15

Maize on the Frontier

Isotopic and Macrobotanical Data from Central–Western Argentina

ADOLFO F. GIL*, ROBERT H. TYKOT†, GUSTAVO NEME‡, AND NICOLE R. SHELNUT§

*Departamentode Antropología, Museo de Historia Natural de San Rafael, San Rafael-Mza. Argentina

†Department of Anthropology, University of South Florida, Tampa, Florida

‡Departamentode Antropología, Museo de Historia Natural de San Rafael, San Rafael, Mza. Argentina

§Department of Anthropology, University of South Florida, Tampa, Florida

Glossary

Guanaco   Common name of *Lama guanicoe*. It is an important wild camelid of South America and is the biggest terrestrial game. It was an important subsistence resource to Pre-Hispanic hunter–gatherers.

Intensification Process   Greater foraging efficiency in response to resource scarcity. This implies bigger extraction cost of food and more productivity by area as a response to include in the human diet lower return rates resources.

Piedmont   The first elevation of the mountains in the transition between the lowland and the highland. In southern Mendoza the altitude is around 1300–1800 meters above sea level (masl).

Puelches   Historic hunter–gatherers who lived south of Mendoza during the Spanish contact.

The introduction of maize is vital to understanding the dispersal of domesticates in Southern America. The Central–Western region of Argentina is thought to be the southern boundary of Pre-Hispanic maize agriculture and appeared to be an ideal location to explore the ways in which this cultigen was introduced. To understand this complex process, we introduce macrobotanical, archaeofaunal, and stable carbon and nitrogen isotope data from the southern region of province of Mendoza. We initially present the archaeobotanical and archaeofaunal record of late Holocene human occupation. The archaeological record for maize, its chronology and abundance is then presented and analyzed in comparison to other resources. The isotopic information includes late Holocene human bone collagen and apatite and tooth enamel samples, as well as animal and plant food resources from several environmental zones. We analyze these data and discuss the role of maize and temporal and spatial aspects of regional variability. Our results indicate that in general maize was never an economic staple and that there was an important variability in C_4 resources use (possibly maize) in the past 4000 years. In contrast, the isotopic data and the kinds of resources exploited show a significant variability between lowland and highland **piedmont.** In light of these data, we discuss various models for the spread of maize in Argentina.

INTRODUCTION

In the past decades there has been an increase in efforts to understand not only the origins of plant domestication but also the incorporation of foreign domesticates imported from neighboring regions [61, 62]. Some research is focused on maize in North America [23, 25] and in South America [26, 59, 65]. In general, maize has been seen as central to

domestication or assumed to be an important cause of cultural change where this resource appeared in the archaeological record. On the frontier, the region where the spread of this resource stopped, it is possible to expect some different regional histories and different consequences of the human strategies with respect to the places where the resources come, but there is little previous research on this topic [23, 25, 62]. This chapter focuses on the incorporation of maize in the southern Pre-Hispanic record, in the region located between northwest Argentina and north Patagonia (Figure 15-1). This region, central and southern Mendoza,

