305). Most of the data supporting these dates comes from the Colorado Plateaus, so is especially applicable to agricultural activates at higher altitudes in the Southwest. This chronology supports research by Hack (1942) who used

geomorphology and ceramics for dating sites in the Hopi area and showed repeated cycles of erosion and aggradation of streambeds (Hack 1942:63).

A summary of tree-ring data also indicates recurring droughts in the northern Southwest about A.D. 715, A.D. 1100, A.D. 1290, and A.D. 1585 (Hack 1942; Schulman 1938). A tree-ring study of samples from Mount Charleston, Nevada, presents a view of climatic conditions in the western Southwest from A.D. 966 to A.D. 1965. This chronology reveals the driest periods as A.D. 1000-1015, A.D. 1120-1150, followed by other dry intervals that are not specified in the text (Larson and Michaelson 1990:241). The most severe drought known to have occurred in the Southwest was the "Great Drought" of A.D. 1276 to 1299 (Douglass 1929; Lipe 1995). The intense severity of the Great Drought may have been one of the factors contributing to population movements in the Southwest of the A.D. 1200's (Lipe 1995).

Climate and environment are but two interrelated elements of successful agriculture, but perhaps are the most basic, because of the parameters they impose upon what a farmer can raise, notwithstanding his technology, available germplasm, labor pool, and social setting. It is the interrelationship of environment, population and behavior that explains the processes of change in the agriculture of the prehistoric Southwest.

POPULATION, AGRICULTURE AND ADAPTATION

Population size is one of the most important variables contributing to the successful adaptation of any human group, and when viewed as interacting with human behavior and the environment, demographic factors enable us to effectively examine the course of cultural evolution in the Southwest.

The cultural evolution of societies is usually seen as a process of change from simpler, or less complex, to more complex societies. In the prehistoric Southwest, there was a wide range of levels of cultural complexity, generally progressing from less to more

complex to more complex over time. This general progression can be summarized as: development beginning from mobile, foraging band-level societies; to segmentary or tribal societies having a primary dependence on cultivated crops (manifested in a sedentary village life); to the development of clans and lineages, or ranked and centralized societies (Brandt 1994:11; Gumerman 1994:11; Service 1971). In the prehistoric Southwest there was a significant degree of variability among past regional cultures and it appears that some groups did become increasingly complex over time, while others increased in complexity, but later opted for a less complex lifeway. Some cultural groups have been difficult to track archaeologically, and seemed to have arisen, flourished, and then disappeared. There is a possibility that those that did apparently disappear may have joined other groups (Lipe 1995:162).

Generally, population numbers are greater in more complex, sedentary, agricultural societies. But when speaking of the prehistoric Southwest, there was a great variability in cultures and their degree of sedentism. Even in historic times, Pueblo peoples who had a high degree of dependence on maize and other cultivated crops were described as "semi-nomadic" (Parsons 1939:14). Ethnographic accounts reveal oral traditions of past migrations of the Zuni, Hopi, Keres, and Isleta groups through their origin myths (Parsons 1939: 210, 270). Viewing past populations of the region as being somewhat, or periodically, mobile is an important factor in understanding the demography of the Southwest, which was one of population settlement, movement and resettlement (Cordell 1984:325).

The practice of agriculture can cause a considerable growth of population, and if unchecked, human numbers may surpass the carrying capacity of the environment, causing a situation that leads to resource stress (Dean 1992:31-32).

Hassan (1978:73) defines “carrying capacity” as: “...the maximum number of people that can be supported by a given subsistence technology under prevailing environmental conditions.” Human behavior will attempt to modify conditions of resource

stress to preserve the population with available technology, and people can respond in several ways to the problem. They can attempt to intensify production, or change their organization of labor (Boserup 1965, Dean 1992), or they can initiate sociocultural changes that "...improve the acquisition, accumulation, preservation, and distribution of resources" (Dean 1992:33). Production can be intensified through double cropping, increased irrigation, establishment of fields farther from living sites, and greater investment of labor in farming (Dean 1992:33; Schlanger 1988:773). Foraging (the gathering of wild plants) can also be intensified. Exchange alliances can be created, reinforced, or expanded, food distribution and storage can be changed or centralized, and resources can be pooled (Dean 1992:33, Hegmon 1992:230; Schlanger 1988:773). The rate of change in cultural evolutionary factors increases when populations are under stress, as innovation provides a selective advantage and often can drive the processes of social transformation (Gumerman 1994:27). If all response mechanisms do fail, a final option of groups under resource stress is population movement (Lipe 1995:161). The archaeological record of the prehistoric Southwest shows significant regional increases and decreases of population, and successive movements of populations over time.

Population numbers in the prehistoric Southwest have been estimated by several researchers for specific areas. There are some important criteria for accurate measurement at any given time period, and we can only estimate, at best, the actual number of people in a particular place and time. Pueblos, rancherias, pithouse hamlets, and dispersed households all require different population estimate methods. The life of structures must be estimated and the number of persons living in each structure must likewise be approximated. Decisions must be made as to the function of rooms, so that storage rooms are not confused with habitation rooms (Crown 1991:291-292; Dean et al. 1994:57).

A SUMMARY OF POPULATION GROWTH IN THE PREHISTORIC SOUTHWEST

During the Late Archaic period in the Southwest (1500 B.C. to A.D. 200) population appears to have increased, and habitation sites were distributed through a wider range of environmental zones (Cordell 1984:166). The density of sites increased, pithouse architecture and storage facilities became more elaborate, burial practices were also more elaborate, and sites probably were inhabited for longer periods (Gumerman 1994:17; Wills and Huckell 1994:34). Conditions were favorable for the adoption of cultivated plants because the climate was wetter and cooler than it had been before, and this was a period with fewer low-frequency changes in climate (Cordell 1984:166; Wills and Huckell 1994:34).

During the period A.D. 200 to A.D. 500 (the Initiation period) there was a steady increase in population in the Southwest (Dean et al. 1994:74, Figure 4.12), and regional differentiation of major cultural traditions (i.e., Mogollon, Anasazi, and Hohokam) began (Gumerman 1994:17). Agriculture assumed more importance, and populations appear to have become more sedentary. The settlement pattern was dispersed, with many small hamlets and households (Gumerman 1994:17-18). Dependence on agriculture increased, as demonstrated by research on carbon isotopes from skeletons from ancient Anasazi Basketmakers (Chisholm and Madsen 1994:251; Wills et al. 1994:309). Major innovations in technology occurred during this time period; among them were the bow and arrow, more efficient food production and storage, ceramics, and irrigation (initiated by the Hohokam in the desert lowlands). Overall regional population was low compared with later periods (estimated at between 2,500 to about 5,000 persons with current methodologies and data) (Dean et al. 1994:74). The people of this time period were healthier (in most locales) than they were in later periods (Martin1994:98). Individuals living in the Southwest during this era were probably able to have a varied diet from

gathered and hunted foods combined with cultivated foods due to the combination of the new agricultural intensification, low population, and a dispersed settlement pattern.

During the period A.D. 500 to A.D. 800 population in the Southwest dramatically grew from about 5,000 to about 40,000 persons (Dean et al. 1994:74). The largest population growth was on the Colorado Plateaus, in the Mimbres Valley and other Mogollon areas, the Hohokam core area, and northern Mexico (Gumerman 1994:19).

On the Colorado Plateaus, populations continued to expand in uplands, with the flourishing of Basketmaker III groups in the Anasazi area. Their pithouse architecture was more substantial and standardized than before, storage facilities were more elaborate, and communal architecture was introduced during this time (Gumerman 1994:19). Some large settlements existed, such as Shabik'eschee Village in Chaco Canyon, New Mexico, and these may represent seasonal aggregations of socially connected groups with communally organized food-sharing (Gumerman 1994:20; Wills et al. 1994:310). Basketmaker III people exploited a wide range of ecosystems, including gathering, hunting, and producing food through agriculture.

Private storage developed in the Mogollon region, as evidenced at the SU site, and probably reflects the development of household economies with a pattern of restricted sharing that encouraged surplus production. This anticipated the private sharing that was thought to be part of the economic system of the Anasazi on the Colorado Plateaus of the period A.D. 750 and later (Wills et al. 1994:312).

Haury (1976:68) believed that at this time, the beginnings of a household-based economy also existed at Snaketown, among the Hohokam, as evidenced by large structures with numerous hearths and large storage pits, and that this may have reflected private storage among extended families.

Agriculture may have been more predictable and profitable during this period, because of the development of more variation in maize of the Southwest A.D. 500 to A.D. 800 (Cutler 1952; 1965, 1966; Jones and Fonner 1954). There is greater diversity of

maize types at Basketmaker III sites than in Basketmaker II sites. New types show up in several differing sites in the Southwest, during this time including those in the Gila Bend, Arizona area (Cutler 1965), Rio Grande sites (Galinat et al. 1970), and Anasazi sites near Durango Colorado (Jones and Fonner 1954). Beans were also introduced to the Southwest during these times, and because they need more consistent care than maize, may have contributed to an increase in human sedentism (Gumerman 1994:19).

Though there appears to have been sufficient land for agricultural and foraging expansion, the rate of human physical infections and nutritional stress was higher than in the preceding 300 years (Gumerman 1994:19).

The period after A.D. 800 to about A.D. 1000 is known as the Expansion period to researchers of the Southwest (Dean et al. 1994:79). Population increased at a high rate from A.D. 800 to A.D. 1000, when the population peaked in the pre-contact Southwest. This has been estimated to have been about 100,000 persons (Dean et al. 1994:74-75; Gumerman 1994:20). A decline in population took place after A.D. 1000 in the San Juan Basin, though numbers continued to increase in other areas, and people who moved out of certain regions were probably absorbed into other groups. Though under environmentally favorable conditions, it appears that the land had reached carrying capacity relative to the technology available to the inhabitants (Dean et al. 1994:75). With continued alluvial deposition, and plentiful and reliable rainfall, population levels remained stable through about A.D. 1150-1200 (Dean et al. 1994:76; Wills et al. 1994:305).

The regional cultural systems of Mogollon, Anasazi, and Hohokam were well defined and elaborated during the Expansion period, and the Southwest as a whole exhibited a number of cultures with wide variation in levels of social complexity (Gumerman 1994:20). Settlement patterns continued a trend from pithouse hamlets to villages in the northern Southwest. In some areas changes in the use of living, working, and storage space led to the beginnings of the transition from pithouse to pueblo villages (Gilman 1983; Cordell 1984).

Dependence on agriculture increased in both highlands and lowlands, where environmental conditions were favorable for agriculture, and enough land with agricultural potential existed during these years to absorb expanding populations (Dean et al. 1994:75). Anasazi populations were still relatively flexible and semi-sedentary, probably because their economies were based upon a combination of gathered wild resources and agricultural success. In some areas it appears that agricultural intensification and increased sedentism were chosen as solutions to growing population (as exemplified at Chaco Canyon) (Wills et al. 1994:314).

Anasazi occupations of most sites were limited in duration, probably because of the overexploitation of local land relative to the size of local populations. Soil could be worn out (especially using dryland farming) and fuel and game could be greatly reduced by large numbers of local residents. Wills et al. (1994:314) suggest that abandonments of regions (such as that of Black Mesa after A.D. 1100) were complete, because social ties were an important part of the Anasazi system of adaptation, and communities preferred to move as a unit because of social and exchange relationships.

Schlanger (1988) suggests that population movements in the prehistoric Southwest were closely tied to local climatic conditions for agriculture. Regarding settlements on the Colorado Plateaus, she documents successive clusterings of site locations at higher and lower altitudes on Black Mesa over the period A.D. 600 to A.D. 1250. At certain times, climatic conditions favored agriculture at higher elevations, and at other times favored it at lower elevations. Farming at these small sites was probably conducted on a relatively small scale, by extended families on a household or co-residential level (Schlanger 1988:783; Wills 1994:317). The lifespan of the structures on Black Mesa was estimated to have been about 15 years, which correlates well with estimates by other researchers for pithouses and pueblo rooms (Crown 1991:310; Hantman 1983:158).

In many areas of the Southwest during the Expansion period people lived in small villages and practiced simple farming that did not entail a great deal of labor. In areas in

which aggregations of people occurred, however, agricultural intensification seems to have been chosen often as a way to support large populations in a local region (Wills et al. 1994:316).

In the Mimbres Valley in the Mogollon area, the first true aggregation of people in the Southwest took place in villages of connected structures resembling later Anasazi pueblos. This parallels later twelfth and thirteenth-century aggregation, but began here before A.D. 1000. The Mimbres one-story contiguous-roomed pueblos do reveal a degree social complexity, possibly indicating the development of moieties, and may point to changes in ideology (Carlson 1981:147-155; Le Blanc 1983:46). Farming was greatly intensified in Mimbres settlements to accommodate expanding populations during the A.D. 1000s and this continued into the A.D. 1100s (Minnis 1985).

At Chaco Canyon, which was a large nucleated settlement system, a high degree of agricultural intensification developed from the A.D. 900s and continued into the A.D. 1100s (Cordell 1984). Large water-runoff catchment areas were exploited to water crops, and elaborate diversion dams, ditches, headgates, and canals were built. Most of the farming was done through complicated exploitation of runoff, though sand dune and dryland farming were undoubtedly practiced. The labor required to immediately respond to rainfall runoff and to maintain the water catchment system would have been considerable, and was probably managed at a level above the household (Cordell 1984:256; Wills et al. 1994:316). The elaboration of agricultural technology and the cooperative labor required to put it into effect indicate a significant degree of social complexity at Chaco.

Because the climate at Chaco was so marginal for the cultivation of maize, beans, and squash, a great deal of labor and planning must have been expended, and a high degree of skill would have been required for agricultural success (Vivian 1970, Winter 1983, Wills et al. 1994). It is important to remember that at the time of its florescence, many other Anasazi groups were living in small hamlets or villages, or in dispersed

households. Settlements in the peripheral Anasazi areas, such as the Virgin Anasazi area, tended to have smaller populations and less complex social patterning.

The Hohokam regional system expanded and reached into the uplands of Arizona during this time period. These people are thought to have been the most sedentary of all prehistoric Southwestern groups, because of the advantages of very successful lowland irrigated agriculture and the close proximity of elevationally differentiated eco zones that contained abundant available resources (Fish et al. 1992:31). The Hohokam are thought to have double-cropped their cultivated plants each season, and to have semi-cultivated wild plants such as *Agave* late in the Expansion period, with a continuation of the practice into the Differentiation period (Bohrer 1970:424; Fish et al. 1992:36).

Through the Differentiation period (A.D. 1000 to about A.D. 1150) high population was maintained at a level slightly below the maximum in the Southwest (Dean et al. 1994:75, 80), and a wide range of levels of social complexities existed (Gumerman 1994:22; Wills et al. 1994:318), with small village farmers practicing less intensive farming techniques, and large, nucleated populations practicing more intensive forms of agriculture (Will et al. 1994:317).

Climatic conditions continued to be very favorable through about A.D. 1130, when a series of more severe droughts and a period of slightly less reliable rainfall began. This signaled a change in high-frequency climatic factors, at a time when populations in the Southwest were relatively high (Dean et al. 1994:75-76; Larson and Michaelson 1990:239, 243).

The broad cultural areas of the Southwest reached their maximum extent by about A.D. 1100, though the Mogollon region seems to have been more distinctive culturally before A.D. 1100, and after that time appears to have some cultural similarities to the Anasazi (Gumerman 1994:22).

After A.D. 1150 the combination of environmental variability and high population in the Southwest seems to have strained the carrying capacity of the land to such a degree

that some populations chose to move to other areas, presumably because further agricultural and foraging intensification was not meeting their nutritional needs (Gumerman 1994:22; Wills et al. 1994: 322). Evidently many groups chose the option of relocation, a practice that seems to have always been a solution for prehistoric Anasazi populations, regardless of size, and must also have been a major part of the Anasazi adaptive system (Wills et al. 1994:322).

By A.D. 1200 (The Reorganization period) populations had begun to move out of the western Southwest, as shown by decreases in the San Juan Basin, Black Mesa area, and Virgin Anasazi region (Dean et al. 1994:79-81). These movements reflect a combination of behavioral, environmental, and demographic factors in the movements of whole populations to new, more promising areas that would accommodate agriculture, hunting and gathering, exchange, and a continuance of social patterns.

After A.D. 1200 population in the Greater Southwest began to decline, mainly in response to worsening environmental conditions, especially after the A.D. 1250s (Dean et al. 1994:76; Lipe 1995:152). Overall numbers for the Southwest region as a whole fell from approximately 95,000 to less than 80,000 by A.D. 1300 (Dean et al.1994:74, Fig. 4.12).

People from the western Southwest had joined others in the San Juan area beginning in the A.D. 1100s, initiating a series of aggregations in the region. Population probably peaked in the Mesa Verde area before A.D. 1250, but environmental conditions worsened considerably after that time. Minor, or secondary erosion intensified into a cycle of major, or primary erosion about A.D. 1275, making floodwater farming more difficult, and even impossible in some areas (Wills et al. 1994:305). High populations would have greatly strained a reduced carrying capacity of the land. Lipe (1995:159) suggests that the Little Ice Age may have caused shorter growing seasons at high elevations such as Mesa Verde, and may have weakened the summer monsoons after A.D. 1250, making rainfall much less reliable in the northwest and western areas of the

Southwest that received the bimodal pattern of moisture. At the same time, the pattern of unimodal rainfall in the eastern and southeastern Southwest may have continued to be reliable. Dean (1992:40) shows that populations in the Southwest tended to move and cluster to areas within the unimodal rainfall region after about A.D. 1300, with the exception of the irrigated desert lowlands of the Hohokam. Apparently, climate changes had the strongest impact on dryland farmers, such as those who farmed upland dry soils in the San Juan area (Lipe 1995:154).

By A.D. 1300 a large part of the Anasazi region had been completely abandoned, and populations rose in the following regions of the Southwest: the Rio Grande Valley, Little Colorado drainage, and Casas Grandes area in Chihuahua (Dean et al. 1994:80-82).

In addition to intensification of subsistence and resource stress, aggregation in the San Juan during the A.D. 1200s seems to have occurred concurrently with social stresses and conflicts (Lipe 1995:157). These problems may have pushed people out of the northwestern Southwest, and reveal a continuance of the Anasazi pattern of periodic resettlement.

The overall health of aggregated populations of the 1200s was poorer than it had been in previous periods, with more frequent diseases, parasites, malnutrition, shorter life-expectancy and iron deficiency anemia. This is especially the case at the late occupations of Mesa Verde (Martin 1994:101, 103, 107). In addition, Martin (1994:107) indicated that Aggregation period individuals exhibited eleven major and persistent nutritional deficiencies resulting from a maize diet, "...and that crowded conditions led to an increased incidence of health problems."

SOCIAL COMPLEXITY AND FOOD-SHARING

The new social and religious forms that appeared in the Upper Little Colorado about A.D. 1300 may have grown out of aggregation (Lipe 1995:163), and developed in

the context of the relative complexity that continued to exist into the historic period among Pueblo societies. Brandt (1994:13) found "...evidence for social ranking, social inequality, and status and prestige differences..." and an elaborate ceremonial life among the Puebloans of the historic period.

Lightfoot (1979:322-323) has suggested that the reduced mobility of aggregated populations in the Southwest beginning in A.D. 1100 may have signaled the development of the combined generalized and balanced reciprocity that characterized Pueblo food redistribution in the historic period, and which still continues today. He outlines two systems of food distribution among contemporary Puebloans. One is between individuals from differing households, clans, moieties, or communities that occurs at unspecified times (generalized reciprocity). The other is the distribution of food within extended social groups that takes place at ceremonies at fixed calendrical times (balanced reciprocity) (Haviland 1993:188; Lightfoot 1979:321; Sahlins 1972:194). Most of the scheduled Puebloan food redistributions took place (and still take place) in kivas during the (still continuing) historic period, but the extent to which we can project that behavior back into the prehistoric period is questionable.

We can see the roots of the modern Pueblo lifeway through archaeology as far back as about the A. D. 1300s, but it is unwise to project that pattern back into time before the Aggregation period, when so many elements of the diverse prehistoric Southwest cultures appear to have been at least somewhat different. This is also true of the Virgin Anasazi, who evidently left their homeland just before the Aggregation period, and did not live in an aggregated settlement pattern themselves (Lyneis 1995:219). We cannot immediately assume that Virgin Anasazi social organization, economy, and systems of food redistribution were quite similar to the aggregated, relatively complex societies of the late prehistoric and historic period Puebloans.

CONCLUSIONS

Throughout the prehistoric period in the Southwest, farming techniques were practiced by hand with simple tools, even though there was a considerable diversity of economic systems and levels of social complexity (Woosley 1980:317). The significant differences in topography, rainfall, temperatures, and length of the growing season in the Southwest necessitated an orientation to the acquiring and transmitting of detailed agricultural knowledge of the local areas that were to be farmed. Considering the simplicity and directness of hand cultivation methods and the varied climates of the region, prehistoric Southwest farmers had considerable success. The record of demography in the pre-contact Southwest reflects this. A continuing increase in population over time from the beginning of hamlet and village farming in the Initiation period through the Expansion period is a good indicator of this success. Conditions conducive for population growth only began to deteriorate when the carrying capacity of the land was reached in the Differentiation period.

The agricultural success of the prehistoric people of the Southwest was accomplished by individuals having a deep understanding of the local agricultural and environmental conditions and limitations, while using a simple technology that required considerable physical labor.

CHAPTER 4

THE VIRGIN ANASAZI: ARCHAEOLOGY, ENVIRONMENT, DEMOGRAPHY, AND BEHAVIOR

The Virgin Anasazi were prehistoric agriculturists, and were the inhabitants of a region located at the far western edge of the prehistoric Anasazi culture area. The Anasazi region has been divided into five sub-regions (displayed in Figure 7) which shows the Anasazi cultural extent and its subdivisions about A.D. 1100, when population in the prehistoric Southwest was near the A.D. 1000 maximum (Dean et al. 1994:75; Lyneis 1995:200). As can be seen from the map, the Virgin Anasazi were the westernmost of the Anasazi groups. They lived in an altitudinally diverse region that included the high-elevation, west end of the Colorado Plateaus in Utah and Arizona, the mid-elevations of the St. George Basin, and the lowland areas of Southern Nevada along the Virgin and Muddy Rivers.

The eastern boundary of Virgin Anasazi territory blended into the Kayenta Anasazi (Lyneis and others 1995:201), but the north, south and west edges of their homeland were more sharply defined because they bordered other cultural or ethnic groups.

The Fremont culture was located to the north and northeast of the Virgin Anasazi, at higher altitudes, in what is now Utah. These people cultivated crops, made pottery, and among the several types of maize that they grew, had a distinctive strain of maize that had

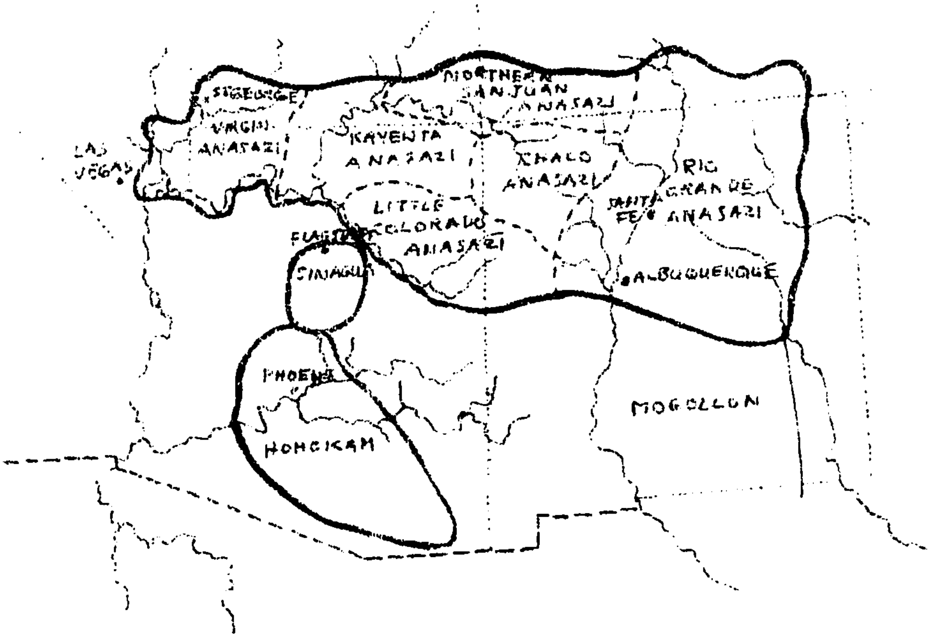

Figure 7. The Anasazi region and its subdivisions, about A.D. 1100. After Plog (1979) and Lyneis (1995).

dented kernels. This maize has been called "Fremont Dent" maize. (This thesis addresses the problems of the origin of Fremont Dent maize in Chapter 7). Fremont Dent maize has been found in sites in and north of the Glen Canyon area, and examples of this maize that are dented in the extreme appear to date from both early and late periods of their occupations in the northern Southwest (Cutler 1966:16; Geib 1996:80-89).

The Hakataya people were located to the south of the Virgin Anasazi, in the Mojave and Sonora Deserts, and were another pottery-making people. Their pottery was thinned by the paddle-and-anvil technique, rather than made from coiling and scraping, as was done by the Anasazi. Some Hakatayans practiced agriculture in favorable locations in conjunction with a mobile lifestyle, while others may have been strictly hunter-gatherers (Schroeder 1979:102; Warren 1984).

The Hohokam were located to the southeast of the Hakataya, and also had a long tradition of paddle-and-anvil technique pottery-making. They were accomplished agriculturists who managed elaborate irrigation systems, and built villages that were laid out in a non-formal manner and often contained a ball-court (Gumerman and Haury 1986:75). They also had a well-developed shell industry that was important in trade with the Virgin and other Anasazi, and the Mogollon peoples (Gumerman and Haury 1986:80).

ENVIRONMENT

Most Virgin Anasazi cultural remains occur north of the Colorado River, which formed the southern boundary of their territory, and about half of their cultural area was in the highlands of the west end of the Colorado Plateaus. Sites in this zone are located at 1525 to 2135 m (Lyneis 1995:202), well within the altitudinal range suitable for dryland farming in most of the Southwest. The uplands of the Virgin Anasazi cultural area are the coolest and wettest parts of their homeland, with rainfall averaging 23 to 33 cm (9 to 12.9 inches) annually. Most of the precipitation falls here in the winter, but is within a bimodal pattern (as demonstrated in Figure 5) (Dean 1992:40; Rose 1989:35), and this limits its

effectiveness. Twenty-three cm of rainfall is considered to be below the minimum, and 33 cm marginal, for dryland maize farming, even in humid climates such as the American Midwest (Shaw 1977:593). Thus, non-irrigated dryland farming in the upland reaches of Virgin Anasazi territory would have been a risky endeavor unless certain microclimates of greater effective moisture were exploited.

Spring and fall are the driest periods of the year in the Virgin Anasazi region, and this would make dryland agriculture extremely difficult because moisture is needed in the spring at planting time, to germinate newly planted seeds of corn, beans, and squash, and was needed throughout the growing season to ensure a successful harvest of maize.

The number of frost-free days in the growing season also varies from year to year and varies according to exposure and location on the plateau rims above the Grand Canyon. The length of the frost-free season shortens with increasing altitude. The average number of frost-free days at Jacob Lake is 98 to 105, and at Bright Angel Station, 101 days. Archaeological site locations along the rim of the canyon, just below the pinyon-juniper forest, are situated in microclimates with a greater number of frost-free days. They are located in areas that tend to trap thermal belts of warm air that become sandwiched between colder upper air and colder air below that has drained into the canyon (Huffman 1993:101-102). This results in a longer growing season for tender cultivated plants, including maize.

Mount Trumbull has an annual range of precipitation of 14.1 cm to 59.8 cm (5.5 to 23.5 inches), which reveals that rainfall in the region is quite variable from year to year (Huffman 1993:30). Even at this, the wettest location in the Virgin Anasazi region, dryland farming would have been uncertain. In fact, the whole western Colorado Plateau region was probably always marginal for dryland farming, considering the combined factors of variable and often ineffectively timed rainfall, short growing seasons, and high rates of evapotranspiration.

As mentioned before, archaeological sites are located at about 1525 to 2135 m on

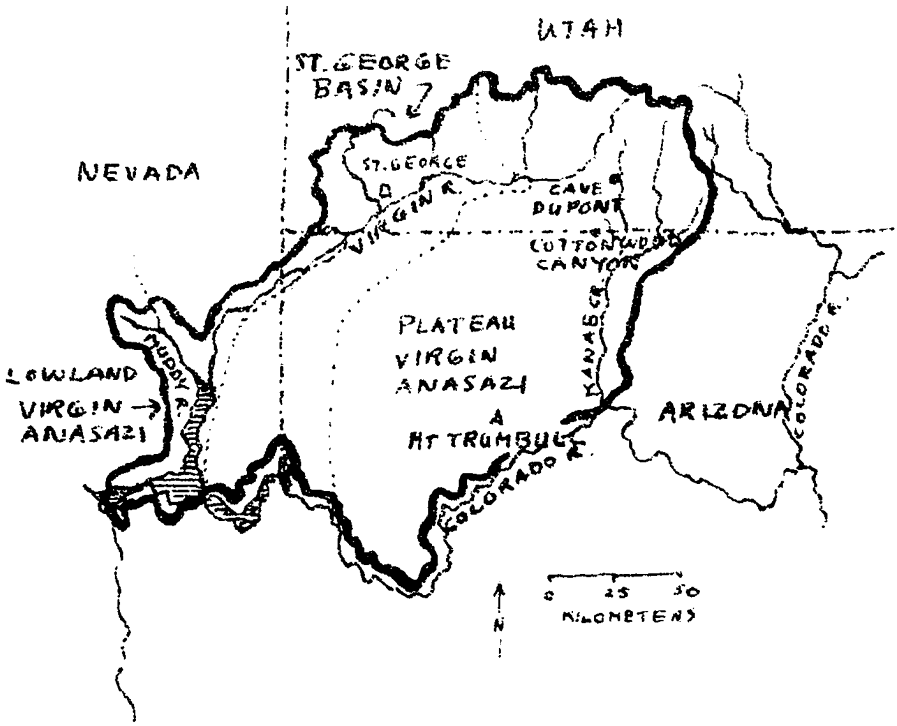

Figure 8. The Virgin Anasazi cultural region. After Lyneis (1995:202).

the plateaus (Lyneis 1995:201), and at 2043 to 2103 m on Mount Trumbull (Huffman 1993:140). Streams would have provided additional possibilities for diversion of water to crops, and several upland sites were located near water sources (Figure 8).

The uplands of the Virgin Anasazi region lie within the Upper Sonoran Life Zone, and are primarily cold desert. The highest elevations have stands of Rocky Mountain Montaine Forest, composed of ponderosa pine (*Pinus ponderosa*) woodlands. At lower elevations are areas of Great Basin Conifer Woodland, a mixture of pinyon and juniper forest (*Pinus edulis*, and *Juniperus osteosperma*). The stands of pinyon-juniper woodland intergrade with greater expanses of Great Basin Grassland. At still lower elevations, Great Basin Desertscrub predominates, with an abundance of sagebrush species (*Artemesia spp.*) and saltbush (*Atriplex spp.*) (Lyneis 1995; Rose 1989; Warren et al. 1982).

Animals commonly found within the plateau area of the Virgin Anasazi homeland include desert cottontail rabbit (*Sylvilagus audobonii*), jackrabbit (*Lepus californicus*), pronghorn antelope (*Antilocapra americana*), mountain sheep (*Ovis canadensis*), and mule deer (*Odocoileus hemionus*) (Huffman 1993:37).

Because elevations in the Virgin Anasazi region generally slope down to the west, and the St. George Basin is at a lower altitude than the plateaus, the basin has a warmer and drier climate. Average annual precipitation averages 20 cm (7.9 inches), and the frost-free season lasts about 224 days (Allison 1990:3; Lyneis 1995:203). Most of the precipitation falls in winter, in a bimodal pattern, as in the rest of the Virgin Anasazi territory. As dryland farming is actually marginal at best in the wetter plateau uplands, it would be nearly impossible to undertake it in the arid, mid-elevation St. George Basin, and it would certainly be impossible in the extremely arid conditions of the lowlands of the Virgin River.

Archaeological sites are located between 800 and 1300 m in the St. George Basin (Lyneis 1995:201), and many of the sites were located near streams and watercourses.

Sites in the uplands surrounding the valley lie in a zone that has flora and fauna resembling that of the Colorado Plateaus, while in the wetter and cooler highest altitudes the land is covered with Upper Sonoran Life Zone vegetation.

Near the valley floor, the characteristic desert vegetation of the Lower Sonoran life Zone becomes apparent. Great Basin Desertscrub, on the lower hillsides, intergrades into the Mojave Desertscrub of the floor of the basin. Characteristic valley floor plants include creosote bush (*Larrea tridentata*), saltbush (*Atriplex canascens*), Mormon tea (*Ephedra viridis*), yucca (*Yucca spp.*), and agave (*Agave spp.*) (Allison 1990:3; Huffman 1993:34; Lyneis 1995:203; Shutler 1961:3). There is abundant plant and animal life connected with riparian ecological communities along the Virgin River and other streams and drainages (Allison 1990:3).

All of the animals previously mentioned as existing on the plateaus were also common in the uplands above the St. George Basin valley floor, but rabbits were probably the most abundant food animal at lower elevations of the basin and in the Virgin River Valley lowlands (Lyneis 1997, personal communication).

Climate and environment of the hot desert lowlands of the Virgin Anasazi region are of special importance to understanding the research undertaken in this thesis, because the site of Black Dog Cave is located there. Presumably all of the maize found at the cave was grown nearby, under the selective conditions imposed by the hot desert climate.

The entire cultural area of the Lowland Virgin Anasazi was contained within the Lower Sonoran Life Zone. Habitation sites were located between 350 m to 500 m in elevation (Lyneis 1995:203), and clustered near the watercourses of the Virgin and Muddy Rivers in the Moapa Valley. The vegetation is Mojave Desertscrub, with creosote bush (*Larrea tridentata*) the most frequent plant, and bursage (*Ambrosia dumosa*), cholla cacti (*Opuntia spp.*) and prickly pear cactus (*Opuntia basilaris*) also common. Along the watercourses both honey mesquite (*Prosopis glandulosa*) and screwbean mesquite (*Prosopis pubescens*) are frequent (Lyneis 1995:204; Shutler 1961:3-4). The average

frost-free growing season is very long in the Moapa Valley, over 230 days or more, depending on siting and cold air drainage. The Virgin River is variable in its streamflow, with a flood period in the spring between March and May. The Muddy River is a spring-fed stream with a relatively consistent flow from year to year, and so it is less subject to either very high water in wet years, or extremely low waters, in dry years (Larson and Michaelson 1990:229).

The Moapa Valley was the farthest west location of population concentrations of the prehistoric Anasazi (Figure 9), though remains of Virgin Anasazi activity have been found in the Mojave Desert at the Halloran Springs Turquoise Mine site. It is probable that these people had some sort of temporary or special-use facilities at the turquoise mining site that enabled them to remain there to acquire enough turquoise for trade or personal use (Warren 1984).

The climate of the lowland Virgin and Muddy River area, including the site of Black Dog Cave, can be understood by examining data from the weather station at Overton, Nevada, at an altitude of 381 m (1250 feet). The station has been moved back and forth between Overton and Logandale since information began to be gathered in 1906, but is now in Overton. Overton and Logandale are 10.3 km apart (6.4 miles), and the cave site is about 15 km (9.32 miles) upstream from Logandale, near the Muddy River (National Weather Service, Office of the Nevada State Climatologist 1994).

The area receives an average of only 13.4 cm (5.31 inches) of precipitation per year, in the bimodal pattern typical of the western Southwest. The greatest mean precipitation falls in the months of January, February, March, and August, but it is grossly inadequate for dryland farming (Tables 1 and 2). Because of this, and assuming a similarity in the climate of the Southwest in prehistoric times, we can be certain that the Virgin Anasazi in the lowlands had to irrigate their cultivated crops. This assumption is also reinforced by the amount of evapotranspiration in the lowland deserts (Figure 4), and by the monthly and annual means of evaporation (Table 3).

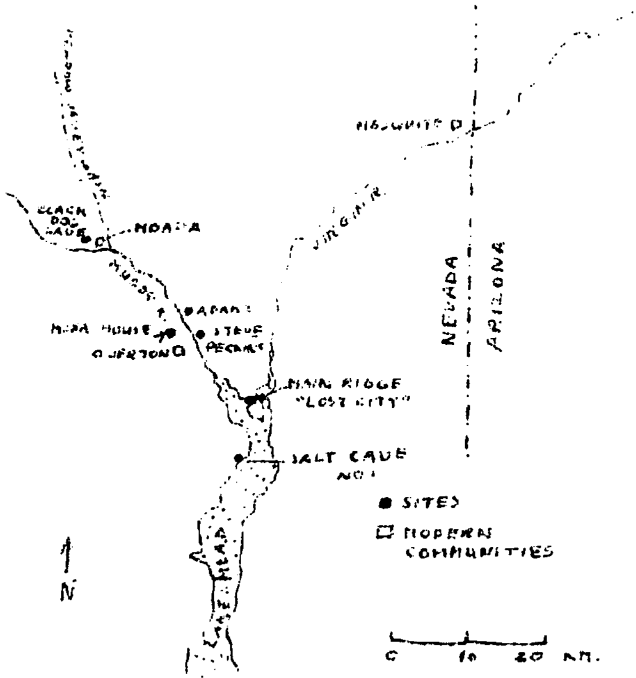

Figure 9. The lowland Virgin Anasazi sites. (Lyneis 1995: Fig. 4, 206).

Table 1. Means and Extremes of Climate in the Moapa Valley, a Climatological Summary of Temperatures Celsius (1906-1992).

Month	Daily Max. Mean Temp. (C)	Daily Min. Mean Temp. (C)	Monthly Mean Temp. (C)	Mean No. of Days 32.2 (C) and Above	Mean No. of Days 0 (C) and Below	Mean Monthly Precip. (Cm)
Jan.	14.9	-0.4	7.2	0	18	1.6
Feb.	18.6	2.40	10.5	0	8	1.6
Mar.	21.5	4.9	13.2	0	3	2.1
Apr.	26.3	7.8	17.1	4	0	0.3
May	31.6	12.5	22.1	16	0	0.7
Jun.	37.8	16.6	27.3	27	0	0.2
Jul.	40.6	20.6	30.6	29	0	1.2
Aug.	39.2	19.9	29.6	28	0	1.4
Sept.	35.6	16.3	26	24	0	0.9
Oct.	28.8	9.5	19.1	0	0	1
Nov.	20.6	3.5	12.1	0	6	1
Dec.	15.4	-0.6	7.4	0	19	1.1
Year	27.6	9	18.5	137	54	13.5

The extreme amount of evaporation, low and unreliable rainfall, high summer temperatures, and low humidity indicate that cultivated crops, including maize, would had to have been frequently and vigilantly irrigated to alleviate ever-present moisture stress during the growing season. High atmospheric temperatures above 32.2 C (90 F) inhibit photosynthesis in maize, reduce leaf initiation, and reduce yields (Lebhenbauer 1914; Tollenaar et al. 1979). So, for successful agriculture in the Moapa Valley the challenge was not one of dealing with cool night temperatures and a short growing season, as in the highlands, but one of coping with high daytime heat in summer months and significant heat stress on the crop.

The Past climate of the Moapa Valley has been partially reconstructed from tree ring analyses of bristlecone pines (*Pinus aristata*) trees on Mount Charleston, about 100 km west of the Moapa valley (Drew 1972; Larson and Michaelsen 1990). Streamflow

Table 2. Means and Extremes of Climate in the Moapa Valley, a Climatological Summary of Temperatures Fahrenheit (1906-1992).

Month	Daily Max. Mean Temp. (F)	Daily Min. Mean Temp. (F)	Monthly Mean Temp. (F)	Mean No. of Days 90 (F) and Above	Mean No. of Days 32 (F) and Below	Mean Monthly Precip. (Inches)
Jan.	58.8	31.2	45	0	18	0.65
Feb.	65.6	36.40	51	0	8	0.63
Mar.	70.7	40.9	55.8	0	3	0.84
Apr.	79.4	46.1	62.8	4	0	0.14
May	89	54.8	71.8	16	0	0.28
Jun.	100.2	62	81.1	27	0	0.07
Jul.	105.2	69.1	87.2	29	0	0.49
Aug.	102.6	67.9	85.3	28	0	0.57
Sept.	96.2	61.3	78.8	24	0	0.36
Oct.	83.9	49.1	66.5	0	0	0.41
Nov.	69.1	38.4	53.8	0	6	0.42
Dec.	59.7	30.8	45.3	0	19	0.45
Year	81.7	49	65.3	137	54	5.31

for the Virgin River was reconstructed for the period A.D. 966 through A.D. 1932. The record shows severe droughts about A.D. 1000 to 1015, A.D. 1120 to 1150, and A.D. 1220 to 1250 (Larson and Michaelsen 1990: Figure 9). Over time, the record as a whole shows significant fluctuations in precipitation amounts and in the volume of the discharge of water in the river; both are common features of desert climates. The report was an evaluation of the conditions that would have been reflected in the streamflow of the Virgin River. Water flow in the Muddy River would have been much more constant and consistent because the Muddy River is a spring-fed stream. During the Pueblo period Virgin Anasazi room densities were much greater along the Muddy River than they were along the Virgin River. Larson and Michaelsen (1990) used this as part of their argument that the abandonment of the area by the Anasazi took place during the Pueblo period, about A.D. 1150, and that it was directly a result of drought. In a convincing rebuttal to

Table 3 Annual Mean Pan Evaporation in the Moapa Valley

Month	Evaporation (Inches)	Evaporation (Centimeters)
January	2.40	6.00
February	3.53	8.90
March	6.07	15.40
April	9.55	24.30
May	12.49	31.70
June	14.69	37.30
July	15.43	39.10
August	13.68	34.70
September	10.40	26.40
October	6.72	17.00
November	4.20	10.60
December	3.17	8.00
Yearly Mean	102.33	259.90

this hypothesis, Allison (1995) has asserted that the abandonment took place later, perhaps in the time span of A.D. 1250 to 1300. This inference is based upon the evidence of several pottery finds from various sites in the Moapa Valley dating to later than A.D. 1200, and from calibrated 14 C dates (Allison 1995:7).

Larson and Michaelsen (1990:239) estimated population for the Moapa Valley at about 200 people at A.D. 700, climbing to about 400 by A.D. 950, to 600 people by A.D. 1000, and peaking at about 900 people at A.D. 1100. They then visualized a steep decline in the numbers of people in the area (interpreted as an abandonment) after that date. Alternatively, Allison interprets a slightly more gradual drop-off in population after A.D. 1100 (Allison 1995: 9-10).

THE ARCHAEOLOGY OF THE LOWLAND VIRGIN ANASAZI

The chronology for the Virgin Anasazi area has been traditionally based upon the Pecos Classification of Anasazi culture originated by A.V. Kidder at the 1929 Pecos

Conference (Cordell 1984:58). Schroeder (1953:18) also used this classification, as do most contemporary researchers today (Lyneis 1992a; 1995). The dating of Virgin Anasazi cultural remains has been accomplished primarily by ceramic studies and cross-dating with Kayenta ceramics, because lowland sites have not yet yielded timbers that can be tree-ring dated. The conventional culture history is presented in Table 4, and discussed below.

Table 4. The Virgin Anasazi Chronology

Basketmaker II	(?300 B.C. to A.D. 400)
Basketmaker III	(A.D. 400 to 800)
Pueblo I	(A.D. 800 to 1000)
Early Pueblo II	(A.D. 1000 to 1050)
Late Pueblo II	(A.D. 1050 to 1150)
Early Pueblo III	(A.D. 1150 to 1225)

Early archaeological work in the Virgin Anasazi area was begun in the 1870s by Dr. E. Palmer, who was primarily an artifact collector (Walling and Thompson 1988:12). N. Judd excavated in Utah and Arizona during the period 1915-1922, but some records of his expeditions have been lost. He noted some of the distinctive characteristics of Anasazi architecture, including slab-lined cists in rockshelters, masonry structures, and cliff dwellings which indicated the western extent of Pueblo culture (Lyneis 1995:205).

J. Nusbaum excavated the Basketmaker site of Cave Dupont, in the eastern highland Virgin Anasazi area, a site that established some of the diagnostic characteristics of Basketmaker II. Some of the earliest, well-preserved maize from the Southwest was found there (Nusbaum 1922:68-69).

Excavations were also undertaken in the early 1930s in Zion National Park, by Ben Wetherill and Elmer Smith. They excavated or tested 12 sites dating from Basketmaker III through Pueblo II (Walling and Thompson 1979:13).

The first archaeological work in the Virgin Anasazi lowlands was done by M. R.

Harrington through the Southwest Museum in Los Angeles in the 1920s. He excavated the "Lost City" sites in 1925 and 1926 and surveyed the Lower Moapa Valley in 1929. Unfortunately, only short accounts of Harrington's extensive work have been published, but many of his unpublished notes were synthesized by Shutler in the Lost City volume (Shutler 1961:1; Lyneis 1995:205). Harrington also worked at Gypsum Cave, published a report (1930) and later worked on a salvage program from 1933 through 1938 that anticipated the flooding of Lake Mead (Shutler 1961:1).

The Moapa Valley site of Mesa House was excavated by I. Hayden, and a report was published by Hayden et al.(1930). This work helped verify a prehistoric Puebloan presence in the Moapa Valley.

Harold Colton (1952) defined the ceramic sequence for the Virgin Anasazi. Albert Schroeder (1955) reported on earlier research in the upper Moapa Valley and produced a chronology for ceramics and architecture for the Virgin Anasazi region.

Shutler (1961) synthesized much of the early work in the Moapa Valley lowland Virgin Anasazi area in an exhaustive report. Many sites were briefly discussed, and archaeological finds were categorized and listed. There was a significant amount of information presented, but one problem that Shutler had with the older site notes was that of assigning specific dates to remains. Consequently, much of the cultural material described in Lost City: Pueblo Grande de Nevada (Shutler 1961) can only be assigned to the Pueblo period (A.D. 800 through A.D. 1225) for the Moapa Valley Virgin Anasazi.

During the 1970s and 1980s, more field research was done in the Virgin Anasazi area by several research groups, including the Bureau of Land Management, private firms, and universities. Published research includes Walling and Thompson (1979), Dalley and McFadden (1985; 1988), Walling et al. (1986), Westfall (1987), Westfall et al. (1987), Tipps (1989), Lyneis et al. (1989), Allison (1990; 1996), (Huffman (1990), and Lyneis (1992a; 1995).

Lyneis (1988) researched the composition of ceramics found in the Moapa valley

and through analysis of varying tempers determined a system of production and exchange that brought pottery to the lowlands from the eastern highland plateaus during the Pueblo period.

Issues of demography and climate concerning the prehistoric lowland Virgin Anasazi have been examined by Larson and Michaelsen (1990) and Allison (1995). The extent of the social complexity of the lowland Virgin Anasazi has been discussed (in two opposing views) by Rafferty (1989, 1990) and Lyneis (1992b).

HABITATION SITES AND SETTLEMENT PATTERNS OF THE LOWLAND VIRGIN ANASAZI

In the lowland Virgin Anasazi area, living sites appear to have been located near land that could be cultivated and irrigated, so site locations were found near flowing water. The greatest concentration of Virgin Anasazi sites was along the perennial, spring-fed Muddy River (Dalley and McFadden 1988:289; Lyneis 1995:210). Structures were built above flood level, on terraces, ridges and knolls.

The earliest sites (Basketmaker II, ?300 B.C. to A.D. 400) include caves or rockshelters and single or multiple pithouses. Black Dog Cave is a rockshelter site, and the cave does have storage cists dug into the floor, as was the case at Cave Dupont, a highland Basketmaker II site (Nusbaum 1922). But a Basketmaker II assignment has not been firmly established for Black Dog Cave, even though the collections from the cave included artifacts that are considered to have characteristics typical of that period (Harrington 1942:174; Lyneis and Winslow 1997; Schroeder 1953:64; Wheeler 1942). (For a discussion of the Basketmaker II problem and this site, see Chapters 6, 7, and 9 of this volume).

Open sites (with groups of one to five pithouses with storage cists outside the structures, but which lack evidence of ceramics) are present in the lowlands and have been

assigned to Basketmaker II (Schroeder 1953). Shutler (1961:13) refers this period as the Moapa phase. A group of pithouses at the mouth of the Muddy at the junction with the Virgin River dating to this time were all large (3 to 7 m in diameter) (10 to 20 feet). Some had hearths inside, and all had adobe plaster floors (Harrington 1937; Shutler 1961:6,13).

The Basketmaker III period (Shutler (1961) Muddy River Phase) sites in the Moapa Valley were also small, and consisted of round or oval pithouses. Some houses had interior storage bins and benches, but not all had hearths. Most pithouses were large (5-7 m in diameter) (15 to 20 feet) though some were as small as 1.5 m (5 feet) in diameter and may have served as storage facilities (Lyneis 1995:211; Shutler 1961:14). All of the sites assigned to Basketmaker III in the lowlands do have evidence of ceramics.

In the Virgin Anasazi area, the Pueblo period (A.D. 800 to A.D. 1225) was named the Lost City phase by Shutler (1961). Because he was using old site descriptions and unpublished notes from early excavations, he had difficulty assigning cultural remains to more specific dates. His Lost City phase included the time period now termed Pueblo I through Late Pueblo II, a time span of about 425 years. Many of the lowland excavated remains are not more specifically assignable to a particular date than to this time period of A.D. 800 to A.D. 1225. Such is also the case with much of the excavated material from Black Dog Cave, which may represent either continuous or repeated use as a storage facility from Basketmaker II through the Pueblo period at that site.

In Pueblo I times among the Virgin Anasazi, pit structures continued to be built for habitation, but the arrangement of storage facilities changed. The shape of the cists became more oval, and tended to be arranged in an arc. They were located outside of the pithouse, either behind it or off from one side of it (Lyneis 1995:211-212). The overall size of the sites continued to be small. Pueblo I pottery sherd occur in these sites, but as Shutler (1961:14) noted, they are often mixed with later Puebloan sherds.

Pithouses were still built as houses by the Virgin Anasazi during Early Pueblo II

times, and lowland sites continued to be small, though there were some large sites on the plateaus, such as the Mecca site (Allison 1988).

By Late Pueblo II, storage rooms were often small surface structures. These have been interpreted as houses by some excavators, but are considered by most scholars to have been actually surface storage rooms. These rooms were often very small and arranged in an arc that defines an outdoor "courtyard" space. Most of the sites of this period were small, and probably were inhabited by families or co-residential groups (Lyneis 1995:215). There were some larger sites, such as Main Ridge, on the Muddy River, that may have housed as many as 100 people during Late Pueblo II. Main Ridge represents a grouping of co-residential or courtyard structure- a house complex with associated surface storage rooms. There were no "public" architectural features such as plazas that would indicate a centralization of social organization (Lyneis 1995:215).

In the Early Pueblo III period (A.D. 1150-1225) the largest lowland site was Mesa House, excavated by Hayden (1930). Habitation and storage structures were arranged in groups around a single courtyard. Hayden interpreted the placement of the site on a mesa 37 m (120 feet) above the river valley as indicating a need for defense, though more recent research reveals other, smaller sites on terraces near the river that do not appear to have been constructed with defense as a priority (Lyneis 1992a:88). No kivas were found in this site (Hayden 1930:83) and none have been found in any of the lowland Virgin Anasazi settlements (Lyneis 1995:217; Shutler 1961:66). Only three to five of the rooms at Mesa House were habitation rooms, and the site probably represents a large extended family, as did other Virgin Anasazi sites from this period (Lyneis 1995:217).