has been proposed as the South American farming frontier, and some hypotheses about the arrival of farming and its chronology have been published [32, 35, 52, 53]. In recent times, accelerator mass spectrometry (AMS) chronology was applied to maize, and stable isotope studies were used to discuss these hypotheses [20, 21, 46, 47]. In this study, the macrobotanical evidence, direct chronology, and stable carbon and nitrogen isotope data on resources and human archaeological samples are presented to understand the meaning of maize in its southern record. The isotopic information includes Holocene human bone collagen, bone
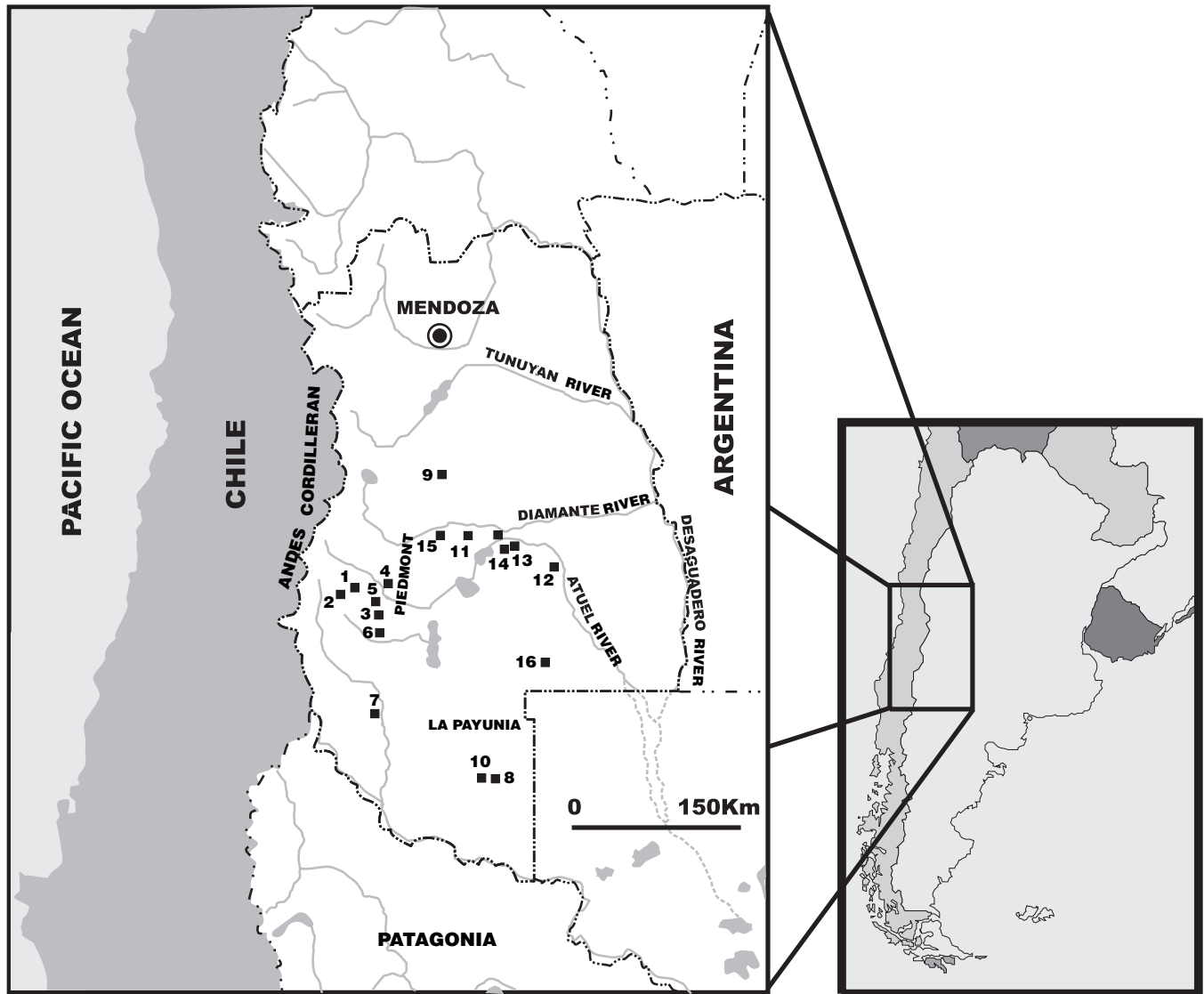
1. Cueva India embarazada; 2. Arroyo El Desecho; 3. Cerro Mesa; 4. Tierras blancas; 5. Ojo de agua; 6. El Chacay; 7. El Manzano; 8. Agua del Toro; 9. Capiz Alto; 10. La Matancilla; 11. Caæada Seca; 12. Jaime Prats; 13. Rincon del Atuel; 14. Gruta del Indio; 15. Medano Puesto Diaz; 16. RQ 1.

FIGURE 15-1   The Pre-Hispanic archaeological sites considered in the chapter where domesticates were recorded.

apatite, and tooth enamel samples, and animal and plant food resources from different environmental regions in central and southern Mendoza. With this information, the relevance of maize in the diet and its spatial and temporal variability is discussed.

ZEA MAYS ON THE FRONTIER: A SOUTH AMERICAN CASE

The most important advance in the study of the incorporation of domesticates in Argentina was made in the 1970s. Little research has been developed regarding this topic [8], and few advances have been made in the past two decades [1, 39]. However, in worldwide research on plant domestication and its spread an important methodological, theoretical, and empirical advance has been realized in the past decade [61]. New standards about remains-recovery techniques, taxonomic identification, and chronology have been proposed, and they need to be incorporated firmly in the study of first farming populations in South America [48, 49, 60].

In South American research, it is suggested that domestication and spread was a slow process, which [1, 8] included different plants [48]. In the central–western part of Argentina, the present archaeological knowledge about the first farming and its role in Pre-Hispanic population has been developed in the same condition as in the rest of northwest Argentina. Until recently the flotation technique was not systematically used, and there are only a few domesticated samples directly dated [4, 21, 38, 39]. Almost all of the archaeological evidence of domesticates in this region come from dry caves. Research surrounding domesticates has generally focused on the chronology of the earliest domesticates, and this has usually been interpreted as evidence of an agricultural economy. The topic generally has been studied with cultural history reconstruction as a primary goal [18, 35, 38, 39]. Important points of debate have centered on whether the first domesticate was associated with ceramics, the chronological order of incorporation, and hypotheses about the origin of these "first farmers" [5, 18, 39, 54]. But little research had been done about the consequences of domesticate incorporation or the subsequent evolution of domesticates in the new human niche. In general terms, it has been assumed that the first record of domesticates has been a causal relationship with the transition to farming, the sedentary life, and the incorporation of ceramic technology [5]. The explanation for the arrival of domestication generally was from a move of human population or diffusions, but few studies have explored the endpoints of the spread and the subsequent history of domesticates after their incorporation. Some research hypothesizes ecological characteristics as significant factors in explaining this region as the last part where domesticates were used in Pre-Hispanic times [5, 33].

There is some regional variability in central–western Argentina in reference to the cultigens associated with the first records of domesticates. In San Juan there are Pre-Hispanic records of *Chenopodium quinoa, Cucurbita maxima, Cucurbita pepo, Lagenaria siceraria, Phaseolus vulgaris* posteriorly *Zea mays;* and *Arachis hypogaea* has been recorded in the latest times [17, 51]. It was not a simultaneous incorporation process, and the first incorporation was quinoa and zapallo and later maize and bean [17]. North of Mendoza, *Chenopodium quinoa, Lagenaria siceraria,* and probably *Zea mays* are the oldest cultigens recorded [6, but see 18 for a discussion]. In central southern Mendoza (see detail) *Zea mays, Chenopodium quinoa, Cucurbita* sp., and *Phaseolus vulgaris* are recorded contemporarily [38; but see 36, the *Cucurbita* sp.], and *Lagenaria siceraria* is chronologically recorded later [21].

The antiquity of maize in central–western Argentina has been a topic of acrimonious debate [5, 18, 39]. Some research has proposed an early entry of maize (ca. 4000 years BP) based basically on a kernel of maize [5, 6]. Other research accepts a later chronology to this domesticate (ca. 2000 years BP) [18, 35, 39]. The direct radiocarbon evidence on maize is in consort with the latter, but few directly dated *Zea mays* samples have been archaeologically recorded in the southern part of this region [21]. In general, the record of domesticates has been interpreted as the consequence of farming society settlement (see details in reference 19) and generally proposed in its first phase as "incipient farming" [17, 35]. If not in all cases, there are trends to assume the arrival of experimental farming families over a previous hunter–gatherer occupation [17, 39, 54, 63]. Recently alternative strategies to hunter–gatherer–farming dichotomy have been proposed and temporal-spatial variability regarding the presence and use of maize is beginning to be considered [21, 47].

THE STUDY AREA

The central and southern areas of Mendoza, located between 33–37° S and 70–67° W, is characterized by its environmental diversity, which includes the Andes Cordillera, a piedmont fringe extending along the mountain front, and a large plain (lowlands) (see Figure 15-1). Archaeologically this geographic portion is includes a mix of cultural areas or subareas: the southern part of central–western Argentina, a transition between central–western Argentina and Patagonia, and northern Patagonia. It is drained by several major streams: the Diamante, Atuel, and Grande rivers. The discharges of these streams are mainly controlled by snowfalls on their headwaters, which were repeatedly glaciated during the Pleistocene [66].