Population probably peaked in the lowland Virgin Anasazi area about 50 years before the peak of population on the plateaus, which was during Late Pueblo II (Aikens 1966:55; Lyneis 1990:24; Huffman 1993:196), so by the time of the Mesa House occupation in Late Pueblo II and Early Pueblo III, the population had begun to decline in the lowlands.

Lowland Virgin Anasazi habitation sites were small in comparison to many other Anasazi sites in the eastern plateaus, and Virgin Anasazi archaeological site remains reveal a pattern of occupation, abandonment, and reoccupation, with location of settlements near arable land (Lyneis 1995:218). Other special use sites exist, such as lithic and sherd scatters, rockshelters, and roasting pit sites. Some of these are located as far away as the Spring Mountains, 100 km distant.

BEHAVIOR, ECONOMICS AND TECHNOLOGY

Neither the lowland Virgin Anasazi, nor any other part of Virgin Anasazi territory shows evidence of the aggregation that began to take place in some parts of the Anasazi region of the Southwest in the late A.D. 1100s and 1200s (Lyneis 1995:219), as described in the preceding chapter. Settlements were small throughout the span of Anasazi occupation, and the people were probably relatively sedentary. Lyneis (1995:226) explains the situation as not one of deep sedentism or short-term sedentism, but of "...small co-residential groups, commonly one or two families, that moved [periodically]," and placed their living sites near agricultural land. Lyneis (1992b:7-80; 1995:226) believes that the number of storage rooms at Main Ridge, though small, indicates a year round habitation and sedentary lifestyle. This pattern of settlement for long periods (12 to 50 years) and then resettlement again, parallels the settlement pattern of the Anasazi living on the Colorado Plateaus through most of the prehistoric period (also described in the preceding chapter).

Burials in the lowland Virgin Anasazi area show great variability in the number and type of artifacts placed in graves. Shutler (1961:43-49) lists a wide variety of articles found in "Lost City" burials, and a varying directional orientation of bodies. Many burials had food or seeds, shell beads, cotton textiles, projectile points and pottery. Schellbach (1930:101) describes a burial from Mesa House that contained maize remains (with dented and pointed kernels) among the other finds. In the burials at Main Ridge, Lyneis (1992b)

also found a wide variability in the number of objects found in graves, concluding that the lowland Virgin Anasazi were not living in a ranked society, but that the burials represented an egalitarian social structure. No evidence of burials of "elites" were found that indicated a "chiefdom," despite Rafferty's (1990) claims.

The absence of aggregation and social ranking, and the presence of small co-residential or extended family groups, leads us to believe that the lowland Virgin Anasazi had a relatively non-complex social organization. Certainly, other contemporary Anasazi groups had a more complex social structure, as evidenced at Chaco Canyon, in the Kayenta region, and in the northern San Juan region.

Changes in architecture and storage over the period of Basketmaker II through Pueblo III in the lowland Virgin Anasazi point to changes in social structure that may have been related to economics and reciprocity. The early (Basketmaker II) sites, such as Black Dog Cave with its small storage cists, and pithouse sites with outdoor storage features, probably represent a public or communal storage pattern. As Wills (1991:92) and Hegmon (1996:226) mention, communal storage often indicates a generalized form of reciprocity that involves an avoidance of risk, resource pooling, and no incentive to create surplus production. Later Virgin Anasazi sites, dating to the Pueblo period, had storage rooms behind, or attached to, the habitation structure. These later sites probably represent a household economic system of less-generalized reciprocity- one that involves more risk-prone strategies and restricted sharing, perhaps pointing to the existence of an incentive for surplus production among the Virgin Anasazi of the Pueblo period.

Hegmon (1996) conducted a computer simulation based upon Hopi ethnographic data that looked at three strategies of storage and reciprocity: one of independence without sharing, one of restricted sharing of only household surplus, and one of pooling of resources. Surprisingly, the most successful long-term strategy for people (at a level of agricultural technology analogous to that found in prehistoric times) is the policy of restricted sharing of household surplus. This is mainly because of the incentive to create

surplus which counteracts periodic food shortages. Environmental variability can result in occasional low crop yields, and the incentive to create surplus produces a greater abundance in storage. Resource pooling does engender the incentive to create a surplus that can be available in times of crop shortfall (some scholars term this a social "buffering mechanism" intended to counteract shortages). Hegmon (1996) sees restricted sharing as growing out of a general consensus of recognition of a strategy that worked for society. This began among the Anasazi in the Expansion Period in the late A.D. 700s with the Prudden unit pueblos on the Colorado Plateaus, and was a socioeconomic change that was likely a factor in the significant economic growth and population increase in the Pueblo period in the Southwest (Hegmon 1996: 240-241).

The pattern of architectural change among the lowland Virgin Anasazi begins with visible, detached storage in the Basketmaker periods, and appears to gradually develop to more private storage during the Pueblo periods. In the latest periods, the ratio of storage rooms to habitation rooms is very high, as at Mesa House, with three to five habitation rooms and 28 to 30 associated storage rooms (Lyneis 1995:217); though this may be due to continued occupation of rooms built in earlier years by a declining population (Shutler 1961:17). Since late period sites are small and probably represent extended families, and the structures are outside in full view of others, they cannot be said to represent private storage to the degree that would be observed in an aggregated pueblo. The sites do indicate however, a probable trend toward the creation of surplus agricultural products, which would be available both as a resource in times of shortfall, and as tradable goods to neighboring hamlets.

Black Dog Cave itself, by virtue of its interior visible storage, probably represents a degree of resource pooling in the Basketmaker periods when the Anasazi were thought to have been semisedentary (there are several pithouses on the mesa above the cave dating to Basketmaker II and Basketmaker III) (Lyneis 1996:3). The use of the cave in the Pueblo period is difficult to determine within the context of resource sharing. It may

represent either a continuance of resource pooling practices, or may have been the storage area for one family, an extended family, or for several families.

Lightfoot (1979) views food redistribution as a buffering mechanism against resource uncertainty that worked well for prehistoric peoples of the Southwest, because of the variability in crop yields from year to year. This includes wild as well as cultivated crops, which are often marginal in the same years when cultivated crops are marginal, in both instances due to the great variability of the Southwest environment (Ford 1972:61).

In his analysis of the food redistribution networks of the historic Pueblo period Lightfoot (1979) investigates the Puebloan economic system for interrelated factors of labor cost, caloric yield of food transported over distances, and efficiency of moving foodstuffs from one place to another. He finds that the maximum sizes of efficient, effective food distribution networks (using a transportation system of foot traffic, as was the case in the prehistoric Southwest) were contained within radii of between 20 km and 50 km (Lightfoot 1979:332). Foods were probably transported over greater distances in prehistoric times, but the efficiency of the movement of bulky, cultivated foods would have been sufficiently diminished over the distances of 20 to 50 km to render such transportation impractical.

Lightfoot's (1974) study has implications for the subsistence and trade patterns of the lowland Virgin Anasazi. There are certainly areas of high ground that would have provided foraging and hunting within 50 km of the Muddy River and Virgin River settlements, and most likely the most highly valued foods (such as meat and pinyon nuts) would have warranted trips of over 50 km. It is probable, however, that the amount of cultivated maize, squash, or beans that would have been transported to greater distances would have been limited because of the lack of efficiency involved their transportation.

Lyneis (1995), in her research on Virgin Anasazi ceramics, discovered that during the Basketmaker III period and later, ceramics were being produced on the eastern Plateaus area near Mount Trumbull 110 km away, and being traded into the lowland

Virgin Anasazi area. Some pottery was produced even farther east and traded into the Moapa Valley. It is difficult to conceive of foodstuffs being traded back to that distance, unless they were highly valued foods; and corn, beans, and squash are all quite bulky to transport. Perhaps salt, cotton, or textiles were being traded out of the valley (Lyneis 1995:231). Textiles were very frequent in burials dating to the Pueblo period at the "Lost City" area (Shutler 1961:43-49), but unfortunately most disintegrated soon after recovery. Other items that were certainly traded into the Virgin Anasazi lowlands included shell beads, turquoise, and obsidian. Most of the shell beads came from either the Gulf of California or the Pacific coast of California, and may indicate connections with the Hohokam trade network (Lyneis 1995:231). There is still much to be learned about Virgin Anasazi trade. Studies need to be conducted of the sources of turquoise found in Virgin Anasazi burials, and an intense analysis of shell beads from Virgin Anasazi sites would increase our understanding of trade as well. If a site with good temporal stratification could be excavated with contemporary scientific precision, we might gain some additional answers about the possibility of a cotton trade among the Virgin Anasazi, and a more complete picture of Virgin Anasazi subsistence.

AGRICULTURAL TECHNOLOGY

In general, the prehistoric agricultural technology of the entire Anasazi cultural area was at a direct, hands-on level. A continuation of this technology appears to have extended from Basketmaker II times until the late nineteenth century among many of the various Anasazi and other Southwest cultural groups. That it lasted so long as a viable technology indicates its relative efficiency. Nusbaum (1922:113-115) found digging sticks at Cave Dupont that closely resemble tools used by historic Zuni, Pima, Papago, Yuma, Apache, and Navajo groups (Buskirk 1986:61; Castetter and Bell 1942:134; Castetter and Bell 1951:150; Cushing 1920:194). These tools were simply constructed of wood, usually hard, sturdy woods such as ironwood, mesquite, or screwbean mesquite (Castetter and

Bell 1942:134). Ethnographies indicate that all of the work of planting and weeding was done with sticks by these peoples.

Shutler (1961:Plate 82a), shows an object labeled a "wooden crook" from the Lost City excavations. It is almost exactly like one of the agricultural implements found by Nusbaum (1922:Plate LVIIb) at Cave Dupont. The Cave Dupont object is about 76 cm (30 inches) long, but we have no size indication in Shutler's picture. Since we have no date or association for the Lost City artifact (Shutler 1961:41), we cannot place it temporally. It does, however, strengthen the probability of Basketmaker II presence in the Moapa Valley by its similarity to the example from Cave Dupont. We must be cautious, though, because of the aforementioned continuity of this agricultural technology and the simplicity of the tools used. However, note the greater elaboration evident in the more recent, historic Zuni planting implements in Figure 10.

The tools used by the Virgin Anasazi were similar to those used by other agriculturists all over the prehistoric Southwest, and similar to those used by other Anasazi, who were living at higher elevations on the Colorado Plateaus and in the Rio Grande Valley. Though their agricultural technology was culturally comparable to other Anasazi, it is interesting to note that the Virgin Anasazi were the only members of Anasazi culture to live and cultivate in a lowland, desert environment. This desert environment would have caused fundamental differences in their subsistence and agricultural practices relative to other Anasazi.

Cordell (1984:189-211) and Woosley (1980:317-333) list several agricultural features of the prehistoric Southwest that vary with local environmental conditions. All of them have to do with control of water and include check dams, bordered gardens, contour terraces, brush dams, diversion dams, headgates, pools, canals, waffle gardens, and akchin fields. Cordell (1984:190, 200) notes that there is little evidence in the Southwest for water control features before A.D. 900, and that the intensification of water control features among the Anasazi reflects human population aggregation, and this appeared

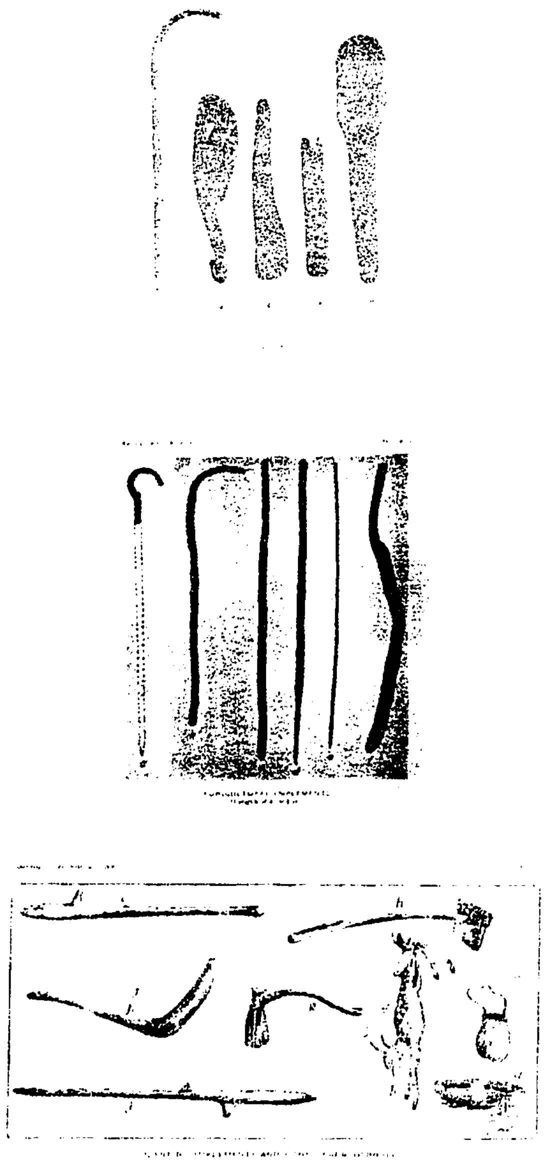

Figure 10. A comparison of wooden digging sticks. Top, wooden artifacts from the Lost City excavations (Shutler 1961:Plate 82). Center, Baskemaker II digging sticks from Cave Dupont (Nusbaum 1922:Plate LVIII). Below, Zuni planting tools from the historic period (Cushing 1920: Plate III).

appeared after about A.D. 1025 in the Chaco area. Since the Virgin Anasazi area never witnessed true population aggregation, significant agricultural features that required a great deal of labor to construct and maintain did not exist here during the Virgin Anasazi cultural florescence. Also, because of the low desert climate and lack of rainfall, only a few types of water control features known to occur in the Southwest probably could have been employed. Bordered gardens, check dams, and contour terraces are associated with dryland farming, which is dependent upon rainfall. Of course, these methods were not applicable to the lowlands of the Moapa Valley. Akchin (or floodwater) farming of arroyo bottoms and alluvial fans was not possible either, because of low summer rainfall here (13.5 cm). In areas where akchin farming is or was practiced, such as at the Hopi mesas and in Hohokam areas such as Gu Achi, annual mean rainfall is over 25 cm. Elaborate dam and headgate systems or irrigation canals have not been found in the Virgin Anasazi area, and probably are not expected, because of the low population and conservative nature of the Virgin Anasazi in comparison to the Plateau-dwelling Anasazi.

Hayden (1930:86-87) and Shutler (1961:6) both thought that simple water diversion by brush dams and small ditches could have been practiced by the Virgin Anasazi along the watercourses of the Moapa Valley. The Muddy River is a perennial stream, and the surrounding flat river bottom has rich, alluvial soil. As long as the stream was not entrenched, the ample water needed for irrigation of cultivated crops during the highly evaporative growing season could have been easily diverted in this manner.

Unfortunately, a geomorphologic study has not been conducted for the lower Virgin and the Muddy rivers, so we cannot know the cycles of erosion that have taken place over the last 2,000 years. Presumably, agriculture was quite successful around Black Dog cave from Basketmaker II times through Pueblo times and later; because maize remains are abundant, and appear to date from Basketmaker II through Paiute occupations.

CHAPTER 5

VIRGIN ANASAZI SUBSISTENCE

In this chapter, I will examine lowland Virgin Anasazi subsistence, and the cultivation and selection of maize by peoples of the Southwest and patterns of behavior that were reflected in everyday life among the people living in the vicinity of Black Dog Cave.

There are a number of questions that can be asked about the nature of Virgin Anasazi subsistence. One concerns the degree to which they depended on the gathering of wild foods in relationship to the amount of cultivated food they consumed. Another concerns how the timing of the procurement of wild foods fit into the scheduling of the labor necessary for the cultivation of crops in the local environment. Also, since they were the only members of the Anasazi to cultivate crops and live in a lowland environment, did their subsistence and maize cultivation and selection behaviors closely resemble those of upland Anasazi dwelling on the Colorado Plateaus, were they more similar to lowland desert peoples, or were they entirely unique?

MAIZE DIETS AND PREHISTORIC HEALTH

It is now generally believed that maize was a significant dietary component of the upland Anasazi dwelling on the Colorado Plateaus. What remains unanswered is whether or not the lowland Virgin Anasazi were as dependent upon maize as were the other

members of their (Anasazi) culture living at higher elevations, who were able to practice non-irrigated maize agriculture.

Chisholm and Matson (1994) examined Anasazi skeletons, using carbon isotope analysis, from the Cedar Mesa area dating from the Archaic period, the Basketmaker II period, and the Pueblo period. Though their sample was fairly small, they showed that Basketmaker II populations from Old Man Cave had a diet of 60% to 80% C4 foods, and Basketmaker II populations at Grand Gulch had a diet of 79% to 84% C4 foods. The carbon isotopes present could only come from a few available and economically useful plants: *Amaranthus spp.*, *Chenopodium spp.*, and *Zea mays ssp. mays*. From the examination of an Archaic period skeleton dating to 6500 to 8500 years ago, Chisholm and Matson estimated that this individual's diet, which included only wild species of C4 plants, of course without maize, probably consisted of a range of 20% to 40% C4 plants and C4 herbivores (Chisholm and Matson 1994:246-247). This disparity of the content of C4 foods between the pre-maize diet of the Archaic period and the Basketmaker II diet reveals a significant contribution of maize, indeed, dependence on maize by Anasazi of the Basketmaker II period. Results of studies on the Pueblo period skeletons revealed a diet of 83% to 87% C4 plants, a slightly greater dependence on maize for that period. Decker and Tieszen (1989) also conducted a carbon isotope study of Basketmaker III to Pueblo III skeletons from Mesa Verde, another upland Anasazi site, and found that their diet probably consisted of 70% to 80% maize.

Stiger's (1979) study of Basketmaker III and Pueblo III coprolites from Mesa Verde revealed maize in 96% of the samples, but also indicated concentrations of *Chenopodium spp.* (25% from Basketmaker III and 31% from Pueblo III) and *Amaranthus spp.* (5% from Basketmaker III and 9% from Pueblo III). Stiger (1979) estimated the maize content in the diet at about 50% for the Mesa Verdeans of both time periods, a lower estimate than that of the carbon isotope studies, because of the significant presence of chenopods and amaranths. Though Chisholm and Matson (1994), and Decker

and Tieszen (1989) both estimated maize as 70% to 80% of diet for upland Anasazi for the time period of Basketmaker II through Pueblo III, the actual ratio of maize in their diet may in fact have been slightly lower because of the use of chenopods and amaranths, which are ubiquitous at many Anasazi sites (although it must be noted that Anasazi diet varied greatly from time to time and place to place) (Lyneis 1997, personal communication). However, we can state with confidence that maize was an important component of prehistoric Anasazi diet in general, from Basketmaker II through the contact period.

Research conducted on human diets that are made up of a significant proportion of maize indicate certain health problems that likely occur unless certain supplements are available. Maize is not a highly nutritious food itself. It is high in A and B complex vitamins, sugars, starches, and oil, but low in proteins and minerals, lysine, and tryptophan (Snow 1990:295-296). A diet high in maize can inhibit the body's absorption of iron; phytic acid in the pericarp (the hull of the grain) inhibits the absorption of iron by the intestinal tract (Snow 1990:295). The low availability of iron (3% to 5%) in a diet of mostly maize must be supplemented by animal proteins and fats, and greens (such as chenopod leaves). Treating green, parched, or raw grains of maize by soaking them in lime-water, or by grinding them with limestone manos and metates will make the little iron existing in maize available to the body, but the high calcium content resulting from lime-treatment may inhibit the body's absorption of iron, so populations could be at risk unless they added iron to their diet (Snow 1990:299). Several things could be added to masa, or maize dough, to increase the iron content, including ashes of bean pods (presumably including mesquite pods, another legume), maize cobs and four-wing saltbush, and mountain sheep manure, crystalline salts, amaranth seeds, animal blood, and lard (Snow 1990:299). Obviously, a diet primarily based on maize consumption would be greatly enhanced by the addition of gathered wild foods. This may be why archaeological and ethnographic studies of prehistoric and historic Southwest diets almost always reveal

a subsistence that is mixed to some degree, and never a diet consisting of cultivated plants alone.

In times of resource scarcity, when populations would have relied on stores of maize more heavily (if they had them) or a diet almost exclusively of maize for long periods, individuals would be more susceptible to iron deficiency anemia (porotic hyperostosis), a problem that appears "...ubiquitous among children and adults throughout the occupation of the Southwest" (Martin 1994:87; Walker 1985). Porotic hyperostosis can be brought on by infection, parasites, and low-iron diet (Spielmann 1992:79), so is not thought to be directly a result of maize diets only, but perhaps is brought on by the combination of several of these factors. The sedentism or semi-sedentism associated with cultivation of crops puts people in very close contact with one another, and water supplies may be easily contaminated. Consequently, diseases and parasites can be transmitted much more easily .

Martin (1994:95-96) explains the dramatic population increases of the Southwest (from Basketmaker II to Pueblo II, that took place in conditions of increasing sedentism and exposure to infection and stressors) through morbidity studies of burial populations. This research reveals that members of the population most at risk of poor health and death were the very young and very old. Individuals aged 20 to 40, the reproductive age group, tended to be less affected by diseases and parasites present. "Demographically, a great majority of the human remains recovered in the Southwest are under the age of 18" (Martin 1994:93). The stresses of the prehistoric lifeway affected children more severely, and infant and childhood mortality was high (Martin 1994:107; Minnis and Redman 1990:290). Iron deficiencies resulting from a maize diet were a factor, along with crowded and unsanitary conditions and health risks including intestinal parasites such as helminths, and lice, arthritis, tuberculosis, and infectious diarrhea (Martin 1994:107).

Virgin Anasazi skeletons have not been extensively studied, and no carbon isotope investigations of skeletal material have been published, so we do not know the percentage

of C4 plants in their diet. We do, however, have some information on their health. Roberts (1991) conducted an informative comparative study of Parowan Fremont, Kayenta Anasazi and Virgin Anasazi skeletal remains. She found that the Virgin Anasazi individuals had the highest frequencies of infectious diseases of the three groups. Frequently occurring diseases include periostitis, osteitis, and linear enamel (hypoplasia) lines, while "...the incidence of porotic hyperostosis was atypically low [at 17%] for a maize subsistence economy" (Roberts 1991:132). The Virgin Anasazi had "...moderate cribra orbitalia and porotic hyperostosis compared to other Southwestern skeletal series" (Roberts 1991:132). They also had the smallest number of children's skeletons. She suggested two alternatives for the higher prevalence of health stressors among the Virgin Anasazi, relative to either the Kayenta Anasazi or Parowan Anasazi: either they lived in more sedentary, crowded conditions, or they had more frequent contact with outsiders due to trade with others which exposed them to a greater number of infectious diseases (for information about Virgin Anasazi trade see Lyneis 1992, 1995).

In his analysis of burials from "Lost City" (a groupage of lowland Virgin Anasazi sites of Basketmaker III through Pueblo II) Shutler (1961:43) found that of 245 skeletons, 142 were adults, 22 were children, and 80 were infants. Evidently childhood mortality among lowland Virgin Anasazi was high, as over 41% of all individuals died before adulthood. This is consistent with morbidity profiles of other contemporary Anasazi groups from the Plateaus.

It appears that Virgin Anasazi experienced similar health profiles as other Anasazi, though they had a lower instance of porotic hyperostosis and cribra orbitalia (both indicators of possible iron deficiency) than that of other, contemporary Anasazi dwelling on the Colorado Plateaus. They may have had a more varied diet, or greater access to iron, or a less substantial parasitic load than their fellow upland-dwelling Anasazi. Enamel hypoplasia in adult teeth is quite reflective of physical stresses during childhood, especially malnutrition in infancy (Goodman et al. 1988:196). Osteitis is bone inflammation, possibly

due to carrying heavy loads, and periostitis results from infections (Goodman et al. 1988:180). Thus, the health profile of Roberts' (1991) sample of Virgin Anasazi skeletal material is quite similar to that of other prehistoric Anasazi, and probably represents a sedentary or semi-sedentary population with a fairly high degree of dependence on maize, though the precise percentage of maize relative to gathered foods cannot be ascertained without further (especially carbon isotope) studies of skeletal material.

UPLAND VIRGIN ANASAZI

SUBSISTENCE

J. Allison (1990), in his master's thesis concerning Virgin Anasazi subsistence in the St. George Basin, presents three alternative models of Virgin Anasazi subsistence. One, presented by Westfall (1987), describes the Virgin Anasazi as having a mixed subsistence economy of horticulture and gathered wild foods (horticulture would seem to indicate the growing of crops on a small scale, and an encouragement of wild plants along with cultivated ones). The second model, developed by Dalley and McFadden (1988), argues that the Virgin Anasazi relied on agriculture almost entirely, with little or no use of wild plant and animal foods. Allison suggests a third model in his thesis: that the Virgin Anasazi had a combined subsistence of agriculture, wild plant and animal procurement, and that this involved some seasonal movement to upland environments (Allison 1990:10).

Huffman (1993) investigated several sites on the Colorado Plateau and in the Grand Canyon in the early 1990s. He acknowledges that most of the habitation sites were located in areas that would have been conducive to agriculture, on the edge of the pinyon-juniper forest (Huffman 1993:84). This was true of sites in the Walhalla, Mount Trumbull, and the Shivwits and Kanab Plateau areas (Huffman 1993:101, 123, 130). Most of these sites date to the Pueblo II period. Huffman (1993:153, 188) notes an increase in agricultural features in Late Pueblo II and early Pueblo III. Population peaked in Late Pueblo II, with a sharp decline in Pueblo III (Huffmann 1993:71). This population

peak is thought to have been 50 years later than the population peak in the lowland locations of the Moapa Valley, where Black Dog Cave is located (Huffman 1993:196; Lyneis 1990:24).

Several *Agave* or *Opuntia* roasting pits were found on the Tuckup Canyon rim, the Kanab Plateau rim, the Shivwits Plateau rim, and Mount Trumbull. A large number of these sites are located on the esplanade, below the rim (the lowest level of the pinyon-juniper forest). Huffman (1993:129, 130, 137) mentions that some of the pits may be Paiute, and that not just *Agave* was found in the pits. Remains in most of the pits included pads and fruits of *Opuntia spp.* (chollas and prickly pears), midden materials, and rabbit, bird and porcupine bones.

The plant and animal assemblages from open and rockshelter upland sites that Huffman investigated include the following macroplant remains: ten-row cobs of maize; quids, fruits, and plant parts of *Agave* and *Yucca*; cordage, grass, cacti parts, wood, pinyon nuts, and acorns (Huffman 1993:130-132, 136). Flotation revealed more species of small-seeded plants including Indian rice grass (*Oryzopsis hymenoides*), barrel cactus (*Echinocereus spp.*), saltbush (*Atriplex spp.*), and prickly pear (*Opuntia spp.*). At site AZ:B:9:302, 51% of seed remains were Indian rice grass.

Animal remains from the plateau and lower canyon sites contained bones of rabbits (*Lepus* and *Silvilagus spp.*), bighorn sheep (*Ovis canadensis*), birds, and porcupine (Huffman 134,228).

Huffman (1993:174) concluded that the subsistence strategy of the Virgin Anasazi of the western Grand Canyon area was one with residences mostly upland, with forage trips into the lowlands in late spring through fall, and winter residence upland. He does not detail how the timing of planting, cultivation, and harvests of cultivated crops fit into the annual food procurement strategies, but states that most of the farming was dryland type (Huffman 1993:174). If these upland dwellers engaged in dryland farming their wild resource foraging would have to have been scheduled to alternate with the responsibilities

of planting, care, and harvest of crops during that same time period of the year, late spring through fall.

In the St. George Basin, Allison (1990) investigated several Virgin Anasazi sites in the Anasazi Valley, Utah, with an emphasis on researching subsistence questions. The sites are just a little higher in elevation than the St. George area, and in the Mohave Desertscrub ecozone, between 900 and 925 m in altitude (Allison 1990:65). The Santa Clara River is a perennial stream in most years and is only dry in severe droughts (Allison 1990:3). The structures were built on low hills or terraces above the streambed. Plant remains from site 42Wsl342 date to before A.D. 1050, and those from sites 42Ws2187 and 42Ws2188 date to after A.D. 1050 (Allison 1990:99).

Macrobotanical remains from these sites included: maize (*Zea mays ssp.mays*) cob fragments, goosefoot (*Chenopodium* and/or *Amaranthus spp.*), *Descuriana*, *Sphaeralcea*, *Nicotiana*, *Mentzelia*, *Echinocereus*, *Corypatha*, and *Amelanchier alternifolia* (Allison 1990:Table 12). Animal remains were also found, including deer (*Odocoileus hemonius*), mountain sheep (*Ovis canadensis*), and rabbits (*Lepus* and *Sylvilagus spp.*). Maize may not appear as well represented as it could have been, due to a sorting bias for small seeds by the excavators; thus weedy plants were found to predominate here (Allison 1990:103). This may reflect weeds colonizing the disturbed soil of fields, or the cultivation or encouragement of certain weedy plants such as amaranths and chenopods for greens and/or seeds.

Allison (1990) synthesizes the plant and animal remains from previous work at some St. George Basin sites, including the Little Man, Quail Creek, and Redcliffs sites (Heath 1986, 1988a, 1988b), the Frei site (Pendergast 1962:134), and the Gunlock Flats site (Day 1967:7). No bone was recovered from Little Man, but mountain sheep was recovered from all but the Frei site, and mule deer from all of them. Both jackrabbits and cottontail rabbits were found in most sites (Allison 1990:34 -44).

The table of plant remains presented in Allison (1990:52) from these Utah sites proves interesting in its percentages of cultigens. Maize is present in 33% of samples from Pueblo I times, then increases to 67% of samples in the Late Pueblo II period, after A.D. 1050. *Chenopodium* and *Amaranthus* species (tallied together because of their morphological similarity) are present in 61% of samples in Pueblo I times, 39% in early Pueblo II, and 58% in Late Pueblo II. Thus, it would appear that these iron-rich plants may have been important from Pueblo I through Pueblo II, and that food production may have increased during Pueblo II in the St. George Basin.

Thompson and Walling (1988) excavated and researched a small Virgin Anasazi habitation and storage site, The South Creek site, near Zion National Park. This site was occupied during Late Pueblo I and Early Pueblo II periods. The site is located at 1273 m, within lower altitudes that necessitate irrigation of crops in the Western Southwest. Animal bone included mountain sheep, elk (*Cervus elaphus*), jackrabbits, and cottontail rabbits (Thompson and Walling 1988:67-68).

In the excavation of Roadrunner Village and nearby sites (Billat et al. 1992) dating from Basketmaker III through Pueblo I times yielded few bones of gopher (*Geomydiae*), mice (*Cricetidae*), rabbits (*Sylvilagus spp.*), and deer (*Odocoileus hemionus*) (Billat et al. 1992:124, 185). Macrobotanical remains were abundant and all soil was screened during excavation. Maize (*Zea mays ssp. mays*) is the most ubiquitous macrobotanical specimen recovered, followed by goosefoot and/or amaranths (*Chenopodium spp. and Amaranthus spp.*), followed next by wild grasses. Buckwheat (*Eriogonum spp.*), cacti, and gourd remains were also found (Billat et al. 1992:140, 185). Cattail (*Typha spp.*), *Chenopodium* and *Amaranthus* pollen are common, and all species were probably used as foods (Billat et al. 1992:185).

The abundance of maize at these sites indicates significant use of maize in the diet in the St. George Basin during Basketmaker II and through Pueblo I. The authors did find that Allison's (1990) model of a mixed subsistence of wild and cultivated foods, with

seasonal movement to upland ecozones for food procurement, to be supported in the floral and faunal assemblage recorded at the Roadrunner Village and associated sites (Billat et al. 1992:135). They thought that because "...environmental conditions are variable and unpredictable on the Colorado Plateau that the Anasazi practiced a variety of adaptive responses, including seasonally or yearly variable degrees of co-dependence on hunting and gathering and agriculture" (Billat et al. 1992:19).

The only beans reported for upland Virgin Anasazi sites are from site ZNP-21 in the eastern St. George Basin. Both common brown beans (*Phaseolus vulgaris*) and tepary beans (*Phaseolus acutifolius*) were reported. *Zea mays ssp. mays*, *Cucurbita* (squash), and *Lagenaria* (gourds) were other domesticates at the site. Most of the finds date to Pueblo II, but the beans were from Basketmaker II levels (Lyneis 1995:221).

When summarized, the upland and St. George Basin Virgin Anasazi sites appear to reveal a mixed subsistence. It is difficult to ascertain the percentage of maize in the diet, but it seems to have been substantial in Pueblo times, and probably was a significant contribution to diet beginning in Basketmaker III times.

LOWLAND VIRGIN ANASAZI SUBSISTENCE

Shutler (1961) reports a great deal of information in his synthesis of lowland Virgin Anasazi sites. He does not include a table of plant and animal remains, but lists the contents of houses and burials, with each feature or site. Because the finds are not separated by period by early excavators, we cannot visualize changes in subsistence that likely occurred during the time covered (Basketmaker III through Early Pueblo III), a span of about 800 years at the most. Paiute remains were also discovered, at levels above the Puebloan, and in his excavations Harrington (unpublished notes) seems to have taken care to separate the Pueblo horizon from the Paiute levels.

Table 5 lists the occurrences of plant and animal remains from 277 burials in the "Lost City" area (Shutler 1961:44-49), encompassing Basketmaker III through Pueblo III periods (about A.D. 400 through A.D. 1250). Maize cobs, meal, and kernels occurred in 12 of them, and were by far the most commonly found macroplant ecofact. Worked bone was also quite frequent, and was present in 21 of them.

Table 6 lists the occurrences of domesticated and wild foods at 14 sites from the lowland Virgin Anasazi area, and because of early excavation methods and some missing records, includes subsistence data from about A.D. 400 (the beginning of Basketmaker III) through the latest Puebloan occupations of the valley about A.D. 1250 (Early Pueblo III). Maize was found at seven of the 14 sites. Squash of various types (*Cucurbita pepo*, *C. mixta*, and *C. palmata*) was found at four sites, and gourds (*Lagenaria spp.*) at three sites. The only site with beans is the Warshield Rockshelter (Shutler 1961:53). It is difficult to know if the sunflower seeds (*Helianthus annuus*) described in the remains from Chuckwalla cave (Shutler 1961:57) are domesticated or wild types, but presumably wild sunflowers could be easily encouraged in the disturbed soil of fields.

The many non-domesticated plants listed in Table 6 indicate that the subsistence of the lowland Virgin Anasazi was probably a mixed one of both wild and domesticated plants. *Agave* in the form of quids were found at many sites, and *Yucca* materials were found at most sites in several forms: quids, fibers, strings, seeds, fibers and woven sandals. Pinyon nuts (*Pinus edulis*) and cattails (*Typha angustifolia*) each occur at four sites. Found in at least two each of the 14 sites are: mesquite (*Prosopis glandulosa*), screwbean mesquite (*P. pubescens*), catclaw (*Acacia gregii*), barrel cactus (*Echinocereus spp.*) and oak acorns (*Quercus spp.*).

Notably missing are small-seeded grasses and samples of *Chenopodium* and *Amaranthus*. Because flotation and screening was not done in the early excavations, many of these were probably missed in the archaeological record in these lowland sites. The faunal assemblage from the 14 sites is summarized in Table 7. The most common

Table 5. Occurrences of Plant and Animal Materials from Lost City Burials.

Type of Ecofact and Artifact	No. of Burials in Which Item Occurred
Domesticates:	
Maize cobs	*****
Maize, charred	***
Maize kernels	*
(Maize) meal	***
Cotton	**
Pumpkin seed	**
Squash seed	*******
Non-domesticates:	
Blackseed (chenopod?)	*
Cedar bark	*
Mesquite bean cake	*
Screwbeans	**
Small seeds (unknown spp.)	*
Unworked Bone and Animal Parts:	
Animal bone (misc.)	**
Antler (misc.)	**
Antler, elk	*
Tortoise shell carapace	****
Wildcat skeleton	*
Worked Bone and Animal Parts:	
Bone awl	******
Bone bead(s)	**
Bone dice	*
Bone gaming piece	*
Bone pendant	*
Bone pin	*
Bone spatula	****
Bone whistle	***
Fur (blanket)	*
Tanned skin	*

species was the desert tortoise (*Gopherus agazzizi*). Other species include mule deer *Odocoileus hemionus*), mountain sheep (*Ovis canadensis*), rabbit (*Lepus spp.*) and

Table 6. Occurrences of Domesticated and Non-Domesticated Plant Foods from 14 Sites in the Lost City Area.

Domesticated Plants	R. Shelter #1	R. Shelter #2	R. Shelter #3	R. Shelter #7	R. Shelter #10	R. Shelter #11	Footprint Shelter	Warshield Shelter	Boulder Rockshelter	Chuckwalla Cave	Salt Cave #1	Salt Cave #2	Salt Cave #3	Open Pit Salt Mine
Beans								*						
Gourd								*		*	*			
Maize		*	*				*	*		*	*		*	
Squash		*					*	*		*				
Sunflower										*				
Non-Domesticated Plants:														
Acacia				*			*							
Agave		*			*	*	*	*	*	*	*		*	*
Barrel Cactus		*						*						
Cattail					*		*		*	*				
Coyote Squash		*												
Mesquite										*	*			
Screwbean Mesquite		*								*				
Oak (Acorn)						*								
Pinyon Nuts		*				*	*	*						
Prickly-Pear								*						
Yucca	*	*		*	*	*	*	*	*	*	*		*	*

Table 7. Occurrences of Faunal Remains from 14 Sites in the Lost City Area.

Faunal Artifact	R. Shelter #1	R. Shelter #2	R. Shelter #3	R. Shelter #7	R. Shelter #10	R. Shelter #11	Footprint Shelter	Warshield Shelter	Boulder Rockshelter	Chuckwalla Cave	Salt Cave #1	Salt Cave #2	Salt Cave #3	Open Pit Salt Mine
Animal skin (unid.)		*												
Bird bones				*			*				*			
Bone (unidentified)	*													
Bone tools	*							*	*		*		*	
Coyote skin						*								
Deer bones		*						*						
Deer skin		*						*	*	*	*			
Deer teeth								*	*					
Feathers								*			*			
Fur (unidentified)													*	
Mt. sheep bones		*							*		*			
Mt. sheep skin		*								*				
Rabbit bones								*				*	*	
Rabbit fur											*			
Rabbit skin									*		*			
Tortoise carapace	*	*						*	*	*			*	

(*Silvilagus spp.*), and bird bones. Preservation in the rockshelters was excellent, as it was in Black Dog Cave, and rabbitskin, rabbit fur, deer skin and feathers was recovered (Shutler 1961:50-60).

SUBSISTENCE AT BLACK DOG CAVE

Black Dog Cave contained a number of pits; many were grass-lined and others were slab-lined or plastered with adobe. Several of the pits contained maize cobs, squash rinds and peduncles; some of the rinds were smooth, and others were warty. There were a few kernels of corn in artifact bags at the Nevada State Museum in Carson City, and these are described in Chapter 6. I also found two beans (*Phaseolus vulgaris*) in an artifact bag with squash seeds and parts, so three of the four domesticated plants of the prehistoric Southwest are represented in the collections taken from the cave. I did not notice any of the distinctive, squarish seeds of gourds (*Lagenaria siceraria*) mixed in with the abundant squash (*Cucurbita spp.*) remains, but many of the "squash rinds" are quite thin, and look very much as if they are the remains of gourds. As seen in Table 6, gourds were found in three "Lost City" sites, and possibly could have been grown at Black Dog Cave as well.

The contents of pits excavated at Black Dog Cave in 1942 and from samples at the museum from “general diggings” are listed in Table 8. Wheeler (1942) reports that many of the pits in the cave were empty (pits 3, 5, 6, 7, 10, 11, 16, 17, 23, 24, 25, and 26), while maize cobs were found in several pits (pits 1, 4, 20, 27, 28, 29, 3O, 31, 33, and 34). Squash rinds, seeds, and other *Cucurbita* parts were found in pits 4, 20, 27, 29, 30, 33, and 34 (Wheeler 1942; Lyneis 1997:15). Several specimen samples were labeled "general diggings," or "backfill," and the beans most likely came from one of these areas, and were not found (or were not listed as found) in a pit. It is possible that small seeds such as *Chenopodium* and *Amaranthus*, were missed, as the excavations were not

Table 8. Cultivated, Gathered, and Hunted Foods from Black Dog Cave.

Pit #	Lining	Maize	Squash	Beans	Seeds	Fur	Feathers
1	Grass	*	*			*	
2	Slabs						
3	Grass						
4	Grass	*	*				
5	Grass						
6	Grass						
7	None						
8	Slabs						
9	Grass						
10	Grass						
11	Grass						
12	Slabs						
13	Grass						
14	No Record						
15	Grass				*		
16	Grass						
17	None						
18	Grass						*
19	Grass					*	
20	Grass	*	*			*	
21	None		*				
22	Grass						
23	Slabs						
24	Adobe						
25	Slabs						
26	Slabs						
27	Slabs	*	*				
28	Grass	*	*				
29	Slabs	*	*				
30	Slabs	*	*				
31	Adobe	*					
32	Grass						
33	Slabs	*	*				
34	Adobe	*	*				
Gen. Dig		*	*	*	*		

screened. All maize remains recovered in the pits were cobs, shanks, or husks, except for an ear with most of its kernels (catalog no. 2-121-176), found in pit #4, and described and photographed in Chapter 6. Pit #28 also contained leather, and bone objects (dice or inlays) (Wheeler 1942:45). Four of the kernels of maize were in sample containers at the museum from the general excavation of room 2, stratum 2, no. 10, and one kernel was in a sample bag from room 2, south side, no. 12. The kernels are described in detail in Chapter 6.

On the surface, it appears that subsistence at Black Dog Cave was primarily oriented toward cultivated plants, because many of the wild plants that occurred in other Virgin Anasazi sites in the Moapa Valley were not listed in the assemblage. Another possibility is that the there was a sampling bias toward cultigens on the part of the excavators.

The number of maize cobs is prodigious, and far outnumbers plant remains of other cultigens, but of course maize cobs preserve well under dry conditions such as those inside the cave. The cob found in the cave that still has kernels attached is described and pictured in Chapter 6 of this volume (Figure 12).

Taking all the data currently available, it is evident that the lowland Virgin Anasazi of the period of at least A.D. 400 through A.D.1250 had a mixed subsistence of both cultivated and gathered plants. Some of the plants and many of the animal remains found in lowland sites had to have been brought there from the uplands, including the following: *Agave*, prickly pear, oak acorns, and pinyon nuts. It is difficult, however, without carbon isotope studies of skeletal material from lowland sites to ascertain what percentage of the lowland Virgin Anasazi diet was composed of cultivated plants, and to know how much of their diet was composed of gathered and hunted foods.

PLANTS AND ETHNOGRAPHY IN THE SOUTHWEST

When we examine the ethnographies of historic Southwest peoples, we have to remember that social, economic, dietary, and food procurement patterns have changed since prehistoric times. Also, European crops tended to fill niches that were once filled in the diet, or interfered with the timing of procurement of other foods, both wild and cultivated. There is also the matter of preservation in the archaeological record. Charred, burned, or roasted plant remains preserve the best in archaeological sites, followed by plants with hard, inedible parts. These are followed in turn by plants with "...somewhat dense parts," and lastly, by plants with soft parts with high water content; these preserve poorly in archaeological sites (Minnis 1981:149).

Even with the excellent preservation of maize cobs, maize (*Zea mays ssp. mays*) was probably the most important domesticated plant for the Virgin Anasazi, and is found from the earliest sites through abandonment of the region in the early to mid 1200s. It is also probable that its importance, or percentage, in the diet changed over time for the Virgin Anasazi. Maize is ubiquitous in both highland and lowland Virgin Anasazi archaeological sites.

Maize was thought to have made up from 50% to 60% of the diet of the aboriginal Pima cultural group before contact disrupted the balance with the addition of new crops (Castetter and Bell 1942:56). The Pima lived in a lowland desert climate with access to nearby uplands, in a similar, though more lush and productive environment than that of the Virgin Anasazi. In poor crop years, the Pima were forced to rely more heavily on wild resources, especially mesquite beans and saguaro fruit, screwbean mesquite, cholla buds and fruits, and increased hunting (Castetter and Bell 1942:57). The nearby Papago, also in a lowland desert environment, were thought to have cultivated only about 20% of their food supply in pre-contact times, and in poor years relied more on wild foods (Castetter and Bell 1942:56).

Rather than stating the percentage of reliance on cultigens for an entire cultural phase for the Virgin Anasazi, it might be more accurate to state that Virgin Anasazi subsistence (at their level of technology, and in an unpredictable climate) was quite dynamic and changed year to year depending on weather and crop success. Ethnographic data show that people tend to revert to less-desired foods in times of stress, and to "famine foods" in times of great need. They also will go farther afield for desired foods.

Historic Southern Paiutes grew maize in the former Virgin Anasazi region, but it was probably not nearly as significant a part of their diet as it was for the Anasazi, because the Paiutes tended to be quite mobile, and relied much more heavily on wild plants than did the more sedentary Anasazi (Fowler 1981:132). The Paiutes are known to have moved seasonally, following the ripening of various wild plant resources and the seasonal movements of animals. Older people stayed in camps year-round (Fowler 1982:127). Pinyon nuts, mesquite, screwbean mesquite, and Indian ricegrass were important gathered plants for the Southern Paiute (Steward 1938:183). Early summer was when the cool season grasses ripened, including *Oryzopsis spp.* (Indian ricegrass), *Mentzelia*, *Sporobolis*, *Elymus*, and *Atriplex* (Fowler 1983:133; Fowler 1986:69). Grass seeds were cached for winter use. Summer was also the time to gather *Chenopodium* seeds. In late August they left the lowlands to gather pinyon nuts on the Kaibab Plateau. If the pine nut crop was poor, they went to the rim of the Grand Canyon to harvest *Agave* (Fowler 1982:127). From mid-October through mid-December the people hunted and consumed their stored foods (Fowler 1982:1 33).

Both mesquite (*Prosopis glandulosa*) and screwbean mesquite (*P. pubescens*) were very important to lowland Colorado River peoples, including the Mohave, Cocopa, and Yuma, and to the desert-dwelling Pima and Papago (now referred to as the Tohono O'odham) (Castetter and Bell 1942, 1951). Mesquite was considered the most important of all food plants by the Pima (Castetter and Bell 1942:63, 1951:186). The green pods could be chewed fresh, and when ripe they could be toasted or parched and pounded into

meal. Toasting kills the burchid beetle larvae that infest the pods. Mesquite beans, pods, and cakes could easily be stored for future use. The trees have a variability in yields with an average of one year out of five of non-fruiting (Nabhan et al. 1979:181). Stands of mesquite exist in the Virgin River and certainly existed along the Colorado River in areas now flooded by Lake Mead, and all along the river to its mouth in the Gulf of California in "...dense stands...on the finer soils of areas flooded only occasionally" (Castetter and Bell 1951:23). Mesquite ranges in altitude up to 1170 m in the Virgin River drainage and into the St. George Basin (Allison 1990:127), and the seed pods ripen from April through September, beginning at low elevations first (Nabhan et al. 1979:181). The Pima and Papago were considered by Nabhan to have a "legume-based diet" with both gathered mesquite and cultivated beans utilized as staple foods (Nabhan et al. 1979:173).

It is not known to what extent the Virgin Anasazi utilized mesquite, but two rockshelter sites and three burials in the lowland "Lost City" sites contained mesquite in Shutler's (1961) report. Hayden also indicates the presence of screwbean mesquite at Mesa House (Hayden 1930:83) and Lyneis (1992b:Table 69) listed screwbean mesquite in the remains from Main Ridge. Mesquite is not quite as plentiful in the Virgin River area as it is in the lower Colorado and Gila River drainages, and may have not been as much a staple for the Virgin Anasazi as it was for the Pima, but would have been a valued dietary item- a very nutritious one with a long season of availability, and one that could be encouraged through management of the groves.

Agave, both *A. utahensis* and *A. deserti*, are the northernmost species of the large genus of *Agave* in North America. *Agave* was undoubtedly an important food source for the lowland Virgin Anasazi, and as seen in the archaeobotanical record in Table 6, has been found in many "Lost City" sites. It has the advantage of being available year-round (Allison 1990:33). The Kaibab Paiutes gathered it in early spring (often a time of low food availability for ethnographically recorded peoples of the Southwest). *Agave* plants were cut off at the base, the leaves trimmed off and then roasted in a pit in the ground.

The heart was pounded into a cake, or roasted, or dried and ground into flour. For the Cocopa, *Agave* was the most important wild plant in spring, being gathered from April on (Castetter and Bell 1951:202). *Agave* is available on mountain foothills on the sides of the Grand Canyon at altitudes of 1000 to 1550 m (Allison 1990:33). It is possible that cutting the plants off and leaving enough leaves for regrowth actually encourages the population of *Agave*, because if the plant is not cut, it will bloom and die in a few years. If the center of the plant is cut off the life of the plant will be extended to about 15 to 20 years before dying (Sheldon 1980:377).

Yucca was another very important plant to the lowland Virgin Anasazi, as demonstrated by the numerous occurrences of it in lowland sites (Table 6). Its hard fibers also preserve well in the record, and many examples of cordage and woven sandals were recovered in the Moapa Valley rockshelters (Shutler 1961:50-60). The Southern Paiute were known to eat the fruits of *Y. baileyi* and *Y. baccata*, the seeds and fruits of *Y. brevifolia* (Joshua tree), and the apical meristem (as in *Agave*) of *Y. utahensis* (Fowler 1986:69).

Several cacti were exploited for food by Southwestern peoples that also occur in archaeological deposits of the Virgin Anasazi, including prickly pear and cholla (*Opuntia spp.*) buds, pads, and fruit, and barrel cactus (*Echinocereus spp.*). The spines of the pads, buds, and bodies of these cacti were burned off in roasting pits and the soft parts were eaten. The fruits of prickly pear are very sweet, and still popular in the Southwest and Mexico, where they are called “tunas” (Russell and Felker 1987:436). Blossoms of chollas were sometimes eaten as a famine food by the Southern Paiute (Kelly 1964:45). The time of gathering the buds of chollas by the Pima was in May, and the fruits were gathered in late summer (Castetter and Bell 1942:59-60). Huffman (1993:130) found that many of the so-called "*Agave*-roasting pits" at sites on Mount Trumbull and the esplanade of the Grand Canyon contained more remains of cholla and other *Opuntias* than they did of *Agave*.

Cool-season upland grasses were gathered in early summer by the Southern Paiute, and were an important source of food. Species harvested include *Mentzelia*, *Sporobolis*, *Elymus*, and *Oryzopsis hymnenoides* (Indian rice grass) (Fowler 1986:69). These may have been more important in the proto-historic period than in the historic period because their use had been superseded by cultivated wheat (a cool-season annual grass) soon after contact. It is also possible that pre-contact use of grasses by Puebloan peoples has been underestimated. John Doebley pointed out that the Yumans used seeds of 29 species of plants, seven of which were grasses (Doebley 1984:53), and the Paiute used 33 species of grasses alone (Doebley 1984:54-58). *Panicum sonorum* and *Oryzopsis hymenoides* were probably the two most important ones in the Southwest in pre-contact times (Doebley 1984:62). This information illustrates the orientation to seeds in the subsistence of peoples of the Southwest that has continued since the Archaic period, as discussed in Chapter 2 of this volume. It is unfortunate that we are unable to know how many of these small-seeded grasses occurred in the deposits of Virgin Anasazi sites that were excavated early in this century, before soils were screened.