The Andes Cordillera consists of several North–South trending mountain ranges with mean elevations of

5000–6000 masl and peaks up to 6500 masl, deeply eroded by both fluvial and glacial processes resulting in broad valleys. At ca. 35° S the mountain landscape is interrupted by the Huarpes depression, a structurally controlled depositional basin of relatively flat surface filled with Plio-Pleistocene deposits, placed between the High Andean ranges and the uplifted San Rafael Block (Figure 15-1).

The piedmont fringe consists of several late Cenozoic alluvial fans and aggradations roughly situated between 1800 and 1000 masl, originating a series of gently sloping surfaces where the present fluvial system is degraded. The plain is an extensive landform descending from 400 to nearly 200 masl at the Desaguadero river. This plain is composed of alluvial sediments deposited by the Diamante and Atuel rivers and covered by a complex and extensive sand dune field. The southernmost part of this lowland comprises the La Payunia volcanic field, an area characterized by an irregular relief resulting from the occurrence of numerous volcanic cones, some reaching almost 3800 masl (Payún Liso volcano) with extensive basaltic plains [22]. The volcanic field has been eroded by local fluvial systems of ephemeral streams. Plant communities of several different phytogeographic provinces (i.e., Monte, Patagonia, High Andes, Subantarctic) are distributed following both altitudinal and latitudinal gradients [12].

DOMESTICATES: MAIZE AND OTHER RESOURCES IN THE LATE HOLOCENE

Figure 15-1 shows the Pre-Hispanic archaeological sites where domesticates were recorded.

Tables 15-1 and 15-2 list the plants and animals identified at archaeological sites (Figure 15-1). In Table 15-3 there is a list of domesticates recorded in the region with a detailed radiocarbon chronology. There are some observations to be made from the resource information. First, the cultigens recorded are *Zea mays, Cucurbita* sp., *Chenopodium quinoa, Phaseolus vulgaris,* and *Lagenaria* sp. Second, domesticates are less abundant than wild plants [28]. Third, *Zea mays* is the more ubiquitous domesticate: There are 17 sites with cultigens recorded and 16 have *Zea mays;* only one with *Zea mays, Cucurbita* sp., *Chenopodium quinoa, Phaseolus vulgaris,* and 12 with only *Zea mays* (Table 15-3). Fourth, it is clear that the domesticates, and particularly *Zea mays,* are more frequent in the middle Atuel Valley surrounding lowlands than in the rest of central–southern Mendoza (Figure 15-1; Table 15-3). The archaeological record of domesticates start ca. 2200 ^{14}C years BP, but only one site has domesticates directly dated in this early time (Gruta del Indio). Already by 1000 ^{14}C years BP there is wider distribution of domesticates, basically *Zea mays,* in central–southern Mendoza (Table 15-3). The wild plants

used are primarily algarrobo (*Prosopis* ssp.), *Chenopodiaceae, Amaranthaceae,* among others [27]. In general, they are C$_3$ plants, but an exception can be *Amaranthaceae* [10]. Regional comparisons about the significance of different wild taxa in the human diet are complicated by the fact that there is only one archaeological site with quantitative archaeobotanical data available.

There is no evidence of animal domestication or archaeofaunal reports of domestication in either central–southern Mendoza or in the rest of central–western Argentina [43]. Only in San Juan province there is archaeological evidence that could indicate the presence of domesticates in recent times [17]. In terms of caloric yield, **guanaco** *(Lama guanicoe)* have been the more important animal exploited, but the diversity of species exploited had a significant variability during the late Holocene and across the region [44]. Others species exploited were Rheidae, Dasypodidae, Testudinidae, and others [43, 44].

ISOTOPIC ECOLOGY AND HUMAN DIET: δ^{13}C AND δ^{15}N INFORMATION

Well-established procedures for extracting bone collagen and bone and tooth enamel apatite were performed in the Laboratory for Archaeological Science at the University of South Florida [64]. Whole and fragmented bone (about 1 gram) and tooth samples were cleaned using ultrasonic vibration and distilled water. From the cleaned bone, 10 milligrams of bone powder were extracted for apatite analysis. Likewise, 10 milligrams of tooth enamel were extracted using a dental drill. Bone collagen was extracted using 2% HCl for 72 hours, dissolving base-soluble contaminants using 0.1 M NaOH (24 hours before and after demineralization), and separating residual lipids with a mixture of methanol, chloroform, and water for 24 hours. Collagen pseudomorphs were analyzed using a CHN-analyzed, coupled with a Finnigan MAT Delta Plus XL, stable isotope ratio mass spectrometer set up with a continuous flow. The reliability of collagen results were determined by percentage yield during processing, and validated by C:N ratios during analysis. Carbonate from apatite and enamel samples was also extracted using established techniques, specifically, the removal of organic components using bleach (24 hours for enamel, 72 hours for apatite), and of nonbiogenic carbonates using buffered 1 M acetic acid (24 hours). Carbonate samples were analyzed using a similar Finnegan MAT Delta Plus XL mass-spectrometer, coupled with a Kiel III device. The precision of the University of South Florida (USF) analyses is about ±0.1‰ for carbon and ±0.2‰ for nitrogen. Results are reported relative to the PDB and AIR standards.

Isotopic information for local resources was obtained from 11 faunal samples (6 species) and 13 plant samples (11

TABLE 15-1 A list of the plants and animals identified at archaeological sites shown in Figure 15-1 [27]

	Archaeological sites			
Taxa	Gruta del Indio	Agua de los Caballos-1	Agua de la Mula-1	Ponontrehua
Equisetum sp.	—	—	—	X
Gramineae	X	X	X	X
Pappaphorum sp.	—	—	—	X
Phragmites comunis	X	—	—	—
Stipa sp.	X	—	—	—
Scirpus sp.	X	—	—	—
Stipa sp.	X	—	—	—
Sporobolus mendocinus	—	X		
Cortaderia sp.	X	—	—	X
Tillandsia sp.	—	—	X	—
Ximenia americana	X	—	X	X
Chenopodiaceae	—	X	—	—
Chenopodium aff. hircinum	—	X	—	—
Chenopodium sp.	—	X	—	—
Amaranthaceae	X	X	—	—
Amaranthus caudatus	X	—	—	—
Bougainvillea spinosa	—	—	—	X
Atamisquea emarginata	—	—	X	—
Prosopis sp.	X	X	X	X
Caesalpinia gilliesii	—	—	X	—
Cassia aphylla	—	—	X	—
Geoffroea decorticans	X	X	X	X
Cercidiun australe	—	X	X	X
Larrea cuneifolia	X	X	—	X
Bulnesia retama	—	X	—	X
Schinus polygamus	—	X	X	—
Condalia microphylla	—	X	X	X
Sphaeralcea mendocina	—	X	—	—
Cactaceae	—	X	X	X
Cereus aethiops	—	X	—	—
Denmoza erythrocephala	—	X		—
Trichocereus candicans	—	X	X	X
Opuntia sulfurea	—	X	—	—
Verbenaceae	—		—	X
Cucurbitaceae	X	—	—	—
Proustia cuneifolia	—	—	X	X
Xanthium spinosum	—	X	—	—
Baccharis sp. ?	—	—	—	—

TABLE 15-2 A list of the plants and animals identified at archaeological sites shown in Figure 15-1