Pinyon nuts (*Pinus monophylla* and *P. edulis*) were very important to upland groups on the Colorado Plateau, including other Anasazi east of the Virgin area. These nutritious nuts were important to the Zuni, Tewa, Southern Paiute, and Kawaiisu, but less important to the Cocopa, Yuma, and Hopi (Bye 1972:80; Castetter and Bell 1951:197; Kelly 1964:43). The Southern Paiutes gathered pine nuts in late summer and fall, roasted them to open the cones, and stored the nuts unhulled (Allison 1990:34). Seeds of *P. edulis*, which grows in upland Utah and to the east into Colorado, were considered to be the preferred choice of the two species in early historic times. *P. edulis* has larger nuts with thinner shells, and was known to have been traded as far from its natural habitat as Mexico in Spanish Colonial times (Robbins et al. 1916:41).

The crop (mast) of pinyon nuts varies from year to year, with an average production of large crops in three years out of 10, with very few seeds and cones

appearing on trees in intervening years (Bye 1985:377). Even today biologists have difficulty predicting long-term production and yields of pinyon nuts (Bye 1985:376). Pinyons are dioecious, and behave differently according to age. Young trees are male dioecious and only produce pollen; middle-aged trees are female dioecious and produce the most and best quality nuts; older trees are both male and female dioecious and produce both pollen and nuts. By cutting older trees pinyon stands could have been managed over the long term to maximize nut production (Bye 1985:378).

In their study of eastern Anasazi nut consumption over time, Floyd and Kohler (1990:154) found decreased use of pinyon in relation to maize by increasingly sedentary Anasazi after A.D. 850. They identified a decline in the use of pinyon nuts as a reflection of the reduced mobility of a population focusing increasingly on cultivated foods, and as a result of overexploitation of pinyon for nuts and firewood. It is possible that the Virgin Anasazi, with their lower populations relative to the eastern Anasazi groups, did not have this problem, and it is likely that pine nuts were always a preferred food item. Pinyon nuts are a valuable dietary component, and would complement a maize diet very well, possibly better than any other food available at the time. They are a source of iron, phosphorus, vitamin A, thiamine, riboflavin, and niacin, in addition to the amino acids tryptophan and cystine (Bye 1985:376). They can be also be easily ground and mixed with ground maize meal. As demonstrated in Table 6, pinyon nuts occurred in archaeological deposits in four lowland Virgin Anasazi sites.

The Southern Paiutes stored pinyon nuts in grass lined pits (Fowler 1986:65). Caches of seeds in parched cones would keep four or five years if the pits were constructed well (Steward 1943:271).

Acorns (probably of the species *Quercus turbinella*) have been found in two of the "Lost City" sites. It is difficult to determine if acorns were a frequently exploited food by the Virgin Anasazi, but we know that they were important ethnohistorically in the Great Basin. The local species *Q. turbinella* has acorns which do not need to be prepared by

leaching, and were picked by the Paiutes and then pit-roasted, shelled, ground into meal, and made into mush (Fowler 1996:65). The Papago valued acorns very highly, but acorns were not plentiful or easy to obtain. The species the Papago used were *Q. kellogii* and *Q. turbinella* (both are under different names in Castetter and Bell [1942:61-62] and have been renamed since the 1940s).

Pigweed (*Amaranthus spp.*) and goosefoot (*Chenopodium spp.*) both were found frequently in more recent excavations of Virgin Anasazi sites, especially in the St. George Basin. Both are known to have been used by many Southwestern aboriginal peoples. The Yuma picked the seedheads, winnowed them, parched them, and ground the seeds into meal (Castetter and Bell 1951:189-190). Goosefoot is an important source of iron, especially as greens. Goosefoot was gathered by the Pima and Papago in early summer, along with saltbush (*Atriplex spp.*) and wild amaranth (*Amaranthus palmeri*).

Amaranthus is an important cultivated species in Mexico, and may have been cultivated by the Virgin Anasazi. Cultivated amaranth seeds and plant parts have been found at Tonto ruin, and at Snaketown, Arizona, two archaeological sites located in lowland desert environments (Bohrer 1970:419).

Though the wild buffalo gourd (*Cucurbita foetidissima*) is not considered a cultigen, seeds found in Virgin Anasazi sites are well outside the present range of this perennial plant, which is to the east- New Mexico and Texas (Bemis et al. 1978:Fig 1). *C. foetidissima* tends to colonize sandy streambanks and roadway banks with disturbed soils. If its prehistoric range was not wider than it is today, and it did not exist in the wild in the Virgin area, it could have been easily started by the Virgin Anasazi from seeds, roots, or runners (Bemis et al. 1978:90). Seeds could have been easily traded into the Virgin area from other Anasazi or from the Hohokam, who were growing or gathering it by A.D. 800 (Bohrer 1970:414). The plant is a perennial and well-adapted to dry climates. It would be an easy plant to encourage, and once started, would be a prodigious producer of seeds and fruits. One plant can produce an average of 272 fruits per plant with an average of 315

seeds per melon (Bemis et al. 1978:91). The seeds are rich in oil and edible; the Pima roasted and ate the seed (Russell 1908:70). The probable use of this plant by the Virgin Anasazi is the most outstanding example of manipulation and encouragement of wild plants in the area, and an indication that some of the native plants of the Southwest were undergoing incipient domestication.

Domesticated gourds (*Lagenaria siceraria*) were cultivated by the Virgin Anasazi, as indicated by their occurrence in three "Lost City" sites (Table 6). Gourds were also grown by the low desert-dwelling Pima, Papago, and Yuma (Castetter and Bell 1942:108; 1951:115-116). They were very useful as water containers, rattles, food containers, and dippers. Richardson (1972:271) revealed that gourds had a world-wide distribution before 12,000 years ago, and were in the Americas before the beginnings of horticulture. It is interesting to note that gourds are one of the oldest of all cultivated plants, but are not specifically food plants (their seeds are edible) and that in a harvest schedule can be left in the field until the last, after other crops have been processed (Castetter and Bell 1942:180). The Pima and Papago each made one planting of gourds, but at different times: "...the Pima planted [gourds] in late March or early April, and the Papago in July" (Castetter and Bell 1942:200). In each case, the gourds were gathered all at once, while still green, but timed so as to be ready after other crops, such as maize, tepary beans, and pumpkins had been harvested.

In the botanical collections from Black Dog Cave at the Nevada State Museum there were ample remains of various varieties of squashes and pumpkins (*Cucurbita pepo*, *C. mixta* and *C. moschata*). *C. pepo* was the first squash species to be grown in the Southwest, from about 300 B.C.; followed by *C. mixta*, from about A.D. 380. The last introduced squash species was *C. moschata*, found in deposits beginning about A.D. 900 (Whitaker 1981:Table 1). A detailed study of squash remains from Black Dog Cave could probably separate the species because there are many well-preserved specimens of rinds, seeds, and peduncles. Squashes and pumpkins were found in nine burials in the "Lost

City" area (Table 5), four "Lost City" habitation sites (Table 6), and in four burials from Main Ridge (Lyneis 1992b:Table 70).

Both tepary beans (*Phaseolus acutifolius*), and common beans (*P. vulgaris*) were grown by the Pima, Papago, Maricopa, Yuma, and Southern Paiutes (Castetter and Bell 1942, 1951; Kelly 1964). The Pima gathered the beans when ripe and dried and stored them. Tepary beans matured later than maize, and so were harvested a bit later (Castetter and Bell 1942:179).

Beans do not often preserve well in archeological deposits, unless in quite dry situations, like inside rockshelters. The only beans reported from lowland Virgin Anasazi sites, up to the present, are those reported here for the first time, from Black Dog Cave, found in general deposits, and not from features. The only other beans (*P. acutifolius* and *P. vulgaris*) reported from Virgin Anasazi sites were found at the ZNP-21 site in the St. George Basin, from Basketmaker II levels (Lyneis 1995:221).

The Pima made two plantings per season of squash, pumpkins, maize and beans. All were planted at the same time, two times a year, the first in late March/early April, and the second in late July/early August. The first harvest was in late June, and the second harvest was in late October/early November (Castetter and Bell 1942:179, 188). Maize matured and was harvested first, followed next by beans, and last by pumpkins and squash. Gourds and cotton were harvested after everything else had been harvested and processed because frost would have no effect on their respective products (Castetter and Bell 1942:179, 180, 188).

The reason the Pima could plant twice was because of the flooding of the Gila River in the spring that left moist planting ground and facilitated the first planting. The second planting was possible because of summer rains that allowed floodwater planting and cultivation. The Pima used both floodwater techniques and water diversion via canals and brush dams (Castetter and Bell 1942:150-169).

The Papago only planted their crops once, and used floodwater farming techniques. "Papago farming plots were almost without exception located at the mouths of washes, where they could be watered by floodwater of the summer rains" (Castetter and Bell 1942:125). Apparently seasonal rains were abundant enough to enable maize cultivation at the mouths of drainages in the Papago region.

On the lower Colorado, where summer rains were scant and extremely unpredictable, the Yuma, Maricopa, and Cocopa were able to plant only one crop of cultivated plants, in areas subject to floodwaters from the Colorado River. Crops were planted as soon as the spring floodwaters receded, in the soft mud. Brush and earth dams were made to divert water into a series of swales, where water could be held for later release to irrigate (Castetter and Bell 1951:132-135). "The pursuit of agriculture on the lower reaches of the Colorado, on the basis of utilizing the summer overflow to supply moisture for growing quick-maturing crops, gives every indication of being ancient" (Castetter and Bell 1951:132). Colorado River water usually receded by late June or early July, and the crop was planted then. The harvest was in late October and early November (Castetter and Bell 1951:145). It is important to note that climatic constraints of having to plant after floodwaters receded, and of plants having to rely primarily on residual moisture, created a highly selective time factor on the crops planted on the lower Colorado that favored maize that matured quickly. This is an interesting parallel to the selective factors acting on maize at high altitudes in the Southwest, where the season is limited by frosts, both early and late. Also, the planting and harvesting of crops twice in a season, as was practiced by the Gila River Maricopa, Pima, and Gila River Yuma, would also favor and select for fast-maturing strains of maize and other crops.

A PROBABLE SEASONAL FOOD-PROCUREMENT CALENDAR FOR THE LOWLAND VIRGIN ANASAZI

From currently available archaeological, climatic and ethnographic data it is possible to recreate a tentative annual calendar of the seasonal food procurement schedule of the Virgin Anasazi for the period A.D. 400 through A.D. 1250. The proportions of gathered foods to wild foods, and the percentage of maize and other cultigens in the diet, would have undoubtedly varied and changed with time, but we can at least visualize a basic plan of the timing and general availability of crops on a month-by-month basis.

January and February. *Agave* and *Opuntia* would be available at middle altitudes, and could be roasted. Animals could be hunted, rabbits and tortoises in the lowlands and deer and mountain sheep in the highlands (rabbits and tortoises were available all year in the lowlands). In these winter months, most of the food needed to nourish the Virgin Anasazi would have to have been taken from stored reserves.

Late March and April. Mesquite pods (*Prosopis spp.*) would begin to be ripe at the lowest elevations, and cholla buds (*Opuntia spp.*) and wild tubers would be ready to harvest. Maize, beans, squash, gourds, amaranth, tobacco and cotton (if grown) could have been planted at this time, in areas of receding flood runoff along the Virgin River, and along the perennial Muddy River.

May. Mesquite would continue to ripen at increasing elevations, and service berries (*Amelanchier spp.*) and other wild berries would be available at high elevations. Late plantings of domesticates could be put in at sites along the Muddy River because of the availability of water.

June. Cool-season upland grass seeds including Indian rice-grass (*Oryzopsis hymenoides)* would be ripe now; saltbush (*Atriplex spp.*) and cattails (*Typha spp.*) would be ready for harvest, and *Chenopodium* greens and seeds would be available in middle and higher altitudes. Mesquite would continue to be available.

July. *Opuntia* cacti species and *Yucca* fruits would be ripe, and *Chenopodium* and *Amaranthus* seeds would be ready for harvesting. Cultivated plants from the first planting of crops would be ready for harvest now, beginning with maize, followed by tepary and common beans, then squash, tobacco, pumpkins, and last by gourds and (possibly) cotton. In late July a second planting of all cultivated crops could take place in areas with sufficient or steady supplies of water, as along the spring-fed Muddy River. The site of Black Dog Cave, along the Muddy River, is one site in which a second crop could be grown because of the ability to divert water in the summer with brush dams.

August. The mesquite growing at the highest elevations would now be ripe (about 1170 m), and in late August pinyon nuts would be ready for harvest at high mountain elevations. Late plantings could be made of domesticated crops in the valley, but they would be at risk of frosts at just about the time that they were ripening in November.

September. The pinyon harvest could continue, along with hunting of highland animals, including deer and mountain sheep. Late in the month the early second crop harvests would begin.

October. This would be the main harvest time for the second crop of domesticated plants, with peak activity in late October, when most July plantings would be ripe.

November. Processing of harvested crops would continue, and the last of the gourds and cotton would be harvested. Hunting could continue.

December. Subsistence would mostly consist of stored and previously gathered foods, but task forces could be sent out on hunting trips. The Virgin Anasazi probably lived on stored foods during December, January, February, and March.

This subsistence system somewhat parallels that of the ethnographic Pima, but the lowland Virgin Anasazi environment was, and is, not as productive as the environment of southwestern Arizona. There are very limited summer rains here (Figure 6) and less

abundant resources (including mesquite). Also, a significant element in Pima diet, the saguaro cactus (*Carnegia gigantea*), does not exist in the Virgin Anasazi area.

The Virgin Anasazi subsistence system has no modern ethnographic analog, primarily because of the unique climate. There were no summer rains to speak of, so crops had to be irrigated. If these people double cropped, or planted their domesticated crops twice a year, they had to rely entirely upon irrigation. The humidity that comes along with summer rains in Arizona, aiding in the pollination of maize, only occurred rarely, and was of shorter duration in the Virgin Anasazi region (as is the situation today) so crop productivity may have been less here.

It is rather obvious from the archaeological data from lowland Virgin Anasazi sites that they had a mixed subsistence; thus, the model of a mixed subsistence, presented by Dalley and McFadden (1987) would seem to be supported for lowland Virgin Anasazi sites.

Whether the Virgin Anasazi sent task forces out to acquire wild plants and animals or traded for upland resources is difficult to answer. It would have been impractical for everyone to go into the uplands to gather or hunt while crops were needing care, especially in March/April, July, and September/October, the busiest times of the annual planting and harvesting schedule.

It is difficult to estimate the percentage of meat and wild and domesticated plants in the Virgin Anasazi diet, for any given period. If they double-cropped, it is likely that they consumed a significant quantity of cultivated plants, especially maize, as they would have had a greater food production than if they only planted one crop. They also would have been required to spend more time planting, harvesting, and caring for plants if they planted and harvested twice. If this was the case, they might not have had as much time to pursue the gathering of wild plants. If the Virgin Anasazi double-cropped, then perhaps cultivated plants would have formed 60% to 70% or more of their diet, as was the case for the Pima, Basketmaker II populations and the later Anasazi of Pueblo times, who lived

to the east of the Virgin Anasazi, on the Colorado Plateaus.

CULTIVATION AND SELECTION OF MAIZE IN THE ETHNOGRAPHIC SOUTHWEST

Examination of planting techniques and seed selection practiced by aboriginal groups located in areas near the Virgin Anasazi region can illuminate probable agricultural and selective practices of the Virgin Anasazi from Basketmaker II through abandonment of the area. Ethnographies have been conducted of the Zuni (Cushing 1920), Pima and Papago (Castetter and Bell 1942), Mohave, Yuma, Maricopa, and Cocopa (Castetter and Bell 1951), and Western Apache (Buskirk 1986). These studies reveal several shared patterns of behavior, and from them we can gain insight into the process of raising maize in the desert Southwest, and possibly a sense of what the planting and selection of maize may have been like for the Virgin Anasazi.

In choosing sites for maize in the lowland Colorado River and the lower Gila River areas, the Papago paid close attention to several factors. Good, dark soil was the most valued kind. If it held a vigorous growth of wild plants, it was probably suitable for planting maize (Castetter and Bell 1942:122). Salt-laden soil was avoided, and could be readily recognized by the growth of saltbush (*Atriplex spp.*), by a white encrustation, by a sticky texture of the soil when wet, or by tasting it (Castetter and Bell 1942:123). Salinity has been a problem for modern farmers in the Moapa Valley, and surely must have been for the Virgin Anasazi, who probably grew crops in local areas for generations (Lyneis 1997, personal communication). The Mohave also were aware of salinity and avoided planting maize in areas where saltgrass (*Distichlis stricta*) was growing (Castetter and Bell 1951:24).

To prepare a field for planting, the Maricopa burned the brush (Castetter and Bell 1951:140). The Western Apache also burned brush and grass, and removed roots from the field (Buskirk 1986:61). The Papago did not have to do much clearing, because they

practiced floodwater farming in arroyo deltas, where vegetation was usually sparse. If a field needed to be cleared, "...the brush was first trampled, then allowed to dry, and burned, after which the roots were pulled out" (Castetter and Bell 1942:125). The River Yuma did not need to prepare fields, and simply planted in the soft mud of the floodplain of the Colorado River after the waters receded in early summer (Castetter and Bell 1951:74-75).

In preparing land for planting the Zuni made brush dams to catch stream waters, in a sort of patchwork pattern, so the water would be slowed and would spread. This would cause it to flow from one area bounded by a brush dam to the next; thus, the water was evenly distributed over a considerable area (Cushing 1920:157-158). This method also collected fine, sandy loam from the floodwaters, which was deposited on the fields, continually enriching them. Both Hayden (1930:85) and Shutler (1961:5) believed that the Virgin Anasazi had used water diversion or brush dam systems along the Virgin and slow-moving Muddy Rivers.

It appears that in nearly every case, aboriginal farmers of the lowland Southwest either planted in a field that was previously moistened, or flooded or irrigated the field before planting. The Western Apache soaked their fields a week or so before planting (Buskirk 1986:65). The Papago planted their seeds in moist ground after the first rains of summer (Castetter and Bell 1942:44). The Pima also planted in moist ground, after the floodwaters of the Gila had receded for their first planting (Castetter and Bell 1942:151) and after the summer rains began for their second planting (Castetter and Bell 1942:144). Planting was done with wooden planting sticks by the following groups: Zuni (Cushing 1920:175), Papago (Castetter and Bell (942:134), River Yuma (Castetter and Bell 1951:94), and Western Apache (Buskirk 1986:61). One Pima man was able to "...plant about a half acre of [maize] or teparies per day" (Castetter and Bell 1942:153). The Pima planted their maize about 10.6 cm (4 inches) deep in hills about 76.2 cm (30 inches) apart (Castetter and Bell 1942:152). The Zuni planted in hills of 12 to 20 seeds "...to great

depths" (Cushing 1920:181).

Cushing (1920:181) describes a great deal of ritual activity surrounding the planting of maize, and this was another consistent pattern of behavior among many groups in the Southwest, as reported in ethnographies. The Zuni ceremonial leader made a ritual planting of six different colors or kinds of maize, and four days passed before the field crop was planted. Directional symbolism and counting of seeds was quite important to the Zuni (Cushing 1920:175). The Zuni recognized six cardinal directions, each with its corresponding color of maize: yellow, north; blue, west; red, south; white, east; speckled, upper (sky); black, lower (earth) (Cushing 1920:175). The Hopi and all other Puebloan peoples placed great significance on the ritual meanings and the colors of maize, in fact, maize was (and is) central to historic Pueblo religion (Ford 1994:515, 517). How far this patterning of behavior extends back into Pueblo history is not known, but ears of maize with feathers, deerskin, and turquoise or hematite tied to them have been found in Pueblo archaeological sites. Morris (1986:125-126) describes and illustrates examples of two of these ritual artifacts from Pueblo III deposits from Antelope House at Mesa Verde. He also found evidence of separation in storage of colors of maize, and of probable storage of ears for seed.

Castetter and Bell (1951:102-104) found that the Papago grew five separate colors of one race of maize, Pima-Papago. The Maricopa grew six different colors in early times, and the Yuma grew five different colors. Among the Pima "...there was no ritual planting by direction as among the Pueblo Indians" (Castetter and Bell 1942:155). Castetter and Bell (1951) list no ceremony surrounding the planting of maize among the Yuma of the lower Colorado River area, but indicate that they had a directional color symbolism: "...white [maize] came from the north and this represented the beginning of life; yellow from the east, blue from the west, and red from the south" (Castetter and Bell 1951:22). It seems that the Yuma planted as quickly as possible, with men, women and children taking part, to get the crop in, and to take advantage of the residual moisture in the soft

river mud left by receding floodwaters (Castetter and Bell 1951:132, 137, 148).

Some of the Western Apache practiced directional planting, but the seeds were not carefully counted into the holes as was practiced by the Zuni (Buskirk 1986:66). Some Apache groups grew separate colors of maize, and all stored each of the colors of seed maize separately (Buskirk 1986:64). The evidence of cross-cultural directional color symbolism and separation of maize by color indicates that these practices may be long-term traditions, also extending back into Anasazi history. Since the Apache were more recent arrivals (relative to the Anasazi) to the Southwest, it appears that they borrowed some of the ritual and cultural meanings associated with maize after they arrived in the Southwest.

The amount of maize planted each season by tribal groups in the western Southwest varied according to their dependence on maize and other cultivated crops. In Hegmon's (1992) study, it was noted that the upland-dwelling Hopi, who depended upon maize for 71% of their diet, planted about 2.43 hectares (six acres) of maize for a family of eight people in one household, four of whom were children (Hegmon 1992:228). Lebo (1991:23) found that the historic Hopi planted enough maize to feed them for two years, as a hedge against crop losses to wind, drought, insects, or animal predations. The average production among the Hopi was about 12 bushels per acre. The amount of land under cultivation was "...traditionally about two times the amount needed to meet minimum dietary requirements of the population for a year" (Lebo 1992:45). The estimates of field production indicate that the Hopi planted about .81 hectare (two acres) per person per year (Lebo 1992:46).

Castetter and Bell (1942:57) estimated the pre-contact Papago diet to have consisted of 50% to 60% cultivated foods, and of this, maize constituted the greatest proportion. They estimated that the Papago had planted from about one-fourth acre to two acres per family of five, and allowing a productivity of 704.78 liters (20 bushels) of maize, teparies or squash per per acre equaled about 3/5 to 5 bushels per person per year

(Castetter and Bell 1942:55-57). The Papago were thought to have depended heavily on gathered and hunted foods. The Pima were thought to have cultivated 50% to 60% of their food supply before European contact, and also depended heavily on gathered and hunted foods (Castetter and Bell 1951:80).

The lower Colorado River peoples depended on maize to an even lesser degree than the Pima or Papago. The Maricopa cultivated about 30% to 50% of their food supply, the Mohave 40% to 50%, the Yuma 35% to 40%, and the Cocopa only about 30% (Castetter and Bell 1951:74). These lower Colorado River tribes could only plant one crop of cultigens a year, using moist muddy areas left by receding river waters, or they waited until the rainy season began in summer, to plant in arroyos and washes (floodwater farming). Some years the rains would not come, and some years the river floods would also fail, or floods would wipe out plantings (Castetter and Bell 1951:152, 161). The average amount of cultivated plants planted for lower Colorado River peoples in pre-contact times was estimated at two acres per family (Castetter and Bell 1951:75), and "...at least half of the crop was eaten as green [maize]" (Castetter and Bell 1951:75).

Ethnographies record that considerable care had to be given to maize crops to ensure a successful yield. The Zuni hoed their maize two or three times a season with wooden tools, and they had to keep a close watch for insects, birds, and other animal pests. Crows were the chief pest to emerging plants, and Cushing (1920:182-185) describes an elaborate "scare-crow" construction built over the Zuni maize fields to protect them from predation. Posts were driven into the ground in the fields and strings were stretched between them, and hung with streamers, rags, and dog and coyote skins that fluttered in the breeze. "Old crows would avoid the field thusly dressed, but young ones do not. Many become caught in hair nooses"...attached to the strings (Cushing 1920:185).

The Pima and Papago used wooden weeding hoes (Castetter and Bell 1942:130), and said that their floodwater fields in washes needed at least two floodings for the maize

to produce ears (Castetter and Bell 1942:171). The Yuma also used wooden agricultural implements, and informants said that they usually hoed and weeded their crops twice during the growing season (Castetter and Bell 1951:151). The crop was protected from predators by the Yuma. "Men and boys went to the fields at night to protect the young plants, at least until they grew large enough so that the seedlings would not be eaten by field mice and gophers" (Castetter and Bell 1951:153). Birds were also a problem for the Yuma, especially when the maize was maturing. Children were sent into the fields "...to drive away birds, rabbits, etc." (Castetter and Bell 1951:154).

The Canyon Creek Western Apache weeded their maize when it was about 15.2 cm (six inches) high, and sometimes weeded again; the Cedar Creek Western Apache weeded their maize only once, when it was about 45.7 cm (18 inches) high (Buskirk 1986:69).

Before the general harvest, many peoples of the Southwest picked some of their maize green, and roasted it. The Zuni (Cushing 1920:203-204), Papago (Castetter and Bell 1942:187), Western Apache (Buskirk 1986:65) and River Yuma (Castetter and Bell 1951:75) all ate some of their maize green. Among the River Yuma "...at least one half [of the maize crop] was eaten as green [maize]" (Castetter and Bell 1951:75). Green maize was roasted in pits overnight, with the husks on, and could be consumed immediately, or dried and hung in storage (Cushing 1920:208).

In the ethnographic literature of the Southwest it appears that the main harvest of maize was usually a group activity involving several age groups working together, and often included ritual activities. The Apache selected "ceremonial stalks" and chose four ears to be used for seed. The maize was then harvested by family groups, piled, and usually husked immediately in the field before moving it to an area to be dried. "Bundles of ten or twelve ears were hung over a tree limb or an improvised drying rack" (Buskirk 1986:71-72). After drying, some of the cobs were shelled, and others might be stored with or without husks. "[Maize] of different colors was almost always stored separately"

Buskirk 1986:73). Maize was stored in pits in the ground, wrapped with grass, or put in pitched baskets, buckskin bags, or pottery vessels placed within the pits. "Seed [maize] was usually stored on the cob at the bottom of the cache" (Buskirk 1986:73-75). Some maize was stored in rockshelters or caves (Buskirk 1986:73-75). Pit-baked and parched maize was not stored in ground caches, and Buskirk does not describe how or where it was stored. The Zuni harvested their main maize crop after frost, and had to keep a close watch for predation from crows and coyotes (Cushing 1920:208, 211). Some of the ears were shucked in the fields, and some was taken to the village with husks still on. The maize was stacked on rooftops to dry. After drying, the maize was separated into color groups, and "nubbin" ears (immature or stunted ears usually from tillers) were separated from good ears (Cushing 1920:212). Some ears were "toasted on the ear" or parched in pits (Cushing 1920:265, 342). Parching would preserve the dried maize well and kill any insects inside the husks.

Harvesting among the Pima was mostly done by women (Castetter and Bell 1942:179). Since there were two plantings of maize, there were two harvests, one in late June, and another in October/November. The maize was considered to be ready when most of the stalks and husks had dried thoroughly (Castetter and Bell 1942:180-181). Some of the maize was husked in the field, and other ears were roasted unhusked for preservation and drying. Ears were then dried on rooftops for ten days (Castetter and Bell 1942:181-182). "...[Maize] was always shelled before being stored, then was ground into meal as needed" (Castetter and Bell 1942:182-183). The Pima's shelled maize was stored in "...large, cylindrical nest-like bins made of arrowweed" (Castetter and Bell 1942:183). The Papago stored their maize ears in baskets placed in pits, and not all in one location (Castetter and Bell 1942:184).

Fast-maturing strains of maize that only took about 50 to 60 days from planting to harvest were grown by the peoples living in the lower Colorado region (Castetter and Bell 1942:187; 1951:157). The River Yuma harvested their green maize in September and

their largest crop of maize in late October and early November (Castetter and Bell 1951:157). For the Maricopa on the Gila River, green maize took only five weeks from planting to be ready to eat (Castetter and Bell 1951:158). The main crop was harvested by simply pulling the plants from the ground, and this was done primarily by women. Some of the maize was husked in the field, and that which was saved for seed was shelled and stored in jars or gourds. "Ears infested with earworm were discarded" (Castetter and Bell 1951:158, 160). Evidently some of the maize that was to be stored was parched (Castetter and Bell 1951:158). Among the lower Colorado River tribes, not as much of their maize crop was stored as among the Pima and Papago, partly because of the danger of floods in the lower Colorado. There, crops were stored in baskets on raised platforms and in clay pots, to protect the stores from floodwater damage.

In this summary of maize cultivation by peoples of the Southwest living near to the Virgin Anasazi area and using a similar technology, there are several patterns of behavior that are consistent and often repeated. These include (1) directional and ritual planting; (2) planting when moisture was already available, or soon to be available to the seeds; (3) cultivation and weeding with wooden instruments; (4) irrigation and water diversion in lowland climates; (5) the consumption of early green maize; (6) group harvesting; (7) husking in the field; (8) the drying and parching of ears; (9) the separation of colors in storage; and (10) storage of the crop in dry, dark places. It is likely that these patterns of the treatment of maize are long-standing traditions that work well in the climate of the Southwest, and have been in place for quite some time. It is also likely that the Virgin Anasazi practiced at least some of them in their cultivation of maize at Black Dog Cave.

The combination of a lowland, hot desert climate that was less productive and drier than the lowland climate of the Pima and Papago, with Anasazi highland technology and practices, created a unique cultural situation for the growing of maize in the lowlands of the Moapa Valley.

Agriculture along the Virgin River itself would have been possible following the

spring runoff, and would have favored quick-maturing maize. The opposing factors of too little moisture (drought) and too much moisture (in the form of floods) would have been very much a part of growing maize along that very dynamic stream. There were no summer rains to speak of to rely on for floodwater farming, and also, very little humidity that would aid in the growth and pollination of the maize crop. Growing maize along the Virgin River would have been limited in its scope and opportunities for success, a somewhat analogous situation to the growing of maize along the lower Colorado River. It would have been possible only when moisture was available, and risky because of the high probability of drought.

Agriculture along the Muddy River would also be a unique prospect for growing maize in the Southwest because it is a perennial, slow-moving, spring-fed stream that has a consistent flow in a lowland desert setting. But the Muddy offers a danger of flooding. There have been significant floods recorded along the Muddy River, including one that swept through the expedition camp a few days after the excavation of Black Dog Cave was completed in the summer of 1942 (Wheeler 1942:16). The growing of maize along the Muddy River would have been nearly a sure thing, with water consistently available for the crop all season and every season. Production would not have been limited by seasonal cycles as it was for the Pima, Papago, and lower Colorado tribes. There was also less risk for the lowland Virgin Anasazi in growing their maize than there was for other members of Anasazi culture living and cultivating on the uplands of the Colorado Plateaus, who depended on rainfall, sand dune fields, or floodwater farming. Because the Muddy River is slow-moving, and the soil is nutrient-rich, they would have been able to easily divert water to crops as long as the stream bed did not become entrenched. Thus, the area around Black Dog Cave would have been an almost ideal place for the Virgin Anasazi to grow large crops of maize, with water available year-round, good soil, a long growing season, and dry storage and safety of the cave.

The following section describes the selection of maize by peoples in the

ethnographic Southwest. There are several consistent patterns of behavior in this also, that give clues to patterns of selection that may have occurred as far into the past as the Pueblo, or even Basketmaker, periods. When these data are combined with what can be gleaned from the archaeological record of maize in the Southwest (as discussed in Chapter 8 of this volume) and with that of the environmental selection continuously taking place in the area, we can gain some insights into what Virgin Anasazi maize and its selection and cultivation were like.

SELECTION OF MAIZE IN THE ETHNOGRAPHIC SOUTHWEST

Several characteristics of maize seem to have been selected for by peoples in the historic period of the Southwest who continued to use prehistoric agricultural technologies. Among these characteristics are ears well-filled with kernels and of uniform shape, specific kernel colors, drought tolerance of plants, size of ears, fast maturity, wind-resistance, and selection for type of endosperm (pop, flint, flour, and dent). [Sweet maize was evidently a post-contact introduction to the Southwest, and has not been found in Anasazi archaeological remains]. Maize was also selected for specific uses in the ethnographic Southwest, including ceremonial functions and grinding, roasting, and boiling.

The Hopi separated colors of maize in storage, and in planting they placed fields of one color of maize separate from other fields (Weatherwax 1954:183). Over time, the Hopi maize plants were selected for quick maturity, drought tolerance, and pollination in conditions of very low humidity. The plants are quite short, with strong stems that resist wind, and the ears are very large in relationship to the plants, when compared to maize plants that have been grown for generations in more humid climates. The mesocotyl, or underground growth stem emerging from the seed and stretching to the surface, of Hopi

maize varieties, is able to grow very long. This characteristic has been selected for, over time by the Hopi, through the planting of their maize seeds 25 to 38 cm (10 to 15 inches) deep (Hack 1942:20). Deep planting enables the seeds to draw on subsurface moisture, and protects young germinating seedlings from late frosts by giving the roots and growing point a growth period before the tip emerges from the soil. It should be remembered that the soil the Hopi plant their crops in is loose and sandy, quite a difference of texture from the heavy clays of the lower Colorado that the Yuma, Cocopa, Mohave, and Maricopa had to contend with. Since lowland varieties of maize (such as the Pima-Papago race) were planted after moisture became available, they did not need to be planted deeply, and so the cultural behavior of deep planting was not a selection factor in the lowlands. Presumably, deep planting would not have been a factor among the Virgin Anasazi at Black Dog Cave, who used the freely available moisture of the Muddy River, and could have easily planted their seeds after the soil was moistened by water diversion.

Ford (1994:515) describes the selection of ears of maize at Zuni, and states that this was common at all pueblos: "...a perfect ear is one that has uniform color (unless it is all-colored), straight rows, no bird or insect damage, and full kernels covering the tip." Cushing (1920:173) indicates that the Zuni selected the finest of the earliest ears for seed for ritual and planting. The Zuni maize was also planted deeply, in sandy soil, so it is probable that their maize plants developed a long mesocotyl, as did the maize at Hopi (Cushing 1920:181).

The Pima grew several colors and types of maize, including flint, pop, sweet, and flour maize. Informants agreed that all of the traditional maize was of a single race of flour maize, Pima-Papago (Castetter and Bell 1942:80). The Pima grew four separate colors of the floury race of Pima-Papago: the white form was the most common, followed by yellow, next by blue, and last by red. The ears of the Pima-Papago maize that Castetter and Bell (1942:180) collected were slender, slightly tapered, of "... rarely more than seven inches in length, and extending from about one and one half inches in diameter at the butt

to about one and one-fourth inches at the tip." Most of the ears were 12-rowed, some were 14-rowed, and a few were eight-rowed (Castetter and Bell 1942:180).

In an experimental plot of Pima-Papago maize varieties that Castetter and Bell (1942) had collected in the 1930s and 1940s and grew in Albuquerque, they observed a great deal of genetic diversity in the Pima-Papago race of maize. Samples from different parts of the reservation "...by no means displayed complete genetic unity" (Castetter and Bell 1942:81). However, all of the plants flowered within 50 to 60 days, and "...made comparatively little demand upon irrigation water" (Castetter and Bell 1942:81). The plants had been selected to withstand the high temperatures and heat stress of the lowlands, to yield well, to mature quickly, and to produce a floury endosperm. A high rate of genetic variation in this historic period maize probably indicates a good deal of exchange and consequent mixing of varieties placed under both the cultural and environmental selective conditions of the lowland Colorado River area, and in the Mohave and Sonoran deserts. Castetter and Bell (1951:101) describe the plants of the Pima-Papago race as having slender stalks, narrow leaves, tillers that were shorter than the main stalks, and stiff, harsh, medium-sized tassels with very large glumes.

As among the Zuni, selection for seed maize by the Pima and Papago was based on similar goals of purity of colors and ears filled with large seeds. Evidently, little emphasis was placed on the selection of ears for regularity of rows of kernels, or on size and shape of the cobs (Castetter and Bell 1942:186).

Among the peoples living in the lower Colorado River area, the maize that Castetter and Bell (1951:105) observed was quite similar to that of the Pima and the Papago. Most of it was flour maize, which they pointed out was culturally selected for, though flint maize stores better and resist weevil damage. Flour maize is less difficult to grind into meal than is flint maize. The maize of the lower Colorado area was also quick-maturing, becoming dry in about 60 to 80 days depending on the strain (Castetter and Bell 1951:106). Green maize for roasting would be ready in about 50 days. Seed

selection was usually done by women. "Long, plump-grained ears, well filled to the tip, were selected for maize seed, and were chosen at husking time" (Castetter and Bell 1951:160). Also, selection was directed toward plants that had great vigor, and for the most productive plants (Castetter and Bell 1951:167).

There is a striking near-uniformity of the goals of the selection of maize among the ethnographically recorded peoples of the Southwest. This examination of peoples living near to the region that the Virgin Anasazi once inhabited reveals selective traditions that are quite similar to each other. These patterns are so similar that they must extend back into the past to some degree. Such generally shared patterns usually have a long history. All over the Southwest, for generations, people have selected for the following characteristics in maize: ears that are well-filled to the tip with kernels, ears with straight rows (usually), and ears of large size. The colors of stored and planted maize tended to be separated by these peoples, and flour maize seems to have been preferred because of its ease of grinding. In the Southwest over time, and through both human and environmental factors, maize plants were also selected in terms of wind-resistance, drought tolerance, greater productivity, and quick maturation.

It is not known if the human patterns of the selection of maize described in ethnographic studies of Southwestern peoples extended as far back into time as when the Virgin Anasazi inhabited the Moapa Valley and lived in the vicinity of Black Dog Cave; however, since the Puebloan and neighboring groups still existing today have so many of the same selective practices in common, it is highly possible that at least some of these behaviors extend as far into time as the period of the Basketmaker II through Pueblo II Virgin Anasazi.

Chapter 6 of this volume will examine the maize remains from Black Dog Cave, and Chapter 8 is a synthesis of the archaeological maize of the Southwest. Some of the elements of the cultural selection of maize in the prehistoric Southwest, and among the Virgin Anasazi, should be revealed from a comparison of the data presented in these two

chapters with the patterns of behavior surrounding the maize cultivation observed in the ethnographic Southwest.

CHAPTER 6

MAIZE REMAINS FROM BLACK DOG CAVE

Black Dog Cave was first discovered in 1936 by workmen of the Civilian Conservation Corps, who found a basket in the cave. S. M. Wheeler then accompanied the men to the cave that spring, but did not do any testing or excavation (Wheeler 1942:1). Wheeler tried to relocate the cave later, in 1939, but could not find the small entrance.

Bradley R. Stuart rediscovered the cave in 1942, while looking for Indian relics and excavating one of the pithouses on the top of the mesa. One of his dogs chased a rabbit into the cave, and could be heard barking underground. He was able to enter the cave through a small hole. Stuart named the large cave "Black Dog Cave" (Wheeler 1942:1).

Stuart conducted some preliminary excavations in the spring of 1942, and discovered several of the pits. Pit #13 contained Pueblo period artifacts, and pit #14 held Paiute articles from the period 1860 to 1900 (Wheeler 1942:6). These finds were of significant enough interest to initiate a formal excavation of the site. In May of 1942, the excavation began as a joint venture of the State of Nevada, represented by S.M. Wheeler, and the Southwest Museum of Los Angeles, California, represented by Mark Harrington.

The site of the cave is on a terrace above the floodplain of the Muddy River. There are several pithouses on the terrace, one of which has been excavated and is thought to date to Basketmaker II (Larson 1978). Schroeder (1953:65) thought that one of the

pithouses (presumably the same one that Larson considered) was "preceramic," which would indicate a Basketmaker II date, and that the others dated to the "Modified Basketmaker" period, now referred to as Basketmaker III.

The soils of the mesa are sandstone and clay overlaid with a "conglomerate cap" of cemented gravel and clay (Lyneis 1997:2; Wheeler 1942:3). The cave contains four "rooms," and only rooms 1 and 2 were excavated. Wheeler thought that the river had eroded the softer soils underlying the harder conglomerate of gravels and clay, hollowing out the cave. He thought that later roof falls had restricted the size of the cave, and that the unexcavated area off the north side of room 3 of the cave may contain more cultural materials (Wheeler 1942:3-4).

Wheeler thought that the south half of room 1 had been used as a dump during occupations of the cave, and states that the stratigraphy was not immediately visible, except toward the north side of room 1 (Wheeler 1942:11).

Pits #1, 2, 3, 4, 9, 10, 12, 15, 17, 18, 19, and 20 were excavated in the south side of room 1, but only Pits #4 and #13 contained objects that appeared as if they had been intentionally placed in them. The others seemed to have been filled with "...miscellaneous items which apparently accumulated accidentally as the pits filled up" (Wheeler 1942:11). Grass-lined Pit #4 contained the extremely well-preserved ear of maize with its kernels (see Figure 12). It is difficult to know to what period this ear dates without a radiocarbon test.

The north half of room 1 was excavated next, and its stratigraphy was more evident to the excavators. Pits #5, 6, 7, 8, 11, 14, 16, 21, 22, 23, and 24 were located and uncovered in this area. The actual floor of the cave during occupation was not reached because of the danger of roof fall (Wheeler 1942:12).

Room 2 was excavated next, and it appeared that water was able to seep into this area, as there was more moisture in the soils and cultural deposits. The complete room could not be excavated because of the danger of possible roof fall. Pits #25, 26, 27, 28,

and 29 were excavated here. All of these pits were located in stratum 3, except for pit #28, which belonged to stratum 2 (Wheeler 1942:13).

After the excavation of room 2, both crews left, and the artifacts were divided between the Southwest Museum and State of Nevada.

The Nevada crew under S.M. Wheeler returned in July, 1942 to continue the excavation of room 2. Pits #30, 31, 32, 33, 34, and 35 were excavated during this last phase of the excavation (Wheeler 1942:15-16). Pit #30 was constructed inside an older lined pit, pit #31. Pit #31 was plaster-lined, and of a different construction than the later slab-lined pits. The plaster lining contained less fiber in the plaster mix, and it was not coated as thickly on the walls of the pit as was the plaster in the other lined pits. Wheeler thought pit #31 was probably the oldest lined pit found at the site, because of its different construction, and the fact that pit #30 was constructed above it at an apparently later date (Wheeler 1942:15-16). The maize cobs found in this pit are also probably some of the earliest found at the site, and C-14 tests have shown them to date to Late Basketmaker II (Figure 25).

The excavation was concluded on July 24, 1942, as fewer specimens were being recovered, and the crew was encountering more moisture in the deposits, which of course would indicate poorer preservation of perishable materials such as plant fibers and maize cobs. The articles from this last phase of the excavation were taken to the Nevada State Museum in Carson City, and were stored with other items from the first phase of excavation.

In March 1997 I was permitted to personally study the collections from Black Dog Cave and to measure and photograph the maize remains. The results of this undertaking are described in this chapter.

COLLECTIONS AT THE NEVADA STATE MUSEUM

From viewing Nevada's half of the collections from Black Dog Cave, preserved at the Nevada State Museum, I could see artifacts that appeared to date from several periods: apparently from Basketmaker II and Basketmaker III through Puebloan times. The cave obviously has a long history of occupation or use as a storage facility. Some objects, including basketry, looked as though they might date from Paiute occupations. Indeed, in spring of 1942, Stuart found a cache of Southern Paiute historic objects that dated to the period 1860 to 1900 (Wheeler 1942:6). Among the samples I viewed at the museum there were some large pieces of corrugated Puebloan pottery, black-on-white painted Pueblo pottery, sandals, basketry fragments, arrow and dart points, feathers, cotton and yucca fiber strings, grass lining from the pits, and several wooden and bone articles. There was an abundance of well-preserved plant remains including squash seeds, rinds and peduncles, beans, and maize kernels, cobs, shanks, and one well-preserved ear of maize with its kernels still attached (from Pit #4; Figure 12).

The collections were stored in several places in the Nevada State Museum, under the number 2-121, the Nevada site and excavation number. The collections in the Southwest Museum in Los Angeles excavated by Mark Harrington are stored under the number 20-F, and those donated by Bradley Stuart under the number 925-G (Lyneis 1997:4). There were several boxes to go through, and preservation of objects is excellent, because most of the cave was so dry. Most of the maize was stored in separate bags, with pit locations and collection numbers attached.

METHODS

Archaeological remains of maize in the American Southwest consist mostly of cobs and parts of cobs, though kernels, shanks, leaves, tassels, and even ears of maize with the kernels still on them have been found.

An ear of maize with its kernels is composed of seeds attached to the female flower spike of a maize plant. The male flowers are located in the tassel of a maize plant. A maize plant usually produces one tassel and several ears. The ears (which include kernels) or cobs (without kernels) are the most useful parts of maize plants in identifying types or races of maize, and it is the cobs that are usually found in archaeological deposits in the Southwest, because they contain several hard parts. If the conditions of preservation are quite dry, as they were at Black Dog Cave, then maize cobs, shanks, and even ears exist in good condition.

An ear of maize is made up of pairs of spikelets, which become grains or kernels of maize once they are pollinated. The skin of each spikelet surrounds the kernel. If an ear of maize dries, and the kernels fall out, the glumes remain attached to the cob and retain the dimension of thickness of the kernels. Each pair of two spikelets is attached by its glumes to one cupule, a cup-like depression that holds the grains of maize. The cupules on the cob circle the rachis (the central stem) of the cob (Figure 11).

In my analysis of maize cobs for archaeological purposes, measurements were taken of the following: cob length; kernel row number; rachis diameter and length; cupule width, length, and depth; cupule wing width; lower glume (cob) diameter; kernel thickness via the width of the glumes; and shank diameter. The shape of the ear is noted as well, as it is an important indicator in the interrelationship of maize races. These variables are described in detail below. All measurements for this study were taken in millimeters and centimeters, using calipers provided by the University of Nevada. Other tools used in the measurement of the cobs from Black Dog Cave included chalk markers, a magnifying glass, measuring tape, razor blade to cut away spikelets for measurement, toothpick, and dental tools.

The system of measurement I used was based upon a combination of the methods of measurements for maize cobs developed by Nicherson (1953) and Bird (1994). My aim was to take measurements that could be used comparatively with other studies of both

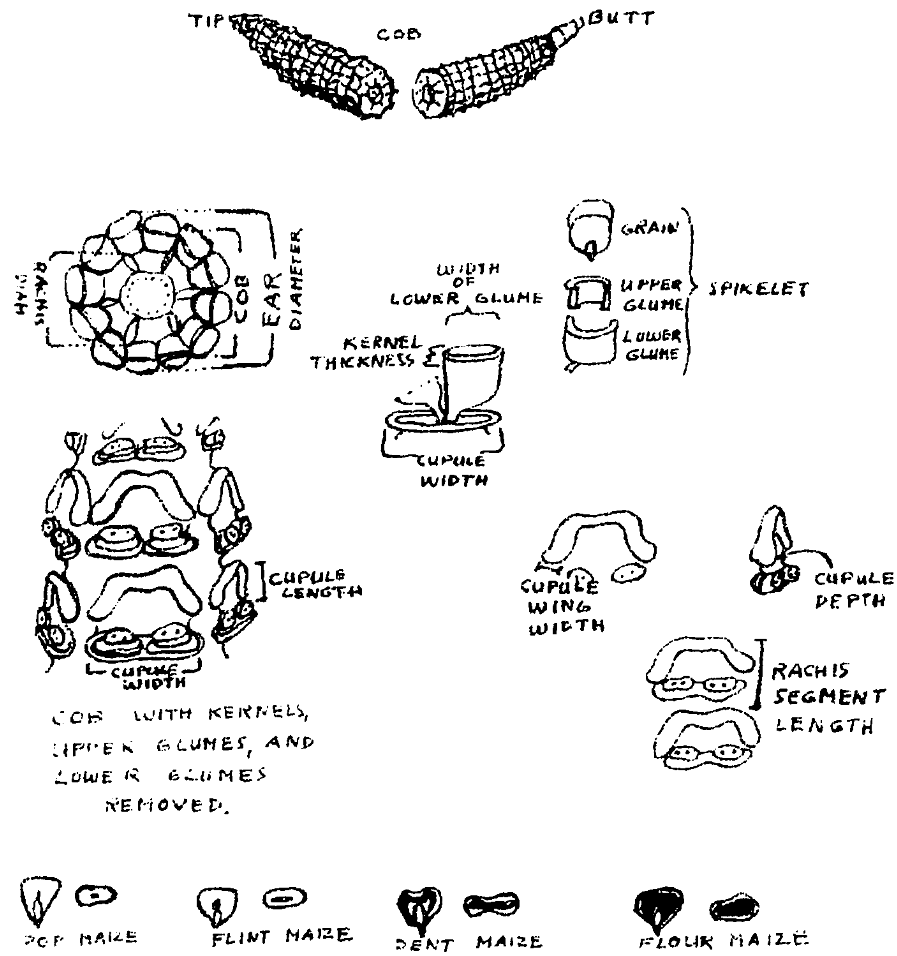

Figure 11. Characteristics of maize cobs used in analysis.

archaeological and contemporary maize. In Chapter 7 of this volume, in which I present the results of the measurements of the ears, tassels and plants of still-existing races of maize of the American Southwest, I used all of the same methods, criteria, and tools for measurement as I did for the measurement of the archaeological maize cobs from Black Dog Cave. Three additional measurements were added, though, color of kernel, type of kernel, and diameter of ear. These three extra measurements were added because the contemporary maize that I raised and measured had kernels present on the cobs. The one ear of archeological maize found was measured for the additional three characters because it had its kernels attached (Figure 12). The measurements of the cupules, rachis, and glumes were taken at the midpoint, lengthwise, of each cob.

In the Nevada State Museum collection, there are nearly 200 maize cobs and fragments. This study examines 55 of these. This sample consists of ecofacts from 18 different features or areas of the cave. Complete and near-complete cobs, with all or most of the variables described, were chosen for analysis.

VARIABLES MEASURED

Cob (piece) length. The complete length of the cob was measured in centimeters, and it was noted if a particular cob was entire, or nearly entire, or a fragment.

Row number. The number of rows of kernels (or glumes if the kernels were missing) was noted. This measurement was taken at the midpoint of the length of the cob, or at what was estimated to have been the midpoint of the cob if the specimen was a fragment.

Rachis diameter. This measurement was taken of the width of the cob, across the cupules (including their wing tips) after the glumes have been removed.

Rachis segment length. This measurement was taken lengthwise on the cob, and includes the distance from the tip of one cupule to the next tip of a cupule, along the rachis.

Cupule width. This is an external measurement of the width of the cupule including the wing tips.

Cupule length. This measurement includes the length of the cupule itself only, and does not include the base of the removed spikelets.

Cupule wing width. This is a very small measurement of the wings of the cupules, and was taken at the midpoint of the wing, to the bottom of the cupule cavity.

Cupule width. This is another measurement of the actual depth of the cupule, made using a toothpick, marked off in .05 millimeter intervals. The deepest part of the cupule was measured and a sight-line was run across the cupule wings.

Lower glume (cob) diameter. This is a measurement of the diameter of the cob including the lower glumes, at the midpoint of the cob. This measurement was not possible on a few specimens that were missing their lower glumes.

Kernel thickness. The thickness of the kernel can be measured in the absence of the kernel by measuring the distance, lengthwise, between the lower glume and the upper edge of the cupule it rises out of.

Shank diameter. This measurement is taken as close to the butt of the cob as is possible, or can be estimated from the scar where a shank has been removed.

Shape of ear. Four basic shapes are used in reference to maize cobs in archaeological deposits: straight, tapered, cigar, and enlarged butt.

RESULTS OF MAIZE ANALYSIS

Fifty-five cobs or fragments of maize cobs were measured in this study of-Black Dog Cave, including the one cob that still contained most of its kernels (Table 10). Eight loose kernels of maize were also measured. Presented here are several tables representing the statistics of measurements of the maize at Black Dog Cave, including a table of measurements of all of the specimens, a table of mean measurements, a table of kernels, a table describing the one ear of maize with its kernels, and a table of maize shanks.

Table 9 is a list of all of the mean measurements of maize from Black Dog Cave, including whole cobs and cob fragments. All of this information was summarized from the measurements of the collections at the Nevada State Museum in Carson City, Nevada.

Table 10 lists the statistical measurements of specimen 2-121-176, the ear of maize with most of its kernels, from pit #4 of the cave. This ear still has a label attached to it that indicates that it was on display at the "L. V. Convention Hall" for a time. There are traces of glue from display, also. The kernels of this ear are of two shades, an orange-brown and reddish brown, and some of the grains have holes that were evidently drilled by weevils or some other insects. Figure 12 is a photograph of this specimen.

Table 11 is a complete table of all of the individual maize cobs that I measured at the Nevada State Museum. Included are the data on each of the specimens I measured out of 18 samples. Every effort was made to make a random sampling, except that entire (whole) cobs were chosen, if possible, for measurement. In Table 10, six of the twelve distinguishing characteristics of the measurements of the cobs from Black Dog Cave are listed, including cob length, row number, rachis diameter, rachis segment length, cupule width, and cupule length.

In Table 12, six additional characteristics of maize cobs not included in Table11 are listed, including cupule width, cupule depth, lower glume (cob) diameter, kernel thickness, shank diameter, and shape of ear. Maize earworm damage was evident on some cobs, and is indicated by an asterisk in Table 12.

Table 13 shows the measurements of several loose kernels of maize that I encountered among other specimens of cultivated plants from Black Dog Cave, in the collections at the Nevada State Musem. Most of the kernels listed in Table 13 are illustrated in Figure 32 of this volume.

Table 14 is a listing of the measurements of the few maize shanks that were among the collections from Black Dog Cave. All of the items listed in Table 14 are illustrated in Figure 33 of this volume. The photograph also includes a few of the squash fragments

Table 9. Mean Measurements of all Maize (55 Cobs from 18 Samples) from Black Dog Cave.

I. Characteristic Measured	Measurement
Mean cob (piece) length	88.3 Mm
Estimated original mean cob length	98 Mm
Mean length of all (16) cobs still entire	106 Mm
Median cob length of cobs still entire	104 Mm
Mean rachis diameter	13.9 Mm
Mean rachis segment length	3.9 Mm
Mean cupule width	6.8 Mm
Mean cupule length	2.2 Mm
Mean cupule wing width	1.4 Mm
Mean cupule depth	1.1 Mm
Mean lower glume (cob) diameter	19.5 Mm
Mean kernel thickness	3.5 Mm
Mean shank diameter	13.2 Mm
II. Shape of Ear (of 55 Cobs)	Number
Straight	14 (25%)
Cigar	28 (51%)
Tapered	13 (24%)
Enlarged butt	0 (0%)
III. Row Numbers (of 55	Number
8-row	4 (7%)
10-row	9 (16%)
11-row	1 (2%)
12-row	24 (44%)
14-row	12 (22%)
16-row	5 (9%)
Mean row number	12.3
IV. Cobs With Maize	Number
Earworm Damage (of 55	6 (11%)

Table 10. Ear of Maize With Most of its Kernels from Pit #4 at Black Dog Cave.

I. Characteristic Measured	Mm
Cob (piece) length	123. (Entire)
Rachis diameter	Not measured
Rachis segment length	4.5
Cupule width	6.5
Cupule length	2.7
Cupule wing width	1
Cupule depth	1.5
Lower glume (cob) diameter	2.7
Kernel thickness	3.5
Shank diameter	135
II. Kernels	Number
Width of kernels	6
Thickness of kernels	3.5
Length (depth) of kernels	6
III. Shape of ear	Straight
Type of endosperm	Flint-flour
Row number	16

that were in the same soecimen bag. Unfortunately, all of the specimens were unprovenienced, so we do not know the precise time or place of their origin.

Tables 15 and 16 are listings of the measurements of maize kernels from other prehistoric sites near Black Dog Cave. None of the measurements of maize from Southern Nevada have been published before, and I have included these two tables of measurements of maize kernels from other sites to serve as material for comparison with the maize from Black Dog Cave.

The Paiute maize from Granary Cave is undoubtedly of a later period than the

Table 11. Summary of All (55) Maize Cobs Measured from 18 Samples From Black Dog Cave, Measured For Six Characteristics.

Proven-ience	Photo-graph	Cob Length (Mm) * = Cobs Entire in Length	Row Number	Rachis Diam. (Mm)	Rachis Seg. Length (Mm)	Cupule Width (Mm)	Cupule Length (Mm)
Unknown	Fig. 13	115.*	10	12.5	4.7	8	2.3
Pit #30?	Fig. 14	91	10	15.5	3.5	4	2
Pit #30?	Fig. 14	79.5	14	17	4.5	8	2.8
Pit #30?	Fig. 14	78	12	17	5.5	8.5	2.5
Pit #30?	Fig. 14	72	10	11.5	4	7.2	2.3
Pit #30?	Fig. 14	61	14	18	4	8	2.5
Pit #30?	Fig. 14	67.5	14	14.5	3.5	6	2
Pit #30?	Fig. 14	37.5	8	5.5	3.7	5	2.75
Pit #30?	Fig. 15	73	12	11.5	3.5	5	2
Pit #30?	Fig. 15	64.5*	11	9	4	9	2
Sample Mean		69.3	11.6	18.7	4	6.75	2.3
Unknown	Fig. 16	11.6*	16	18	4	8	1
Unknown	Fig. 16	195.5*	12	15	4.5	8	2.75
Sample Mean		156*	14	16.5	4.3	8	1.9
Pit #30?	Fig. 17	51	10	11	3.2	6	2.75
Pit #30?	Fig. 17	142*	12	12	3.7	6	2.5
Sample Mean		96.5	11	11.5	3.5	6	2.6
Pit #30, #6	Fig. 18	92	14	14	3.75	6	2
Pit #30, #6	Fig. 18	95*	16	17	4.25	6	2
Sample Mean		93.5	15	15.5	4	6	2

Table 11. Continued

Provenience	Photograph	Cob Length (Mm) * = Cobs Which Are Entire in Length	Row Number	Rachis Diam. (Mm)	Rachis Seg. Length (Mm)	Cupule Width (Mm)	Cupule Length (Mm)
Rm. 2, S. Side	Fig. 19	167*	12	13	4.2	6.75	2.5
Rm. 2, S. Side	Fig. 19	99.5	14	14	4	6.5	2.5
Rm. 2, S. Side	Fig. 19	69*	12	11	3	6	2
Rm. 2, S. Side	Fig. 19	100	14	16	3.5	7	2.5
Rm. 2, S. Side	Fig. 19	65	12	8	3	7	2.5
Rm. 2, S. Side	Fig. 20	76	14	10.5	3.2	4.5	1.5
Sample Mean		81	13	12	3.5	6.3	2.3
Pit #34, #9	Fig.21	41	12	15	2	7.5	1.5
Pit #34, #9	Fig. 21	37	12	11	3.5	5.5	2
Pit #34, #9	Fig. 21	44.5	12	9	3	5	2
Sample Mean		40.8	12	11.6	2.8	6	1.8
Rm. 2, Str. 2	Fig. 22	60.5	16	19.5	4	8	2
Rm. 2, Str. 2	Fig. 22	71.5	12	10.5	4	5	3
Rm. 2, Str. 2	Fig. 22	35	10	13	4	7.5	3.75
Sample Mean		55.6	12.6	14.3	4	6.8	2.9

Table 11. Continued.

Provenience	Photograph	Cob L. (Mm) * = Cobs Entire in Length	Row Number	Rachis Diam. (Mm)	Rachis Seg. Length (Mm)	Cupule Width (Mm)	Cupule Length (Mm)
No. 2, Str. 3	Fig. 23	69	14	23	5	9.5	2.5
No. 2, Str. 3	Fig. 23	68	12	14.5	3	8	1.75
No. 2, Str. 3	Fig. 23	51	8	6.5	3.5	6	1.5
Sample Mean		62.6	11.3	14.6	3.8	7.8	1.9
Unknown	Fig. 24	79	12	10.5	4	6.5	2
Unknown	Fig. 24	60	8	7.5	4	8	2.25
Sample Mean		69.5	10	9	4	7.25	2.1
Pit #31, Str. 3	Fig. 25	145	12	10.5	4.5	6	2
Pit #31, Str. 3	Fig. 25	54	12	8.5	3.5	5	2
Pit #31, Str. 3	Fig. 25	30.5	14	11	4	6	2
Sample Mean		76.5	12.6	10	4	5.6	2
Gen. Dig	Fig. 26	72.5	14	18.5	4	8	2
Gen. Dig	Fig. 26	60.5	10	13.5	3	6	1.75
Sample Mean		66.5	12	16	3.5	7	1.9
Rm. 2, Str. 2	Fig. 27	75	12	19	3	7	1.5
Rm. 2, Str. 2	Fig. 27	84.5	12	10	3.5	6	2.75
Rm. 2, Str. 2	Fig. 27	72	12	13.5	4.25	8	3

Table 11. Continued.

Provenience	Photograph	Cob L. (Mm) * = Cobs Entire in Length	Row Number	Rachis Diam. (Mm)	Rachis Seg. Length (Mm)	Cupule Width (Mm)	Cupule Length (Mm)
Rm. 2, Str. 2	Fig. 27	62*	12	9	4	6	2
Sample Mean		73.3	12	12.8	3.7	6.8	2.3
Rm. 2, S. Side	Fig. 28	153	12	17	4.5	4.75	2.5
Rm. 2, S. Side	Fig. 28	110	16	12	3.75	5.75	2.25
Rm. 2, S. Side	Fig. 28	56*	10	13	4	8.5	2.5
Sample Mean		106	12.6	14	4	6.3	2.4
Gen. Dig, Rm. 2	Fig. 29	78	12	16	4.9	9	2.5
Gen. Dig, Rm. 2	Fig. 29	73	14	17	3.75	7	2
Sample Mean		75.5	13	16.5	4.3	8	2.25
Rm. 2, Str. 3, #5	Fig. 30	159*	12	16	4.5	7.5	1.5
Rm. 2, Str. 3, #5	Fig. 30	104.5*	14	14	5	5.5	2
Rm. 2, Str. 3, #5	Fig. 30	104.5*	12	12.5	3.5	7.5	1.75
Rm. 2, Str. 3, #5	Fig. 30	93*	10	11	4	8	2
Rm. 2, Str. 3, #5	Fig. 30	83.5*	8	12	4	9	2.25
Rm. 2, Str. 3, #5	Fig. 30	43*	10	8	2.5	6	1
Sample Mean		98*	11	12.2	3.9	7.25	1.8

Table 11. Continued

Provenience	Photograph	Cob L. (Mm) * = Cobs Entire in Length	Row Number	Rachis Diam. (Mm)	Rachis Seg. Length (Mm)	Cupule Width (Mm)	Cupule Length (Mm)
Corn Cob Dart"	Fig. 31	60.5	12	19.5	-	-	-
Ear With All its Kernels	Fig. 12	123*	16	-	4.5	6.5	2.7
Mean of 18 Samples		84.3	12.3	13.9	3.9	6.8	2.2

Table 12. Summary of All (55) Maize Cobs Measured from 18 Samples From Black Dog Cave, Measured For Six Characteristics.

Proven-ience	Photo-graph	Cupule Wing Width (Mm)	Cupule Depth (Mm)	Lower Glume (Cob) Diam. (Mm)	Kernel Thick-ness (Mm)	Shank Diam. (Mm)	Shape of Ear * = Cobs With Maize Earworm Damage
Unknown	Fig. 13	1.5	1	17.5	-	17.5	tapered
Pit #30?	Fig. 14	2	1.75	18	3	-	tapered
Pit #30?	Fig. 14	1.75	2	22.5	4	16.5	cigar
Pit #30?	Fig. 14	1.75	1	20	3	11.5	cigar
Pit #30?	Fig. 14	1.5	1	17	3	-	cigar
Pit #30?	Fig. 14	1.5	1	21	3.5	-	tapered
Pit #30?	Fig. 14	1.5	0.75	15	2.5	-	straight
Pit #30?	Fig. 14	1	0.5	10	3	-	straight
Pit #30?	Fig. 15	1	1	15	2.5	5	cigar
Pit #30?	Fig. 15	2.5	2.5	20	4	4.5	cigar
Sample Mean		1.6	1.3	17.6	3.2	9.2	
Unknown	Fig. 16	1	0.75	24	3.5	16	tapered
Unknown	Fig. 16	1.5	1.5	20	4	-	straight
Sample Mean		1.3	1.1	22	3.8	16	
Pit #30?	Fig. 17	1.5	1	13	4	-	cigar
Pit #30?	Fig. 17	1.5	1.25	21	3	11	cigar
Sample Mean		1.5	1.1	17	3.5	11	
Pit #30, #6	Fig. 18	1	1.25	18.5	3.5	13	straight
Pit #30, #6	Fig. 18	1	2	24	3.5	11	*cigar
Sample Mean		1	1.6	21.2	3.5	12	

Table 12. Continued.

Provenience	Photograph	Cupule Wing Width (Mm)	Cupule Depth (Mm)	Lower Glume (Cob) Diam. (Mm)	Kernel Thickness (Mm)	Shank Diam. (Mm)	Shape of Ear * = Cobs With Maize Earworm Damage
Rm. 2, S. Side	Fig. 19	1.5	1	20.5	4	14	straight
Rm. 2, S. Side	Fig. 19	1.5	1.5	23	4	9	cigar
Rm. 2, S. Side	Fig. 19	1.5	1.5	17	3	8.5	tapered
Rm. 2, S. Side	Fig. 19	1	1.5	23.5	4	7	cigar
Rm. 2, S. Side	Fig.19	2	1	17.5	3.5	6	cigar
Rm. 2, S. Side	Fig. 20	1	1	18	3	9	cigar
Sample Mean		1.4	1.3	20	3.6	8.9	
Pit #34, #9	Fig. 21	1	0.75	16	2	-	tapered
Pit #34, #9	Fig. 21	1	0.75	0.17	3.5	-	tapered
Pit #34, #9	Fig. 21	0.5	0.75	12	2	-	tapered
Sample Mean		0.8	0.75	15	2.5	-	
Rm. 2, Str. 2	Fig. 22	1	1	27.5	3	19	cigar
Rm. 2, Str. 2	Fig. 22	1.75	1.75	17.5	3	8	*straight
Rm. 2, Str. 2	Fig. 22	3	2.5	16	4	-	cigar
Sample Mean		1.9	1.75	20.3	3.3	13.5	

Table 12. Continued.

Proven-ience	Photo-graph	Cupule Wing Width (Mm)	Cupule Depth (Mm)	Lower Glume (Cob) Diam. (Mm)	Kernel Thick-ness (Mm)	Shank Diam. (Mm)	Shape of Ear * = Cobs With Maize Earworm Damage
No. 2, Str. 3	Fig. 23	2	2	27.5	4.5	19	cigar
No. 2, Str. 3	Fig. 23	1.5	1	18	3	-	cigar
No. 2, Str. 3	Fig. 23	1.5	0.75	11	2.5	-	straight
Sample Mean		1.6	1.2	18.8	3.3	19	
Unknown	Fig. 24	1.5	2	17.5	4	8	*cigar
Unknown	Fig. 24	2	0.5	16	3	-	straight
Sample Mean		1.8	1.25	16.7	3.5	8	
Pit #31, Str. 3	Fig. 25	0.5	0.5	19	3	11	straight
Pit #31, Str. 3	Fig. 25	1	0.75	15	3.5	-	cigar
Pit #31, Str. 3	Fig. 25	1	1	13.5	3.5	-	straight
Sample Mean		0.8	0.8	15.8	3.3	11	
Gen. Dig	Fig. 26	1.5	1.5	26	3.5	-	tapered
Gen. Dig	Fig. 26	1.5	1	19	4	-	*cigar
Sample Mean		1.5	1.25	22.5	3.8	-	
Rm. 2, Str. 2	Fig. 27	1.25	0.5	20	3.9	10.5	cigar
Rm. 2, Str. 2	Fig. 27	0.5	0.5	16.5	3.5	7.5	cigar
Rm. 2, Str. 2	Fig. 27	2	1.5	20	4	7	cigar

Table 12. Continued.

Proven-ience	Photo-graph	Cupule Wing Width (Mm)	Cupule Depth (Mm)	Lower Glume (Cob) Diam. (Mm)	Kernel Thick-ness (Mm)	Shank Diam. (Mm)	Shape of Ear * = Cobs With Maize Earworm Damage
Rm. 2, Str. 2	Fig. 27	1	0.5	19.5	3	9	straight
Sample Mean		1	8	19	3.6	0.85	
Rm. 2, S. Side	Fig. 28	2	1	25	3.75	-	*tapered
Rm. 2, S. Side	Fig. 28	1.5	1.75	23	4	-	tapered
Rm. 2, S. Side	Fig. 28	2.5	2	16	4	-	cigar
Sample Mean		2	1.6	21	3.9	-	
Gen. Dig Rm. 2	Fig. 29	2	2	20.5	3.5	-	cigar
Gen. Dig Rm. 2	Fig. 29	1.25	1.5	21.5	2.5	14	cigar
Sample Mean		1.6	1.8	21	3	14	
Rm. 2, Str. 3, #5	Fig. 30	1.5	1.75	24	4	20.5	straight
Rm. 2, Str. 3, #5	Fig. 30	1	1.5	20	4	10	tapered
Rm. 2, Str. 3, #5	Fig. 30	1.5	1	20	3.5	11	cigar
Rm. 2, Str. 3, #5	Fig. 30	1.75	1.5	18	3.5	-	cigar
Rm. 2, Str. 3, #5	Fig. 30	2	1	16	3	9	tapered
Rm. 2, Str. 3, #5	Fig. 30	1.5	1.5	14	2.5	3.5	*cigar
Sample Mean		1.5	1.4	18.6	3.4	10.8	

Table 12. Continued.

Proven-ience	Photo-graph	Cupule Wing Width (Mm)	Cupule Depth (Mm)	Lower Glume (Cob) Diam. (Mm)	Kernel Thick-ness (Mm)	Shank Diam. (Mm)	Shape of Ear * = Cobs With Maize Earworm Damage
"Corn Cob Dart"	Fig. 31	-	-	20	3	-	straight
Ear With All its Kernels	Fig. 12	1	1.5	27	3.5	13.5	straight
Mean of 18 Samples		1.4	1.1	19.5	3.5	13.2	

Table 13. Loose Maize Kernels from Black Dog Cave.

Proven-ience	Photo-graph	Width (Mm)	Thick-ness (Mm)	Depth (Mm)	Color
Pit #4	Fig. 12	6	3.5	6	orange-brown
Rm. 2, Str. 2	Fig. 32	9	4.5	7.5	orange-tan
Rm. 2, Str. 2	Fig. 32	7.5	4.5	8	orange-brown
Rm. 2, Str. 2	Fig. 32	5	4.75	6.9	orange
Rm. 2, Str. 2	Fig. 32	6	4	5.5	orange
Sample Mean		6.9	4.4	7	
Rm. 2, S. Side	Fig. 28	9	5.5	4	varieg-ated red-brown
Gen. Dig	no photo.	5	4	7	brown-tan
Gen. Dig	no photo	5.5	3.5	6	orange-tan
Sample Mean		5.25	3.75	6.6	
Mean of 4 Samples		6.6	4.28	6.36	

maize from Black Dog Cave, as the kernels of maize from Granary Cave were found inside a Paiute basket. I took the samples for this table directly out of the basket of loose kernels at the Nevada State Museum. The artifact number of the basket is 2-120-166. Wheeler (1942) described and illustrated this basket and its contents in his report on Granary Cave (Wheeler 1942:10, 14-15). All of the kernels had floury endosperms.

Table 14. Maize Shanks from Black Dog Cave.

Provenience	Photograph	Shank Diameter (Mm)	Length (Mm)	No. of Husk Scars
Unknown	Fig. 33	21	70	7
Unknown	Fig. 33	12.5	51	5
Unknown	Fig. 33	11	34	5
Sample Mean		14.8	51.6	5.6

Table 15. Measurements of Maize Kernels from Paiute Occupations At Granary Cave, Nevada.

Provenience	Kernel Width (Mm)	Kernel Thickness (Mm)	Kernel Depth (Mm)	Color
Basket # 2-120-166	7.5	4	6.75	orange-tan
Basket # 2-120-166	7.5	5	7	orange-tan
Basket # 2-120-166	8	4.25	7	red-orange
Basket # 2-120-166	7.25	3.5	5	red-tan
Sample Mean	7.5	4.1	6.4	

Table 16. Measurements of Maize Kernels from Firebrand Cave, Nevada.

Provenience	Kernel Width (Mm)	Kernel Thickness (Mm)	Kernel Depth (Mm)	Color
Unknown	6	3.5	6.5	brown-orange
Unknown	6	6.5	6.9	brown-tan
Unknown	6	4.5	6	orange-tan
Unknown	7	4	6.5	brown-tan
Unknown	7	6	6	brown-tan
Unknown	7	4	7.5	brown-tan
Unknown	6	3.5	8	brown-tan
Sample Mean	6.4	4.6	6.8	

The maize kernels from Firebrand Cave, a recently discovered site in southern Nevada, were measured during July 1997 with the kind permission of L. Blair of the Marjorie Barrick Museum of Natural History at the University of Nevada, Las Vegas. These kernels were of the flint and flint-pop type, and may be as old or older than the earliest maize from Black Dog Cave. Several of the kernels are isodiametric in shape, as are the kernels of some Basketmaker II maize.

DISCUSSION

In going through the collections of maize from Black Dog Cave at the Nevada State Museum in Carson City, Nevada, I encountered 18 separate sets of artifacts that included maize remains. Fifty-five cobs of maize were measured, including two cobs on sticks (Figure 16), a "corncob dart" (Figure 31), several maize kernels (Figures 28 and 32), and one ear of maize with most of its kernels attached (Figure 12). All of the objects

that were measured were photographed, and are illustrated in this volume, with the exception of two kernels of maize from the "general diggings" at Black Dog Cave, and the kernels from Granary and Firebrand caves, the quantifications of which I have included here (in Tables 15 and 16) for purposes of comparison with kernels from Black Dog Cave.

The ear of maize with all its kernels (Figure 12, collections number 2-121-176) was found in pit #4, a grass-lined pit. Part of pit #4 was excavated into pit #8, a partially slab-lined pit, so we know that pit #4 was later than pit #8 (Wheeler 1942:21). The stratum of origin of both pits was "indeterminate" (Wheeler 1942:21, 25) so it is difficult to date the ear from pit #4 without a radiocarbon test. Wheeler listed other maize cobs and squash fragments among the contents of pit #4, but I was not able to find any other artifacts in the collections at the Nevada State Museum that were labeled "pit #4." Perhaps they may be among the artifacts from Black Dog Cave that are stored at the Southwest Museum in Los Angeles.

The ear of maize with its kernels from pit #4 (see Figure 12 and table 10) has kernels of two shades, orange-brown and reddish brown. Maize kernels fade with age, with most of the colors becoming a dark orange (Cutler 1966:10; Morris 1986:124; Nusbaum 1922:68). It is probable that this ear originally had yellow and blue kernels. Yellow kernels are thought to fade to orange, and blue kernels are thought to fade to brown. This ear of maize has 16 rows of kernels but the size of the kernels is fairly small (6 mm wide, 3.5 mm thick, and 6 mm deep). These measurements are in the range of kernel size from several Basketmaker II sites including Cottonwood Cave (with a mean kernel width of 6 to 7 mm and kernel thickness of 4 mm) (Hurst and Anderson 1949), Talus Village and North Shelter sites in the Durango, Colorado area (with a mean kernel width of 6 to 7 mm and a kernel thickness of 3.5 to 4 mm and a kernel depth of 6 to 7 mm) (Jones and Fonner 1954), Painted Cave (with a mean kernel width of 6 to 8 mm) (Anderson 1945), and Tularosa Cave (Basketmaker II levels) (with a mean kernel thickness of 4.7 mm) (Cutler 1952).

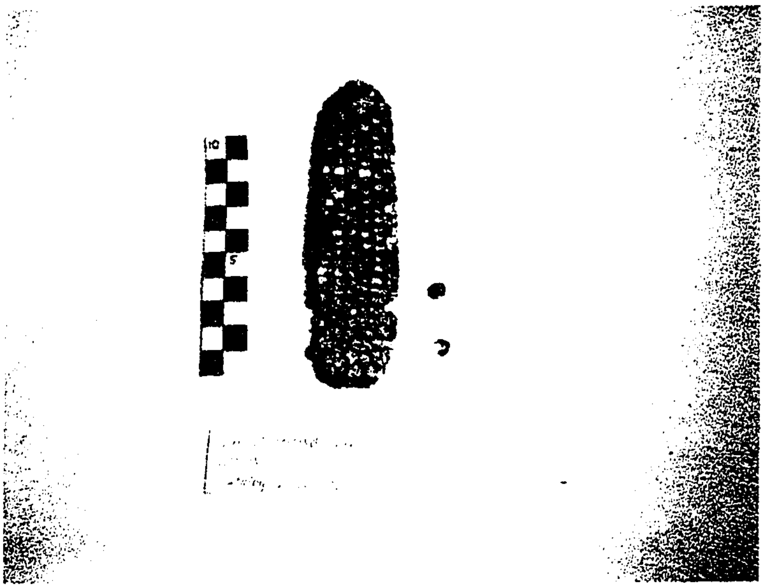

Figure 12. The ear of maize with colored kernels, from pit #4. Weevil damage is evident on some of the kernels.

Figure 13. Maize cobs from Black Dog Cave that were once used in a museum display. The cob at far left was measured for this study.

Figure 14. Maize cobs (probably from pit #30). All seven cobs and fragments in this photo were measured.

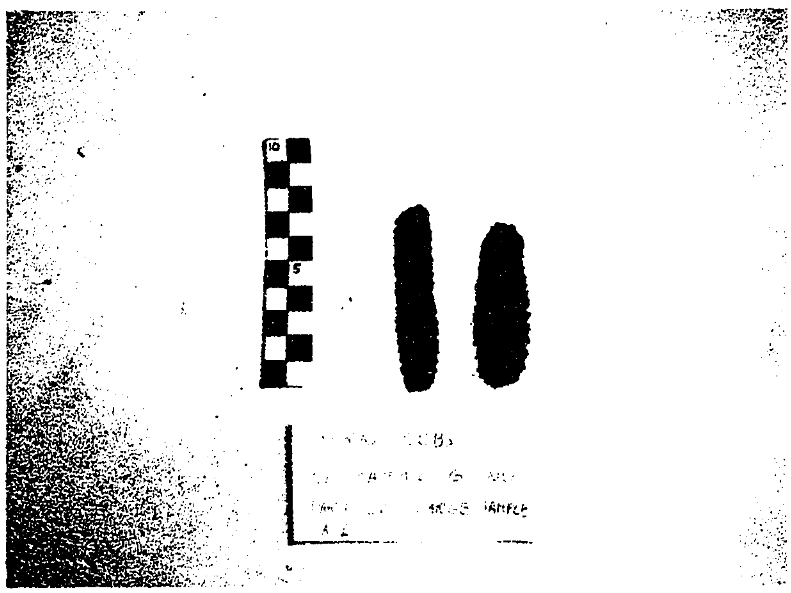

Figure 15. Maize cobs (probably from pit #30). Both cobs were measured.

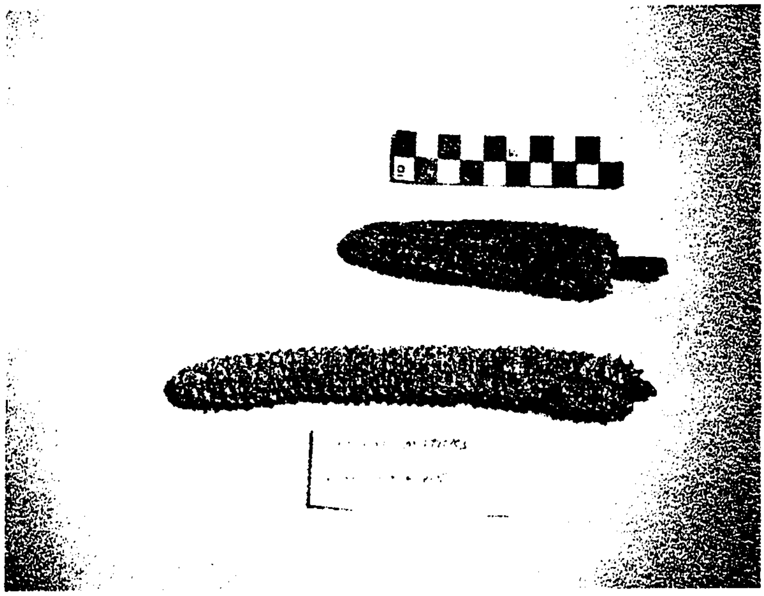

Figure 16. Two maize cobs on sticks. Both cobs were measured and are among the longest cobs in the collection.

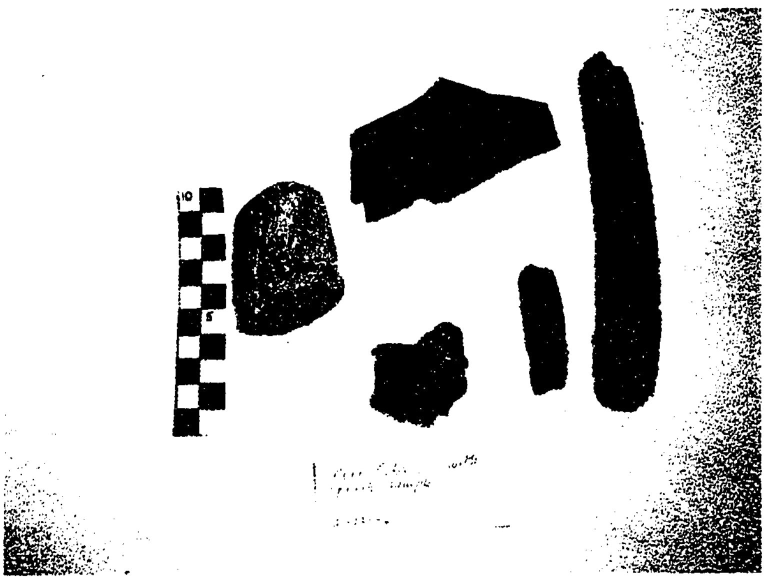

Figure 17. Two cobs from pit #30, that were stored with a sample of squash fragments. The large cob had one red kernel still attached to the rachis.

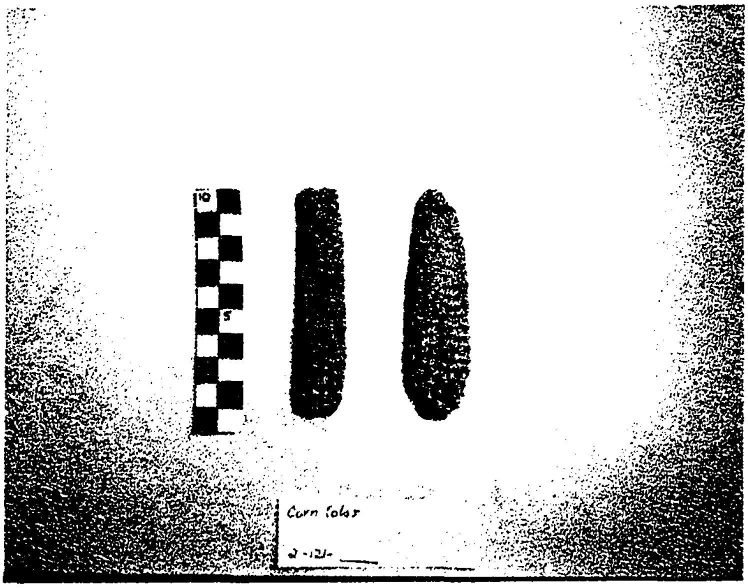

Figure 18. Two cobs from pit #30. The one on the right has maize earworm damage at its tip.

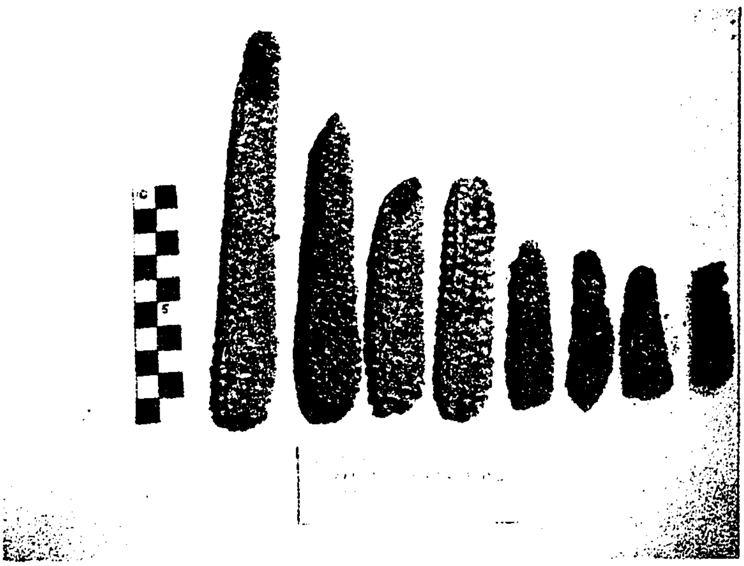

Figure 19. Cobs from room two, south side. These were measured from left to right: cobs one, two, three, four, and five.

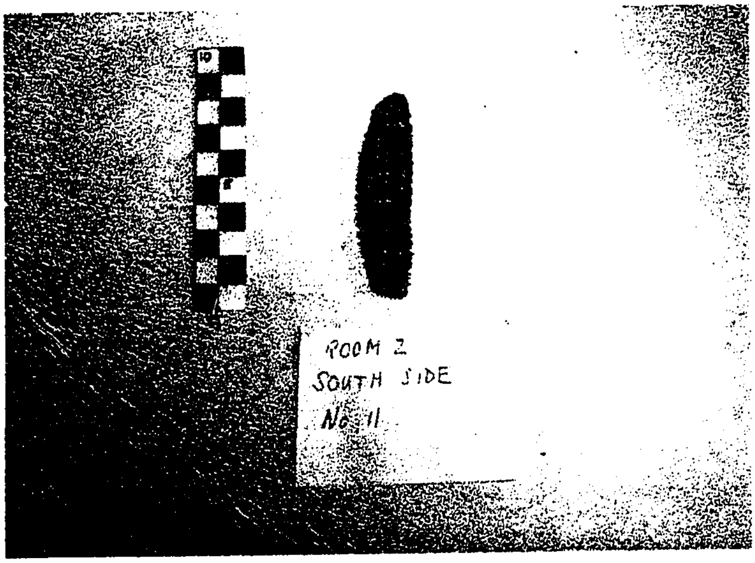

Figure 20. A maize cob from room 2, south side, no. 11, (part of the sample depicted in Figure 19).

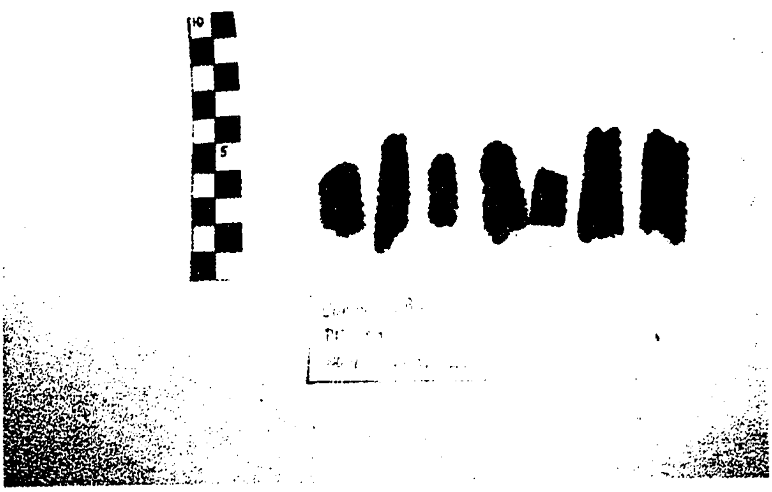

Figure 21. Maize cobs from pit #34. Though these are fragments, note the tapered shape of the cobs.

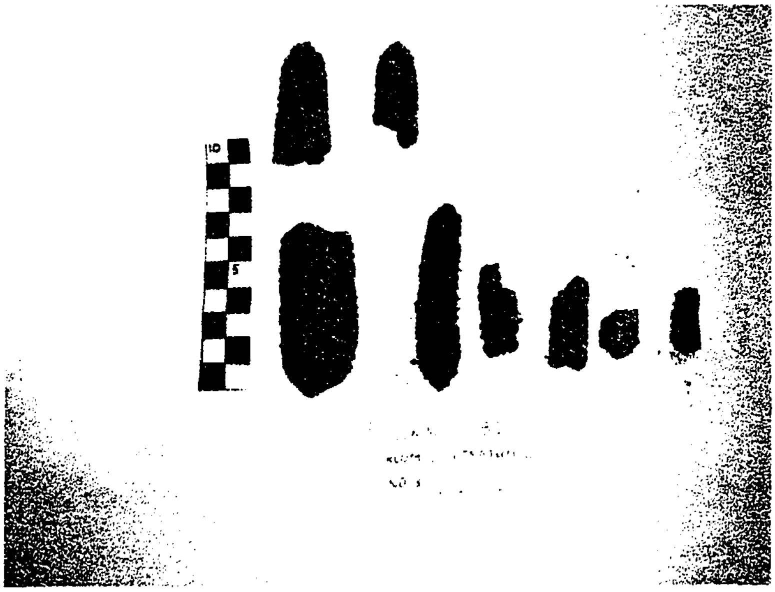

Figure 22. Cobs from room 2, stratum 2, no. 8. Measured left to right: cobs one, two, and three.

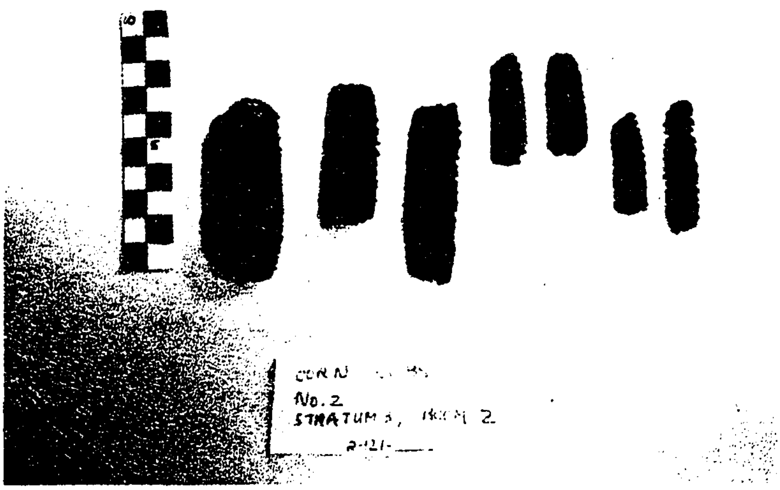

Figure 23. Cobs from number 2, stratum 3, room 2. Measured from left to right: cobs one, two and three.

Figure 24. Maize cobs with no provenience. Measured from left to right: cobs one and five.

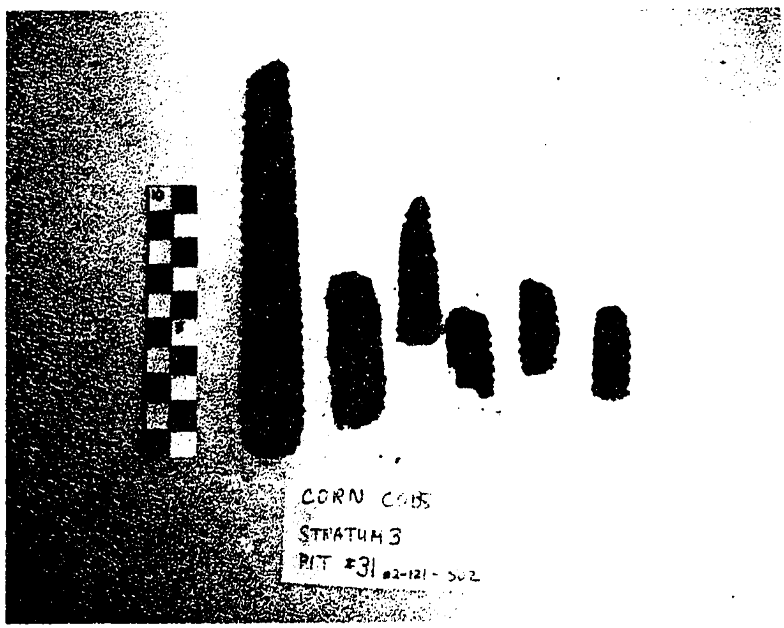

Figure 25. Maize cobs from pit #31. Measured left to right: cobs one, three, and four.

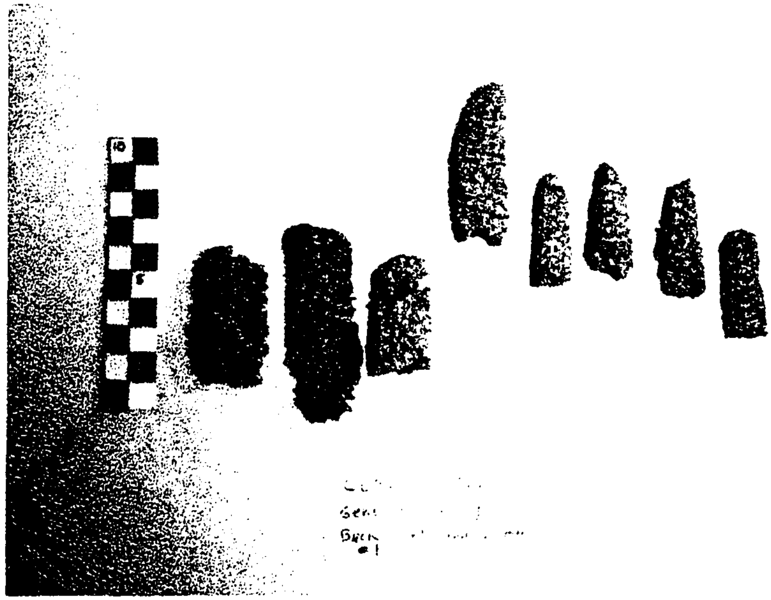

Figure 26. Maize cobs from general diggings, back fill, dirt and dump. Measured left to right: cobs two and four.

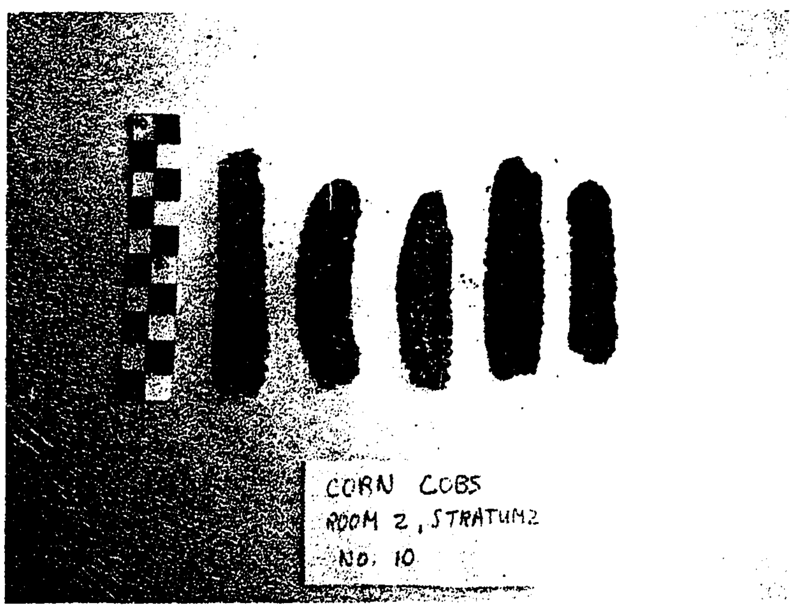

Figure 27. Maize cobs from room 2, stratum 2, no. 10. Measured left to right: cobs one, two, three, and four.

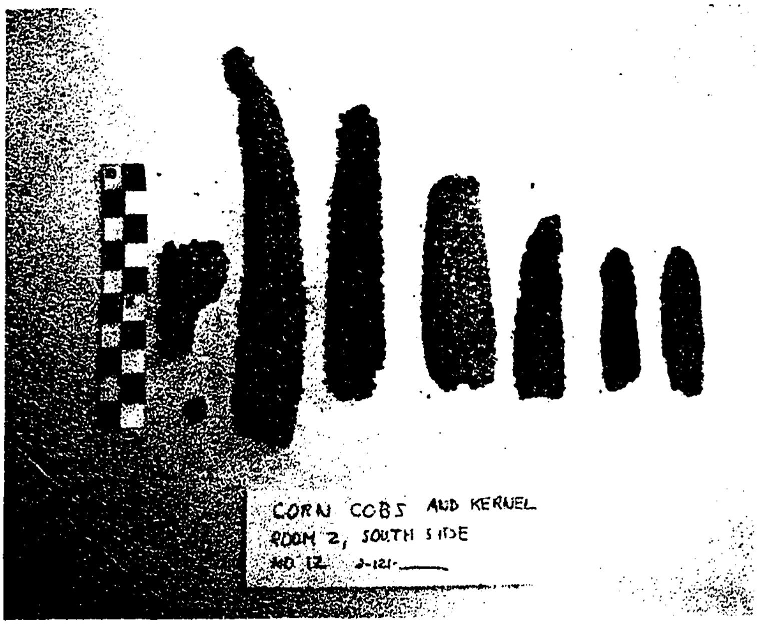

Figure 28. Maize from room 2, south side, no. 12. Measured left to right: cobs two, three, seven, and the maize kernel.

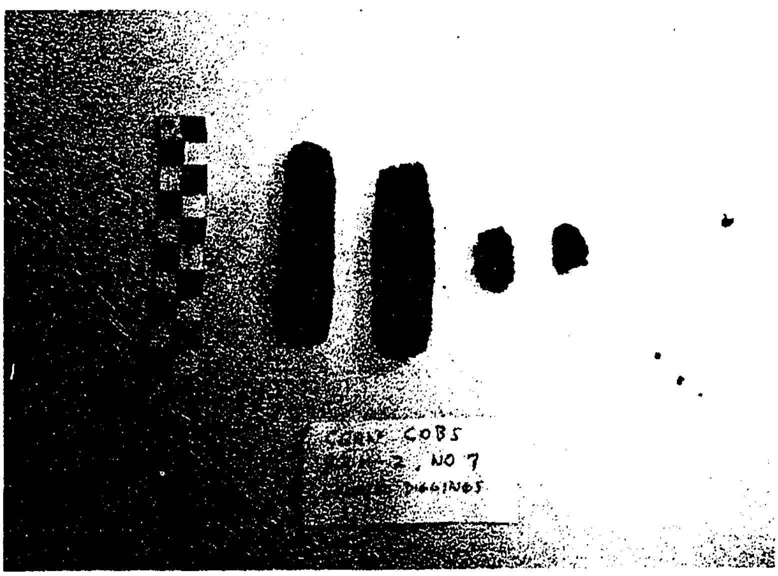

Figure 29. Maize found in general diggings, in room 2, no. 7. Measured left to right: cobs one and two.

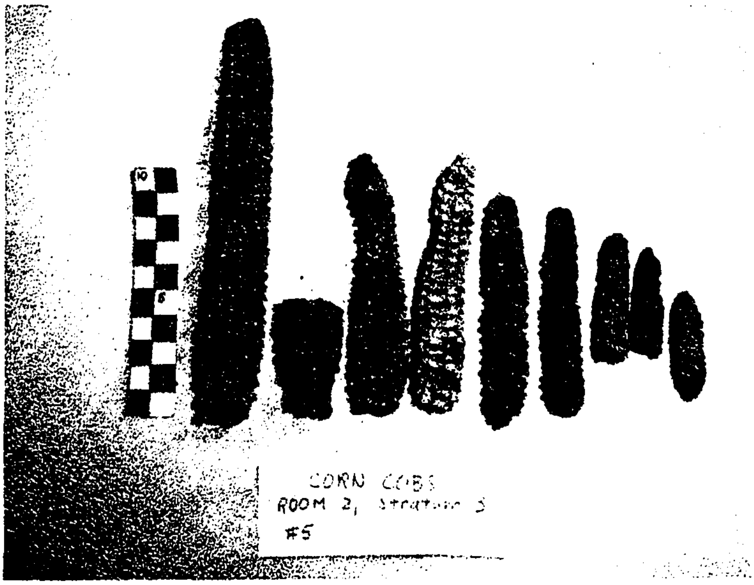

Figure 30. Maize cobs from room 2, stratum 2, #5. Measured left to right: cobs one, three, four, five, six, and nine.

Figure 31. "Corncob dart." A grass inflorescence has been inserted into the bottom of this fragmentary cob.

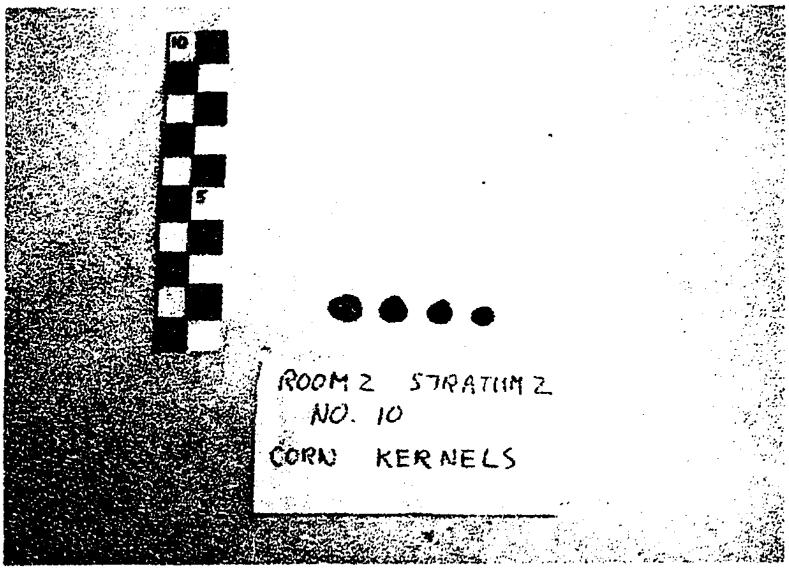

Figure 32. Four kernels of maize from room 2, stratum 2, #10, measured left to right, as listed in the order presented in Table 11.

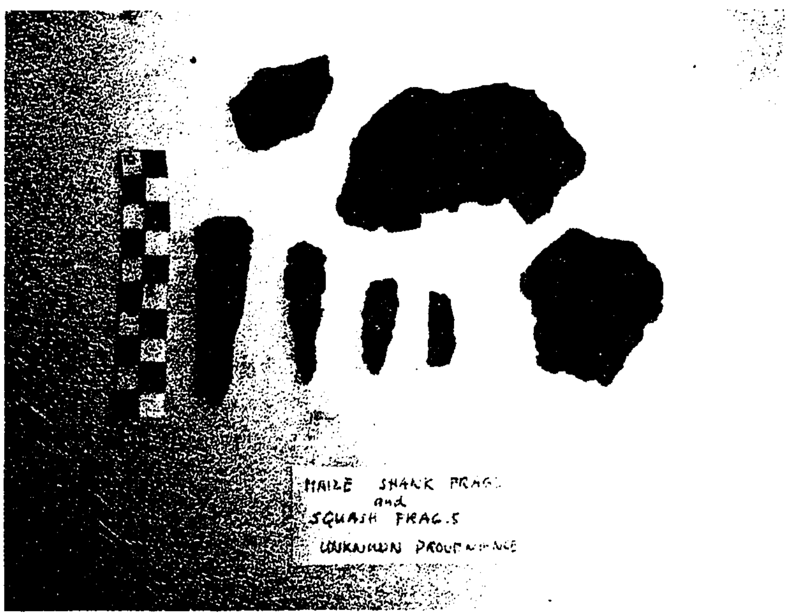

Figure 33. Squash and maize shank fragments (with no provenience) measured left to right: shanks one, two, and three.