TAXA	Cueva de Luna	Alero Puesto Carrasco	Cueva A° Colorado	Agua de Los caballos-1	Puesto Ortubia-1	La Corredera	Los Leones-3	Los Leones-5	Los peuquenes	Arroyo Malo-3	Arroyo Malo-1	Ojo de Agua	La Peligrosa-1	El Indígeno
Ave indet.	X	X	X	X	—	X	X	X	X	X	—	X	—	X
Ave grde.	X	X	—	—	—	—	—	X	—	—	—	X	—	—
Ave chica	X	X	—	—	—	—	—	—	—	X	—	—	—	—
Emberizidae	X	—	—	X	—	—	—	—	—	—	—	—	—	—
Zenadia auriculata	—	—	—	X	—	—	—	—	—	—	—	—	—	—
Eudromia elegans	—	—	—	X	—	—	—	—	—	—	—	—	—	—
Falconidae	X	—	—	—	—	—	—	—	—	—	—	—	—	—
Passeriiforme	X	—	—	X	—	—	—	—	—	—	—	—	—	—
Rheidae	X	X	—	—	—	X	—	—	—	—	—	X	X	—
Pterocnemia pennata	X	X	—	—	—	—	—	—	—	—	—	—	—	—
Rhea americana	—	X	—	—	X	—	—	—	—	—	—	X	—	—
Dasypodidae	X	X	X	X	X	X	X	X	—	X	—	X	X	—
Euphratyni	X	X	—	—	—	—	—	—	—	—	—	—	—	—
Chaetophractus sp.	X	X	—	—	—	—	—	—	—	—	—	—	—	—
Chaetophractus villosus	X	X	—	—	—	—	—	—	—	—	—	—	—	—
Zaedyus pichyi	X	X	—	X	—	—	X	X	—	—	—	—	—	—
Carnivoro	X	X	X	X	—	—	—	—	—	X	—	—	—	—
Conepatus sp.	X	X	—	—	—	—	—	—	—	—	—	—	—	—
Felis concolor	X	—	—	—	—	—	—	—	—	—	—	—	—	—
Artiodactyla	X	X	X	X	X	X	—	—	X	X	X	X	—	X
Camelidae	X	X	—	X	X	X	X	X	X	X	X	X	X	X
Lama Guanicoe	X	X	X	X	—	—	—	—	X	X	X	X	—	X
Ozotocerus bezoarticus	—	X	—	—	—	—	—	—	—	—	—	—	—	—
Lagidium viscacia	—	—	X	—	—	—	X	—	—	—	—	—	—	—
Mammalia indet	X	X	X	X	X	X	—	X	X	X	X	X	X	X
Mammalia (big size)	X	X	X	X	X	X	X	—	X	X	X	X	X	X
Mammalia (médium size)	X	—	—	X	X	—	—	—	—	—	—	—	—	—
Mammalia (small size)	—	X	—	X	X	X	X	—	—	—	—	—	—	—
Herviboro	—	—	—	X	X	—	—	—	X	—	—	—	—	—
Chiroptera	—	—	—	—	—	—	—	—	—	X	—	—	—	—
Reptilia	—	—	—	—	—	X	—	—	—	—	—	—	—	—
Iguánide	—	—	—	—	X	X	—	—	—	—	—	—	—	—
Testudinidae	—	—	—	X	X	X	—	—	—	—	—	—	—	—
Mollusca	—	—	—	—	—	—	—	—	X	—	—	—	—	—
Microvertebrados	X	X	X	X	X	X	X	—	X	X	—	—	X	—

TABLE 15-3   Southern Mendoza Domesticated. It is included the direct radiocarbon chronology or samples with direct primary contextual association.

Archaeological site	Radiocarbon date	Taxa	References
Gruta del Indio	2210 ± 90 (GrN-5493) 2095 ± 95 (GrN-5398) 2200 ± 70 (LP-823) 2065 ± 40 (GrN-5396)	*Phaseolus vulgaris* *Phaseolus vulgaris* *Chenopodiun quinoa* *Zea mays* *Cucurbita* sp.	[29, 30, 31, 38, 53, 55]
Reparo de las Pinturas Rojas		*Zea mays*	[34]
Zanjón del Morado		*Zea mays*	[34]
Cueva del Cerro Negro		*Zea mays*	[34]
Reparos del Rincón		*Zea mays*	[34]
Zanjón del Buitre	605 ± 40 (AA-26195)	*Zea mays*	[21, 31, 53]
Cueva Patas de Puma		*Zea mays*	[53]
Cueva Kilómetro 15		*Zea mays*	[53]
Cueva de la Bruja		*Zea mays*	[53]
Cueva Ponontrehue		*Zea mays* *Cucurbita* sp.	[34, 38]
Cueva Agua de la Mula		*Zea mays* *Cucurbita* sp.	[38]
Gruta de Las Tinajas	modern (LP-1137)	*Zea mays* *Cucurbita moschata*	[40]
El Indígeno	1045 ± 45 (AA-26192)	*Zea mays* *Lagenaria* sp.	[37, 41, 42] [37, 41, 42]
Agua de los Caballos	365 ± 40 (AA-26196) 740 ± 40 (AA-26194)	*Zea mays* *Zea mays*	[20]
Puesto Ortubia-1	910 ± 40 (AA-26197)	*Zea mays*	[20]
Los Leones-5		*Cucurbita* sp. (?)	[20]
Puesto Carrasco		*Lagenaria* sp.	[14]