From the statistical data I have gathered on archaeological maize of the Southwest (presented in Chapter 8), it appears that all of the maize kernels dating to Basketmaker III levels in the Southwest in general were larger in all dimensions than the kernels from Black Dog Cave, except for the maize from a group of Basketmaker III sites near Durango, Colorado, that had a mean kernel thickness of 3.3 mm (Cutler 1963)

Most of the maize from later periods in the Southwest also had kernels of larger dimensions, except for the maize from a group of Hohokam sites in the Gila Bend, Arizona, area dating from A. D. 500 to A. D. 1450 (Cutler 1965). Unfortunately, kernel sizes were not listed for the earliest periods at these sites, but the maize at AZ T:13:2 (A. D. 900-1100, the Sacaton Phase) revealed a mean kernel width of 5 mm, a kernel thickness of 3.2 mm, and a kernel depth of 5.2 mm. Maize from site AZ Z:1:11 (A. D. 1150-1450, the Classic phase) had a mean kernel width of 5.3 mm, a kernel thickness of 3.2 mm, and kernel length of 6.1 mm.

The continuation through time of the growing of small-seeded maize among the lowland Hohokam is reflective of the continued use of the maize race Pima-Papago, which was adapted to lowland environmental conditions. Environmental selection would have favored this race of maize in the hot, lowland climate. Continued use of Pima-Papago maize would also reflect cultural selection for certain characters considered desirable in the maize. The Hohokam must have had cultural and economic reasons for continuing to raise the Pima-Papago race of maize.

The ear of maize with its kernels from Black Dog Cave is quite close in all of its statistical measurements to Basketmaker II maize and to the Pima-Papago maize sub-race Onaveno, frequent in sites dating to early periods in the Southwest (see Chapters 7 and 8). The kernels of Onaveno are of an intermediate flint-flour type, and occur on cobs with (usually) 16 rows.

There are few differences in this ear with its kernels (Figure 12 and Table 10) found at Black Dog Cave, from Basketmaker maize, which is typical Onaveno maize, the

flinty sub-race of Pima-Papago maize (Cutler 1966:14; Nusbaum 1922:67-69; Wellhausen et al. 1952:198-199). Basketmaker maize usually averages 12 to 14 rows of kernels, but 8, 10, 16 and 18-rowed ears are known. The ear from Black Dog Cave is 16-rowed, and is shaped as a straight cigar, a little straighter than most Basketmaker maize cobs. It is possible (or, probable) that this ear is later in age than the Basketmaker II cobs from pit #31, which have been radiocarbon dated to A. D. 258-410 and A. D. 248-390, at one Sigma (Figure 25). The ear with kernels may date from Basketmaker III occupations at Black Dog Cave, or from the Pueblo period, or even later.

Table 13 shows the measurements of eight kernels of maize from Black Dog Cave, from four samples. One of the samples was from the ear of maize with its kernels from pit #4, just described. One collection (of two kernels) was from general diggings, and two collections were from room 2, stratum 2, south side (one was of four kernels, the other of one kernel). Mean measurements of all kernels together are 6.6 mm for kernel width, 4.28 mm for kernel thickness, and 6.36 mm for kernel depth. These means are within the range of Basketmaker maize and early examples of the flinty Pima-Papago race of maize, known as Onaveno (Cutler 1966:14). All the kernels have an intermediate flint-flour endosperm, which is more resistant to insects in storage, but harder to grind into meal than is flour maize. No dent, pop, or true flour kernels were found among the collections from Black Dog Cave.

Most of the kernels measured were colored (due to age) orange or orange-tan, which means that they were probably originally yellow, or possibly blue. One of the kernels measured (from room 2, south side, no. 12, shown in Figure 28) was red-brown variegated with yellow. This was the largest kernel from the site, with a kernel width of 9 mm, a thickness of 5.5 mm, and a depth of 4 mm. Red and variegated kernels occur in early Pima-Papago and Onaveno maize, and red is a very primitive color in maize, found in some of the earliest sites and in the most primitive existing races of maize (Cutler 1966:10). One other red kernel was still in place on one of the cobs I measured, in a

sample probably from pit #30 (Figure 17, the large cob on the right). I did not measure this individual kernel, except for its thickness (3 mm).

Tables 15 and 16 are included in this volume to compare dimensions of maize kernels from Black Dog Cave with kernels from other cave sites in the Moapa Valley. Included are measurements of kernels from a contemporary or earlier cave site (Firebrand Cave, Table 16) and kernels from Paiute occupations at a nearby site, (Granary Cave, Table 15).

Through the generosity of L. Blair, I was allowed to measure seven maize kernels collected from Firebrand cave, now in the collections of the Marjorie Barrick Museum of Natural History at the University of Nevada, Las Vegas. The measurements of these kernels are quite similar to those from Black Dog Cave and all of them, except one pop kernel, were flint-flour kernels that were similar in color to the kernels from Black Dog Cave. It is very likely that the maize found at Firebrand Cave was of the same Basketmaker/Onaveno race of maize that was raised at Black Dog Cave, though the endosperms of these kernels appear to be even more flinty. Cultural artifacts found at Firebrand Cave may date quite early (atlatls and basketry were present) (L. Blair; personal communication) and it would be interesting to have the maize radiocarbon dated.

At Granary Cave in Southern Nevada, Bradley Stuart conducted an excavation during 1941. No signs of Pueblo occupations were found, but both Basketmaker and Paiute objects were discovered, including a twined Paiute basket filled with kernels (artifact number 2-120-166). The measurements of the kernels from the basket's contents are summarized in Table 15. These kernels, from Paiute occupations (or uses) of the cave, had soft, floury endosperms unlike the flint-flour kernels of maize from either Firebrand Cave or the Black Dog Cave. The mean width of the kernels from Granary Cave was one millimeter greater than the kernels from the other, earlier sites. Thickness and depth (length) of the kernels were similar to the kernels from the other caves. The color of the kernels from Granary Cave was a mixture of red and orange kernels that were probably

originally red and yellow.

If I may generalize from one sample of Paiute maize, it appears that Paiute maize was as of the floury variant of the Pima-Papago race of maize and was slightly larger in kernel size than was the earlier Pueblo and Basketmaker maize. This floury Paiute maize would have been easier to grind than the flint-flour Onaveno maize that was found at Black Dog Cave.

A total of 55 cobs (including the ear with its kernels, the "corncobs on sticks," and the "corncob dart") were measured in this study of maize from Black Dog Cave. Table 9 presents mean measurements for all cobs of maize from the cave, taken from 18 samples in the collections at the Nevada State Museum.

The maize from Black Dog Cave has small cobs, with a mean cob length of 10.6 cm (106 mm) (this measurement was taken from 16 cobs which are still entire in their length). The size range of cobs that are still entire in length indicates a degree of variation in the maize at Black Dog Cave. The longest cob is 195.5 mm, followed by the next longest one of 167 mm, and another of 159 mm. The shortest cob is 43 mm in length, the next smallest is 56 mm in length, with a smaller one of 62 mm. The median cob is 104 mm long (slightly over 4 inches).

Most of the ears are cigar-shaped (51%), with fewer straight (25%) and tapered (24%) cobs. The mean row number of all specimens is 12.3, and the largest number of cobs (44%) have 12 rows of kernels. There is a certain degree of variation in row numbers, with a total of: 7% 8-rowed cobs, 16% 10-rowed cobs, 2% 11-rowed cobs, 44% 12-rowed cobs, 22% 14-rowed cobs, and 5% 16-rowed cobs. The mean kernel thickness (taken in absence of the kernels) for 55 specimens is 3.5 mm.

All of these measurements, when taken together, indicate that most of the maize grown at Black Dog Cave was probably of the race Onaveno, a sub-race of Pima-Papago maize. This was a 12-rowed race of maize with usually yellow, and sometimes red, white, blue or variegated kernels of the flint or flint-flour type. The glumes on most of

the specimens I measured were firm, which is typical of Onaveno maize.

Four cobs are 8-rowed, all of them small, with lengths of 37.5 mm, 51 mm, 60 mm, and 83.5 mm. The only 8-rowed cob that is still entire in its length is the last one listed (about 3 1/4 inches long). One of these cobs, (Figure 24, far right) appears to have the long and tough glumes that are thought to represent the "tripsacoid" influence from maize's wild ancestor teosinte, that became increasingly common in the prehistoric Southwest during the Basketmaker III period (A.D. 500-700). The beginnings of this "tripsacoid" influence on maize of the Southwest were shown from archaeological evidence found at Tularosa Cave (Cutler 1952) and at Coxcatlan Cave, Mexico (Mangelsdorf 1974:178). (See Chapter 8 for a discussion of 8-rowed forms of maize in the prehistoric Southwest). The 8-rowed forms of maize from Black Dog Cave may represent a variation of the Basketmaker/Onaveno or Chapalote races, or may represent proto-Maiz de Ocho. The mean diameter of the rachis of the four specimens of 8-rowed cobs from Black Dog Cave is 7.8 mm, well within the average diameter of racially defined proto-Maiz de Ocho (3.6 to 8.8 mm).

It is possible that the early 8-rowed maize found at Black Dog Cave and at other sites in the Southwest was a separate variety that was raised in addition to others, perhaps for special purposes, or early-maturing. Or, the 8-rowed cobs may have come from tillers (the secondary shoots of the maize plants) of the Basketmaker/Onaveno maize. A third possibility is that they may be examples of the 8-rowed, late-season ears that tend to develop late in the growing season, during cool autumn weather, on second-crop stands of maize even when seed from 10 or 12-rowed varieties has been planted. (In Chapter 7 of this volume is a discussion of environmental effects on maize in the Southwest).

Several ears from Black Dog Cave show evidence of maize earworm damage caused by the larvae of the moth *Heliothis zea*. These are indicated with a * symbol in Table 12. I recognized the evidence of damage from this insect immediately, because maize earworms had attacked some of the maize ears that I raised for this study (described

and discussed in Chapter 7). A total of 6 cobs (11%) of the 55 cobs from Black Dog Cave show evidence of maize earworm damage. Nusbaum (1922:69) also found evidence of maize earworm damage to the Basketmaker II maize found at Cave Dupont.

In analyzing the collections from Black Dog Cave, I encountered one sample that contained several squash parts and maize shanks, all unprovenienced. Table 14 lists the measurements of three of the shanks. The mean shank diameter in this sample is 14.8 mm, mean shank length is 51.6 mm, and the number of husk scars averages 5.6 per shank. This data from shanks may give further clues to the racial composition of the maize at Black Dog Cave. The only complete shank has 7 husk scars, which is very close to the mean number of husks of the following, still-existing varieties of maize that I raised for this study, in Las Vegas: Flor del Rio Pop (6.3), Argentine Pop (6.4), Tohono O'odham Flour (6.6), Hopi Yellow (7.3), Tabloncillo Perla (7.3), and Moqui (Hopi) Blue (8). (See Chapter 7 for a discussion).

The most uniform sample of maize from Black Dog Cave is from pit #34, in room 2 of the cave (Figure 21). All of the cobs in this collection have 12 rows, and are quite small. I estimated their average original length to have been about 62 mm. The mean kernel thickness is 2.5 mm (also quite a small measurement in comparison to that of the other samples). The ears all have a slightly more tapered shape than most of the other cobs at Black Dog Cave, which tend to be mostly cigar-shaped. These specimens (from pit #34) are all very fragile, almost carbonized, and I have the impression that the specimens were very old. Since pit #34 was the last to be excavated, and Wheeler said that "...the deposit was not getting any drier..." (Wheeler 1942:16). The pit may have been subjected to greater levels of moisture in the soil than the other pits in the cave. Wheeler did mention however, that pit #34 was "...similar to pit #31 in construction."

Figure 25 is a photograph of maize cobs from pit #31; this pit was found under pit #30. Pit #31 is most likely older than pit #30, and Wheeler shows a drawing of pit #30 intruding into pit #31 (Wheeler 1942:48). The contents of this pit included maize cobs,

charcoal ash, and gravel. The pit was lined with adobe plaster, and was 1.64 m (5.4 feet) in diameter. This measurement is very close to the average measurement of the pits (or cists) at Cave Dupont that Nusbaum stated "...averaged 5 feet in diameter" (Nusbaum 1922:23). Though pits #31 and #34 were not slab-lined, many of the pits in Black Dog Cave were slab-lined, as were those at Cave Dupont.

In March 1997, two samples of two of the maize cobs (see Figure 25) from pit #31 (which the excavators thought was one of the oldest pits) were allowed to be taken from the Nevada State Museum by Dr. M. Lyneis and sent to the A. M. S. facility of the University of Arizona, at Tucson, for carbon-isotope measurement. The radiocarbon ages of the samples were 1710 +/- 45 years B.P., and 1735 +/- 45 years B.P. Calibrated dates on the maize were as follows:

Sample 1, AA 25317BDC-31-1:

One Sigma cal. A.D. 258 to A.D. 294.

Two Sigma cal. A.D. 238 to A.D. 429.

Sample 2, AA 25318BDC-31-2:

One Sigma cal. A.D. 248 to A.D. 390.

Two Sigma cal. A.D. 223 to A.D. 419.

These radiocarbon dates of maize from Black Dog Cave strongly reinforce the presence of Basketmaker II Anasazi at the cave. Also reinforced is the hypothesis (Lyneis, 1997) that Basketmaker II Anasazi were farming maize in the lowlands and using water diversion, a form of irrigation, rather than floodwater farming, as they did at higher altitudes. Thus Basketmaker agriculture can no longer be associated with floodwater farming only, as it had been in the past (Matson 1991). Also established is a Basketmaker II presence much farther west than highland location of Cave Dupont, in the lowlands of the Moapa Valley, in present-day Nevada.

CHAPTER 7

TESTING AND DEFINING LIVING AND EXTINCT RACES OF MAIZE IN THE LOWLAND SOUTHWEST

The classification of archaeological remains of maize from the American Southwest has been traditionally based on comparisons of statistical measurements of maize cobs and kernels. Cobs and kernels preserve well in archaeological sites, especially in dry conditions, as inside of Black Dog Cave and other rockshelters. During the twentieth century maize remains from many sites have been analyzed, measured and assigned to race, and a large database has resulted.

The concept of "races of maize" was developed in the 1940s by Anderson and Cutler (1942:71): "For the classification of *Zea mays* we shall define the word race as loosely as possible, and say that a race is a group of related individuals with enough characteristics in common to permit their recognition as a group." Races of maize were thought of as peaks or groupings of common genes that are individually significant enough to define a group, or race (Anderson and Cutler 1942:71; Sanchez and Goodman 1992:73). The criteria for assignment of living examples of maize to races include measurements of cobs, kernels, tassels, leaves, stems and roots. Because cobs and kernels are usually all that remain in archaeological deposits, the measurements of cobs and

kernels have been used to assign archaeological maize to races through comparison with data taken from living plants that have been used to define the races of maize.

Anderson and Cutler (1942) defined four racial complexes of maize existing among indigenous peoples of the contemporary American Southwest. Their classification was designed to encompass variation in living maize grown by indigenous peoples of the Southwest, in the large geographic region usually defined as the Southwest (from eastern New Mexico to the west, including Arizona, southern Colorado, and southern Utah, bordering on Nevada; or the area from Las Vegas, New Mexico, to Las Vegas, Nevada). Anderson and Cutler(1942) studied 50 collections of maize obtained from Native American tribes in the Southwest made during the first few decades of the twentieth century. They sorted the maize into groupings, and separated it into four degrees of type: Pueblo, an eastern highland race; Intermediate Pueblo; Intermediate Pima-Papago; and Pima Papago, in the far western lowlands. They identified two distinct races, Pueblo and Pima-Papago, noting a series of intermediate forms between the two. These two races can be said undeniably to exist today among Native Americans in the Southwest.

Anderson and Cutler (1942:80-84) also described three other races, Mexican Pyramidal, Guatemalan Tropical Flint, and Guatemalan Big Grains, which they believed had mixed with the Pueblo and Pima-Papago maize after Spanish contact.

Carter and Anderson (1945) revised and broadened the definitions of living American maize to four racial complexes, and even included archaeological maize: (1) Basketmaker, (2) Hohokam, (3) Mexican Plateau, and (4) Eastern North American. Jones and Fonner (1954:107) revised this into four complexes: (1) Hohokam-Basketmaker complex, (2) Mexican complex, (3) Eastern complex, and (4) Tropical Flint complex. The Pueblo race had been eliminated by Carter and Anderson and was subsumed into the Eastern complex, perhaps because in the 1940s it was thought that maize from the Eastern Woodlands had entered the Southwest during the prehistoric period. Later studies have shown the reverse to be true, with a directional flow of eight-rowed forms of maize from

Southwest to the Northeast, during the period A.D. 500 to A.D. 700, and after (Galinat 1988:682).

In 1952, Races of Maize in Mexico, by E.J. Wellhausen, L.M. Roberts, E. Hernandez X. and P.C. Mangelsdorf, was published. This was the first of a series of volumes that sought to define existing races of maize in the entire region of North and South America. Maize races in the entire continent of South America and in Central America, Mexico, and Cuba were described statistically in this series of books. Two great geographic centers of morphological diversity in maize were identified- the regions surrounding the countries of Peru and Guatemala. Both areas have a wide range of altitudes, climates, and ethnic groups, which may account for the great diversity of maize found. Over 300 races were defined for all areas of the Americas, except the U.S.A. and Canada, and since the 1950s new races of maize have been discovered, defined, and added to the early database on maize races. In viewing the Races of Maize books, the incredible variability in maize becomes evident. Maize is the most mutable plant in nature, and the complexity of its history is astonishing.

In the Races of Maize books, the prevailing theoretical bias was centered toward factors having to do with hybridization, partly due to the influence of P.C. Mangelsdorf. The classification system used attempted to define maize evolution through hybridity and to identify the most primitive to the most advanced forms of maize in the Americas. Other forms of evolution, such as adaptive radiation, convergent evolution, genetic drift, and environmental and human selection were not explored as well as they could have been (Doebley 1990:20).

Since the first definitions of races of maize were formulated in the 1940s, archaeologists have attempted to assign the remains of prehistoric maize found in archaeological sites of the Southwest as belonging to living races, through a use of the existing modern racial definitions. Though this practice has been criticized (Winter 1983) it is a practical method of categorizing prehistoric maize and comparing it with

contemporary, existing races of maize.

In early studies of archaeological maize of the Southwest, it may have first seemed that the evolution of maize through time in the region had a fairly simple history, with distinct, separate arrivals of discrete races of maize at specific periods. Today, with the large database of information available on archaeological maize, it appears that ten or eleven races of maize either arrived from Mexico or originated in the American Southwest during the prehistoric period.

In reviewing the literature on archaeological maize, and comparing the results of many studies, I found that the following races were considered to have been present in the prehistoric American Southwest: proto-Maiz de Ocho, pre-Chapalote, Reventador, Maiz de Ocho, Basketmaker/Onaveno/Pima-Papago, Fremont Dent, Mexican Pyramidal (Pepitilla), Maiz Blando de Sonora, and Pueblo. [For a summary of statistical data of the evolution of maize through time in the Southwest, see Chapter 8].

Sanchez G. and Goodman (1992) have described and classified several new races of maize in Mexico, among them Blando de Sonora, a race that is closely related to the Pima-Papago race of maize that evolved in the American Southwest. They defined several previously poorly described living races of Mexico using morphological measurements as their criteria for definition, as had been done for the racial definitions presented in the Races of Maize books. In my testing of races of maize of the American Southwest that are generally thought to be descended from, and closely related to, prehistoric races of maize of the Southwest, I have used the same system of classification as was used in the Races of Maize books, and in the article by Sanchez and Goodman (1992). By comparing the data I have gathered from the living races I have raised in the local lowland Southwest climate, with the data taken at high altitudes in Mexico, differences will be seen in the measurements of the ears, row numbers, leaves, stems, and tassels of maize raised here, from the measurements of the same races of maize raised in Mexico. In this way, the effect of lowland environmental conditions may be clearly seen on races of maize of the

Southwest. The information I have personally gathered from living plants of maize raised in the local, lowland Southwest climate at Las Vegas, Nevada, is presented in this volume and is listed in Tables 25-31. Data previously gathered by others on races of both living and extinct races maize as grown in modern Mexico, in the modern American Southwest, and in the prehistoric Southwest is synthesized and presented in Tables 17-22 and Tables 32-42.

In recent years a new method of testing evolutionary relationships between races of maize has developed- isozyme studies. In this process molecular systematic studies are conducted from living material taken from maize plants. Gelatin slides are stained, and 12 different enzyme systems of maize can be read. Interpretations can be made of the interrelationships of races of maize using this method, which reveals the degree of genetic closeness evident in the relationships between individual specimens. The distinguishing data are evident in seven of the ten maize chromosomes (Doebley et al. 1983:102-105). This information can be compared to the large database of morphological characters of races of maize in the Southwest and Mexico.

Doebley (1990:6) found that maize races tended to segregate into closely related complexes that "...have often evolved in response to environmental constraints associated with altitude." This factor is an aid in determining which races of maize are lowland or highland races, and which ones are adapted to both high and low altitudes.

Doebley et al. (1983) reported the isozyme relationships of collections of maize made from several Native American tribes and villages of the Southwest (Doebley et al. 1983:108, Fig. 3). In a later article, Doebley (1990) presented the isozyme relationships of several races of maize of the Southwest and Mexico (Doebley 1990:22, Fig 6). By comparing the two graphs that were presented in these two articles the relationships between individually defined races of maize can be seen. In Figure 34 I have placed drawings of the two graphs side by side.

In the upper graph (Doebley et al. 1983:108 Figure 3), two principal components

of the isozyme relationships of modern Puebloan maize have been plotted, and the results pooled according to tribal-linguistic associations. Note that Puebloan maize groups together in an inverted cone shape. These represent highland collections of the Pueblo race of maize. Papago maize, which is a lowland race of maize, is segregated toward the bottom of the graph. The data from this graph indicate that modern Pueblo maize is made up of a varied ancestry, but clusters fairly close together for the two principal components.

In the lower graph (Doebley 1990:22 Figure 6), the two principal components of an isozyme analysis of races of maize from the American Southwest and Mexico is represented. The various living races of Southwest maize segregate by altitude, with most of the Southwestern races of maize that are known from archaeological contexts grouping on the negative side of the graph, fairly close together. Two races that appear widely separated are Chapalote and Reventador, thought to be closely related by Wellhausen et al. (1952). Interestingly, almost all of the living maize races traditionally assigned to archaeological contexts in the Southwest (Chapalote, Reventador, Basketmaker/ Onaveno/Pima-Papago, and Maiz de Ocho) are lowland races in their Mexican habitat (Bretting and Goodman 1989:108). I have circled the lowland races of maize of the American Southwest in the lower graph. The existing mid-elevation and highland races of Mexico are clustered to the right of the graph, and these have been circled also.

One race of maize of the prehistoric Southwest that was not a lowland race was the unknown ancestor of Fremont Dent maize. This ancestor was postulated to be a member of a highland race and considered to be of the Mexican Pyramidal complex, which hybridized with existing Southwest races, to create the dented Fremont maize (Jones and Fonner 1954:114). Cutler (1966:15) thought that the ancestor of Fremont maize was some form of Conico, but Doebley's (1990:22, Fig.6) graph shows a distant relationship of traditional Southwest races and modern Pueblo maize to Conico and the Conico group of races. The graph also shows a close relationship of the Southwest races of maize with Pepitilla, a medium-altitude maize from the Oaxaca region of Mexico. Pepitilla has a

conical ear, and rice-like or "shoe-peg" kernels, that apparently carry the dent gene. This was probably the unknown "Mexican Pyramidal" ancestor that brought dent genes and tapered cob shapes into northern Southwest maize around A.D. 400. Pepitilla has a very high mean row number (15.5). Ears of maize resembling Pepitilla were found at a prehistoric Fremont site in Yampa Canyon, Colorado, dating to A.D. 400-800 (Anderson 1948:91-92). Some of the cobs had pointed kernels, as does Pepitilla, and others were pointed dents, all had 16 rows or more. These maize cobs from Yampa Canyon are some of the most extreme ears (in their ear and kernel shape) ever found in archaeological contexts in the Southwest. Less than 1/3 of Fremont maize was dent maize, and most of it was Onaveno or Maiz Blando (Cutler 1966:15).

In the lower graph, the close relationship can be seen between maize races Pepitilla and Harinoso de Ocho Occidentales (the western form of Maiz de Ocho), Harinoso de Ocho Occidentales and Tabloncillo, and Pepitilla and Tabloncillo Perla. Reventador, Harinoso de Ocho, and Chapalote are all rather isolated from the other races usually assigned to archaeological contexts in the Southwest.

Chapalote is an ancestor of the diverse Pueblo race of maize that began to develop it the A.D. 1000s. The clustering of all the races of the Southwest highlights the possibility of close genetic relationships among them. In the upper graph Pueblo maize in general is quite isolated from Pima-Papago maize, especially among the Hopi and Western Keres, and the maize of the Puebloan groups is rather closely related. This contradicts the assumptions of Anderson and Cutler (1942) who had sorted collections of Southwest maize by morphology, and who thought that Hopi maize was closer to Pima-Papago maize than to the maize of the eastern Pueblos. The data of Doebley et al. (1983:112) show exactly the opposite in their isozyme studies: western Pueblo (Hopi) maize is morphologically closer to Pima-Papago maize, but eastern Pueblo (Tewa) maize is closer isozymically to Pima-Papago maize. The lowland Pima-Papago race is quite separated from the highland Pueblo maize; this is consistent with Doebley's findings that races

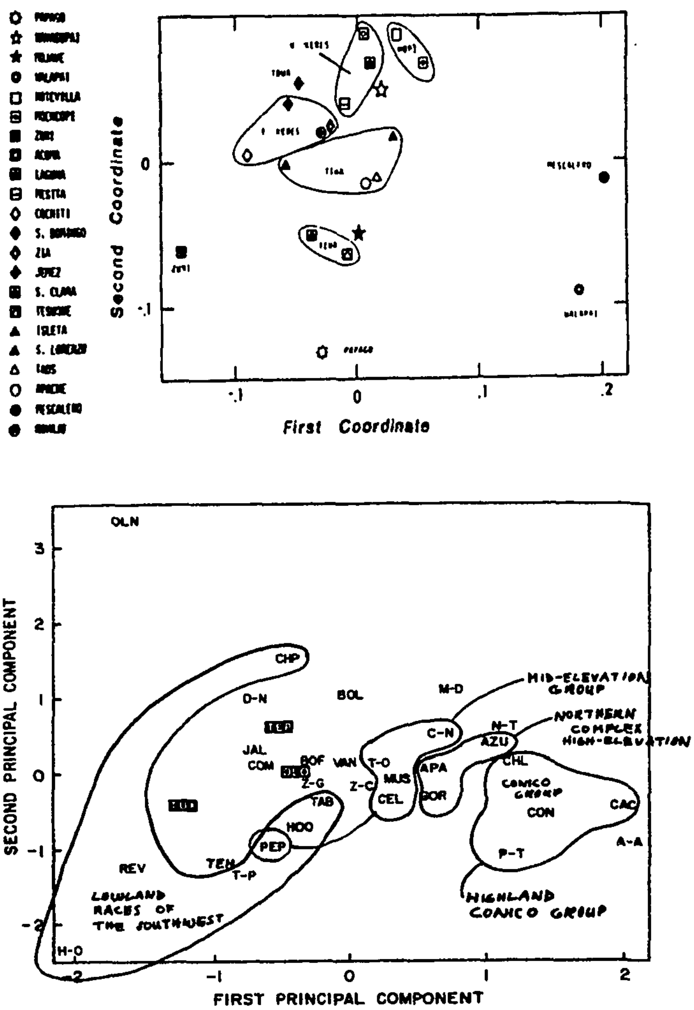

Figure 34. Isozyme relationships of the living races of maize of the Southwest. This is a comparative diagram. The upper graph is based on Doebley et al. (1983:108, Fig. 3) the circled areas represent maize collections from tribal groups that have been pooled together. The lower graph is based on Doebley (1990:22, Fig. 6), and is a plotting of two principal components from an isozyme analysis of races of maize of the American Southwest and Mexico. Key: CHP = Chapalote, REV = Reventador, H-O = Harinoso de Ocho, T-P = Tabloncillo Perla, PEP = Pepitilla, HOO = Harinoso de Ocho Occidentales, TAB = Tabloncillo, CON = Conico.

of maize in Mexico seem to be segregated isozymically by altitude (Doebley 1990:6). The morphological similarities of Pima-Papago and western Pueblo (Hopi) maize may be due to adaptations to drier climate and much higher rates of evapotranspiration of the western Southwest (see Figures 4, 5, and 6 of this volume).

Sanchez and Goodman (1992:80) considered the maize race Blando de Sonora to be the same as Pima-Papago, and Onaveno maize to be actually the sub-race Blando de Sonora with a flinty endosperm. Basketmaker has also been considered an early form of Onaveno maize (Jones and Fonner 1954), and some confusion exists in the literature about the precise definitions of each of these four. There is so much diversity in prehistoric Southwest maize that it is difficult to sort out the various races easily. Also, if proto-Maiz de Ocho, pre-Chapalote, Basketmaker and Fremont Dent are each considered viable races, then it should be stated that they are all extinct today in the Southwest and in Mexico. These four races will be described in as much detail as possible in the following section, along with living races of maize that are still existing in the American Southwest and Mexico.

THE CLASSIFICATION OF RACES OF MAIZE OF THE AMERICAN SOUTHWEST

Several specific parts of the maize plant are used in the classification of maize into races through morphological characters. These include characteristics of the ear, the vegetative characters of the plant, and characters of the tassel (Wellhausen et al. 1952:22). I am including a synthesis of statistical information that defines the modern, living races of maize that are widely considered to be analogous to or to have descended from archaeological maize from the prehistoric period in the Southwest. Also included is some statistical information on four races of maize that are now extinct in the Southwest and in Mexico: proto-Maiz de Ocho, pre-Chapalote, Basketmaker, and Fremont Dent. Information on these is scant in comparison to the other races, because the statistics that

have been used to identify them as races are based solely on archaeological material. Another factor affecting the data base on these races is that only the characters of the ears can be measured. Data on the tassels and vegetative parts of the plants of extinct races of maize is unavailable. Data on some of these races is partial, because complete statistical measurements have not been not published, or are not available, for some of them. The greater part of the information synthesized in this volume (Tables 17-22, Tables 32-42) was taken from Races of Maize in Mexico (Wellhausen et al. 1952), but also from other sources (Anderson and Cutler 1942; Anderson 1944; Carter and Anderson 1945; Hurst and Anderson 1949, Nicherson 1953; Jones and Fonner 1954; Cutler 1966; Mangelsdorf 1974; Upham et al. 1987; Galinat 1988; Bretting and Goodman 1989; Sanchez and Goodman 1992; Adams 1994).

THE METHODS OF MEASUREMENT OF MAIZE CHARACTERISTICS

The methods used in the measurements of maize plants for this study were based upon the classification system first proposed by Anderson and Cutler (1942) and later developed by Wellhausen et al. in Races of Maize in Mexico (1952). Nicherson (1953) and Bird (1994) have also contributed to the measurement of cobs and kernels of maize. In this study of maize I wanted to use a system of classification that would be useful, in that comparisons could easily be made between the data synthesized from past studies of maize, with the data that I gathered personally and have presented in this volume.

This chapter proceeds with the following topics: (1) a definition of methods used; (2) summary of data defining races of maize analogous to, or having descended from, prehistoric maize of the Southwest; (3) summary of studies of environmental effects on maize; (4) presentation of data that I gathered from an experiment testing the behavior of the previously defined races of maize under local Southwest growing conditions at Las Vegas, Nevada (designed to be as close as possible to the growing conditions at Black

Dog Cave, and (5) a discussion of the findings.

In the summary of measurements of cobs and ears of the races of maize from the work of others and presented in Tables 17-22 and Tables 32-42, the methods used by the researchers were essentially the same as those I employed to study and describe the archaeological maize from Black Dog Cave in Tables 9-16 of this volume. The methods of measurement of the tassels and vegetative parts of the maize plants described below were used in the original classification of the races of maize, and I used this same system in my own testing of races of maize here in the lowland Southwest. The data I personally gathered on the cobs and ears of living maize of the Southwest are presented in this chapter in Tables 25 and 26, while data on the leaves, stems and tassels of the living maize are presented in this chapter in Tables 27-31. All of the measurements were taken using the metric system for convenient comparison.

Much of the data summarized here (from the work of others in Tables 17-22 and 32-42) that define living races of maize were gathered at Chapingo, Mexico, at a high altitude of 2250 m (6858 feet). Data on the morphology of prehistoric forms of living races and of extinct races were taken from published reports on archaeological maize of the American Southwest and in Mexico.

MEASUREMENT CHARACTERS USED IN THIS STUDY

For a complete description of the methods used in these measurements of the maize ears, kernels, and cobs used in this study, please refer to "Measurements of Maize" in Chapter 6 of this volume. Below are descriptions of 21 measurement characters of maize plants used in this study.

Altitude. The altitudinal range for each race of maize. This describes the altitude at which each race is grown and was collected in Mexico.

Days to Maturity. The number of days from planting to mid-silking.

Days to Ripe. The number of days from planting until kernels on the ear are ripe and dry.

Height of Plant. A measurement of the plant from the ground level of the stalk to the node at the base of the tassel peduncle.

Height of Ear. This measurement is taken from the ground level to the vertex of the angle of insertion of the uppermost ear on the stalk.

Total Number of Leaves per Plant. Self-explanatory

Number of Leaves Above Uppermost Ear. Self-explanatory.

Total Number of Ears per Plant. An index of productivity that is useful to agriculturists.

Number of Ears Pollinated. An important measure related to productivity and environmental adaptability of a particular race.

Length of Leaves. A measurement taken from the leaf arising from the node of the uppermost ear insertion, from ligule to tip of the leaf.

Width of Leaf. A measurement of the same leaf arising from the node of the uppermost ear insertion, at the mid-point of its length.

Leaf Area. This is a measurement using a method described in Races of Maize in Peru (Grobman et al. 1961:121). It is the product of 3/4 X length X width X number of leaves, and is calculated and given in centimeters squared.

Number of Veins per Leaf. A measurement used to calculate the venation index. The number of veins at the midpoint of the leaf are counted.

Venation Index. This measurement is a ratio between the number of veins in the leaf and the maximum width of the leaf. Venation indexes are higher in primitive races of maize.

Internode Patterns. The length of successive internodes (the areas of the stem between the leaves) on the stalk, from the base of the plant upward. This measurement is taken and presented in diagrams that display a visual pattern of successive internode

elongation from the base of the stem of a maize plant to the bottom of the tassel peduncle (see Figures 35-39 for graphics displaying the internode patterns of several of the living races of maize tested in this study). The numbers and lengths of successive internodes are given at the base of the diagram for each race of maize. Internode lengths vary within a race when that race is grown at a different altitude than it is normally adapted to. Internode lengths are greater in the hotter climatic conditions of the lowlands.

Number of Nodes. Self explanatory.

Stalk Width. This measurement is taken at the first internode above ground level.

Prop Roots. A score of 1 was given for each whorl of prop roots and their mean total number was listed.

Number of Tillers. The number of tillers (side-stems of the maize plant) are counted and averaged for the race.

Pubescence. The degree of pubescence of the leaves is assessed, with a score range from 0 to 4, with 0 being no pubescence, and 4 being very pubescent.

Number of Husks. The number of husks surrounding each ear is counted.

Below are descriptions of eight additional measurement characters of tassels used in this study.

Length of Peduncle. A measurement of the stalk of the tassel; the distance from the uppermost node of the stalk to the lowermost branch of the tassel.

Tassel Length. The distance from the point of origin of the lowermost branch of the tassel to the tip of the central spike.

Length of the Branching Space of the Tassel. A measurement of the distance between the point of insertion of the basal tassel branch and uppermost branch of the tassel, along the axis of the tassel.

Percent of Branching Space. A percentage figure measuring the distance of the

tassel that exhibits branches. The length of the average space on which branches occur is divided by the tassel length.

Length of Central Spike of the Tassel. Self-explanatory.

Total Number of Primary Branches. Self-explanatory.

Total Number of Secondary Branches. Self-explanatory.

Total Number of Tertiary Branches. Self-explanatory.

THE DEFINITION OF RACES OF MAIZE OF THE SOUTHWEST

In Tables 17-22, I have synthesized information from many sources in an attempt to statistically identify the races of maize found in the prehistoric and contemporary Southwest. These are organized into 15 groups of races of maize, including extinct prehistoric races, prehistoric forms of still-existing races, and contemporary races. Following the tables is a written description and explanation of each of the races, both the extinct and contemporary ones, as defined here statistically. Most of.them have been vaguely known before this study in the literature of the prehistoric Southwest. To my knowledge, this is the first study in many years to attempt to categorize the morphology of all of the races of maize of the Southwest quantitatively, and the first to correlate that information with isozyme studies.

Table 17 is a synthesis of the mean measurements of cobs and ears of maize taken from many research studies on both the prehistoric races of maize and the living races of maize of the American Southwest. The races of maize are listed in the order of their appearance in the prehistoric and historic Southwest. Several of the prehistoric races are now extinct and only known from archaeological material. Table 17 lists six of the characters of the cobs and ears of this maize, and Table 18 lists another six characters of the ears and cobs.

Tables 19, 20, 21, and 22 list the vegetative and tassel characters of several still-living races of maize that have been found in the prehistoric and historic Southwest. The statistics used for the definition of these races were taken at Chapingo, Mexico, in the 1950s at a high altitude. It is the statistics from the previous studies of Southwest races of maize (synthesized in Tables 17-22) that will bear interesting comparison with the statistics taken by myself from maize raised for this study, and summarized in Tables 25-31.

PROTO-MAIZ DE OCHO

This race of maize is probably the earliest one that occurs in the Southwest, with the possible exception of pre-Chapalote. The name of this extinct race [proto-Maiz de Ocho] was originated by Walter Galinat, as a reference for very early eight-rowed forms of the still-living, recognized race Maiz de Ocho (Upham et al. 1987). "Proto-Maiz de Ocho" refers to possibly unrelated precursors of the later eight-rowed forms that began to increase in frequency about A.D. 600 at Tularosa Cave, New Mexico (Cutler 1952). Several small, eight-rowed cobs of maize were found at Tornillo Shelter and Rollerskate Shelter, and the earliest were radiocarbon dated to 3175±240 B.P. from zone D at Rollerskate Shelter (Upham et al. 1987:412; Upham et al. 1988). Ten-rowed, 12-rowed and 14-rowed cobs were also found in the same levels, but were assigned to the Chapalote race. The presence of eight-rowed cobs this early indicates that eight-rowed forms have existed in the Southwest for a very long time. But these early eight-rowed cobs were very different from the much larger race of Maiz de Ocho as it is known from the period A.D. 600 to today. By referring to Tables 17 and 18, the differences in the mean size of the rachis between the extinct race proto-Maiz de Ocho and the still living race Maiz de Ocho are evident. The mean dimension of the rachis of Maiz de Ocho is 4.09 mm wider than that of proto-Maiz de Ocho. It is unfortunate that more complete published measurements of the cobs are not available to enable us to make greater comparisons.

Table 17. Summary of Measurements of the Races of Maize of the Southwest, Characteristics of the Cobs.[a]

Race and Status	Sample No. and Date of Origin	Cob Length (Mm)	Row No.	Rachis Diam. (Mm)	Rachis Seg. Length (Mm)	Cupule Width (Mm)	Cupule Length (Mm)
Proto-Maiz de Ocho (extinct)	Sample 1 (5500 B.P.)	22	7.3	-	-	-	-
Proto-Maiz de Ocho (extinct)	Sample 2 (3175 B.P.)	-	8	6.95	-	-	-
Proto-Maiz de Ocho (extinct)	Sample 3 (2500-2225 B.P.)	-	8	6.31	-	-	-
Proto-Maiz de Ocho (extinct)	Sample 4 (A.D. 632)	-	8	6.57	-	-	-
Mean of 4 Samples		22	7.8	6.61	-	-	-
Pre-Chapal-ote (extinct)	Sample 5 (3010-2340 B.P.)	7.3	10.7	7.5	-	-	-
Pre-Chapal-ote (extinct)	Sample 6 (Un-known)	35	12	-	-	-	-
Mean of 2 Samples		21.1	11.3	7.5	-	-	-
Chapal-ote (living)	Samples 7 and 8 (3010-2340 B.P.)	110	12.3	11.2	-	5.5	-
Basket-maker (extinct)	Sample 9 (A.D. 200-300)	115	14	-	-	-	-
Basket-maker (extinct)	Sample 10 (A.D. 200-300)	80	14	-	-	6	-
Basket-maker (extinct)	Sample 11 (A.D. 46-324)	55	14	-	-	-	-
Basket-maker (extinct)	Sample 12 (A.D. 50-500)	-	14	-	-	-	-
Mean of 4 Samples		83.3	14	-	-	6	-

Table 17. Continued.

Race and Status	Sample No. and Date of Origin	Cob Length (Mm)	Row No.	Rachis Diam. (Mm)	Rachis Seg. Length (Mm)	Cupule Width (Mm)	Cupule Length (Mm)
Onaveno (still-living)	Sample 13 (2300 B.P.- A.D. 900)	-	12	-	-	-	-
Onaveno (still-living)	Sample 14 (Early BM II)	-	11.8	-	-	6.9	-
Onaveno (still-living)	Sample 15 (A.D. 46-324)	55	14	-	-	-	-
Mean of 3 Samples		55	12.9		6.9	-	-
Pima-Papago (still-living)	Sample 16 (A.D. 500-700)	114	12.3	-	-	-	-
Pima-Papago (still-living)	Sample 17 (modern)	120	12	-	-	-	-
Pima-Papago (still-living)	Sample 18 (modern)	225	13	-	-	7	-
Mean of 3 Samples		153	12.4	-	-	7	-
Reventador (still-living)	Samples 19 and 20 (2300 B.P.- present)	165	11.9	11.2	-	5	-
Pepitilla (still-living)	Samples 21 and 22 (A.D. 400- present)	123	15.5	12.5	-	5	-
Fremont Dent (extinct)	Sample23 (A.D. 400- 800)	-	14	18.6	-	11.5	-
Fremont Dent (extinct)	Sample 24 (A.D. 339- 1011)	116	11.3	11.8	-	7.9	-
Fremont Dent (extinct)	Sample 25 (A.D. 339- 1011)	-	13.7	-	-	-	-
Fremont Dent (extinct)	Sample 26 (BM III?)	-	11.8	-	-	7.6	-
Mean of 4 Samples		116	12.7	15.2	-	9	-

Table 17. Continued.

Race and Status	Sample No. and Date of Origin	Cob Length (Mm)	Row No.	Rachis Diam. (Mm)	Rachis Seg. Length (Mm)	Cupule Width (Mm)	Cupule Length (Mm)
Harinoso (Maiz) de Ocho (still-living)	Sample 27 (A.D. 500-700-present	191	8	10.7	-	8	-
Harinoso de Ocho Occident-ales (still-living)	Sample 28 (A.D. 500-700-present)	171	9.9	-	-	-	-
Tabloncillo (still-living)	Sample 29	164	9.1	12.5	-	9	-
Tabloncillo Perla (still-living)	Sample 30	170	8.3	-	-	-	-
Pueblo (prehistoric form)	Sample 31 (A.D. 900-1150)	-	10.78	-	-	7.2	-
Pueblo (prehistoric form)	Sample 32 (A.D. 1125-1175)	-	10.1	-	-	5.5	-
Pueblo (prehistoric form)	Sample 33 (A.D. 1200-1250)	-	11.2	-	-	7.2	-
Pueblo (prehistoric form)	Sample 34 (A.D. 1250-1300)	-	10.8	-	-	8	-
Pueblo (prehistoric form)	Sample 35 (A.D. 1350-1380)	-	10.7	-	-	7.7	-
Mean of 5 Samples		-	10.7	-	-	7.1	-
Pueblo (still-living)	Sample 36 (modern)	210	13	-	-	8.5	-
Pueblo (still-living)	Sample 37 (modern)	170	15	-	-	8.5	-
Mean of 2 Samples		190	14	-	-	8.5	-

Table 17. Continued.

[a] Data from (by sample number): (1) (Mangelsdorf et al. 1964:542; Mangelsdorf 1974:167) radiocarbon date, (Smiley 1994:176) twenty-six cobs were measured from San Marcos Cave, Mexico; (2) (Upham et al. 1987:416) four cobs measured from Tornillo Shelter, Zone D, radiocarbon date; (3) (Upham et al. 1987:413-416) eight cobs measured from Rollerskate Shelter, levels 6-9, obsidian hydration date; (4) (Upham et al. 1987:413-416) four cobs measured from Rollerskate Shelter, level 3, obsidian hydration date; (5) (Mangelsdorf 1949:219; Wills 1983:127) nineteen cobs measured from the lowest strata at Bat Cave, radiocarbon date, (Wills 1983:127); (6) (Mangelsdorf 1974:158, 159) one cob measured from the lowest strata at Swallow Cave, level 13; (7) (Wills 1988:109) radiocarbon date; (8) (Wellhausen et al. 1952:211-222) three to five cobs measured at Chapingo, Mexico; (9) (Nusbaum 1922:67-70) thirty-three ears measured from Cave Dupont, culturally assigned date; (10) (Nicherson 1953:84-97) six cobs measured from White Dog Cave, culturally assigned date; (11) (Jones and Fonner 1954:93) an unknown number of cobs measured from BM II sites in the Durango/La Plata area, tree-ring date; (12) (Hurst and Anderson 1949:163) fourteen cobs measured from Cottonwood Cave, culturally assigned date; (13) (Cutler and Blake 1976:365) eleven cobs measured from Snaketown, culturally assigned date; (14) Cutler 1968:371-378) twenty-nine cobs and seven hundred sixty-five kernels measured from sites near Navajo Mountain, Utah, culturally assigned date; (15) (Jones and Fonner 1954:93) two cobs measured from Talus Village, in the Durango area, tree-ring date; (16) (Anderson and Blanchard 1942:832) two hundred twenty-two ears measured from Mummy Cave in the Canyon del Muerto, culturally assigned date; (17) (Carter 1945:308) sixty-two ears measured from modern collections; (18) (Nicherson 1953:84-88) twenty-five ears measured from modern collections; (19) Anderson (1944) first described Reventador, date assigned by Cutler and Blake (1976:365); (20) (Wellhausen et al. 1952:211-222) three to five ears measured at Chapingo, Mexico; (21) (Anderson 1948:91-92) culturally assigned date of ears of Pepitilla from Yampa Canyon; (22) (Wellhausen et al. 1952:211-222) three to five ears measured at Chapingo, Mexico; (23) (Cutler 1966:27; Geib 1996:88) radiocarbon date, one hundred twelve cobs measured by Cutler from the Alvey site, near Glen Canyon; (24) (Cutler 1966:25; Geib 1996:84) radiocarbon date, three cobs measured from Sheep Horn Alcove, sample 1; (25) (Cutler 1966:25-39; Geib 1996:84) radiocarbon date, seven cobs measured from Sheep Horn Alcove, sample 2; (26) (Cutler 1966:114-118) fifty-four cobs measured from Caldwell Village, Utah, culturally assigned date; (27) (Cutler 1952: Upham et al. 1987) culturally assigned date from Tularosa Cave, Georgetown phase, for origin of Maiz de Ocho, statistics (Wellhausen et al. 1952:211-222) three to five ears measured at Chapingo, Mexico; (28) (Cutler 1952; Upham et al. 1987) culturally assigned date from Tularosa Cave, Georgetown phase, for origin of Maiz de Ocho Occidentales, statistics (Wellhausen et al. 1952:211-222) three to five ears measured at Chapingo, Mexico; (29) (Wellhausen et al. 1952:211-222) three to five ears measured at Chapingo, Mexico; (30) (Wellhausen et al. 1952:211-222) three to five ears measured at Chapingo, Mexico; (31) (Morris 1986:115-128) six thousand two hundred seventy-five cobs measured from Pueblo II levels at Antelope House in the Canyon de Chelley, Arizona, culturally assigned date; (32) (Davidson et al. 1982:1099-1188) three hundred three cobs measured from Bis sa'ani Ruin, culturally assigned date; (33) (Morris 1986:115-128) two thousand nine hundred forty-one cobs measured from Middle Pueblo III levels at Antelope House, Canyon de Chelley, Arizona, culturally assigned date; (34) (Morris 1986:115-128) six thousand nine hundred eighty-nine cobs measured from Late Pueblo III levels at Antelope House, Canyon de Chelley, Arizona, culturally assigned date; (35) (Cutler and Eickmeir 1962:48-54) twenty-five cobs measured from the Box Canyon site, New Mexico, culturally assigned date; (36) (Nicherson 1953:84-88) seven ears measured from modern collections of Hopi White Flour maize; (37) (Nicherson 1953:84-88) eleven ears measured from modern collections of Hopi Blue Flour maize.

Table 18. Summary of Measurements of the Races of Maize of the Southwest, Characteristics of the Cobs.[a]

Race and Status	Sample No. and Date of Origin	Cupule Wing Width (Mm)	Cupule Depth (Mm)	Lower Glume (Cob) Diam. (Mm)	Kernel Thickness (Mm)	Shank Diam. (Mm)	Shape of Ear
Proto-Maiz de Ocho (extinct)	Sample 1 (5500 B.P.)	-	-	-	-	-	cigar
Proto-Maiz de Ocho (extinct)	Sample 2 (3175 B.P.)	-	-	-	-	-	-
Proto-Maiz de Ocho (extinct)	Sample 3 (2500-2225 B.P.)	-	-	-	-	-	-
Proto-Maiz de Ocho (extinct)	Sample 4 (A.D. 632)	-	-	-	-	-	-
Mean of 4 Samples		-	-	-	-	-	cigar
Pre-Chapal-ote (extinct)	Sample 5 (3010-2340 B.P.)	-	-	-	-	-	-
Pre-Chapal-ote (extinct)	Sample 6 (Un-known)	-	-	-	-	-	cigar
Mean of 2 Samples		-	-	-	-	-	cigar
Chapal-ote (living)	Samples 7 and 8 (2470 B.P.-present)	-	-	22	4.1	9.7	cigar
Basket-maker (extinct)	Sample 9 (A.D. 200-300)	-	-	-	-	-	cigar
Basket-maker (extinct)	Sample 10 (A.D. 200-300)	-	0.75	-	4.3	9	cigar
Basket-maker (extinct)	Sample 11 (A.D. 46-324)	-	-	-	-	-	cigar
Basket-maker (extinct)	Sample 12 (A.D. 50-500)	-	-	-	4	13	cigar
Mean of 4 Samples		-	0.75	-	4.2	11	cigar

Table 18. Continued.

Race and Status	Sample No. and Date of Origin	Cupule Wing Width (Mm)	Cupule Depth (Mm)	Lower Glume (Cob) Diam. (Mm)	Kernel Thickness (Mm)	Shank Diam. (Mm)	Shape of Ear
Onaveno (still-living)	Sample 13 (2300 B.P.-A.D. 900)	-	-	-	-	-	-
Onaveno (still-living)	Sample 14 (Early BM II)	-	-	-	-	-	-
Onaveno (still-living)	Sample 15 (A.D. 46-324)	-	-	15	3.75	-	-
Mean of 3 Samples		-	-	15	3.75	-	-
Pima-Papago (still-living)	Sample 16 (A.D. 500-700)	-	-	-	-	-	-
Pima-Papago (still-living)	Sample 17 (modern)	-	-	36	-	14	cigar
Pima-Papago (still-living)	Sample 18 (modern)	-	0.75	-	4	14	cigar
Mean of 3 Samples		-	0.75	36	4	14	cigar
Reventador (still-living)	Samples 19 and 20 (2300 B.P.-present)	-	-	19.6	3.6	8.8	cigar
Pepitilla (still-living)	Samples 21 and 22 (A.D. 400-present)	-	-	25	3.5	12	tapered
Fremont Dent (extinct)	Sample 23 (A.D. 400-800)	-	-	26	-	-	-
Fremont Dent (extinct)	Sample 24 (A.D. 339-1011)	-	-	20.5	-	-	tapered
Fremont Dent (extinct)	Sample 25 (A.D. 339-1011)	-	-	-	4.2	14.2	-
Fremont Dent (extinct)	Sample 26 (BM III?)	-	-	-	-	-	-
Mean of 4 Samples		-	-	23.2	4.2	14.2	tapered

Table 18. Continued.

Race and Status	Sample No. and Date of Origin	Cupule Wing Width (Mm)	Cupule Depth (Mm)	Lower Glume (Cob) Diam. (Mm)	Kernel Thickness (Mm)	Shank Diam. (Mm)	Shape of Ear
Harinoso (Maiz) de Ocho (still-living)	Sample 27 (A.D. 500-700-present)	-	-	21.7	4.4	14	straight
Harinoso de Ocho Occident-ales (still-living)	Sample 28 (A.D. 500-700-present)	-	-	-	4.5	11.7	straight
Tabloncillo (still-living)	Sample 29	-	-	23.4	4.3	11	straight
Tabloncillo Perla (still-living)	Sample 30	-	-	-	4.2	10.7	straight
Pueblo (prehistoric form)	Sample 31 (A.D. 900-1150)	-	-	-	3.8	-	tapered-cigar
Pueblo (prehistoric form)	Sample 32 (A.D. 1125-1175)	-	-	11.1	-	-	-
Pueblo (prehistoric form)	Sample 33 (A.D. 1200-1250)	-	-	-	3.95	-	tapered-cigar
Pueblo (prehistoric from)	Sample 34 (A.D. 1250-1300)	-	-	-	3.99	-	tapered-cigar
Pueblo (prehistoric from)	Sample 35 (A.D. 1350-1380)	-	-	-	4.2	-	mixture of all 4 ear shapes
Mean of 5 Samples		-	-	11.1	3.98	-	mixture
Pueblo (still-living)	Sample 36 (modern)	-	0.25	-	4.7	-	straight
Pueblo (still-living)	Sample 37 (modern)	-	0.5	-	4.2	-	cigar
Mean of 2 Samples		-	0.38	-	4.45	-	mixed

Table 18. Continued.

[a] Data from (by sample number): (1) (Mangelsdorf et al. 1964:542; Mangelsdorf 1974:167) radiocarbon date, (Smiley 1994:176) twenty-six cobs were measured from San Marcos Cave, Mexico; (2) (Upham et al. 1987:416) four cobs measured from Tornillo Shelter, Zone D, radiocarbon date; (3) (Upham et al. 1987:413-416) eight cobs measured from Rollerskate Shelter, levels 6-9, obsidian hydration date; (4) (Upham et al. 1987:413-416) four cobs measured from Rollerskate Shelter, level 3, obsidian hydration date; (5) (Mangelsdorf 1949:219; Wills 1983:127) nineteen cobs measured from the lowest strata at Bat Cave, radiocarbon date, (Wills 1983:127); (6) (Mangelsdorf 1974:158, 159) one cob measured from the lowest strata at Swallow Cave, level 13; (7) (Wills 1988:109) radiocarbon date; (8) (Wellhausen et al. 1952:211-222) three to five cobs measured at Chapingo, Mexico; (9) (Nusbaum 1922:67-70) thirty-three ears measured from Cave Dupont, culturally assigned date; (10) (Nicherson 1953:84-97) six cobs measured from White Dog Cave, culturally assigned date; (11) (Jones and Fonner 1954:93) an unknown number of cobs measured from BM II sites in the Durango/La Plata area, tree-ring date; (12) (Hurst and Anderson 1949:163) fourteen cobs measured from Cottonwood Cave, culturally assigned date; (13) (Cutler and Blake 1976:365) eleven cobs measured from Snaketown, culturally assigned date; (14) Cutler 1968:371-378) twenty-nine cobs and seven hundred sixty-five kernels measured from sites near Navajo Mountain, Utah, culturally assigned date; (15) (Jones and Fonner 1954:93) two cobs measured from Talus Village, in the Durango area, tree-ring date; (16) (Anderson and Blanchard 1942:832) two hundred twenty-two ears measured from Mummy Cave in the Canyon del Muerto, culturally assigned date; (17) (Carter 1945:308) sixty-two ears measured from modern collections; (18) (Nicherson 1953:84-88) twenty-five ears measured from modern collections; (19) Anderson (1944) first described Reventador, date assigned by Cutler and Blake (1976:365); (20) (Wellhausen et al. 1952:211-222) three to five ears measured at Chapingo, Mexico; (21) (Anderson 1948:91-92) culturally assigned date of ears of Pepitilla from Yampa Canyon; (22) (Wellhausen et al. 1952:211-222) three to five ears measured at Chapingo, Mexico; (23) (Cutler 1966:27; Geib 1996:88) radiocarbon date, one hundred twelve cobs measured by Cutler from the Alvey site, near Glen Canyon; (24) (Cutler 1966:25; Geib 1996:84) radiocarbon date, three cobs measured from Sheep Horn Alcove, sample 1; (25) (Cutler 1966:25-39; Geib 1996:84) radiocarbon date, seven cobs measured from Sheep Horn Alcove, sample 2; (26) (Cutler 1966:114-118) fifty-four cobs measured from Caldwell Village, Utah, culturally assigned date; (27) (Cutler 1952: Upham et al. 1987) culturally assigned date from Tularosa Cave, Georgetown phase, for origin of Maiz de Ocho, statistics (Wellhausen et al. 1952:211-222) three to five ears measured at Chapingo, Mexico; (28) (Cutler 1952; Upham et al. 1987) culturally assigned date from Tularosa Cave, Georgetown phase, for origin of Maiz de Ocho Occidentales, statistics (Wellhausen et al. 1952:211-222) three to five ears measured at Chapingo, Mexico; (29) (Wellhausen et al. 1952:211-222) three to five ears measured at Chapingo, Mexico; (30) (Wellhausen et al. 1952:211-222) three to five ears measured at Chapingo, Mexico; (31) (Morris 1986:115-128) six thousand two hundred seventy-five cobs measured from Pueblo II levels at Antelope House in the Canyon de Chelley, Arizona, culturally assigned date; (32) (Davidson et al. 1982:1099-1188) three hundred three cobs measured from Bis sa'ani Ruin, culturally assigned date; (33) (Morris 1986:115-128) two thousand nine hundred forty-one cobs measured from Middle Pueblo III levels at Antelope House, Canyon de Chelley, Arizona, culturally assigned date; (34) (Morris 1986:115-128) six thousand nine hundred eighty-nine cobs measured from Late Pueblo III levels at Antelope House, Canyon de Chelley, Arizona, culturally assigned date; (35) (Cutler and Eickmeir 1962:48-54) twenty-five cobs measured from the Box Canyon site, New Mexico, culturally assigned date; (36) (Nicherson 1953:84-88) seven ears measured from modern collections of Hopi White Flour maize; (37) (Nicherson 1953:84-88) eleven ears measured from modern collections of Hopi Blue Flour maize.

Table 19. Summary of Measurements of the Races of Maize of the Southwest, Vegetative Characteristics of the Plants.[a]

Race	Altitudinal Range (In M)	Height of Plants (Cm)	Total No. of Leaves	No. of Leaves Above Ear
Chapalote	100-600	160	12.8	4.6
Reventador	0-1500	150	11	4.9
Pepitilla	1000-1700	270	14.9	5.1
Harinoso de Ocho	0-100	160	12.1	4.3
Harinoso de Ocho Occidentales	0-1500	200	14.3	4.9
Tabloncillo	0-1500	240	14.6	5
Tabloncillo Perla	0-1000	150	10.4	4.1

[a] Data from information in Wellhausen et al. (1952:211-222).

Table 20. Summary of Measurements of the Races of Maize of the Southwest, Vegetative Characteristics of the Plants.[a]

Race	Width of Leaves (Cm)	Length of Leaves (Cm)	Leaf Area (Cm Squared)	Venation Index	Number of Husks
Chapalote	7.6	80.5	5872.6	2.62	7.8
Reventador	7.1	75.7	4434.1	3.33	7.8
Pepitilla	8.4	85	7978.9	2.78	14.6
Harinoso de Ocho	8.6	84.3	6578.7	2.56	8.8
Harinoso de Ocho Occident-ales	8.7	89.5	8349.7	3.24	7.6
Tabloncillo	8.6	79.8	7514.6	3.56	9.2
Tabloncillo Perla	7.7	61.8	3712.6	3.23	7.6

[a] Data from information in Wellhausen et al. (1952:211-222).

Table 21. Summary of Measurements of the Races of Maize of the Southwest, Characteristics of the Tassels.[a]

Race	Length of Peduncle (Cm)	Length of Tassel (Cm)	Length of Branching Space (Cm)
Chapalote	6	35.8	9.2
Reventador	1.9	40.7	7.6
Pepitilla	3.2	38.6	11.7
Harinoso de Ocho	4.2	41.9	11.2
Harinoso de Ocho Occidentales	7.3	39.2	8.2
Tabloncillo	7.2	40	9
Tabloncillo Perla	9.1	37	12.4

[a] Data from information in Wellhausen et al. (1952:211-222).

Table 22. Summary of Measurements of the Races of Maize of the Southwest, Characteristics of the Tassels.[a]

Race	Percent of Branching Space	No. of Primary Branches	No. of Secondary Branches	No. of Tertiary Branches
Chapalote	26	13	16	0
Reventador	19	8.4	5.9	0
Pepitilla	35	21.8	10.9	0
Harinoso de Ocho	25	10	12	0
Harinoso de Ocho Occidentales	20	8.8	9.5	0
Tabloncillo	23	8.8	11.5	0
Tabloncillo Perla	32	13.2	13	0

[a] Data from information in Wellhausen et al. (1952:211-222).

In the study of early maize from San Marcos Cave, Mexico, Mangelsdorf et al. (1964:542) found that the earliest cobs of maize from the lowest levels of the cave had eight rows, and some had four rows. These cobs came from levels dated to 5500 B.P. (Smiley 1994:176). The cobs were very small, with lengths of 19 to 25 mm, with a mean length of 22 mm (Mangelsdorf et al. 1964:542). Mangelsdorf called these early maize cobs "wild maize," and believed that maize had originated as a unique species of *Zea* that had not evolved from wild teosinte. Today, theories of the evolution of maize are leaning more towards the hypothesis that cultivated maize evolved from wild teosinte (Beadle 1939, 1980; Doebley 1990; Galinat 1971; Iltis 1970; Sundberg et al. 1994). Most researchers now believe that the earliest recovered cobs at San Marcos Cave are examples of early cultivated maize. Because the cobs of the earliest maize known have four and eight rows, it appears that proto-Maiz de Ocho has been in existence for a very long time.

In the Southwest, the specimens of maize from the lowest levels at Tornillo Shelter (Upham et al. 1987) and Bat Cave (Wills 1988:127) are the earliest dated macro-remains of maize known for the region at the present time. The maize from Bat Cave is thought to belong to the pre-Chapalote and Chapalote races (Ford 1984; Wills 1988), and it is probable that the maize known as proto-Maiz de Ocho from Tornillo and Rollerskate Shelters may actually be eight-rowed segregates of early Chapalote (pre-Chapalote) maize. Many of the very small ears from Bat Cave may actually be unpollinated ears, or ears from tillers (Wills 1988:127). Environmental conditions can cause the production of ears with fewer rows, and may have had that effect on the otherwise 12-rowed Chapalote grown at these early sites (for a discussion of the environmental effects on maize, see the section on that subject following in this chapter).

PRE-CHAPALOTE

"Pre-Chapalote" was a name originated by (Mangelsdorf et al., 1956) for a race of maize first represented by some very small cobs of maize found at Romero Cave, Mexico.

The cobs of pre-Chapalote are cigar-shaped and very similar to Chapalote, but smaller. Mangelsdorf (1974:155) later considered the earliest maize from Bat Cave to be pre-Chapalote and also considered a single cob from Swallow Cave to represent the race of pre-Chapalote (Mangelsdorf 1974:158-159) (Tables 17 and 18). Cutler (1966:13-14) described pre-Chapalote as having 12 to 14 rows of kernels, and reported finding cobs of pre-Chapalote in southern and central Arizona in archaeological deposits dating before A.D. 1100.

In Tables 17 and 18 the statistics on the extinct maize race pre-Chapalote show it to have had a very small cob with a mean length of 21.1 mm, a mean row number of 11.3, cigar shaped ear, and slightly larger mean rachis dimension (by 0.89 mm) than proto-Maiz de Ocho. When looked at together, proto-Maiz de Ocho and pre-Chapalote appear to have been quite similar, and further study of collections of early specimens of these races needs to be conducted to determine if they are indeed two separate races, or actually one race of maize exhibiting slight variations in rachis size and row number.

CHAPALOTE

It has been recognized that Chapalote was one of the earliest races of maize to have entered the Southwest, and most of the early maize from Bat Cave and Tularosa Cave is considered to be Chapalote (Mangelsdorf and Smith 1949; Cutler 1952). Chapalote, as it occurs in living populations in northwestern Mexico today, is a lowland race of maize, but it can be grown and will produce ears up to 2200 m (Wellhausen et al. 1952:56). The area in which Chapalote still survives today as a relict population is in the lowland deserts of Sonora and Sinaloa, where climate is quite arid, and undoubtedly plants that are grown there are subject to extremely high rates of evapotranspiration. Thus, Chapalote is an altitudinally adaptable race that withstands desert conditions; this may be why it was the most important race of maize in the early (the Late Archaic) Southwest.

Chapalote is a pop maize and also a weak form of pod maize with rather long

glumes and a brown pericarp (Wellhausen 1952:57). Chapalote is still recognized as a primitive type of maize that has many teosintid influences (Figures 39, 41-43, and 58-60). Chapalote's influence on the maize of the prehistoric Southwest is quite evident over time, and its influence can still be seen in its descendants (Figures 51-55). The long, slender cobs of some Pueblo maize varieties, such as Hopi Blue Flour (Figure 51), are probably due to a significant degree of germplasm in Pueblo maize issued from Chapalote. Isozyme studies reveal a probable close genotypic relationship of Chapalote to the maize still grown by Puebloan peoples (see Figure 34).

In Tables 17 and 18, it can be seen that the average length of cobs of Chapalote is about 110 mm. Cobs of Chapalote are cigar shaped (Figure 41), and mean row number is 12.3. Kernels are small and often show striations on them from the pressure of the husks. Seed color is usually brown and the texture of the endosperm is either pop or flint (Wellhausen 1952:54-56).

The closest race, statistically, to Chapalote in the prehistoric Southwest was Basketmaker (Tables 17 and 18), but Onaveno, the flint form of Pima-Papago, is thought to be morphologically closer to and to be the descendant of Basketmaker maize (Jones and Fonner 1954; Sanchez and Goodman 1992:80). Since living tissue is required to conduct isozyme studies, we may never know how closely related the living race of Chapalote is to the extinct Basketmaker race of maize, but if living populations of their descendants are compared, as in Figure 34, it is possible that they are closely related. Undoubtedly crosses occurred between Chapalote maize and Basketmaker/Onaveno maize during prehistoric times, because the two races are often found together in archaeological sites (see Chapter 8).

BASKETMAKER

The name "Basketmaker" originated from studies of maize found at Basketmaker II sites in Northern Arizona, southern Utah, and Western Colorado, including Cave

Dupont, Cottonwood Cave, and White Dog Cave (Carter and Anderson 1945; Hurst and Anderson 1949; Nicherson 1953; Nusbaum 1922). Typical ears of Basketmaker maize are cigar shaped with long glumes which often protrude beyond the kernels, as do those of modern and prehistoric Chapalote. The kernels of Basketmaker maize are usually arranged in 12 or 14 rows, and are often isodiametric (shaped like small hexagons and set in a hexagonal pattern, as a honeycomb) (Hurst and Anderson 1949:164). In Tables 17 and 18, the statistics of several samples of archaeological Basketmaker maize are listed. The mean cob length from five samples is 83.3 mm, with a mean row number of 14, a mean cupule width of 6 mm, a mean cupule depth of 0.75 mm, a mean kernel thickness of 4.2 mm, and a mean shank diameter of 11 mm. These statistics are very close to the mean statistics of the maize from Black Dog Cave presented in this volume (Tables 9-12). The mean measurements of Basketmaker maize are also quite close to statistics of the sample of maize remains from pit #31 at Black Dog Cave, which has been radiocarbon dated to A.D. 248-390 at 1 Sigma, or Late Basketmaker II (Lyneis 1998). Some of the ears of Basketmaker maize at Cave Dupont (Nusbaum 1922:69) showed evidence of maize earworm damage, as did some of the ears from Black Dog Cave (Tables 9-12).

The kernels of Basketmaker maize seem to have had endosperms that were sometimes flinty and sometimes floury. The maize from Cottonwood Cave was flint (Hurst and Anderson 1949:164). The maize from Cave Dupont was a combination of ears that had both flinty (18) and floury (15) endosperms (Nusbaum 1922:68).

ONAVENO

It is difficult to separate the extinct race of Basketmaker maize from Onaveno, which is a living variant or sub-race of Pima-Papago maize with flint kernels (Cutler 1966:14). A few major differences between the two are that Basketmaker maize ears are more truly cigar shaped, with a tapered tip and a compressed butt, while Onaveno maize ears are straight, and statistics indicate that Onaveno kernels (at 3.75 mm in mean

thickness) are smaller in mean thickness than those of Basketmaker maize (4.2 mm) (Tables 17 and 18). The statistics I have compiled for Onaveno in these tables are from prehistoric samples of Onaveno; statistics for living plants of Onaveno are unavailable. [In my study of living races of maize of the Southwest, I did not raise any plants of Onaveno maize]. Wellhausen et al. (1952:198) gave a brief description of Onaveno and considered it to be a subrace of Maiz Blando de Sonora, which is another name for Pima-Papago (Anderson and Cutler 1942; Cutler 1966:14). Anderson and Cutler (1942:84) recognized the similarities of the living race of Pima-Papago maize to extinct Basketmaker maize. Cutler considered Onaveno to be a flint form of Pima-Papago, with the only difference being that Pima-Papago (Maiz Blando de Sonora) has flour kernels and Onaveno has flint kernels.

In Tables 17 and 18 the statistics for Onaveno are quite similar to those for Basketmaker maize, but cob length and kernel thickness is smaller in Onaveno, while ear shape is straight in Onaveno (Wellhausen et al. 1952:198) and is cigar-shaped in Basketmaker. One difference (statistically) between Basketmaker and Onaveno is that the data for Basketmaker sites were taken at high altitudes in the Southwest, while those for Onaveno were taken from sites in lowland, hot climates. It is possible that maize of the Basketmaker period from highland sites was introgressed with some genetic material from stands of Chapalote, whereby it acquired the cigar shaped cob. The relict population of the lowland variant, Onaveno, survived over two millennia in the lowlands of Sonora, while the highland variant, Basketmaker, became extinct in the Southwest after A.D. 500. Isozyme studies have not been conducted on the living plants of the race Onaveno, but it is highly probable that it is very close isozymically to the living race of Pima-Papago (Figure 34).

The maize that was grown by the Virgin Anasazi from the A.D. 200s through A.D. 1225 at Black Dog Cave appears to have been a mixture of both races Onaveno and Basketmaker. Some cobs were cigar-shaped while others were straight, or tapered.

[Because I have not found any pop kernels in any of the collections at the Nevada State Museum, I cannot say whether true Chapalote maize was grown during this period at Black Dog Cave]. The mean kernel thickness from loose kernels measured from Black Dog Cave, 4.25 mm (Table 13), more closely approaches Basketmaker kernel measurements, 4.2 mm (Table 18), than the mean kernel thickness of Onaveno maize, at 3.75 mm(Table 18). Meanwhile, the mean kernel thicknesses taken from cobs from Black Dog Cave, 3.5 mm (Table 12), are closer to mean thickness measurements for the kernels of Onaveno maize, at 3.75 mm (Table 18). Also, mean row numbers of cobs found at Black Dog Cave (12.3 rows) (Table 11) are closer to the Onaveno statistics (12.4 rows) (Table 17) than they are to the mean row numbers of Basketmaker maize (14 rows) (Table 17). But all of the other measurements of Black Dog Cave maize (cob length, cupule width, cupule depth, and cob shape) are closer to those of Basketmaker maize.

Since maize found at Black Dog Cave may represent an extended period of time, and until further radiocarbon tests are done on specific samples, it can be said that the maize from pit #31 was almost certainly Basketmaker maize, and that Onaveno maize was raised there also, and most likely continued to be raised during the Pueblo period, perhaps because it was more successful as a crop in the hot, lowland environment than any other race. The ear of maize with all its kernels found at Black Dog Cave (Table 9 and Figure 11), is a good example of the range of measurements found in Onaveno, and the ear bears a striking resemblance to the examples of Onaveno maize illustrated in Wellhausen et al. (1952:198).

PIMA-PAPAGO

This race of maize is grown in the hot desert lowlands of the Southwest today by the Pima and Papago tribes (Figures 44-46 and 61-63). Anderson and Cutler (1942) were the first researchers to classify Pima-Papago maize. It is a flour maize with ears averaging about 153 mm long (Table 17). The kernels are often isodiametric, as in Basketmaker

maize, but the mean kernel thickness of modern living Pima-Papago is a bit smaller than that of Basketmaker (by 0.2 mm). The color of the kernels of Pima-Papago maize is most commonly white or yellow (Anderson and Cutler 1942:84) but can be red, blue, or variegated red and white (Cutler 1966:14).

In Tables 17 and 18, I have tabulated data on the maize race Pima-Papago from many sources, with measurements from both prehistoric and modern collections. Row number averages 12.4, cupule width 7mm, cupule depth 0.75 mm, cob diameter 36 mm, kernel thickness 4 mm, shank diameter 14 mm, and cobs are a straight cigar shape.

In my study of living races of maize of the Southwest, presented later in this chapter, I have compiled new data on cobs and ears of Pima-Papago maize, and included new data on the tassels and vegetative characters of the plants. This constitutes a much more complete statistical definition of the Southwest race Pima-Papago (Figures 35, 39, 44-46, and 61-63; and Tables 25-31).

REVENTADOR

The maize race Reventador is a relict representative of a primitive type of maize, though it is a less primitive race than Chapalote. It is a pop maize, but with longer cobs than Chapalote. As can be seen from isozyme studies (Figure 34), Reventador is close to Chapalote in some respects and distant in others. Wellhausen et al. (1952:93-94) believed the two races to be closely related. Reventador (Figures 47 and 64) has characteristics that indicate a close relationship with teosinte (as does Chapalote, see Figures 39, 41-43, and 58-60), including a grass-like appearance to the plants, and a highly indurated rachis (Wellhausen et al. 1952:94). Reventador also tends to produce staminate tips on the ears as well (Figure 47).

In Tables 17 and 18 the statistical mean measurements are given for living populations of Reventador as it is grown today in western Mexico as far north as Sonora, at altitudes from sea level to 1500 m (Wellhausen 1952:92-93). The cobs of Reventador

average longer than those of Chapalote (by 55 mm), but the kernels and shanks are smaller and the row number is lower than that of Chapalote.

Reventador has been identified in archaeological contexts of the prehistoric Southwest from mostly lowland sites in Arizona (Anderson 1950:162-163; Bohrer et al. 1969:3-4; Cutler and Blake 1975:268), and its germoplasm is undoubtedly existing in races of maize grown in the Southwest today.

In the section of this chapter on testing races of maize in the lowland Southwest I have presented new data on the maize race Reventador. The data gathered on ears, tassels, and the vegetative characters of the plants of Reventador were collected from plants grown for this study in the lowland desert climate of Las Vegas (Tables 25-31, Figures 47 and 64).

PEPITILLA AND FREMONT DENT

In many early archaeological sites in the northern Southwest, archaeologists have occasionally uncovered maize cobs with a mildly to strongly tapered shape, and with pointed or dented kernels. The earliest examples of this type of maize have been found at sites dating to Basketmaker II times, including Basketmaker II sites near Durango, Colorado (cobs) (Jones and Fonner 1952:110), sites in Yampa Canyon, Colorado (cobs and kernels) (Anderson 1948:91-92), and Dupont Cave, Utah (some dented kernels) (Nusbaum 1922:68). This dented maize with tapered cobs was primarily associated with the Fremont Culture during the period A.D. 400-1100. The Fremont people occupied areas of medium to high elevations in Utah and Colorado. Not all Fremont maize was dented. Cutler (1966:15) stated that less than 1/3 of Fremont maize was dent corn, and that most of it was Onaveno or Maiz Blando (Pima-Papago). It is interesting to note, however, that dented maize kernels were found among the Basketmaker II Anasazi as well as the Fremont.

Anderson and Cutler (1942:80-81) were the first to recognize the difference and

importance of dent maize to the Southwest by assigning samples of maize with dented kernels to the "Mexican Complex" of maize that is derived from highland locations of central Mexico. Anderson and Cutler described the distinctive characteristics of the Mexican Pyramidal cluster of races as having short and tapered (pyramidal) cobs with pointed, dented or rounded kernels that are long, and usually white in color, but sometimes red or black. The earliest examples of this maize were found only at medium to high altitudes in the Fremont and Anasazi cultural areas, and not in the lowland Hohokam areas (Jones and Fonner 1952:113). This led to the questions of why pyramidal, dented maize was found early in the highlands but not in the lowlands, and of what could be the route of introduction of this maize to the prehistoric Southwest from such a great distance as central Mexico (Jones and Fonner 1952; Cutler 1966). Jones and Fonner suggested that Mexican Pyramidal maize may have entered the Southwest through the Mogollon region, and that a re-examination of early maize from Bat Cave or Tularosa Cave might reveal some dented maize. It is noteworthy, though, that the most extreme and earliest examples of tapered dented maize were found at Yampa Canyon in the northern Southwest, (Anderson 1948:92). The cobs shown in Anderson's illustration bear close resemblance to Pepitilla, a race of maize from medium elevations in central Mexico, and a member of the Mexican Pyramidal complex. Wellhausen et al. (1952:141) noted this in their descriptive account of the still living race of maize, Pepitilla. Also noted was Pepitilla's resemblance to the "gourd-seed" or shoe-peg maize of the Southeastern United States.

Wagner (1994) in an account of prehistoric maize of the Eastern Woodlands, indicates the presence of gourd-seed and shoe-peg dented maize in the Southeast around A.D. 1700, and mentioned that it may have been introduced by the Spanish (Wagner 1994:338). The origin of southern dent maize is not well understood, because of the paucity of archaeological material, but it is generally agreed that it post-dated the appearance of dented maize in the Southwest.

In my examination of the data on Southwest maize through isozyme studies, I was attempting to analyze the relationship of races of maize found in prehistoric contexts and their living descendants. In examining the lower of the two graphs by Doebley et al. (1983:108) and Doebley 1990:22) (Figure 34), I realized that if other components of this isozyme analysis showed a similar relationship among maize races of the Southwest, then it might help explain the unknown ancestor of Fremont Dent maize. In the lower graph (Doebley et al. 1990:22) the only medium or high altitude race of maize that is a member of the Mexican Pyramidal Complex, as identified by Anderson and Cutler (1942) and Jones and Fonner (1952), that shows an isozymically close relationship to other races of maize of the Southwest, is Pepitilla. Admittedly, maize with dent germoplasm that was introduced by the Spanish after contact could have affected the isozyme pattern, but it is much more likely that the Pepitilla maize introduced in Late Basketmaker II times affected the gene pool of maize of the Southwest from that time on. This is especially probable because the most extreme examples of maize with tapered, or pyramidal cobs, with pointed and dented kernels were found so early in the archaeological sequence (in the examples from Yampa Canyon, dating to A.D. 400-800 (Anderson 1948:92).

Cutler (1966:15) believed that a race of Mexican Pyramidal maize was responsible for the origin of Fremont Dent maize, but he did not know which one. He thought it might be Conico, or Conico Norteno (Cutler 1966:15). If other components in this isozyme study indicate a similar relationship of Pepitilla to other races of maize of the Southwest, then it is probable that the true ancestor of Fremont Dent was most probably Pepitilla (Figure 34, and Figure 57), and Conico and Conico Norteno are not as closely related to the other Southwest races of maize, being far to the right in this graph of isozyme relationships.

It is not known what the route of introduction of this dented maize was, but it is likely that remains of early dented pyramidal maize have not been found in archaeological sites in the lowlands because the race of Pepitilla was only adapted to medium or high

altitudes, and probably pollinated poorly in the hot, dry conditions of the lowlands. It is noteworthy also, that Pepitilla is the only race of maize that has been linked to prehistoric maize in the Southwest that was a mid to high altitude race. All of the other living relict populations of the races of maize known to have had descended from races of the prehistoric Southwest are lowland races.

Pepitilla, as it is found today, is grown at altitudes of 1000 to 1700 m in central Mexico (Wellhausen et al. 1952:140), but also has been collected more recently among the Tarahumara of Chihuahua, in an area much closer to the American Southwest (Native Seeds SEARCH seed catalog 1997:39). Pepitilla has conical or pyramidal cobs (Figure 57) with very long, pointed grains with a high mean row number (15.5), and the cobs shell easily (Wellhausen et al. 1952:140-141). In appearance it resembles a pod corn without the long glumes covering the kernels. Thus, it has some characteristics of primitive maize. In Tables 17 and 18 the statistical measurements of ears and cobs of Pepitilla are given. Cob length averages about 123 mm, and kernel thickness and shank diameter are rather small. I compiled data on the extinct race of Fremont Dent maize from archaeological samples that appeared to contain high percentages of the dented Fremont maize cobs (Tables 17 and 18). The mean cob length of the extinct race of Fremont Dent was 116 mm, and row number varied, but averaged at 12.7. Note that the rachis diameter was wider than any previous race of Southwest maize, and cupule width, cob diameter and shank diameter were also wider than any known before.

I found no dented maize kernels in the collection of maize from Black Dog Cave, though some of the kernels were rather long, at 7.5, 7.0, and 6.9 mm in length (Table 13). Several of the maize cobs from Black Dog Cave were tapered in shape (Figures 16, 19, 21), though less so than those illustrated in Cutler (1966:46, Figure 6) as examples of Fremont Dent maize. It is possible that the close proximity of the Virgin Anasazi to the Fremont Culture may have allowed some interchanges of maize, but further study is needed of maize from the area to make informed judgments of the relationship of Virgin

Anasazi maize to Fremont Maize.

HARINOSO DE OCHO AND HARINOSO DE OCHO OCCIDENTALES

In Figure 34, it can be seen that isozymically, the living race of maize Harinoso de Ocho Occidentales is much closer to other races of Southwest maize than is Harinoso de Ocho itself. Harinoso de Ocho is another name for Maiz de Ocho. The word "harinoso" refers to the floury composition of the endosperm, and the word “occidentales” refers to the western sub-race of Maiz de Ocho that is, incidentally, grown at higher altitudes than Harinoso de Ocho but farther south (Wellhausen et al. 1952:73). It is this western form of Maiz de Ocho that is probably the one most closely related to prehistoric forms of Maiz de Ocho. The kernels of Harinoso de Ocho Occidentales tend to be more brightly colored than those of Harinoso de Ocho, which are most commonly white. The Occidentales form of Maiz de Ocho also bears a close resemblance to Tabloncillo, which is isozymically positioned between Chapalote and Harinoso de Ocho Occidentales (Wellhausen 1952:71) (Figure 34). In Wellhausen et al. (1952:70) it is mentioned that Harinoso de Ocho Occidentales is a maize selected for roasting ears (elotes), which is a traditional way of preparing maize that is thought to have been practiced during the prehistoric period among the Puebloans and other indigenous peoples. It is possible that eight-row forms of maize were especially suited to the purpose of roasting, or perhaps matured earlier, and were used for that purpose. Immature ears are usually used for roasting by the lower Colorado River tribes (Castetter and Bell 1951:75), the Zuni (Cushing 1920:205-208), and others.

Maiz de Ocho is one of the most well-known races of maize of the Southwest, and its origin and spread has been the subject of much research (Galinat and Gunnerson 1963; Galinat and Campbell 1967; Galinat et al. 1970; Upham et al. 1987; Upham et al. 1988).

Though very early forms of proto-Maiz de Ocho may indicate a very early presence of eight-rowed forms of maize in the prehistoric Southwest, fully evolved Maiz de Ocho as it is known statistically and in the literature appeared first in the Mogollon region, around A.D. 500-600, at several sites including Rollerskate Shelter, Tornillo Shelter (Upham et al. 1987) and Tularosa Cave (Cutler 1952:177). [For a detailed discussion of the occurrences and spread of eight-row forms of maize in the prehistoric Southwest, see Chapter 8].

I have included statistics (taken by others) on living populations of both Harinoso de Ocho and Harinoso de Ocho Occidentales in Tables 17 and 18, so they can be compared to each other and to other races of maize. Both races have rather long cobs in comparison to prehistoric forms of maize, and a much wider cupule width. Following the section in this chapter on the environmental effects on maize, I have compiled data that were personally taken from plants of Maiz de Ocho, through my testing of races of maize in Las Vegas, that will reveal its behavior in lowland hot desert climates (as that at Black Dog Cave). [Please see Tables 25-31 and the photographs of the cobs and plants in Figures 49 and 65].

One maize cob from Black Dog Cave approaches the measurement statistics of modern Maiz de Ocho. It is an eight-rowed cob from Room 2, stratum 3, #5, at Black Dog Cave, and is illustrated in Figure 30; it is the sixth cob from the left. The cob is entire in its length, has very firm glumes and wide cupules. With a cupule width of 9 mm, it has a slightly wider cupule width than the mean cupule width of Harinoso de Ocho (8 mm). But the length of the cob from Black Dog Cave is only 83.5 mm, less than half the mean length of living examples of both H. de Ocho and H. de Ocho Occidentales (Tables 17 and 18). The kernel thickness of the prehistoric cob is only 3 mm, and it has a straight tapered shape. The other three eight-rowed cobs from Black Dog Cave are quite a bit smaller, and fall toward the range of proto-Maiz de Ocho. Without knowing their radiocarbon dates it is difficult to know how old they are, but there is a strong possibility that they are cobs from tillers, or cobs from lower positions on the main stalk under the primary ear or

ears.

TABLONCILLO AND TABLONCILLO PERLA

I have included data on these two races because isozyme studies have shown that they are related to the maize of the Southwest (Figure 34). Tabloncillo may be especially important because it is (isozymically) located midway between the races of Chapalote and Harinoso de Ocho Occidentales. Wellhausen et al. (1952:70, 71, 100) saw close hybridity relationships between Tabloncillo, Harinoso de Ocho Occidentales, and Reventador, and isozyme comparisons have shown their hypotheses to be correct in at least some respects. It would appear from Figure 34 that Tabloncillo is almost directly at the center of the interrelationships of the races of maize that comprise the modern race Pueblo.

I have compiled my own statistical data on the ear, tassel and plant morphology of both Tabloncillo and Tabloncillo Perla (Tables 25-31). The cobs and plants of both of these maize races are illustrated in Figures 48-50 and 65-66. These two races, which are closely related to living races of maize found in the Southwest today, have not previously been directly identified with the American Southwest, but further research on existing populations of Southwest maize may instruct us to the degree of their presence in the area today.

PUEBLO

Pueblo maize has a very complicated history. It was recognized to be a very variable race of maize by Carter and Anderson (1945:299-315). As they were in the process of examining modern collections of Pueblo maize, they recognized that the collection was quite variable in several of the morphological characters of the ears, including row number, color, ear shape, type of endosperm (whether pop, flint, dent, or flour), shank diameter, and kernel width. They measured and scored several collections of

Pueblo maize, and noted three major ancestral influences on living Puebloan maize: the Hohokam-Basketmaker Complex, the Mexican (Pyramidal) Complex, and an Eastern Complex. Thus, a great deal of heterogeneity was recognized in modern Pueblo maize.

Carter and Anderson recognized the prehistoric arrival of Basketmaker II maize to the Southwest, and the arrival of eight-row types (Maiz de Ocho) in Basketmaker III to Pueblo I times. They also noted the influence of dented maize in the northern Southwest, though they did not know which race had brought in the dent characteristic. They also recognized the later arrival of other types of maize, that had perhaps traveled to the Southwest with the Spanish (Carter and Anderson 1945:314).

Jones and Fonner (1954:115) and Nicherson (1953:107) also recognized the influence of an Eastern Complex of maize on Puebloan maize, but placed the date of its introduction at about A.D. 700. It is now known that eight-rowed and dented forms of maize all appeared much earlier in the Southwest than they did in the Eastern Woodlands or in the Great Plains (Wagner 1994:342-346). It is probable that the "eastern influence" on Anasazi maize of the Southwest that was described by both Jones and Fonner (1954) and Nicherson (1953) was actually the influence of Pepitilla with its genetic characteristics of tapered cobs and dented kernels. The influence of Maiz de Ocho also must have had an impact on Southwest maize as well during the prehistoric period. It has been recognized that modern Pueblo maize also has been influenced by maize brought by the Spanish after contact (Adams 1994:293; Carter and Anderson 1945:314). Post-contact Pueblo maize has much larger cobs with larger shanks than prehistoric Pueblo maize (Adams 1994:293) (Tables 17 and 18).

In Chapter 8 are tables that give descriptions of Pueblo maize from various sites of the Southwest over time, and indications about the origins of the race. In archaeological collections from sites in the northern Southwest, the variety and heterogeneity of maize specimens recovered increases during the period A.D. 1000-1300. Evidently, as the Pueblo period progressed, more and more different types of maize were grown together

by people living at any one particular site. This is probably a reflection of improving economics and trade during the Pueblo II period (also called the Differentiation period), and probably reflects the impact on races of maize caused by the movement and coming together of peoples in the Pueblo III period (also known as the Aggregation period). It is known that when several different types of maize are brought together and grown in proximity that they will cross-breed. This can cause an acceleration of evolution, a situation of punctuated equilibrium, with an explosion of new forms appearing. This, in combination with human selection, would have fostered the development of new and diverse types of maize and must have contributed to the co-evolution of Pueblo maize and Pueblo peoples.

In Tables 17 and 18, I have synthesized statistical measurements of prehistoric collections of maize that researchers have designated as belonging to the Pueblo race of maize. Only a few statistics were available for comparison, but some information can be gained from the table for prehistoric Pueblo maize. Row number averaged 10.7, showing the influence of Maiz de Ocho, and mean cupule width was very near to that of Maiz de Ocho as well. Kernel thickness was less than most other races, but if a mean kernel width were available, it would probably be wider than that of previous races. An obvious increase in the size of the cobs of Pueblo maize took place between A.D. 1000 and A.D. 1380; it is unfortunate that more data has not been published on the morphological statistics of prehistoric Pueblo maize.

The modern race of Pueblo maize has not been fully described in the literature, but I have included statistics on two varieties in Tables 17 and 18 that will give information on previous work in defining this modern race. The cob length of Pueblo maize is quite long, averaging 190 mm, and the row number is rather high, at 14. Cupule width is very large in comparison to prehistoric races, and kernel thickness is also large. Cupule depth is rather shallow, which is to be expected due to the influences of Maiz de Ocho, with its large rachis.

In Tables 25-31 I will present statistics on several varieties of Pueblo maize that I raised and tested in Las Vegas, and this information will define the Pueblo race of maize morphologically. Several variants of Pueblo maize are illustrated in Figures 51-55 (ears) and Figures 68-72 (plants).

ENVIRONMENTAL EFFECTS ON THE GROWTH OF MAIZE PLANTS

As any other plant in nature, maize has limits to its general adaptability to environmental conditions and climate. Certain climatic restrictions pose limits on the productivity of maize, and these have been generally characterized. Even though there is great variability in the races of maize and in the time required for maturity of the kernels, researchers have defined a series of conditions that are considered optimum for maize growth and productivity.

Maize is a warm weather crop but not a hot weather crop, and has limits both in its tolerance to heat and cold. The lower temperature limit of maize growth has been more fully defined than the upper limit. Very little maize is grown where the mean summer temperature is below 19 C (66 F), or where mean summer night temperatures are below 13 C (55 F) (Shaw 1977:592). The optimum temperature range for modern hybrid maize is in regions where "...the warmest month isotherms range between 21 C (70 F) and 27 C (80 F) and the freeze-free season is 120 to 180 days in duration" (Shaw 1977:592). If these statistics are compared to the mean monthly temperature in the Moapa Valley, in the vicinity of Black Dog Cave (Tables 1 and 2), it can be seen that only the months of May and September have a mean temperature between 21 C and 27 C. The other spring and fall months are colder, and the summer months are hotter in mean temperature. One great agricultural advantage of the Moapa Valley's lowland desert location is its very long freeze-free season of 230 days or more.

As well as a rather specific optimum temperature range, maize has a rather high

moisture requirement, and the optimum average moisture consumption rate of maize is 47 cm (18.4 inches) in a humid climate (Shaw 1977:593). In the lowland desert of the Moapa valley, with annual pan evaporation rates at 259.9 cm (102.33 inches), the moisture requirement for maize plants would be much greater, and for the Virgin Anasazi, the greatest environmental obstacle to high productivity of the maize they grew would have been heat and moisture stress.

This is quite a different climatic limitation than that experienced by the highland Anasazi, such as the prehistoric and modern Hopi, who grew and still grow their maize on the Colorado Plateau. Hopi farmers experience a short freeze-free season and have a dependence upon rainfall for crop success (Lebo 1991). Climatic and environmental conditions combined with human selection over many generations of the crop and of the people have shaped Hopi maize in ways that have produced varieties adapted to the local climatic conditions of the area. Still, the area in which the Hopi farm is at the limit climatically of maize production (Lebo 1991:179).

For the Virgin Anasazi, the challenge for successful maize agriculture in the Moapa Valley would have not been that of cold nights, drought, and a short season, but one of coping with moisture and heat stress on the maize crop during the growing season. Frequent irrigation would have been necessary during June, July and August, when temperatures and pan evaporation were at their highest.

Shaw (1977) has defined seven stages in the growth of maize plants, from planting to the maturation of the grains. These include: (1) before planting; (2) planting to emergence; (3) the early vegetative growth period from emergence to about five weeks after emergence; (4) late vegetative growth to tasseling; (5) tasseling, silking and pollination; (6) production of the kernels (grains); and (7) maturation of the kernels (Shaw 1977:594). Stages two through seven are all quite affected by environmental conditions, but the most critical stage of the growth of maize is during stage five, when flowering (tasseling, silking, and pollination) takes place (Shaw 1977:594). Moisture or heat stress

can have the most impact during this stage, and crop yields can be most affected by adverse environmental conditions during flowering (Hall et al. 1980; Hall et al. 1981; Shaw 1977).

Stress at silking was found to reduce maize yields by 7% per day in a test conducted by Claasen and Shaw (1970). Voldarski and Zinevich (1960) also reported that stress at the flowering stage resulted in a reduction of the number of grains per ear. Bebecel and Eftimescu (1973) found that high temperatures (above 32 C (90 F) during silking and pollination caused maize tassels and other reproductive parts to form more quickly than normal, and caused a higher rate of kernel abortion. They also found that if moisture and heat stress were severe, silking could be delayed until after all or most of the pollen had been shed, which would result in poorly pollinated or completely aborted ears. High night temperatures also have an adverse affect on the flowering stage of maize plants. Peters et al. (1971) found that night temperatures of 29.4 C or higher (85 F) during flowering and ripening of grains reduced maize yields by nearly 40%, much greater than the reduction of yields experienced under nights below 16.6 C (61.8 F). The high temperatures and moisture stress of the low desert must have certainly made growing maize in the vicinity of Black Dog Cave more difficult for the Virgin Anasazi than would be first imagined. Crop practices and the timing of planting and harvest would have been correlated to the limitations of the local climate.

There are several important environmental variables that can affect the growth and flowering, and therefore the productivity, of maize plants. These include altitude, photoperiod (daylength), temperature, and moisture stress. The effects of altitude have not been researched as well as one would like, but certain trends that apply to the behavior of maize plants at differing elevations have been noted by researchers. Mangelsdorf et al. (1961) found that a combination of human and environmental selection of maize at high altitudes in Peru resulted in shorter plants, with fewer leaves, and ears positioned closer to the base of the plant and arising from a thicker region of the stalk. These high altitude

plants were found to be more resistant to drought, wind, and hail, and to mature more quickly (Mangelsdorf et al. 1961:59). The maize varieties grown by the Hopi also exhibit a number of characters that may be related to altitude, including short, tillering plants with fairly narrow leaves, ears positioned low on the stalk (Figures 68 and 70), and early maturity (Tables 25-29).

Manrique and Hodges (1991) conducted an experiment in which they raised two crops of maize plants at separate altitudes and in separate photoperiods (daylengths) in Hawaii. In natural photoperiods (about 12 hours) the maize plants grown at 640 m in altitude took longer to reach tassel initiation than those grown at 282 m (Manrique and Hodges 1991:307). In longer photoperiods (17 and 20 hours) the maize grown at 640 m tasseled first, and the maize plants grown at 282 m had delayed tasseling, perhaps because the greater number of leaves produced at lower elevations delayed tasseling. They concluded that delayed tasseling responses to photoperiod declined as temperatures increased (Manrique and Hodges 1991:309). This does underscore the adaptability of maize, and may explain why it can be grown successfully (within limits) at high altitudes. It also may indicate why, in prehistoric times, lowland races of maize from western Mexico, such as Chapalote, were able to be grown at varying altitudes in the Southwest. The time of maturation of maize would still take longer at higher altitudes, especially in the Southwest, because of lower temperatures. Shuster (1981:114) tested Pima-Papago maize at Dolores, Colorado (2103 m in altitude) and at Tucson, Arizona (728 m in altitude), and found that maize took 115 days to mature at Dolores, and 65 days to mature at Tucson. The fact that the maize did mature at all at a high altitude does show the adaptability of maize, and of the Pima-Papago maize race.

Maize is a daylength sensitive plant, and if seed is brought from a tropical latitude where days are about 12 hours long, and planted and grown farther north during a part of the season when the days are longer, the plants (of most varieties of maize) will not initiate tassels and pollen until the length of day approaches 12 hours. Hunter et al. (1974)

showed that with longer photoperiods there was an increase in the vegetative growth of maize plants before tassel initiation, at differing temperatures: 20 C (68 F); 25 C (77 F); and 30 C (86 F). They found that different races and varieties of maize with differing genotypic makeups varied in their response to photoperiod. Certain genotypes could be selected for early flowering that were insensitive to photoperiod (Hunter et al. 1974:71, 73).

Kiniry et al. (1983) demonstrated that maize plants respond to photoperiod only during a short time of their growth cycle. They are sensitive from four to eight days before tassel initiation, through silking, pollination and fertilization, and then become insensitive to photoperiod again. Stevenson and Goodman (1972) tested maize plants in differing temperatures and photoperiods and concluded that in areas of lower latitude selection is <u>against</u> long daylength strains of maize, but that the <u>reverse</u> is true in higher latitudes where selection is against short daylength sensitive strains. In northern areas with shorter seasons, cooler temperatures, and drought, environmental selection alone is for <u>fast-maturing</u> varieties of maize. This, combined with human selection for early maturing varieties, would speed up the evolution of early varieties of maize, and could account for the fairly rapid northward movement of maize into the Southwest during prehistoric times.

The growth of maize plants is affected by temperature. As mentioned before, maize has lower limits of tolerance to cold temperatures, and too high temperatures can also be detrimental to the growth of the plants. At high temperatures, moisture stress is increased. This may partly occur because high temperatures cause greater vegetative growth. Colidago and Brown (1975) found that high temperatures of 30 C (86 F) resulted in a significant increase in the number of leaves. Hunter et al. (1974) showed that at high temperatures of 35 C (95 F), and in long photoperiods, the delay in initiation of tassels was less than that of maize plants grown at lower temperatures in the same photoperiod. These results clearly show the accelerated growth and maturation of maize plants grown

at high temperatures.

In hot climates, moisture stress in maize can be a major problem limiting the productivity of the crop. At high temperatures, the evapotranspiration of the plants can exceed the intake of moisture from the soil. Additional factors in moisture stress are the low humidity of the desert at high temperatures, winds, which move moisture away from the surface of the leaves, and the effect of solar radiation. If maize plants begin to wilt, they are in moisture stress, and photosynthesis is interrupted (Barnes and Wooley 1969). Downey (1971) found that if leaf turgidity is 70% or less, photosynthesis is at zero.

Several tests on the effects of moisture stress in maize have reveal that changes take place in the morphology of the ears, and in the success of the reproductive cycle of maize. Mackey (1983) found that under moisture stress maize plants produced smaller ears with fewer kernels per ear, but the kernels were full-sized. Moisture-stressed plants also matured later. Mackey (1983:216) discovered that "...though row number is genetically determined, there is a relationship between lower row numbers and lower moisture availability..." He concluded that: "The mechanism or process for this must be that longer ears with larger numbers of rows mature later or slower than do smaller ears with fewer numbers of rows" (Mackey 1983: 216). The results of this study do have interesting implications for the increasing frequencies of eight-row maize cobs in the Mogollon region around A.D. 600, and the corresponding increase in eight-row ears at Mesa Verde about A.D. 1100-1150. This presents the following questions: what is the degree of influence of hybridity with Maiz de Ocho, the degree of human selection, and the degree of environmental selection for fewer rows of kernels in prehistoric eight-row forms of maize.

Because lowland Virgin Anasazi maize was irrigated, there was not such a problem involved in watering the plants, as there was for Anasazi living in the highlands and growing maize at highland locations, when seasonal rains were sparse. The most important problem in the way of crop success for the Virgin Anasazi would have been

moisture stress during the critical period of tasseling, silking, and pollination. Local desert high temperatures, winds, and intense insolation would have raised evapotranspiration rates to extremely high levels.

Moisture stress, with its accompanying effect of reducing photosynthesis, has been shown to cause delays in the initiation of silking of maize, and an increase in the interval between the beginning of pollen shedding and the appearance of the silks on the upper and basal ears of maize (Hall et al. 1981:27). If the plants shed all their pollen before the silks have grown enough to be receptive to pollen, pollination will be poor or nonexistent, and the crop will suffer.

Barnes and Wooley (1969) conducted studies on moisture stress in maize, and found that silking was delayed by moisture stress, and that fertilization of the ears was reduced in single-eared varieties when compared to multi-eared varieties. Apparently multi-eared varieties of maize presented more opportunities for pollination of the ears, and were more successful under moisture stress (Barnes and Wooley 1969:788).

Warrington and Kanemasu (1983:749-750) studied the effects of heat on maize plants, and found that the optimum growing temperature for maize was 30 C (86 F), and "...developmental rates for tassel initiation and anthesis [flowering period] both declined above 28 C (82.4 F). A constant temperature of 40 C (104 F) was found to be effectively lethal for both root and shoot growth (Lehenbauer 1914; Warrington and Kanemasu 1983:749, 752). Warren and Kanemasu (1983:753).concluded that mean temperatures above 28 C (82.4 F) had a negative effect on the growth, tasseling, silking, pollination and fertilization of maize plants

A system of measurement of the growth and development of maize plants in relationship to temperature has been designed that is an index of crop maturity and crop success. It measures the accumulation of the number of Growing Degree Units (GDU) (also called growing degree days) of maize (Coelho et al. 1980; Shaw 1977:598-600). The GDU system uses temperature unit numbers based on air temperature data to

calculate the number of degrees per day that the mean temperature rises above a base temperature of 10 C (50 F), which is the minimum temperature at which maize grows well. The upper temperature limit of optimum growth for maize is 30 C (86 F). The GDU system measures an accumulation of a day's productive growing degrees between 10 C and 30 C (50 F and 86 F). When the growing degree days for a complete season are added together (accumulated) an index of maturity for maize for the growing season is calculated.