taxa) from this region (Table 15-4). The isotopic analyses indicate that, in general, the animals have a low value in $\delta^{13}C$ (−19.2‰) and average $\delta^{15}N$ value (4.6‰). In contrast, plants have a low $\delta^{13}C$ value (−21.8‰) with average $\delta^{15}N$ (7.2‰). The *Zea mays* $\delta^{13}C$ values (avg. = −9.6‰) have no significant difference from corn samples from other regions, and they are enriched in carbon isotopic value in contrast to all noncorn plants tested. The $\delta^{15}N$ value on domestic plants is highly variable with *Cucurbita maxima* and *Lagenaria* sp. having the highest values and *Chenopodium quinoa, Phaseolus vulgaris,* and *Zea mays* having the lowest values. The $\delta^{15}N$ value on wild plants is higher in lowland than in highland areas with significant differences between the samples tested so far. This may be caused by differential responses to arid conditions and is the subject of further testing.

The range of carbon isotope values in guanaco collagen sample is unexpectedly large (−19.1 to −14.2‰). A similar situation has been observed in North America with *Bison bison* [63]. The guanaco samples from lowlands have more enriched $\delta^{13}C$. The other guanaco isotopic information comes from the piedmont and highland areas and is similar to guanaco isotopic values from other parts of Patagonia, around −19‰ [3, 15]. Camelid collagen samples recorded in the Puna, Fernández, and Panarello show a correlation between altitude and isotopic values, with the guanaco from low altitudinal levels having carbon isotopic values that are higher in respect to high altitudinal guanaco [15]. Cavagnaro [9] shows a clear pattern of grass distribution as a function of altitude where C_4 is dominant at lower elevations and C_3 is dominant in higher elevations. This grass distributional pattern parallels isotopic information from *L. guanicoe* in these regions. But there is only one sample of guanaco from each region and more information about the carbon isotopic value from this species will be obtained to check this trend. Another aspect to consider about the isotopic value of resources is that the $\delta^{15}N$ value for highland resources is lower than in the rest of central–southern Mendoza. Unfortunately, there is not at present $\delta^{15}N$ for fauna from lowland

A. F. Gil et al.

TABLE 15-4 Southern Mendoza resources isotopic information ($\delta^{13}C$ and $\delta^{15}N$)