The following is an example of a daily heat unit calculation: If the mean daily temperature is 26.3 C (79.3 F) then the number of growing degrees for the day is 16.3 C (29.3 F). These are the degrees above 10 C (50 F). To alleviate an excessive accumulation of growing degrees above the optimum of maize growth of 30 C (86 F), which could cause a misinterpretation, the amount of the daily maximum that exceeds 32.2 C (90 F) is subtracted from the degree accumulation for each day. This accounts for the period of the day when temperatures are high, growing temperatures are above optimum, and the plants are in moisture stress (Newman and Blair 1969; Shaw 1977:600).

Growing degree units average about 13.9 C (25 F) per day for most maize. This averages to 97.3 C (176 F) per week (Coelho et al. 1980; Lebo 1991; Shuster 1981). This translates to an average of 437.85 GDU C (792 GDU F) per month, and 1459 GDU C (2640 GDU F) for the entire maize growing season, based on a crop maturity period of 105 days (15 weeks). The lower limit of GDU for a week to mature maize is about 77.7 GDU C (140 GDU F). The lower limit of GDU per season is 1165.5 GDU C (2100 GDU F) to allow for the maturity of a maize crop (Aldrich et al. 1986:20; Lebo 1991:210, 212).

The equation for calculating GDU per day is:

$$\frac{\text{daily max temp} + \text{daily min temp}}{2} - 10\text{ C} - \text{days} + 32.2\text{ C} = \text{GDU}$$

By referring to Tables 1 and 2 in Chapter 3 of this volume (the climatological summary of temperatures Celsius and Fahrenheit for the Moapa Valley) the growing

degree days for maize grown by the Virgin Anasazi in the area of Black Dog Cave can be calculated. This information enables us to gain insight into the productivity of the maize grown by the prehistoric lowland Virgin Anasazi.

As discussed in Chapter 3, the stable factors of the climate of the Southwest are thought to have changed little in the past 3,000 years (Dean 1992:29; Dean et al. 1994:54; Wills et al. 1994:305). This indicates that the daily and monthly minimum, maximum, and mean temperatures probably have not changed appreciably since the period of the inhabitation of the Moapa Valley by the Virgin Anasazi (Basketmaker II to Late Pueblo III) (Lyneis 1992a; 1995).

Tables 23 and 24 are listings of the mean accumulated monthly growing degree units (GDU) for the maize growing season of March, April, May, June, July, August, September, October and November in the Moapa Valley, Nevada. The accumulated total number of growing degree units for the entire season is also given. The effect of high summer temperatures on the growth of maize in the Moapa Valley can be seen in Tables 23 and 24. Maize plants would begin to experience moisture stress in June and would endure significant moisture stress in June, July, August and September. Because these tables only show monthly mean accumulations, it is difficult to see the effect of extremely hot periods of weather that could be very harmful to stands of maize grown in the valley. Several consecutive days with temperatures above 40 C (104 F) would cause severe moisture stress to a stand of maize. Several consecutive days of temperatures of 43 C (110 F) in a row could be disastrous, especially if high temperatures coincided with the tasseling, silking, and pollination of the maize crop. The highest temperatures of the season in the Moapa Valley usually occur in the month of July, when the mean daily maximum temperature is 30 C (87.2 F) with a mean daily maximum of 40.6 C (105.2 F) (also, see Tables 1 and 2). Record temperatures of 49 C (120 F), have occurred in July, and temperatures of 43 C (110 F) usually occur a few days each year (Climate Summary of the Office of the Nevada State Climatologist:1994; personal experience). Stands of

Table 23. Growing Degree Units (Days) of Maize in the Lowlands of the Moapa Valley (Celsius).

Month	Daily Mean Temp. (C)	Base Temperature (C)	GDU Per Day (C)	Mean Degrees C Over 32.2 C Per Day	No. of Days in the Month	GDU for the Month
March	13.2	10	3.2	0	31	99.2
April	17.1	10	7.1	0	30	213
May	22.1	10	12.1	0	31	375.1
June	27.3	10	17.3	5.6	30	351
July	30.6	10	20.6	8.4	31	378.2
August	29.6	10	19.6	7	31	390.6
September	26	10	16	3.4	30	378
October	19.1	10	9.1	0	31	273
November	12.1	10	2.1	0	30	63
Mean Accum. GDU Per Season (C)						2521.1

Table 24. Growing Degree Units (Days) of Maize in the Lowlands of the Moapa Valley (Fahrenheit).

Month	Daily Mean Temp. (F)	Base Temperature (F)	GDU Per Day (F)	Mean Degrees F Over 90 F Per Day	No. of Days in the Month	GDU for the Month
March	55.8	50	5.8	0	31	179.8
April	62.8	50	12.8	0	30	384
May	71.8	50	21.8	0	31	675.8
June	81.1	50	31.1	10.2	30	627
July	87.2	50	37.2	15.2	31	682
August	85.3	50	35.3	12.6	31	703.7
September	78.8	50	28.8	6.2	30	678
October	66.5	50	16.5	0	31	511.5
November	53.8	50	3.8	0	30	114
Mean Accum. GDU Per Season (F)						4555.8

maize would have to be frequently and vigilantly irrigated during such extremes of heat to ensure crop survival.

In Tables 23 and 24 the accumulated growing degree units (daily growing units, or GDU) for maize crops in the Moapa Valley, Nevada, were calculated using a base temperature of 10 C or 50 F. This was subtracted from the daily mean temperature, then the mean number of degrees per day over 32.2 C or 90 F was subtracted from that. This figure was multiplied by the number of days in the particular month represented in the sixth column, and the GDU for each month was calculated in the seventh column. The mean number of GDU per season is given also in the bottom row of the tables. The detrimental effects of local high summer temperatures that cause moisture stress in maize and lower the number of GDU can be seen for the Moapa Valley during the months of June, July, and August.

For the Virgin Anasazi, it obviously would have been prudent to time the planting of their maize crops in the Moapa Valley so as to not have them in the tasseling, silking, and pollination cycle (the most critical period for maize growth and development) during the hottest weather. If, as discussed in Chapter 5, the Virgin Anasazi actually planted two crops of maize per year, the first crop of maize (if planted in late March) would be ripening about the beginning to the middle of July. Tasseling, silking, and pollination would have taken place in late June. Since the odds are that most years the hottest weather of the year is in the last two weeks of July and the first two weeks of August, the first crop of maize of the year for the Virgin Anasazi would probably go through its reproductive cycle and mature before the hottest weather of the season.

If the second crop of maize was planted after the middle of July, high temperatures could interfere with germination of seeds, which germinate best between soil temperatures of 20 C (68 F) and 30 C (86 F) (Blacklow 1972; Shaw 1977:602-603). If seeds were planted deeper during the second planting, actual germination temperatures would be cooler than if they were planted nearer to the surface. Constant temperatures of 40 C

(104 F) and above were found to be lethal to both root and shoot growth in maize (Blacklow 1972; Warrington and Kanemasu 1983). Thus, the major risk for the second crop of maize for the Virgin Anasazi would be during the germination period, and during the first few weeks of growth, until the weather cooled down again.

If the Virgin Anasazi planted a second crop of maize before the first one was ripe, they would avoid the risks of too much heat during germination, but this would double labor efforts for the people by having twice as much maize in the fields at one time. If they waited to plant until they had harvested the first crop (and harvest is a major outlay of labor), then they would probably have had to plant the second crop a bit deeper in the ground, water carefully, and take a chance that an extremely hot period would not occur during germination. This second crop would have to be planted by the middle of July in order to have enough time left in the season to mature the maize.

By referring to Tables 23 and 24, information can be gained about the parameters of the timing of planting and harvesting of maize crops in the Moapa Valley. If the first crop was harvested by the middle of July, the growing degree days would total 1227.4 GDU C (2207.6 GDU F), certainly much more than the minimum of 1165.5 GDU C (2100 GDU F) required for the maturity of a crop of maize. If the second crop was planted in the middle of July, the growing degree days would total 1293.7 GDU C (2348.2 GDU F), also more than enough growing degree days to mature a second crop. But if the second crop was planted about the first of August, the GDU would only total 1104.6 GDU C (2007.2 GDU F) well below the minimum growing degree days to mature maize, because of both late summer heat and autumn coolness.

We cannot know if the Virgin Anasazi actually planted two crops of maize per year, but from the data gathered and presented here, it certainly appears that they could have. Double cropping would have been an excellent way to guard against shortfalls of the total food supply of the year. As shown in my summary of a probable food procurement calendar for the Virgin Anasazi in Chapter 5, double cropping of maize and

other domesticated crops would fit in well with the seasonal labor requirements of gathered and hunted foods, and would be possible within the climatic parameters of the Moapa Valley.

TESTING LIVING RACES OF MAIZE IN THE LOWLAND SOUTHWEST

In an effort to gain information on the behavior of the growth of maize in the hot, lowland desert climate in the climate zone of Black Dog Cave, I conducted a project in which I planted, raised, and harvested plants of several of the defined races of maize known to have descended from prehistoric maize of the Southwest. I tested 15 samples of seed of races and varieties of maize, and a sample of teosinte. Seeds of 15 other races or varieties of maize were planted, but the data on their morphological characters proved to be irrelevant to this study. Seed for the project was obtained from several sources, including Plants of the Southwest Seed Company of Santa Fe, New Mexico, Native Seeds/SEARCH Seed Company of Tucson, Arizona, The Maize Genetics Cooperation, Urbana Illinois, CORNS Seed Preservation Service, Turpin, Oklahoma, and The USDA Agricultural Research Service, Iowa State University, Ames, Iowa. Seed from the last source arrived too late to plant, but all other seed was planted. A listing of the maize races and varieties planted for this study and the sources for the particular seed samples is as follows:

Source: Plants of the Southwest, Santa Fe, NM: Alamo-Navajo Blue Flour (Race: Pueblo); Papago Flour (Race: Pima-Papago).

Source: CORNS Seed Preservation, Turpin, OK: Chapalote Type (Race: Chapalote); Moqui (Hopi) Blue Flour (Race: Pueblo); Anasazi Flint/Flour (Race: Pueblo).

Source: Maize Genetics Co-op, Urbana, IL: Chapalote 89-(38-41) (Race: Chapalote).

Source: Native Seeds/SEARCH Tucson, AZ: Chapalote MD8502 (Race: Chapalote); Harinoso de Ocho ZMOI-004 (Race: H. de Ocho); Tabloncillo ZMII-007 (Race: Tabloncillo); Reventador Z02-002 (Race: Reventador); Maiz Blando de Sonora ZMO9-009 (Race: Pima-Papago); Tabloncillo Perla ZMII-006 (Race: Tabloncillo Perla); Tohono O'odham Flour (Race: Pima-Papago); Hopi Yellow Flour (Race: Pueblo); Santo Domingo White Flour (Race: Pueblo); Teosinte *Zea mays ssp. mexicana* (Nabogame teosinte).

My aim in this study was to recreate growing conditions for maize that would duplicate as closely as possible the conditions at Black Dog Cave. I planted the maize seeds for the test a bit later than I preferred, but I had to wait until all the seed arrived from the suppliers.

Half of the seeds for this project were planted on May 22, 1996, and the other half on May 23, 1996, in sandy soil enriched with organic compost, at my home in Las Vegas, Nevada. The elevation of the test site is 615.69 m (2020 feet), which is 234.69 m (770 feet) higher in altitude than the altitude of Black Dog Cave, but well within the Lower Sonoran Life Zone. The seed was planted in shallow depressions dug into the soil in hills of eight seeds, at a depth of 9 to 10 cm (3 to 4 inches) deep. The temperature at the time of planting averaged between 20 C and 32.7 C (68 F and 91 F). This weather continued during the time of emergence, until about June 1, 1996, when the temperatures climbed. Daily high temperatures then began reaching above 37.8 C (100 F). The first seedlings to emerge were apparent on May 29, 1996, only seven days from planting. By May 31, all of the varieties were up, after a period of only nine days from planting. Temperatures were very hot for most of the summer. On June 5, the maximum temperature was 42.2 C (108 F) on June 6 and June 8 the maximum temperatures were 44.4 C (112 F). Temperatures continued with maxima over 37.8 C (100 F) most of the rest of the summer, until September 4, 1996, the first day since June 22 to have a maximum temperature of less than 37.8 C (100 F).

The maize plants grown for this project were irrigated every other day with a good soaking, as they would be if irrigated from water diverted via brush dams from the Muddy River in the Moapa Valley. Such frequent watering was necessary to preserve leaf turgidity, and most of the plants had begun to wilt by mid-day the second day after watering. In other words, a deep watering was required by the plants to keep them from wilting. Most of the maize plants had achieved one m (39.37 inches) in height by June 22, 1996, one month after planting.

In the most severe period of heat that summer, from July 1 to July 16, several days in a row had maximum temperatures of 44.4 C (112 F) and were followed by very warm nights. Besides wilting, most of the plants exhibited damage to the growing tips, in the case of which new leaves became transparent and adhered together, then turned brown. What happened to the leaves at the growing point would be analogous to steam-cooking. I teased some of these adhering leaves apart, and the true growing point continued to elongate, but the leaves that had adhered together revealed the heat damage thereafter.

The first maize variety to tassel and silk was Tohono O'odham Flour, a 60-day maize from the Pima-Papago area, and most likely a member of the Pima-Papago race selected for early maturity. The tassels appeared on July 20, 1996, 59 days after planting. The tassels of the first plant to tassel of Tohono O'odham Flour were topped with a rudimentary ear of maize, exhibiting both male and female parts on the tassel- a very primitive trait in maize (Figure 40). This plant did have normal ear development on the actual ears on the stalk, and all of the ears were completely dry and ripe by August 10, 1996.

Most of the other maize varieties I planted were silking by August 10, except two of the samples of Chapalote: 89-38-41 and MD8502. Both of these samples of Chapalote were grown from seed collected in Mexico, and were probably adapted to the shorter (approximately 12-hour) daylengths of tropical latitudes. Thus, they exhibited delayed silking. In addition, moisture stress caused by the hot, dry conditions probably also

delayed their silking. The teosinte plants also silked very late in the season, about the same time as the two Chapalote samples (about September 5). The other sample of Chapalote, from Oklahoma, labeled "Chapalote Type," was adapted to the shorter daylengths of our latitude, and the plants of this variety silked by August 10, later than most of the other samples I tested, but not as late as the two samples of Chapalote from tropical latitude seed-collection sources. This reveals that although Chapalote is a variety that is adaptable to differing altitudes and daylengths, it is not a particularly "early" race of maize. Human and environmental selection would have been necessary during the Late Archaic period, when the adoption of maize cultivation took place, to adapt Chapalote (or pre-Chapalote) to the climate of the Southwest with its (relative to Mexico) short daylengths, moisture stress conditions, and varying altitudes.

Another interesting feature of the plants of all three samples of Chapalote that I grew was that they were quite wind-resistant. After a severe wind storm on July 26, 1996, many of the plants of several races and varieties of maize I was testing had fallen over, but none of the Chapalote plants was knocked down. This indicates another feature of the adaptability of Chapalote to the climate conditions of the Southwest.

About August 1, 1996, I began to notice holes drilled into the husks of many of the ears of maize. This proved to be evidence of maize earworms, the larvae of a moth, *Heliothis zea (Boddie)*. Maize earworms are migratory insects that, in their adult form, fly long distances of up to several hundred miles and lay eggs in maize cobs (Westbrook et al. 1995). Varieties of maize with very tight husks, such as Chapalote and Pima-Papago, seem more resistant to attacks of the insect, because the tight pressure of the husks does not permit much room for the insect to get into or in which to move around. It appeared that damage was much worse on ears with loose husks, which exhibited a very large larva inside. The Virgin Anasazi had problems with maize earworms, as evidenced by damage on some of the cobs from Black Dog Cave (Chapter 6).

METHODS OF DEFINING THE LIVING RACES OF MAIZE OF THE SOUTHWEST

The methods of measurement of the ears, tassels, and plants of the races and varieties of maize that I tested were virtually identical to those described earlier in this chapter under the heading of "Methods of Measurement of Maize Characteristics." The conditions under which I selected, planted, and grew the maize have just been described. I made photographs of the cobs and plants of the maize that I grew (Figures 40-56 and 58-73), using the same cm stick that I used for the maize cobs from Black Dog Cave.

To photograph the plants of the maize that I raised for this study, I made a large backdrop to stand the plants against that would indicate their size. A plywood board was painted white and sectioned with black tape spaced at 25 cm intervals, and a 1 m stick (also sectioned into 25 cm intervals) was placed at the left edge of the board. The entire board backdrop was 243 cm tall (2.43 m). Some of the maize plants were too tall to be shown in their entirety against this backdrop, and so were cut into two, or sometimes three, segments and placed next to each other to photograph. In all cases the lowest section of the plants, with the roots, is on the left side of the picture and the top part of the plant including the tassels, is on the right.

Tables 25-31 present the measurements of the living races of maize that I raised for this study. Information presented here indicates the behavior in the Southwest of the well-known defined races of maize known to have descended from prehistoric races of maize. With this information I attempt to add to the known measurements of many of these races, including the Pima-Papago race and Pueblo race, which have been poorly defined before this study. In all cases, at least four cobs of each race or variety were measured, and four complete tassels and plants were measured as well. In the definition of some of the races (including Pima-Papago and Pueblo), three or more collections were measured, which means that 12, 16, or 24 or more plants and cobs were measured and their averages totaled. The mean measurements for each race or variety are given as a

statistical definition of that particular race.

Figures 35-39 are visual representations of the internode patterns of the races of maize that I grew and tested. These graphs trace the growth patterns of the main plant stems of the maize race described, by showing the lengths of successive internodes (the distances between leaf nodes) of each race shown, beginning with measurements taken at the base of the plant, and then continuing to be taken upward, node by node. The graphs display the specific behavior patterns of the growth of each particular race of maize under the environmental conditions of the hot, lowland, desert Southwest. These graphs are meant to be used in comparison with the very different internode patterns displayed in the graphs in Races of Maize in Mexico (Wellhausen 1952), which display data (on many of the same races) that were taken at high altitudes in Mexico. To my knowledge, the morphological statistics and the internode patterns of the indigenous Southwest races Pima-Papago and Pueblo have not been intensely researched or displayed anywhere before. Thus, the graphs and statistics presented in this study function as the defining documents of the morphology of these two races of maize.

DISCUSSION

From the information I have gathered and presented in Tables 25-31 and Figures 35-39, it appears that some of the races of maize that had been previously defined in the highlands of Mexico do grow differently in the lowlands of the American Southwest. Many of the races of maize grew much taller in the Las Vegas area than in the Mexican highlands, and the pollination of cobs was not generally as complete here in the lowland Southwest as was the case in most of the previous statistical studies conducted in Mexico or in other cooler climatic regions (Figures 40-56). It is therefore likely that the intense summer heat of our lowland climate, which causes significant moisture stress on plants, also has definite effects on both morphology of the cobs and vegetative growth of the plants.

Table 25. Summary of Measurements of the Races of Maize of the Southwest, Taken from Living Plants Tested at Las Vegas, Nevada, Six Characteristics of the Cobs.

Race	Photo-graph	Cob Length (Mm)	Row No.	Rachis Diam. (Mm)	Rachis Seg. Length (Mm)	Cupule Width (Mm)	Cupule Length (Mm)
Chapalote Type	Fig. 41	243	16.5	15.8	3.7	5.8	1.8
Chapalote 89-38-41	Fig. 42	155	10	9	4.4	5.8	2.4
Chapalote MD8502	Fig. 43	159	10.5	12.1	5.5	7.2	2.5
Mean: Chapalote		185	12.3	12.3	4.5	6.2	2.2
Papago Flour	Fig. 44	195	12.7	18	5	6.5	2.8
Blando de Sonora	Fig. 45	147	8.2	11.7	5.8	4.8	3.4
Tohono O'odham	Figs. 40, 46	168	11	10	3.8	6.1	1.9
Mean: Pima-Papago		170	10.6	13.2	4.8	5.8	2.7
Revent-ador	Fig. 47	130	16	13.5	3.6	4	2.1
Harinoso de Ocho	Fig. 48	151	11	16.5	6	6.6	3
Tabloncillo	Fig. 49	132	8	21	5.5	5.8	3
Tabloncillo Perla	Fig. 50	167	10	11	6.6	9.3	4.5
Moqui (Hopi) Blue	Fig. 51	253	12.5	14.1	4.7	7.1	2.1
Alamo-Navajo Blue	Fig. 52	223	13	18	3.6	6.2	1.9
Hopi Yellow	Fig. 53	151	10.3	13.8	3.9	7	2
Santo Domingo White	Fig. 54	223	11	14	5.5	7	2.3
Anasazi Flint/ Flour	Fig. 55	200	11.2	11.3	4.3	6.1	2.2
Mean: Pueblo		210	11.6	14.2	4.4	6.7	3.3
Nabogame Teosinte	Fig. 56	-	-	-	-	-	-

Table 26. Summary of Measurements of the Races of Maize of the Southwest, Taken from Living Plants Tested at Las Vegas, Nevada, Six Characteristics of the Cobs.

Race	Photo-graph	Cupule Wing Width (Mm)	Cupule Depth (Mm)	Glume (Cob) Diam. (Mm)	Kernel Thickness (Mm)	Shank Diam. (Mm)	Shape of Ear
Chapalote Type	Fig. 41	1.6	1.3	24.8	3.75	11.5	cigar
Chapalote 89-38-41	Fig. 42	1.9	1.4	18	4.1	7.8	cigar
Chapalote MD8502	Fig. 43	1.9	1.9	22.5	4.8	9	cigar
Mean: Chapalote		1.8	1.5	21.7	4.2	9.4	cigar
Papago Flour	Fig. 44	1.2	1.4	27.5	4.9	19.7	cigar
Blando de Sonora	Fig. 45	2.8	1.8	22	6	9	straight
Tohono O'odham	Figs. 40, 46	1.4	1.1	18.2	3.8	10	straight
Mean: Pima-Papago		1.8	1.4	22.5	4.9	12.9	straight/ cigar
Revent-ador	Fig. 47	1.1	1.5	22.5	4.3	10	taper/cig.
Harinoso de Ocho	Fig. 48	2.1	2	21.8	7	9	stra/cig.
Tabloncillo	Fig. 49	2.4	1.8	21	6	7.6	stra/cig.
Tabloncillo Perla	Fig. 50	2.8	2	20.5	3.6	8	cigar
Moqui (Hopi) Blue	Fig. 51	1.3	1.2	22.7	5	19.5	straight
Alamo-Navajo Blue	Fig. 52	1.6	1	25	5.6	17.7	straight
Hopi Yellow	Fig. 53	1	1.1	19.5	5.5	15.2	straight
Santo Domingo White	Fig. 54	1.5	1	24	5.3	22	straight
Anasazi Flint/ Flour	Fig. 55	1.7	0.9	19	4.1	12.2	stra/cig.
Mean: Pueblo		1.4	1	22	5.1	17.3	straight
Nabogame Teosinte	Fig. 56	-	-	-	-	-	-

Table 27. Summary of Measurements of the Races of Maize of the Southwest, Taken from Living Plants Tested at Las Vegas, Nevada, Six Vegetative Characteristics of the Plants.

Race	Photo-graph	Days to Mid Silk	Days to Ripe	Height of Plant	Height of Ear (Cm)	No. of Leaves (Main Stalk)	No. of Leaves Above Ear
Chapalote Type	Fig. 58	95	112	224.9	164.3	17.8	5.5
Chapalote 89-38-41	Fig. 59	95	115	231.3	117.3	17.8	6.8
Chapalote MD8502	Fig. 60	115	130	308.6	230	24.5	6
Mean: Chapalote		101	119	254.9	170.5	20	6.1
Papago Flour	Fig. 61	60	100	165.3	85.8	11.5	5.5
Blando de Sonora	Fig. 62	65	108	242.6	143.2	15	5.5
Tohono O'odham	Fig. 63	46	71	131.1	58.1	8	3.5
Mean: Pima-Papago		57	93	179.6	95.7	11.5	4.8
Revent-ador	Fig. 64	115	130	247.8	175.1	17.5	6.3
Harinoso de Ocho	Fig. 65	115	140	260.4	185.8	18.3	5.5
Tabloncillo	Fig. 66	60	100	258.5	163.5	15.5	5.5
Tabloncillo Perla	Fig. 67	60	100	203.2	135	13.8	4.8
Moqui (Hopi) Blue	Fig. 68	60	105	234.4	135.4	12.3	4.8
Alamo-Navajo Blue	Fig. 69	60	100	199.1	90.6	14	6.3
Hopi Yellow	Fig. 70	65	100	116.6	6.2	11.5	5.3
Santo Domingo White	Fig. 71	60	105	222.5	125.8	15	6.2
Anasazi Flint/ Flour	Fig. 72	60	105	171.9	86.6	12.8	5.6
Mean: Pueblo		61	103	188.9	100	13.1	5.6
Nabogame Teosinte	Fig. 73	142	157	207	184	23	1.3

Table 28. Summary of Measurements of the Races of Maize of the Southwest, Taken from Living Plants Tested at Las Vegas, Nevada, Six Vegetative Characteristics of the Plants.

Race	Photo-graph	Total No. of Ears	Length of Leaf (Cm)	Width of Leaf (Cm)	Leaf Area (Cm Squared)	No. of Veins Per Leaf	Venation Index
Chapalote Type	Fig. 58	2.2	89.2	7.6	9050	26	3.42
Chapalote 89-38-41	Fig. 59	3.3	92.6	6.6	8158	23	3.48
Chapalote MD8502	Fig. 60	5.8	110.8	9.3	18934	28.3	3.04
Mean: Chapalote		3.7	97.5	7.8	12047	25.7	3.31
Papago Flour	Fig. 61	1.8	118	9.1	9261	24.5	2.69
Blando de Sonora	Fig. 62	4.5	99	8	8910	24.5	3.06
Tohono O'odham	Fig. 63	1.8	83	6	2988	15	2.5
Mean: Pima-Papago		2.7	100	7.7	7053	21.3	2.75
Revent-ador	Fig. 64	5	128.3	8.1	13640	34	4.19
Harinoso de Ocho	Fig. 65	2.8	110.7	10.5	15924	31.5	3
Tabloncillo	Fig. 66	3.8	115.5	7	9466	25.5	3.61
Tabloncillo Perla	Fig. 67	1	110.1	8.8	10018	25.8	2.93
Moqui (Hopi) Blue	Fig. 68	3	131.8	6.9	8389	26.8	3.88
Alamo-Navajo Blue	Fig. 69	2.3	109.5	7.3	8393	26.5	3.63
Hopi Yellow	Fig. 70	3.5	113.5	7	6852	26.2	3.75
Santo Domingo White	Fig. 71	1.5	126.8	7.6	10841	24.5	3.22
Anasazi Flint/ Flour	Fig. 72	3.3	121.6	6.5	7588	24	3.69
Mean: Pueblo		2.6	120.6	7	8413	25.6	3.63
Nabogame Teosinte	Fig. 73	154	48.7	4.2	3528	15.8	3.76

Table 29. Summary of Measurements of the Races of Maize of the Southwest, Taken from Living Plants Tested at Las Vegas, Nevada, Five Vegetative Characteristics of the Plants.

Race	Photo-graph	Stalk Width (Cm)	No. of Prop Roots	No. of Tillers	Degree of Pubesc-ence	No. of Husks
Chapalote Type	Fig. 58	2.4	4.8	2	1.4	8.6
Chapalote 89-38-41	Fig. 59	2.3	4	0.5	1.5	9.8
Chapalote MD8502	Fig. 60	2.6	7.3	1.3	1.3	8.9
Mean: Chapalote		2.4	5.3	1.2	1.4	9.1
Papago Flour	Fig. 61	2.7	0.7	2	0.8	9.2
Blando de Sonora	Fig. 62	2.5	2.5	1.8	1.8	8.5
Tohono O'odham	Fig. 63	2.1	0.5	1.3	1	6.6
Mean: Pima-Papago		2.4	1.2	1.8	1.2	8.1
Revent-ador	Fig. 64	2.7	4.8	2.5	2.3	9.3
Harinoso de Ocho	Fig. 65	2.5	4.8	2	1	11.4
Tabloncillo	Fig. 66	2.4	1.5	1.2	0	10.1
Tabloncillo Perla	Fig. 67	2.3	2.3	1.8	0	7.6
Moqui (Hopi) Blue	Fig. 68	2.8	2.3	2	1	8
Alamo-Navajo Blue	Fig. 68	2.5	1	2	1	9
Hopi Yellow	Fig. 70	2.6	0.2	2	1	7.3
Santo Domingo White	Fig. 71	2.5	3.2	1.8	0	10.3
Anasazi Flint/ Flour	Fig. 72	2.3	1	4.3	0.8	8.9
Mean: Pueblo		2.5	1.5	2.4	0.8	8.7
Nabogame Teosinte	Fig. 73	1.2	4.3	8.5	0.4	3

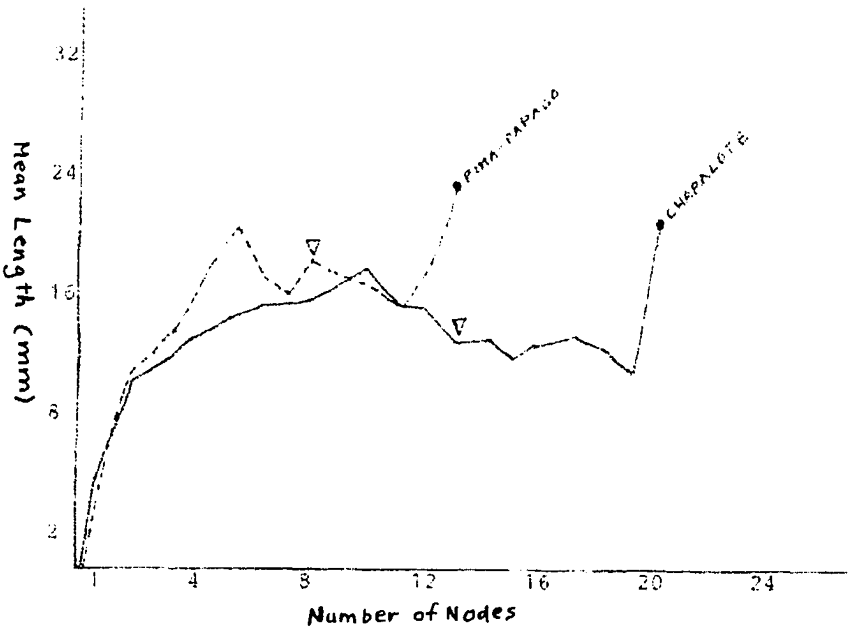

Figure 35. A Graphic representation of the internode patterns of the Southwest maize races Chapalote and Pima-Papago. Measurements are given in cm, and were taken from plants grown for this study. The vertical axis of the graph represents the mean length of the internodes of the plants of the race portrayed. The horizontal axis exhibits the modal number of nodes for the race of maize represented. The maize race Chapalote is depicted by a solid line (____), and the maize race Pima-Papago by a dashed line (-----). The position of the uppermost ear is marked by a triangle, and the base of the tassel by a dot at the end of the graph.

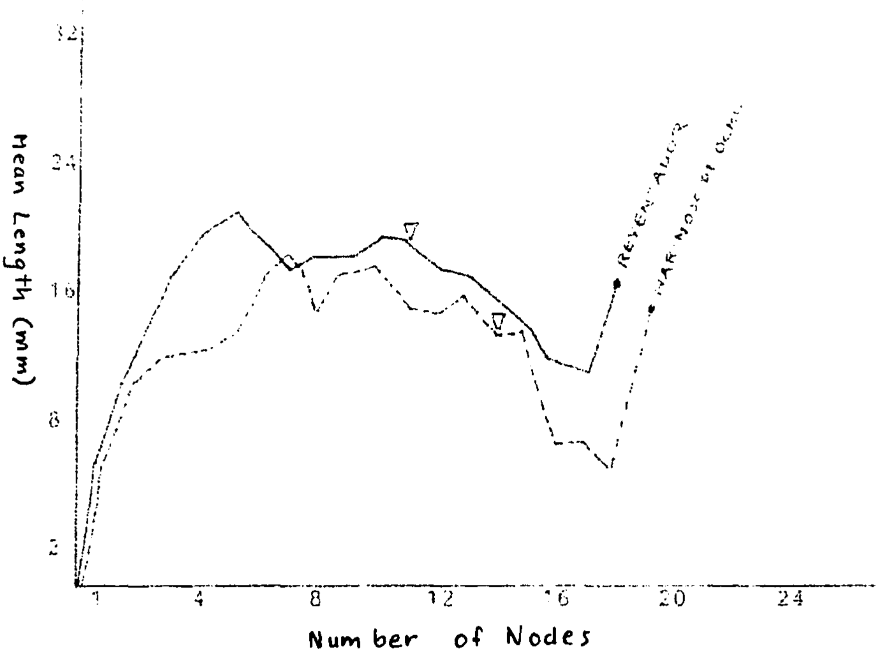

Figure 36. A Graphic representation of the internode patterns of the Southwest maize races Reventador and Harinoso de Ocho. Measurements are given in cm, and were taken from plants grown for this study. The vertical axis of the graph displays the mean length of the internodes of the plants of the race portrayed. The horizontal axis exhibits the modal number of nodes for the race of maize represented. The maize race Reventador is depicted by a solid line (____), and the maize race Harinoso de Ocho by a dashed line (-----). The position of the uppermost ear is marked by a triangle, and the base of the tassel by a dot at the end of the graph.

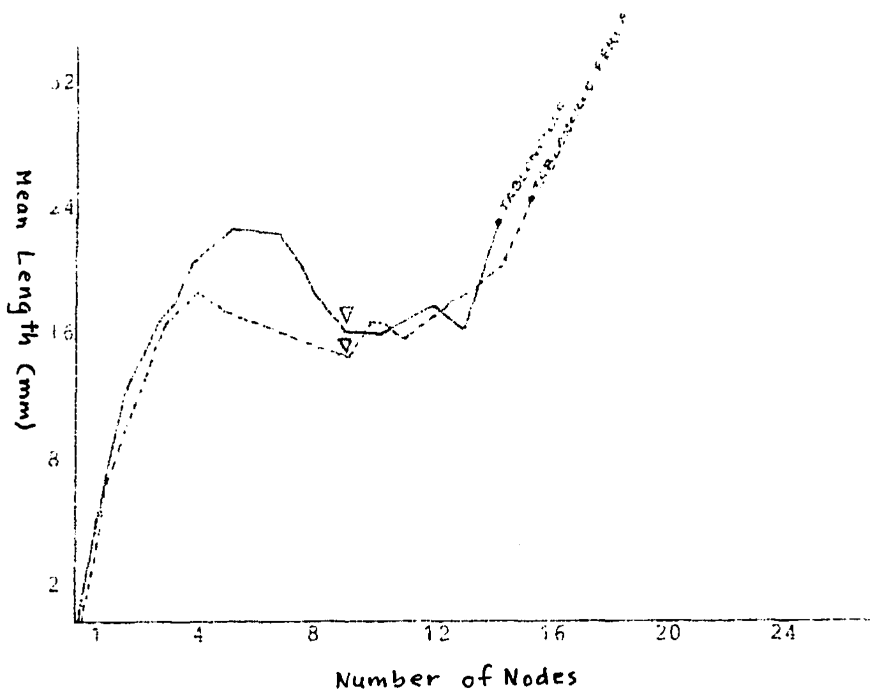

Figure 37. A Graphic representation of the internode patterns of the maize races Tabloncillo and Tabloncillo Perla. Measurements are given in cm, and were taken from plants grown for this study. The vertical axis of the graph represents the mean length of the internodes of the plants of the race portrayed. The horizontal axis exhibits the modal number of nodes for the race of maize represented. The maize race Tabloncillo is depicted by a solid line (____), and the maize race Tabloncillo Perla by a dashed line (-----). The position of the uppermost ear is marked by a triangle, and the base of the tassel by a dot at the end of the graph.

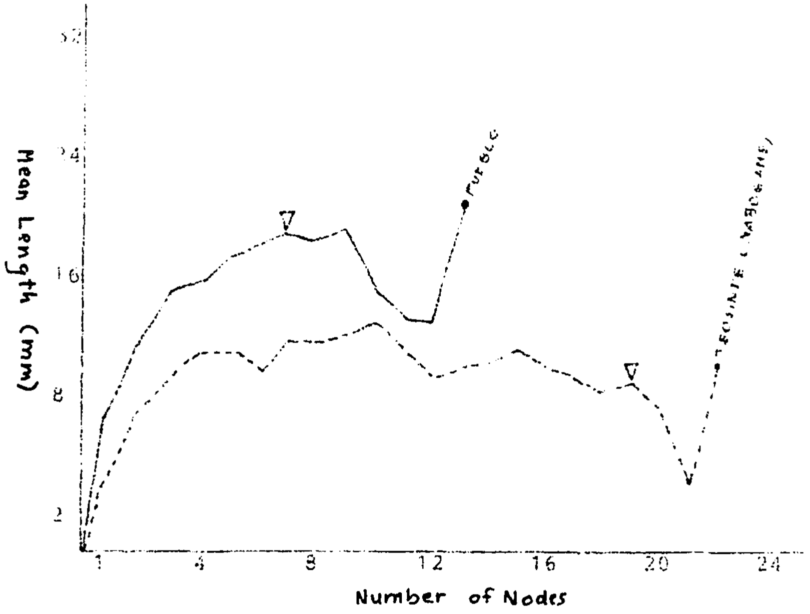

Figure 38. A Graphic representation of the internode patterns of the Southwest maize race Pueblo and the wild relative of cultivated maize, Nabogame teosinte (*Zea mays ssp. mexicana*). Measurements are given in cm, and were taken from plants grown for this study. The vertical axis of the graph represents the mean length of the internodes of the plants of the race portrayed. The horizontal axis displays the modal number of nodes for the race of maize represented. The maize race Pueblo is depicted by a solid line (____), and the wild relative of maize, Nabogame teosinte, by a dashed line (-----). The position of the uppermost ear is marked by a triangle, and the base of the tassel by a dot at the end of the graph.

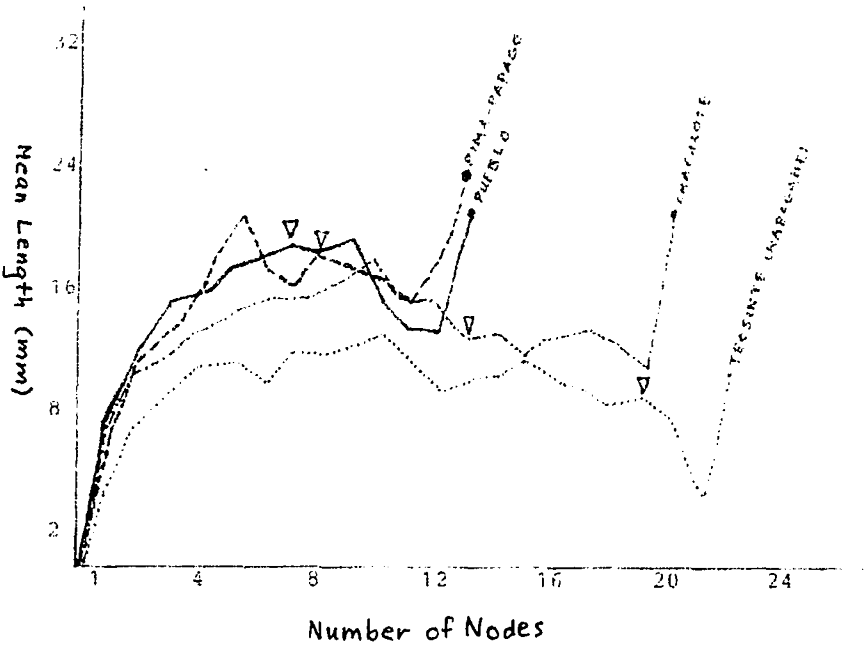

Figure 39. A Graphic representation of the internode patterns of the Southwest maize races Pueblo, Pima-Papago, Chapalote, and and the wild relative of cultivated maize, Nobogame teosinte (*Zea mays ssp. mexicana*). Measurements are given in cm, and were taken from plants grown for this study. The vertical axis of the graph represents the mean length of the internodes of the plants of the race portrayed. The horizontal axis displays the modal number of nodes for the race of maize represented. The maize race Pueblo is depicted by a solid line (____), Pima-Papago by a dashed line (-----), Chapalote by a dotted and dashed line (_._._._.), and Nabogame teosinte by a dotted line (.......). The position of the uppermost ear is marked by a triangle, and the base of the tassel by a dot at the end of the graph.

Table 30. Summary of Measurements of the Races of Maize of the Southwest, Taken from Living Plants Tested at Las Vegas, Nevada, Five Characteristics of the Tassels.

Race	Photograph	Length of Peduncle (Cm)	Tassel Length (Cm)	Length of Branching Space (Cm)	Percent of Branching Space	Length of Central Spike (Cm)
Chapalote Type	Fig. 58	24.4	44.7	15.8	35	27.5
Chapalote 89-38-41	Fig. 59	20.3	37.5	18.8	50	17.5
Chapalote MD8502	Fig. 60	16.5	48.7	15.5	31	30.6
Mean: Chapalote		20.4	43.4	16.7	38	25.2
Papago Flour	Fig. 61	20.3	45.4	15.1	33	29.6
Blando de Sonora	Fig. 62	22.5	49	23	47	25.6
Tohono O'odham	Fig. 63	24.9	35.9	9.5	26	10
Mean: Pima-Papago		22.5	43.4	15.8	35	21.7
Revent-ador	Fig. 64	16.2	57	20.3	36	35.8
Harinoso de Ocho	Fig. 65	14.3	47.6	21	44	26.6
Tabloncillo	Fig. 66	22.9	60.4	24	39	38
Tabloncillo Perla	Fig. 67	24.5	52.3	23.4	45	29.5
Moqui (Hopi) Blue	Fig. 68	24.8	40.1	19.3	48	27.9
Alamo-Navajo Blue	Fig. 69	23.1	54	18.6	34	30.1
Hopi Yellow	Fig. 70	12.6	40.5	11.6	28	28.8
Santo Domingo White	Fig. 71	22.9	46.4	19.4	41	24.7
Anasazi Flint/ Flour	Fig. 72	24.9	38.2	15.9	41	24.7
Mean: Pueblo		21.6	43.8	16.9	38	27.2
Nabogame Teosinte	Fig. 73	11	17.4	4.6	26	12

Table 31. Summary of Measurements of the Races of Maize of the Southwest, Taken from Living Plants Tested at Las Vegas, Nevada, Four Characteristics of the Tassels.

Race	Photograph	Length of Uppermost Primary Br. (Cm)	Total No. of Primary Branches	Total No. of Secondary Branches	Total No. of Tertiary Branches
Chapalote Type	Fig. 58	18.4	8.8	2	2.5
Chapalote 89-38-41	Fig. 59	9.3	19.2	2.5	1
Chapalote MD8502	Fig. 60	18	8.8	3	2
Mean: Chapalote		15.2	12.3	2.5	1.8
Papago Flour	Fig. 61	15.6	8.5	2.8	1.3
Blando de Sonora	Fig. 62	14.9	12.3	1.6	1.3
Tohono O'odham	Fig. 63	10	8.2	1.2	0.3
Mean: Pima-Papago		13.5	9.6	1.8	0.9
Revent-ador	Fig. 64	18.1	14.8	3.2	3
Harinoso de Ocho	Fig. 65	20.8	20.8	1	1
Tabloncillo	Fig. 66	19.9	12.5	5	1.3
Tabloncillo Perla	Fig. 67	13	12.5	2.3	2
Moqui (Hopi) Blue	Fig. 68	15.6	17.2	2.2	2
Alamo-Navajo Blue	Fig. 69	15.8	16.5	3.3	1.5
Hopi Yellow	Fig. 70	12.2	6.8	1	2.5
Santo Domingo White	Fig. 71	18.4	19.7	1.8	1.8
Anasazi Flint/ Flour	Fig. 72	19.5	13.5	2	1
Mean: Pueblo		16.3	14.7	2	1.8
Nabogame Teosinte	Fig. 73	7.1	3.8	2	0

By comparing the data in Tables 17-18, which are summaries of the measurements of cob morphologies synthesized from previous studies, to the data on cob morphologies gathered from the plants I grew for this study, summarized in Tables 25 and 26, it is obvious that there are morphological differences in the measurements of the cobs of the races of maize as grown here in the lowland Southwest, from measurements taken in other locales. Almost all of the earlier studies of maize, from which we get these earlier statistics, were conducted in regions other than the American Southwest. By comparing the data on the measurements of the living races of maize it can be seen that there are variations in row number, length of cob, and kernel thickness that may be due to local climate. The cob lengths of the living races Chapalote, Pima-Papago, and Pueblo are greater in the lowland Southwest, but the lengths of Reventador, Harinoso de Ocho, Tabloncillo, and Tabloncillo Perla are shorter.

The row number of the cobs also varied quite a bit in this test. Some of the races that were raised in Las Vegas under the conditions of heat and moisture stress had fewer rows of kernels on their cobs than the numbers reported for the same races in other studies. Other races did not. Row numbers were lower for Pima-Papago, Tabloncillo, and Pueblo, and higher for Reventador, Harinoso de Ocho, and Tabloncillo Perla. Interestingly, the average row number for the cobs of Chapalote as raised by this study was the same as that of those raised in the Mexican highlands. Some of the variations observed in row number may be due to variations in seed strains, but environmental factors (heat stress at the time of silking, pollen shed, fertilization, and ear formation) that do affect row number, as discussed earlier in this chapter, cannot be ignored, and are probably revealing themselves here.

Without exception, kernel thickness was greater in the lowlands. This was most likely a function of poor pollination, which enabled the kernels that were fertilized to grow larger, in the absence of neighboring kernels, whose presence would undoubtedly have restricted their size. Smaller cobs with fewer rows of kernels are thought to be a result of

moisture stress, as discussed earlier. Since this condition occurred on about half of the plants, it is probable that it was caused by moisture stress on the plants.

It is likely that the poor pollination observed on many of the cobs raised in the lowlands was also a result of moisture stress. As mentioned before, moisture stress during tasseling, silking, and fertilization may be quite detrimental to the rates of pollination of a crop of maize. High temperatures and high levels of evapotranspiration can induce moisture stress, which inhibits photosynthesis, and this in turn delays silking (Hall et al. 1981:27). If the interval between pollen shed and silking is extended by moisture stress, the plants may shed all or most of their pollen before the silks are ready to receive it. This appears to have been the case with some of the varieties and races of maize that I raised for this study. Pollination was especially poor on the cobs of Chapalote 89-38-41 (Figure 42), Chapalote MD8502 (Figure 43), Harinoso de Ocho (Figure 49), Tabloncillo Perla (Figure 50), and Santo Domingo White (Figure 54). High temperatures at the time of silking have been shown to reduce pollination and result in a number of aborted ears (Bebecel and Eftemescu 1973). As described previously, temperatures were very high during the summer of 1996, when the maize plants grown for this study were silking. Varieties that silked late were the ones that exhibited the poorest rates of pollination, except for Santo Domingo Flour. It is possible that Santo Domingo Flour is poorly adapted to lowland conditions, but Harinoso de Ocho and the two Chapalotes that silked late are supposed to be adapted to lowland desert conditions. Photoperiod can delay initiation of tasseling in maize, but this could be advantageous in hot climates, because tasseling, silking, and fertilization would take place during a cooler period of season, when the days approached 12 hours (during the month of September in Las Vegas), but the plants would be exposed to moisture stress for virtually the entire summer if planted in March. The plants I raised of both Chapalote MD8502 and Harinoso de Ocho tasseled late, and shed all their pollen at least a week before they began to silk. I believe that the reason this happened was that the plants were reacting to weeks of moisture stress.

The races and varieties that pollinated the best, and had ears filled with kernels, all silked and matured earlier rather than later. These included Chapalote Type (Figure 41), Pima-Papago (Figure 44), Tohono O'odham (Figure 46), Moqui Blue (Figure 51), Hopi Yellow (Figure 53), and Anasazi Flint/Flour (Figure 55). All of these matured within 115 days, and all were races or varieties known and commonly raised in the American Southwest today, with the exception of Chapalote. This does bring in the issue of environmental and human selection. Farmers would tend to save and plant the seed from maize ears that were filled with kernels. This has been shown to be the case with several of the indigenous peoples of the Southwest (Chapter 5). By planting seeds of maize plants that had ears that were well-pollinated, they would be automatically selecting for maize genotypes that would pollinate under conditions of heat and moisture stress.

In Tables 27-29 the effects of low altitude and high temperatures on the vegetative characters of plants of the races of maize of the Southwest can be seen. When measurements presented here are compared with those of previous studies made in cooler climates at higher altitudes, it can be seen that maize plants grow much larger in the hot desert lowlands. When compared with data presented in Wellhausen et al. (1952:211) the plants I raised of Chapalote were 48% taller, the plants of Reventador were 40% taller, and the plants of Harinoso de Ocho were 39% taller. The leaf area calculation in Table 28 undoubtedly would be much higher for plants grown in the lowlands, than that for the same plants grown at higher, cooler altitudes.

Figures 35-39 reveal the internode patterns of the races I tested. The triangle symbol indicates the position of the uppermost ear on the stalk and the last internode shown is marked by a dot that indicates the base of the tassel peduncle. The plants of these races, as grown in the hot lowlands of the Southwest, do not appear to have longer nodes than those grown at higher altitudes and cooler temperatures, but they do have a greater total number of nodes, which means that some races of maize are quite influenced environmentally. Some did not grow much taller than previous studies indicated.

Tabloncillo, for example, only grew 7% taller. I would also suspect that some of the Pueblo maize varieties do not grow as tall in the highlands of the Colorado Plateau as they do here in the lowlands.

In Figures 35-39, the graphs of internode patterns of the races of maize raised for this test are presented. The greater height of the plants and the greater number of leaf nodes of maize plants as grown in the lowland Southwest are quite evident. The graphs I have constructed bear close comparison with those of the same races of maize presented in Races of Maize in Mexico (Wellhausen et al. 1952). The race Harinoso de Ocho, as grown in Las Vegas, exhibited 18 nodes, while it only exhibited 12 at Chapingo (Figure 36) and (Wellhausen et al. 1952:223). The internode patterns of Reventador and Tabloncillo were similar to those displayed in Wellhausen, but the internode patterns of Chapalote and Harinoso de Ocho were quite different.

In Figure 35 the internode pattern of Chapalote, constructed from measurements of plants grown here in the lowland Southwest, is much different than the internode pattern graphed for Chapalote in Wellhausen et al. (1952:223). Plants of Chapalote (averaged from three samples with a total of 18 plants) as grown in the lowland Southwest exhibited twenty nodes, while those grown at Chapingo, Mexico, only exhibited eight nodes. The reason for this may be that the seeds collected of the lowland-adapted race of Chapalote were taken to the Mexican highlands by Wellhausen et al. (1952) and grown under the dissimilar environmental conditions there. The highland conditions of Chapingo are very different from those under which Chapalote is grown in the lowland habitat where it is most often planted (in Sonora and Chihuahua). By basing the racial definition of Chapalote on statistics taken from plants grown out of their most frequent environmental context (the low desert), Wellhausen et al. (1952) produced a distorted statistical definition of Chapalote. This definition heightened its primitive aspects, and did not emphasize the aspects of its productivity, wind-resistance, and special adaptability to varying altitudes and to extremes of heat and moisture stress. Wellhausen et al.'s (1952)

racial definition of Chapalote also did not explore its relationship to teosinte.

In studying the internode diagrams I constructed from the measurements of the plants I tested, I was struck by the similarity of the internode pattern of Chapalote to the probable wild ancestor of maize, teosinte. I displayed the internode patterns of Chapalote and teosinte together in Figure 39. It may be that Chapalote often introgresses with teosinte in its Mexican habitat, because Chapalote tends to enter its reproductive cycle very late (or at the same time), as does teosinte. Plants of Chapalote could receive pollen from teosinte, and hybridity could be one reason for their similar internode patterns.

Also shown in Figure 39 are the internode patterns of the two races of maize that were developed in the American Southwest, Pima-Papago and Pueblo. Their internode patterns are very similar, and this is another example of their morphological similarity, though they are not all that closely related isozymically (Figure 34).

In Tables 30-31 are summaries of the measurements of the characters of the tassels of the living races of maize having affinities to or descended from the races of maize of the Southwest. Without exception, the lengths of the tassels of the plants grown in the lowlands of the Southwest were greater than the tassel lengths of those grown and measured in cooler, highland climates (Wellhausen et al. 1952:212). The percent of the branching space of the tassel was also greater in the lowlands. This greater length of the tassels and tassel branching space could also be a function of the high growing temperatures of the lowland desert climate.

The shapes of the plants and the tassels of the races of maize of the Southwest can be seen in Figures 58 through 73, in photographs of the plants that were raised for this study. Most of the plants of these races have rather open tassels, without an abundance of tassel branches, which may be another indicator of the genetic interrelationships of the races of maize of the Southwest.

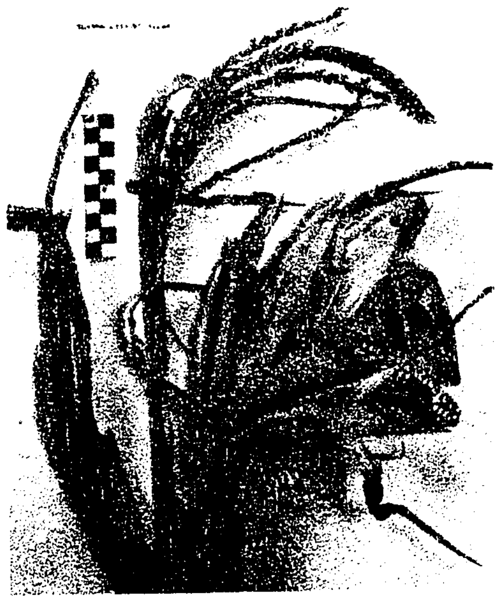

Figure 40. Tohono O'odham Flour.

Figure 41. Chapalote Type.

Figure 42. Chapalote 89-38-41.

Figure 43. Chapalote MD8502.

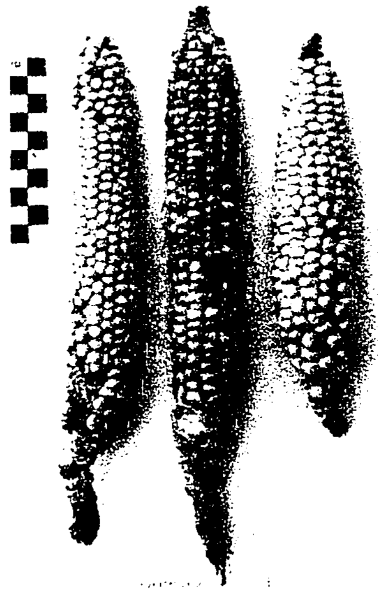

Figure 44. Papago Flour.

Figure 45. Blando de Sonora.

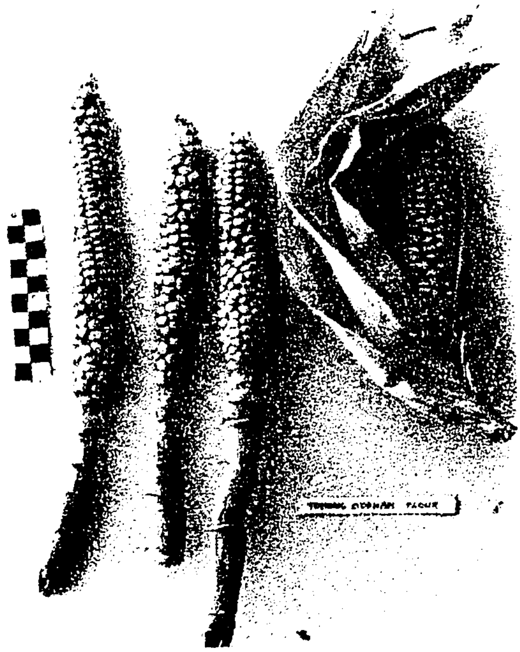

Figure 46. Tohono O'odham Flour.

Figure 47. Reventador.

Figure 48. Harinoso de Ocho.

Figure 49. Tabloncillo.

Figure 50. Tabloncillo Perla.

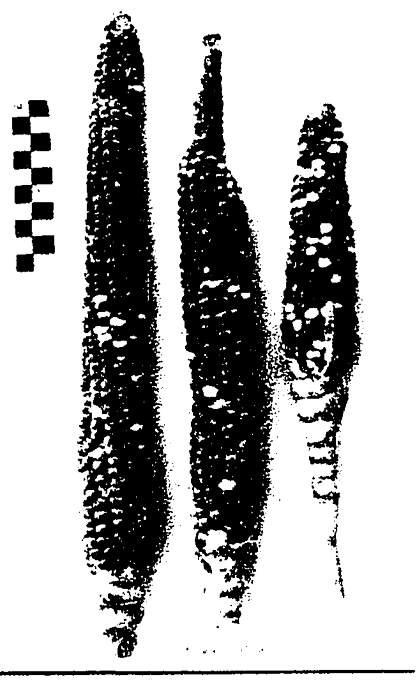

Figure 51. Moqui (Hopi) Blue Flour.

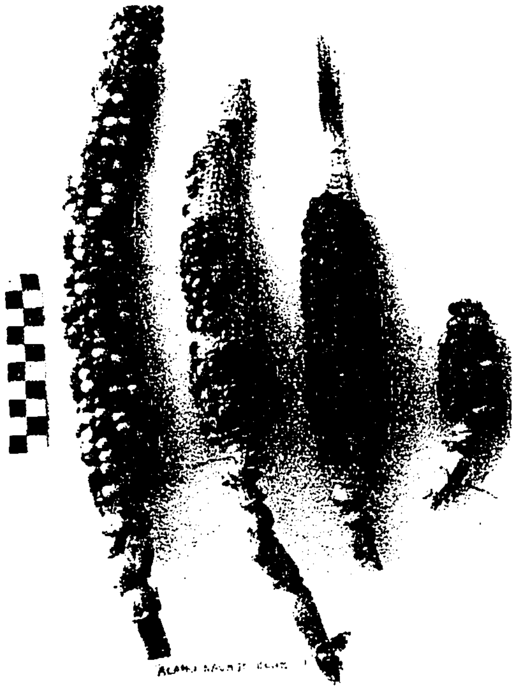

Figure 52. Alamo-Navajo Blue Flour.

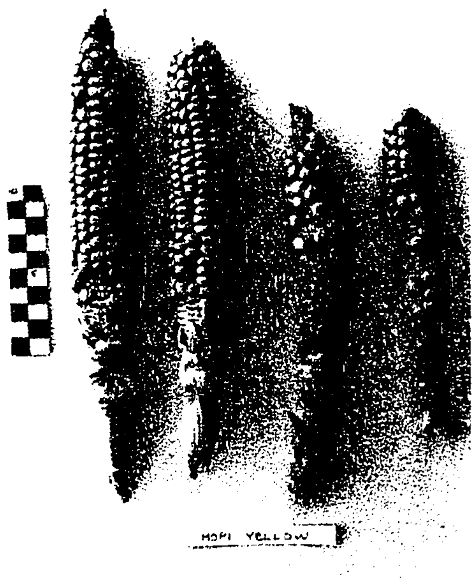

Figure 53. Hopi Yellow Flour.

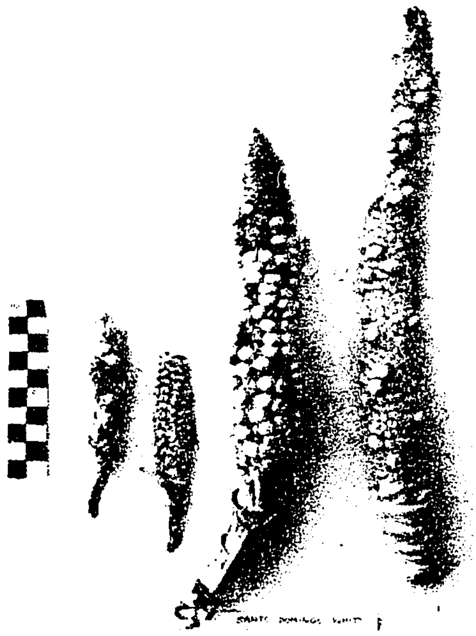

Figure 54. Santo Domingo White Flour.

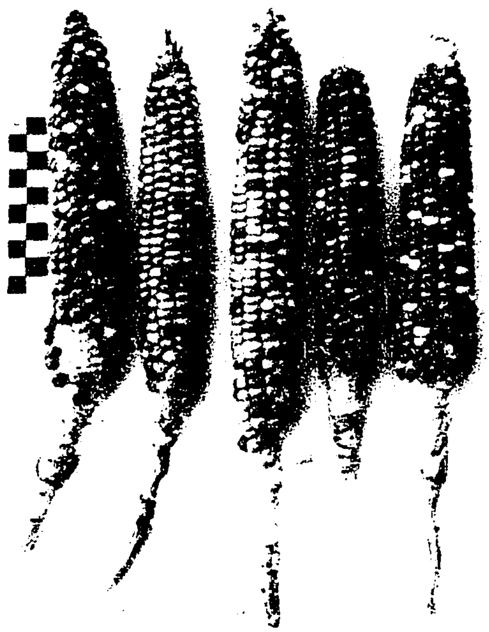

Figure 55. Anasazi Flint/Flour.

Figure 56. Nabogame Teosinte (*Zea mays ssp. mexicana*).

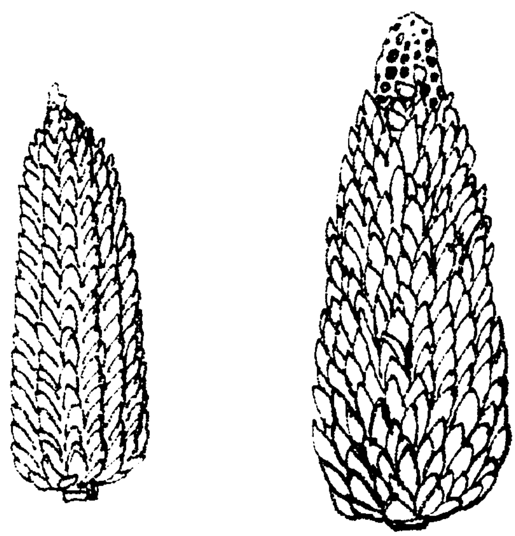

Figure 57. Pepitilla. Drawn by the author, after Wellhausen et al. (1952).

Figure 58. Chapalote Type. Plant is bisected.

Figure 59. Chapalote 89-38-41. Plant is bisected.

Figure 60. Chapalote MD8502. Plant is bisected.

Figure 61. Papago Flour. Plant is entire.

Figure 62. Blando de Sonora. Plant is bisected.

Figure 63. Tohono O'odham Flour. Plant is entire.

Figure 64. Reventador. Plant is bisected.

Figure 65. Harinoso de Ocho. Plant is bisected.

Figure 66. Tabloncillo. Plant is Bisected.

Figure 67. Tabloncillo Perla. Plant is bisected.

Figure 68. Moqui (Hopi) Blue Flour. Plant is bisected.

Figure 69. Alamo-Navajo Blue. Plant is entire.

Figure 70. Hopi Yellow Flour. Plant is entire.

Figure 71. Santo Domingo White Flour. Plant is bisected.

Figure 72. Anasazi Flint/Flour. Plant is entire.

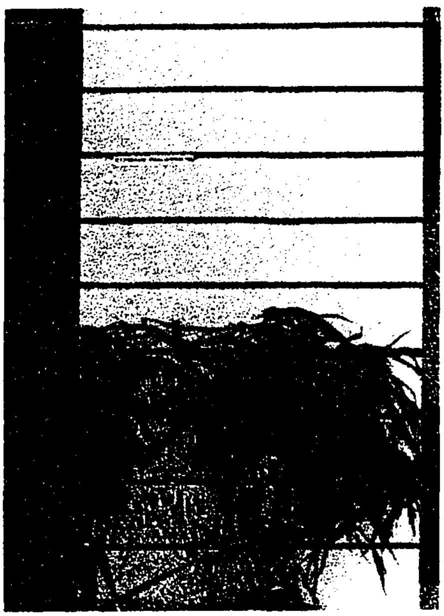

Figure 73. Nabogame Teosinte *(Zea mays ssp. mexicana)*. Plant is entire.

CHAPTER 8

A SYNTHESIS OF THE MAIZE OF THE PREHISTORIC SOUTHWEST

Remains of maize have been found at archaeological sites in the Southwest that have dated as old as 3,000 B.P. Macro-remains of maize have been radiocarbon dated to 3175±240 B.P. from Tornillo Shelter, Mogollon region (Upham et al. 1987:412). Maize remains from Bat Cave, which is also in the Mogollon region, have been radiocarbon dated to 3120±70 B.P. (Wills 1988:108-109). Very early macro-remains of maize have been recovered in the Anasazi region, on the Colorado Plateau, in the area of Chaco, that radiocarbon dated to 2720±265 B.P. (Simmons 1986:70-80). Also, maize radiocarbon dated to 2780±90 B.P. was found in southern Arizona at the Milagro site (Huckell 1988:61). From these very old dates on maize from the Southwest, it appears that maize was being grown in very diverse climates in may areas of the Southwest between 3,000 and 2,700 years ago. Radiocarbon dates on charcoal in association with maize pollen have dated earlier than the preceding dates from actual maize samples, but as charcoal often dates older than its time of burning ("old wood" may have been used as fuel), those dates have not been included here.

In this chapter, Tables 32-42 are summaries of the measurements of maize cobs from sites of the prehistoric period of the Southwest. These statistical tables enhance this discussion of early maize of the Southwest by quantifying as much information as possible about the evolution and changes of maize during prehistoric times, from its introduction in

the Late Archaic period, to about A.D. 1450. The methods used to measure the maize synthesized here are essentially the same as those I described and used to measure the maize from Black Dog Cave, and to measure the living maize described in the last chapter. Since so much early data on the morphology of maize found in the Southwest has not been published, I am forced in these statistical tables to list the measurements of only four of the morphological characters of the cob: row number, cupule width, kernel thickness, and assignment to race by researcher. These tables are separated into collections of maize from specific time periods, roughly corresponding to the chronology of the Pecos Classification of Anasazi prehistory designed by Kidder in 1929. The tables are also separated as to altitude, with high altitude sites above 1548 m (5,000 feet) separated from those of lowland sites below that altitude.

As discussed in Chapter 7 of this volume, the earliest maize in the Southwest is thought to have belonged to the races proto-Maiz de Ocho and pre-Chapalote. These were followed by the introduction of, or by the selection for, the larger cobs of Chapalote. Cobs of maize resembling the modern living race Chapalote were found at Bat Cave (Wills 1988:109). As has been previously mentioned, Chapalote was essentially a lowland race, but was adaptable and could form ears at fairly high elevations. From the data gathered in Chapter 7, it can be seen that living plants of Chapalote are wind-resistant and productive, with an average of 3.7 ears per plant (see Table 28). Chapalote, as an altitudinally adaptable and productive race that withstood arid conditions, was the most successful candidate for the adoption of maize cultivation by peoples of the Southwest during the Archaic period. Table 32 lists Archaic period sites where pre-Chapalote has been found. These early cobs were quite small, and row numbers were a bit higher in the lowland sites than the highland sites. Early Chapalote from Tumamoc Hill and the Alvey site had a mean row number (12.5) very close to that of modern, living examples of Chapalote (12.3) (see Table 25). True Chapalote from Tularosa Cave is listed in Table 35, and is listed along with contemporary collections of mostly Basketmaker maize. Overall, row

Table 32. Summary of Measurements of Maize Cobs from Archaic Period Sites of the Southwest, Measured For Four Characteristics.[a]

Site	Sample Number	Row Number	Cupule Width (Cm)	Kernel Thickness (Cm)	Type or Racial Assignment
Highland Sites (Above 1548 M)					
Bat Cave Level 1	1	10.7	-	-	pre-Chapalote
Tularosa Cave, Level 14	2	11.5	-	-	pre-Chapalote
Mean:		11.1	-	-	pre-Chapalote
Lowland Sites (Below 1548 M)					
Alvey Site	3	12	-	-	flint
Tumamoc Hill, AZ	4	13	3.8	-	early Chapalote

[a] Data from (by sample number): (1) Mangelsdorf (1949:219); (2) Cutler (1952:461-479); (3) Geib (1996:39); (4) Fish et al. (1986:569).

numbers during the Basketmaker II period A.D. 50 to A.D. 500 appear to have been rather high, with a mean of 12.8 rows for all highland sites (Table 33). It is interesting that the mean row numbers for the same period were lower in the lowlands (only 10.9, Table 34), though the sample here is admittedly small.

Reventador is another very early race of maize grown in the Southwest, and as a living race is also quite productive, producing an average of five ears per plant. It is adapted to, and was usually found, at lower elevation archaeological sites in the Southwest (Anderson 1950:162-163; Bohrer et al. 1969:3-4; Cutler and Blake 1975:268). The first listing of Reventador shown in Tables 32-42, which quantify the measurements

Table 33. Summary of Measurements of Maize Cobs from Highland Sites of the Southwest, A.D. 50 to A.D. 500, Measured For Four Characteristics.[a]

Sites (All Above 1548 M)	Sample Number	Row Number	Cupule Width (Cm)	Kernel Thickness (Cm)	Type or Racial Assignment
Cottonwood Cave	1	14.2	-	6.5	Basketmaker
Cave Dupont	2	14	-	-	Basketmaker (flint/flour)
Navajo Mt. Sites	3	11.8	6.9	-	Onaveno
Durango, CO Area Sites	4	13	-	-	Basketmaker/ Mex. Complex
Talus Village (Floor 2a)	5	-	-	3.7	-
Talus Village (North Shelter)	6	11	-	5	-
Tularosa Cave Level 9	7	12	-	4.7	Chapalote
White Dog Cave	8	14	-	4.3	Basketmaker
Mean:		12.8	6.9	4.8	Basket/ Onaveno/ Chap/Mex.

[a] Data from (by sample number): (1) Hurst and Anderson (1949:161-167); (2) Nusbaum (1922:67-70); (3) Cutler (1968:371-378); (4) Jones and Fonner (1954:93-115); (5) Jones and Fonner (1954:93-115); (6) Jones and Fonner (1954:93-115); (7) Cutler 1952:461-479); (8) Nicherson (1953:84-97).

of archaeological cobs of maize from the Southwest, is from a site dating to the period A.D. 900 to A.D. 1000. Undoubtedly Reventador did occur much earlier than this date. Early maize remains are sometimes difficult to assign to race, or are so fragmentary that they defy description, and this may be why more maize belonging to the race Reventador has not been identified in archaeological collections.

The early races pre-Chapalote, proto-Maiz de Ocho, Chapalote, and Reventador were all races of maize that possessed a hard, flinty endosperm and would be classified as

Table 34. Summary of Measurements of Maize Cobs from Lowland Sites of the Southwest, A.D. 50 to A.D. 500, Measured For Four Characteristics.[a]

Sites (All Below 1548 M)	Sample Number	Row Number	Cupule Width (Cm)	Kernel Thickness (Cm)	Type or Racial Assignment
Triangle Cave, UT	1	11.3	6.6	-	-
Pantry Alcove, UT	2	11.5	7.1	4	Fremont Dent/ Onaveno
Ventana Cave	3	11	-	-	Pima-Papago
Mean:		10.9	6.8	4	F. Dent/ Onaveno/ Pima-Papago

[a] Data from (by sample number): (1) Geib (1996:84, 88); (2) Geib (1996:84, 88); Cutler (1966:25); (3) Haury (1974:161-169).

pop or flint maize. Another early race, the flint maize race Onaveno, was evident in the Southwest about 2300 B.P., and was found at Snaketown (Cutler and Blake 1976:365). Basketmaker maize, the flour variant of Onaveno, began to appear in the Southwest about A.D. 50 (Table 33). It is possible that peoples such as those that inhabited the regions in the proximity of White Dog Cave and Cave Dupont were purposefully selecting for forms of Onaveno with floury endosperms, and through this action, created the floury variant of Onaveno known as the Basketmaker race. This is significant culturally, because flour maize is more easily ground into meal than flint maize. Conversely, environmental selection does favor flint maize, because it is more resistant to insects in storage, and in the field. Onaveno and Basketmaker are represented today by the living race of flour maize Pima-Papago, which has thicker kernels and larger, longer cobs than its prehistoric forms (Tables 17-18, and Figures 44 and 46).

The similarity of the maize from Black Dog Cave (see Tables 9-14) to other Basketmaker II maize is evident by comparing it to the statistics in Table 33. Row number at Black Dog

Table 35. Summary of Measurements of Maize Cobs from Highland Sites of the Southwest, A.D. 500 to A.D. 700, Measured For Four Characteristics.[a]

Sites (All Above 1548 M)	Sample Number	Row Number	Cupule Width (Cm)	Kernel Thickness (Cm)	Type or Racial Assignment
BR-45 Site	1	11.2	5.7	-	Maiz de Ocho/ Pima-Papago
Durango Sites, North Shelter	2	13.3	-	4	Basketmaker/ Mex. Complex
Durango Sites, South Shelter	3	-	-	5	Fremont Dent/ Basketmaker
Durango Sites, BM III	4	12	7.3	3.3	Pima-Papago
Black Mesa, BM III Sites	5	11.8	5.4	-	Onaveno
Tularosa Cave Level 6	6	11	-	5	Maiz de Ocho/ Chapalote
Caldwell Village	7	11.8	7.6	-	Fremont Dent/ Onaveno
Yampa Canyon	8	-	-	-	Fremont Dent/ Pepitilla
Boca Negra Cave	9	-	4.5	-	Maiz de Ocho/ Pima-Papago
Artificial Leg Site	10	13.2	-	-	Maiz de Ocho/ Pima-Papago
Mean:		12	6.1	4.3	F. Dent/Onav/ M. de O/Pima/ Mex C./ Chap/Basket

[a] Data from (by sample number): (1) Galinat et al. (1970:313-331); (2) Jones and Fonner (1954:93-115); (3) Jones and Fonner (1954:93-115); (4) Cutler (1963:46-47); (5) Cutler and Blake (1976:106); (6) Cutler (1952:461-479); 1956:174-183); (7) Cutler 1966:113-118); (8) Anderson (1948:92); (9) Galinat et al. (1970:313-331); (10) Galinat et al. (1970:313-331).

Cave had a mean of 12.3, and the maize from highland Basketmaker sites had a mean row number of 12.8. The mean cupule width at Black Dog Cave is 6.8 mm, and the mean cupule width from highland Basketmaker sites is 6.9 mm. The mean kernel thickness at Black Dog Cave (3.5 mm) is much less than that at the combined highland Basketmaker II

Table 36. Summary of Measurements of Maize Cobs from Lowland Sites of the Southwest, A.D. 500 to A.D. 700, Measured For Four Characteristics.[a]

Sites (All Below 1548 M)	Sample Number	Row Number	Cupule Width (Cm)	Kernel Thickness (Cm)	Type or Racial Assignment
Canyon del Muerto	1	12.3	-	-	Pima-Papago
Sheep Horn Alcove	2	11.3	7.9	-	Fremont Dent
Sheep Horn Alcove	3	13.7	-	4.2	Fremont Dent
Hogup Cave	4	9.6	-	-	Fremont Dent/flints
Gila Bend Sites	5	12	3	3.2	Chapalote
Mean:		11.8	5.8	3.7	Pima-P/F. Dent Chap/flints

[a] Data from (by sample number): (1) Anderson and Blanchard (1942:834-835); (2) Geib (1996:84); and Cutler 1966:25); (3) Geib (1996:84); and Cutler (1966:25); (4) Cutler (1970:27); (5) Cutler (1965:108-109).

sites (4.3 mm.). Maize from lowland Basketmaker II sites had a lower mean row number (10.9) than did the maize at Black Dog Cave (12.3).

There is a great deal of statistical similarity of the Black Dog Cave maize to the maize from lowland sites of the Southwest of the period A.D. 500 to A.D. 700 (Table 36). The mean row number at Black Dog Cave (12.3) compares well with the mean row number from all lowland sites of the period (11.8), and the mean kernel thickness at Black Dog Cave was 3.5 mm, while the mean kernel thickness of all other sites combined was 3.7 mm. The small mean kernel size at Black Dog Cave is most likely a reflection of the abundance of the remains of the flint form of Basketmaker maize, Onaveno, which has a small kernel size than the larger kernels of other races grown during this period. As discussed in Chapter 7, the statistics of measurement of prehistoric Onaveno maize are very close to those of the maize from Black Dog Cave. In addition, the similarities of the

Table 37. Summary of Measurements of Maize Cobs from Both Highland and Lowland Sites of the Southwest, A.D. 700 to A.D. 900, Measured For Four Characteristics.[a]

Site	Sample Number	Row Number	Cupule Width (Cm)	Kernel Thickness (Cm)	Type or Racial Assignment
Highland Sites (Above 1548 M)					
Antelope Hse.	1	10.7	7.2	3.5	-
Tularosa Cave Level 4	2	9.3	-	4.6	Maiz de Ocho
Chaco Canyon (3 Sites)	3	10.3	-	-	Mixture
Mean (H. Sites):		10.1	7.2	4	Mixture of Races
Lowland Sites (Below 1548 M)					
Snaketown AZ	4	13.4	-	-	Pima-Papago
Mean L. Sites):		13.4	-	-	Pima-Papago

[a] Data from (by sample number): (1) Morris (1986:115-128); (2) Cutler (1952:461-479; 1956:177); (3) Winter (1983:430); (4) Cutler and Blake (1975:270); (5) Cutler (1965:108-109).

statistics of Black Dog Cave to those of the sites from the period A.D. 500 to A.D. 700 reflect the continued occupation at Black Dog Cave through that time.

The possible origin of Fremont Dent maize was as a hybrid form of Basketmaker maize and the Mexican mid-altitude race Pepitilla, during Late Basketmaker II (about A.D. 400); this was discussed in Chapter 7. The route of the introduction of Mexican pyramidal forms of maize into the prehistoric Southwest has long been speculated, as no examples of early dented, beaked, or pointed kernels have been found along the general pathway of Chapalote forms of maize from Mexico (through the Mogollon region and into

Table 38. Summary of Measurements of Maize Cobs from Highland Sites of the Southwest, A.D. 900 to A.D. 1000, Measured For Four Characteristics.[a]

Highland Sites (All Above 1548 M)	Sample Number	Row Number	Cupule Width (Cm)	Kernel Thickness (Cm)	Type or Racial Assignment
Higgins Flat Pueblo	1	10.5	-	4.8	Pima-Papago
Spadefoot Toad Site	2	10	6.2	4.6	-
Guadalupe Ruin (Chacoan Occupation)	3	9.8	5.3	3.2	Maiz de Ocho
Tsegi Canyon	4	11.2	-	-	Pueblo/flint/ pop
Salmon Ruin (Chacoan Occupation)	5	11.9	-	-	flour/flint/ pop
Pueblo Alto (Chaco)	6	10.5	-	-	-
Bis sa'ani Ruin	7	10.1	5.5	-	-
Pueblo Bonito (Mesa Verdean Occupation)	8	11.6	-	-	-
Lower Chaco River Sites	9	10.8	5.1	-	-
Mean:		10.7	5.5	4.2	Mixture

[a] Data from (by sample number): (1) Cutler (1956:174-183); (2) Toll (1983:331-350); (3) Pippin (1987:139-140); (4) Jones and Fonner (1971:3); (5) Doebley and Bohrer (1983:19-37); (6) Donaldson and Toll (1982:1099-1180); (7) Donaldson and Toll (1982:1099-1180); (8) Winter (1983:430); (9) Winter (1983:441).

the Colorado Plateau area). Before this study, the true origin of Fremont Dent was unknown, and little evidence of dented, beaked, or pointed kernels had been reported from lowland areas. In reviewing the literature on all of the sites of the Southwest that had statistical information on maize, I discovered that dented kernels of maize had been found in a burial at Mesa House, as described by Schellbach (1930:101). The maize from this

Table 39. Summary of Measurements of Maize Cobs from Lowland Sites of the Southwest, A.D. 900 to A.D. 1000, Measured For Four Characteristics.[a]

Lowland Sites (All Below 1548 M)	Sample Number	Row Number	Cupule Width (Cm)	Kernel Thickness (Cm)	Type or Racial Assignment
Paiute Cave (Puebloan)	1	11.5	-	4.8	flint/flour
Gila Bend Sites	2	12	-	3.6	Reventador/ Pima-P/ Maiz de Ocho
ZNP-21 AZ	3	11.5	-	5	Pima-Papago/ Fremont Dent
Alvey Site	4	12	7.5	-	-
Triangle Cave, UT	5	11	7.6	3.9	Fremont Dent
Grand Canyon Sites	6	8	8.3	-	Onaveno/ Pima-Papago/ Fremont Dent
Mean:		11	7.8	4.1	Mixture

[a] Data from (by sample number): (1) Harrington (1930:116-117); (2) Cutler (1965:108-109); (3) Jones (1955:183); (4) Geib (1996:39); (6) Cutler and Blake (1980:209-212).

burial probably dated to between A.D. 1150 to A.D. 1250. Schellbach said that the grains of maize from this burial were of the type that "...approaches the pointed peg shapes of the grains of dent [maize]." This evidence of shoe-peg type kernels of maize (Pepitilla maize) in the Moapa Valley, several hundred years later than the Yampa Canyon, may reveal some interesting possibilities. There probably was an exchange of maize between the Virgin Anasazi and Fremont. Also, Pepitilla maize was possibly grown in the lowlands, and the pathway of introduction of Pepitilla maize might have been through the lowlands, and not necessarily through the highlands. The Moapa Valley is the farthest west location, and one of the few lowland locations, in which any kernels of this distinctive maize have been found that dated to the prehistoric period. To further investigate the possibility that

Table 40. Summary of Measurements of Maize Cobs from Highland Sites of the Southwest, A.D. 1150 to A.D. 1300, Measured For Four Characteristics.[a]

Highland Sites (Above 1548 M)	Sample Number	Row Number	Cupule Width (Cm)	Kernel Thickness (Cm)	Type or Racial Assignment
Guadalupe Ruin (Mesa Verdean Occupation)	1	11.4	5.6	3.4	Early Pueblo
Salmon Ruin (Mesa Verdean Occupation)	2	11.5	-	4.7	flour/flint/ pop
Westwater Ruin	3	10	7	4	M. de O/ Chapalote
Red Bow Cliff Dwelling	4	9.5	-	-	Pima-Papago/ Chapalote
Carter Ranch Site	5	13	-	-	Pima-P/Ona/ Chapalote
Wetherill Mesa	6	12.9	-	-	Pima-P/Ona/ Reventador
Step House (Mesa Verde)	7	9.3	-	-	Onaveno/ M. de Ocho
Long House (Mesa Verde)	8	9.5	-	-	Onaveno/ M. de Ocho
Mug House (Mesa Verde)	9	9.4	-	-	Onaveno/ M. de Ocho
Antelope Hse. (Middle P III)	10	11.2	7.2	3.9	flour/flint
Antelope House (Late P III)	11	10.8	8	4	flour/flint
Casa Grandes, Mexico	12	9.2	5.7	-	Ona/M. de O/ M. Blando
Casa Grandes, Mexico	13	9.9	5.7	-	Ona/M. de O/ M. Blando
Mean:	10.6		6.5	4	Mixture

[a] Data from (by sample number): (1) Pippin (1987:139-140); (2) Doebley and Bohrer (1983:19-37); (3) Winter (1981:180-181); (4) Cutler and Blake (1980:183-189); (5) Cutler (1964:227-234); (6) Cutler and Meyer (1965:136-190); (7) Cutler (1965:136-190); (8) Cutler (1965:136-190); (9) Cutler (1965:136-190); (10) Morris (1986:115-128); (11) Morris 1986:115-128); (12) Cutler (1974:76); (13) Cutler (1974:76).

Table 41. Summary of Measurements of Maize Cobs from Lowland Sites of the Southwest, A.D. 1150 to A.D. 1300, Measured For Four Characteristics.[a]

Lowland Sites (Below 1548 M)	Sample Number	Row Number	Cupule Width (Cm)	Kernel Thickness (Cm)	Type or Racial Assignment
Defiance House	1	10.8	-	-	flint/dent
Bobocomari Village	2	11	-	3.5	Pima-Papago/ Pueblo
Escalante Ruin	3	10.1	5.4	-	Onaveno
Tonto Cliff Dwelling	4	10.1	-	4.5	Pima-Papago/ Chapalote
Gila Bend Sites	5	13.7	-	-	Pima-P/Ona/ Chapalote
Mesa House, Moapa Valley	6	8	-	-	Pepitilla/ flint/pop
Mean:		10.6	5.4	4	Mixture

[a] Data from (by sample number): (1) Cutler (1966:25, 40); (2) Jones (1951:15-19); (3) Hall (1974:203); (4) Steen et al. (1962:100-103); (5) Cutler and Blake (1975:270); (6) Schellbach (1930:101).

the pathway of pyramidal forms of maize might have been a lowland one, more research needs to be done on collections of maize from the lowland Southwest of the prehistoric period . Listed In Table 34 is one of the first appearances of Fremont Dent, from Pantry Alcove, Utah (contemporaneous with Basketmaker II), and in Table 35, there are several listings of the appearance of Fremont Dent maize in sites of the period from A.D. 500 to A.D. 700.

The maize race Maiz de Ocho, as it is defined, first appeared in the Southwest in the Mogollon region at Tularosa Cave and Bat Cave during the Georgetown Phase,

Table 42. Summary of Measurements of Maize Cobs from Both Highland and Lowland Sites of the Southwest, A.D. 1300 to A.D. 1450, Measured For Four Characteristics.[a]

Site	Sample Number	Row Number	Cupule Width (Cm)	Kernel Thickness (Cm)	Type or Racial Assignment
Highland Sites (All Above 1548 M)					
Clanton Draw, New Mexico	1	11.1	5.8	3.7	Pima-Papago/ Onaveno
Box Canyon Site	2	10.7	7.7	4.2	Pima-P/Pueblo Onaveno
Mean:		10.9	6.7	3.9	Pima-Papago/ Pueblo/ Onaveno
Lowland Sites (All Below 1548 M)					
Gila Bend Sites	3	12	-	-	Pima-Papago
(S. Paiute Occ.)	4	11	-	-	flint/flour
Mean:		11.5	-	-	Pima-Papago/ flint/flour

[a] Data from (by sample number): (1) Cutler and Eickmeir (1962:48-54); (2) Cutler and Eickmeir (1962:48-54); (3) Cutler (1965:108-109); (4) Harrington (1930:122-123).

between A.D. 500 and A.D. 700 (Cutler 1952:461-479). After A.D. 700, eight-rowed forms of maize appeared with much greater frequency all over the Southwest, in both lowland and highland sites, but they were much more frequent in highland sites. Whether the reason for this was cultural selection by highland groups for eight-rowed forms, or that there is stronger environmental selection for eight-rowed cobs at higher altitudes, is difficult to say. The increasing numbers of eight-rowed forms of maize could be very well

be caused by a combination of both human and environmental selection.

As discussed in the summary of several studies of the environmental effects on maize summarized in Chapter 7, fewer row numbers in maize cobs can be caused by both cooler temperatures, drought, or moisture stress. But Maiz de Ocho is a flour maize, and its appearance in the Mogollon region in the period A.D. 500 to A.D. 700 may well be partly due to the fact that flour maize was valued culturally, because of the ease of grinding it into meal.

Eight-row maize became common in the northern Southwest during the period A.D. 900 to A.D. 1100 and later (Table38). This increase in frequency of eight-rowed cobs took place at some Chaco Canyon sites and Chaco outliers, but not at all (Donaldson and Toll 1982; Pippin 1987; Winter 1983). Later, during the A.D. 1115-1220 Mesa Verdean occupations of the Chacoan region and at Mesa Verde itself, eight-rowed forms were the most frequent type of maize grown, judging from the remains found. At other contemporaneous nearby sites, such as Guadalupe Ruin and Salmon Ruin, the situation was reversed, and types of maize were grown that produced cobs with higher row numbers (Table 40). Maize cobs from very late occupations at Mesa Verde have very low mean row numbers, including those from the cliff dwellings of Step House, Long House, and Mug House. Because eight-rowed maize is so often found at highland sites, it may be a distinct possibility that Maiz de Ocho of the prehistoric highland sites was specially selected to grow in dryland plots, and so was infrequent in the lowlands, where all maize had to be irrigated. Still, the impact of eight-rowed maize must have affected maize grown in the lowlands also, because the mean row number of maize cobs from lowland sites of this period (A.D. 1150 to A.D. 1300) is 10.6, the lowest mean row number for maize cobs from lowland sites for the entire prehistoric period (Table 41).

The maize races Pima-Papago and Pueblo are both thought to have originated and developed in the American Southwest. Pima-Papago was a flour maize selected out of the flinty Onaveno, and first appeared in the Southwest about A.D. 500. It was noted in the

maize remains from Ventana Cave (Haury 1974:161-169). Pima-Papago usually has a row number of 12, but can vary from ten to 14. Tables 17-18, summaries of data taken from the work of others defining Pima-Papago as a race indicate that the mean row number is 12.4. In Tables 25 and 26, summaries of measurements of maize cobs that I raised for this study, the mean row number of Pima-Papago was 10.6, lower because of the fewer row numbers caused by the inclusion of cobs of Blando de Sonora, a variant of Pima-Papago. Also, the row numbers of cobs from plants of Blando de Sonora that I raised may have been lower because of introgression with other maize germplasm at the Mexican source of the seed. Without the inclusion of Blando de Sonora, the mean row number of cobs of the race Pima-Papago in Tables 25 and 26 would be 11.8, which is much more typical of the maize race Pima-Papago.

Floury Pima-Papago and flinty Onaveno maize continued to be raised for a very long period in the lowland prehistoric Southwest, especially among the lowland-dwelling Hohokam (see Table 42), and both Onaveno and Pima-Papago maize are still grown today by the Pima and Papago, perhaps because these two variants of the race Pima-Papago are so well adapted to hot, lowland desert conditions.

The Pueblo race of maize is another of the races of maize that originated in the prehistoric Southwest. I have attempted to define the race Pueblo quantitatively as it existed during prehistoric times (Tables 17 and 18) and as it exists now as a living race of maize (Tables 25-31). Pueblo has long been recognized as a heterogeneous race of maize, and it has been shown in this thesis to probably have a mixed ancestry, through the isozyme diagram in Figure 34. Chapalote has been its major ancestor, but germplasm of Harinoso de Ocho (Maiz de Ocho), Pepitilla, and possibly Pima-Papago were also included in the ancestry of the Pueblo race of maize.

Pueblo, as a race that is identifiable in prehistoric remains, became apparent in the archaeological record after A.D. 1000. Maize remains from the sites of Guadalupe Ruin (Pippin 1987) and Bobocomari Village (Jones 1951) that date from A.D. 1150 to A.D.

1300 were designated racially as Pueblo.

In the period from about A.D. 1200 to A.D. 1300, and especially after A.D. 1250, there was a great deal of human population movement in the Southwest. This time span has been known as the Aggregation Period (Dean et al. 1994:76; Lipe 1995:152) and was discussed in Chapter 3 of this volume. By viewing Tables 40 and 41, a listing of measurements of races of maize remains from archaeological sites dating to A.D. 1150-1300, it is obvious that there were many races and variants of maize being grown all over the Southwest at that time. Some sites show quite a mixture of races, which would have been grown in at least some proximity. During the Aggregation Period, when great numbers of people began to move to new areas of the Southwest and began to gather together and live in larger groups, they presumably brought their maize seed with them. This would have caused the many variants and types of maize brought from diverse locations in the Southwest to suddenly be grown together in close proximity. What probably resulted from this bringing together of so many variants of living maize was an acceleration of the evolution in maize grown by the newly aggregated populations, with a combining of several germplasms into the new maize race, Pueblo. Thus, the combined social factors of aggregation and selection were responsible for a punctuated evolutionary situation creating the new Pueblo race.

It is unfortunate that more data on the measurements of maize is not available from the late prehistoric period (after A.D. 1300) because it would be easier to identify which aspects of the modern Pueblo race of maize originated before the contact period, and which originated after the introduction of new forms of maize by the Spanish.

In Tables 17 and 18 is a summary of measurements defining prehistoric Pueblo maize, and in Tables 25-31 and Figures 38-39 are summaries of measurements taken from the maize plants that I raised for this study, that define the unique, modern living race of Pueblo maize. The photographs (Figures 51-55, 68-72) visually reveal the level of diversity that exists in living Pueblo maize.

CHAPTER 9

CONCLUSIONS

In this thesis I have addressed several issues pertaining to the maize of the prehistoric Southwest and the site of Black Dog Cave, through the gathering, synthesizing, and comparison of data. Living races of maize were grown and tested at Las Vegas, Nevada, in a climate similar to that of Black Dog Cave, and the validity of the concept of races of maize as applied to prehistoric maize was addressed.

First, theories of the domestication of plants and the co-evolution of plants and humans were explored, and then the adoption of agriculture in the prehistoric Southwest and its impact on human populations was presented. The local environment of the Virgin River and Moapa Valleys was examined and followed by a summary of the cultural history of the Virgin Anasazi, including a detailed discussion of their subsistence and diet. The maize from the site of Black Dog Cave was carefully studied and the data was presented in detail. A summary of both the extinct and the living races of maize having descendance from, or close relationships to the archaeological maize of the prehistoric Southwest was made, and then living plants of the living races maize of the Southwest were tested in a lowland desert climate and redefined statistically as to how they grow in the lowlands of the Southwest. Finally, a statistical summary of maize from the prehistoric Southwest was created, and the data were presented in a series of tables. This leaves us in a position to re-examine the questions that were posed at the outset of research, and to look again at

the hypotheses about this project that were formulated in Chapter 1.

The first question presented asked if maize plants behave differently at lower altitudes than they do at higher altitudes. It is obvious from the previous studies of the environmental effects on maize and from the testing of plants of maize here in the Las Vegas Valley that maize plants do behave differently in the lowlands. The effects of lower altitudes in desert climates on maize plants include hastened tasseling responses as temperatures increase (Manrique and Hodges 1991), and inhibited photosynthesis and moisture stress at high temperatures which can cause early pollen shed, delayed silking, and changes in the morphology of the ears (Barnes and Woolley 1969; Hall et al. 1981; Mackey 1983).

The data gathered by myself on the effects of the lowland desert climate on maize plants includes: poor pollination of ears as observed in this test; increases in the height of plants and number of leaf-nodes on the plants as observed in this test; and significant moisture stress to the plants as observed in this test. The environmental conditions of the hot lowlands would select for plants that could withstand the moisture and heat stress of the area, and people would naturally select for plants that could pollinate fully in this climate, and would mature ears full of kernels. Those plants that could pollinate early and avoid the hottest weather, thereby being exposed to the least length of time in heat and moisture stress, would have the advantage. Therefore early-maturing varieties would be selected for, environmentally, in the lowlands of the desert Southwest. Also, varieties of maize that had tight husks and harder, flinty seeds would also be environmentally selected for because of their insect resistance on the plant (from maize earworms) and in dry storage off the plant (from weevils).

The testing of living races of maize undertaken here looked at the question of the validity of the concept of races of maize, and whether or not the statistical measurements of living races of maize could be applied to prehistoric maize. To test this, I did make a statistical summary of the measurements of maize considered to be ancestral to, or to have

relationships with, living races of maize. This involved defining several of the prehistoric races of maize from data gathered on archaeological maize (presented in Tables 17 and 18).

The value of isozyme studies, of which I was at first very suspect, did throw new light on the interrelationships of the maize of the Southwest, and enabled me to discover the probable ancestor of Fremont Dent maize (Pepitilla), hitherto unknown and only speculated. Isozyme studies also revealed how closely related to each other the living races of maize of the Southwest are today. Isozyme studies, when used in tandem with morphological studies of maize, enable us to further understand the complex relationships of living and prehistoric maize, and rather than replacing or negating morphological studies, enhance them.

The statistics defining prehistoric races of maize turned out to be useful in identifying not only the relationships of prehistoric maize to the living races of maize of the Southwest, but also in examining and establishing the relationships of the prehistoric maize of the Southwest to the maize from Black Dog Cave and to the maize from other prehistoric sites. Differences in prehistoric maize were observed by time period, and by altitude (Tables 32-42).

The redefinition of the living races of maize of the Southwest through my tests establishes a more complete set of statistics than has ever been made in defining two races that originated in the Southwest, Pima-Papago and Pueblo. The data defining recognized races of maize as they grow in the hot lowlands of the desert Southwest reveals some morphological differences from the races of maize as they were defined in the 1950s in the highlands of Mexico, and describes how those races would behave in the local climate of sites such as Black Dog Cave.

The testing of the living races of maize of the Southwest points out that environmental selection on maize in this climate and altitude zone is very strong, perhaps an even stronger force than human selection.

As far as human selection by the prehistoric Virgin Anasazi, and of what characteristics the prehistoric Virgin Anasazi selected for in their maize, we can only gain inferences that will answer these questions from examining the maize found at Black Dog Cave, and from the patterns of selection of other peoples of the Southwest known through ethnographic studies. These studies show that most of the people of the ethnographic Southwest selected for the following characteristics in their maize: ears that were well-filled with kernels and of uniform shape, specific kernel colors, drought tolerant and wind resistant plants, and specific types of endosperm (i.e. pop, flint, flour, or dent).

The one ear of maize from Black Dog Cave with its kernels still attached was obviously two-colored. That is, it was not uniform in color, but it had been very well-pollinated and was originally filled with kernels when it was harvested. It was of the flint race Onaveno, the flint form of floury Basketmaker maize. The collection of maize from the cave as a whole closely resembled other prehistoric collections of Onaveno and Basketmaker maize, two races that are represented today by the living race Pima-Papago. Onaveno maize was grown by the Hohokam, contemporary neighbors of the Virgin Anasazi, from 300 B.C. to A.D. 1450. The abundance of shell beads and cotton textiles thought to have been traded from the Hohokam to the Virgin Anasazi has been often cited as evidence of trade and exchange between the Virgin Anasazi and the Hohokam (Lyneis 1995:23). It is probable that the Virgin Anasazi obtained maize germplasm from the Hohokam as well, but more likely that when they settled the area sometime in Basketmaker II times, that either the Virgin Anasazi themselves, or the environmental factors of the lowland desert climate, selected more strongly for flint forms of maize, rather than flour forms.

The Virgin Anasazi probably also grew some of the flour maize we know as Basketmaker, judging by some of the cobs from the collection, but it is likely that the reason more maize of the Onaveno type has been uncovered at Black Dog Cave was that Onaveno was better adapted to the hot, lowland climate and more resistant to the insects

(including maize earworms) of the area than any other maize available at the time. Also, since there were eight-rowed cobs among the assemblage, early forms of the flour race Maiz de Ocho may have been grown by the Virgin Anasazi as well, but were probably poorly adapted to the local climate, and therefore not a major crop.

It is also probable that the Virgin Anasazi grew some of their maize to use as roasting ears (greenmaize), because some of the cobs in the collections from Black Dog Cave at the Nevada State Museum appear to have had their kernels cut from the cobs before they were mature.

It may be possible that the Virgin Anasazi tried to grow some of the maize that other Anasazi in the highlands to the east of them grew, but that the Onaveno race of maize was better-adapted, and so continued to be grown over time, just as it was by the Hohokam through most of their cultural history. So, as to the question of whether the Anasazi grew maize that was more similar to other Anasazi, or more similar to the Hohokam, it would have to be said that their maize was more similar to the maize of the highland Basketmaker II peoples of the Colorado Plateau during the period A.D. 50 through A.D. 900 (compare Tables 10 and 11 with Tables 33-36), and more similar to the maize of the Hohokam during the period from A.D. 900 through A.D. 1250 (compare Tables 10 and 11 with the data from Gila Bend Sites in Tables 38-41).

As to the question of a Basketmaker II presence at Black Dog Cave, the radiocarbon dates on maize from pit #31 have proven occupation of the cave between A.D. 258 and A.D. 294 at one Sigma in sample one, and between A.D. 248 and A.D. 390 at one Sigma in sample two. The similarity of the maize from Black Dog Cave maize to the maize of the Basketmaker II peoples of the Colorado Plateau area is striking, and this reinforces the probability that there was a Basketmaker II presence in the lowlands, and that these people used water diversion as a means to water their crops, and did not practice floodwater farming only, as proposed by Matson (1991).

Four hypotheses were proposed at the outset of the research for this project, and I shall now address each one in turn.

Hypothesis 1: "Maize should grow and flower differently in the desert lowland climate of the Virgin Anasazi area than it does in the highland climates of the Colorado Plateaus and Mexico." This hypothesis has been proven correct, as evidenced by the data from both studies, and by testing of the living races of maize and comparing their defining statistics as taken in this climate with those taken in the highlands of Mexico.

Hypothesis 2: "Virgin Anasazi maize should be more similar to highland Anasazi maize than to lowland Hohokam maize because of cultural selection." This hypothesis has been proven to be partially correct, for it appears that when Basketmaker II peoples moved west into the lowlands of the Virgin River and Moapa Valleys, they brought typical Basketmaker and Onaveno maize with them, and that their maize resembled that of other highland Anasazi for a time. Later, after about A.D. 900, however, their maize remained in a rather conservative state. This conservatism parallels the condition of maize of the Hohokam. Onaveno maize continued to be the race primarily grown by the Hohokam and Virgin Anasazi after A.D. 900. Though I do not have actual radiocarbon dates on any other maize samples from Black Dog Cave, the presence of artifacts dating to the Pueblo period in association with some of the maize would indicate a long presence at the cave, and the mean statistics of the combined samples of all the Black Dog maize indicate a degree of conservatism and continued predominance of Onaveno maize at the site through the Puebloan abandonment.

Hypothesis 3: "Virgin Anasazi maize should show a similar level of diversity to that of other Anasazi living in the highlands, due to cultural reasons." There is indeed a degree of diversity in the maize found at Black Dog Cave, but it is difficult to compare the maize from this site to others in the highlands because of a lack of published data from other sites. One site that does have a great deal of data that can be compared timewise with the Black Dog Cave site is the Antelope House site in Canyon de Chelley, Arizona

(Morris 1986:110-128). This was a highland Anasazi site, roughly contemporary with the occupations of Black Dog Cave from Basketmaker III, Pueblo I, II, and III. The maize from this site is more diverse than that from Black Dog Cave. There were flint, flour and dent ears, and much more flour maize than at Black Dog. Some of the ears of maize at Antelope House also have larger grains and fewer numbers of rows than the Black Dog Cave maize, and there is a greater diversity in the shapes of the cobs as well. This contrasts with the maize from Black Dog Cave, which is mostly in the racial range, statistically, of Basketmaker/Onaveno maize throughout the occupation of the site.

Hypothesis 4: "At least some of the maize from Black Dog Cave should be representative of Basketmaker II maize, thus strengthening the case for a Basketmaker II presence in the western lowlands." This hypothesis has been proven to be true, by virtue of the radiocarbon dates on the two samples of maize from pit #31, dating to Basketmaker II, and by the general similarity of the maize from Black Dog cave to Basketmaker II maize from the sites on the Colorado Plateau.

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IMAGE EVALUATION TEST TARGET (QA-3)