Taxa	Environment	Location	Sample code	C:N	$\delta^{15}N$ ‰	$\delta^{13}C_{co}$ ‰	Code	$\delta^{13}C_{ca}$ ‰	Code	$\delta^{13}C_{en}$ ‰
Lama guanicoe	Highland	Arroyo El Desecho-10 (A1-3-3-311)	USF-6170	3.3	—	−19.1	USF-5905	−10.7	—	—
Lama guanicoe	Lowlands	Agua de Los Caballos-1 (A1-11-414)	USF-6171	3.3	—	−14.2	USF-5906	—	—	—
Lama guanicoe	Footplain	Cueva de Luna (D4-6-67)	USF-6172	3.3	4.0	—	USF-5907	−11.1	—	—
Lama guanicoe	Highland	El Indígeno (H21-2)	—	—	—	—	—	—	USF-6173	−9.1
Lama guanicoe	Highland	El Indígeno (H21-3-18580)	USF-6179	3.4	4.3	−18.8	USF-5913	−8.9	—	—
Cholephaga melanoptera	Footplain	Actual (Malargue)	USF-6174	3.3	4.1	−22.0	USF-5908	−11.5	—	—
Rhea americana	Footplain	Alero Pto. Carrasco (S87-5-2)	USF-6175	3.4	5.7	−20.0	USF-5909	−11.8	—	—
Pterocnemia pennata	Footplain	Alero Pto. Carrasco (S91-3B-36)	USF-6176	3.4	4.6	−20.6	USF-5910	−12.1	—	—
Pterocnemia pennata	Footplain	Alero Pto. Carrasco (S91-4-1553)	USF-6180	3.4	4.9	−21.0	USF-5914	−11.5	—	—
Lagidium viscacia	Highland	Arroyo El Desecho-10 (A1-6-2-402)	USF-6177	3.4	3.7	−19.3	USF-5911	−9.1	—	—
Chaetophractus villosus	Footplain	Alero Pto. Carrasco (S87-4-71)	USF-6178	3.3	5.6	−17.7	USF-5912	−11.1	—	—
Zea mays	Lowland	Cueva Zanjón del Buitre (seed)	USF-6181	—	3.4	−9.7	—	—	—	—
Zea mays	Lowland	Gruta del Indio (N°3500, seed)	USF-6182	—	3.9	−9.6	—	—	—	—
Cucurbita maxima	Lowland	Gruta del Indio (level 4; cáscara)	USF-6183	—	13.1	−23.2	—	—	—	—
Lagenaria sp.			USF-6184	—	10.4	−25.4	—	—	—	—
Chenopodium sp.			USF-6185	—	6.9	−27.6	—	—	—	—
Prosopis sp.	Lowland	Rincón del Atuel (fruit, actual)	USF-6186	—		−23.9	—	—	—	—
Prosopis sp.	Lowland	Agua de Los Caballos-1 (level 6, endoca)	USF-6191	—	11.6	−24.9	—	—	—	—
Cassia arnotiana	Highland	Arroyo Malo, actual (fruit)	USF-6187	—	1.6	−25.4	—	—	—	—
Phaseolus vulgaris var. oblongus	Lowland	Gruta del Indio (atuel II, seed)	USF-6188	—	5.5	−24.0	—	—	—	—
Geoffroea decorticans	Lowland	Agua de los Caballos (level 6, endocarpo)	USF-6189	—	14.0	−20.2	—	—	—	—
Geoffroea decorticans	Lowland	Rincón del Atuel (fruit, actual)	USF-6190	—	—	−20.8	—	—	—	—
Condalia microphylla	Lowland	Cuadro Benegas (actual, fruit)	USF-6192	—	—	−25.3	—	—	—	—
Schinus polygamus	Highland	Arroyo Malo, actual (fruit)	USF-6193	—	1.6	−24.4	—	—	—	—

areas, where a large number of the human samples come from.

In this study, we processed 29 human samples, obtaining 25 $\delta^{15}N$ and $\delta^{13}C$ values for collagen ($\delta^{13}C_{co}$), 26 $\delta^{13}C$ for carbonate ($\delta^{13}C_{ca}$), and 16 $\delta^{13}C$ for enamel ($\delta^{13}C_{en}$) (Table 15-5). These samples range chronologically over the past 5500 years, but primarily date to the past 2000 years (Table 15-5). They came from lowland (21 human samples from 9 archaeological sites), piedmont (6 human samples from 6 archaeological sites), and highland (2 human samples from 2 archaeological sites) regions. These samples have a $\delta^{15}N$ average of 10.3‰ (SD: 1.4; range 6.4 to 12.9‰) and a $\delta^{13}C_{co}$ average of −16.0‰ (SD: 1.5; range −18.8 to −13.9‰). In bone apatite, the $\delta^{13}C$ average is −10.3‰ (SD: 1.5; range −13.0 to −7.9‰) and in the enamel the $\delta^{13}C$ average is −10.5‰ (SD: 1.6; range −12.7 to −8.6‰). The $\delta^{13}C_{en}$ average has little difference with $\delta^{13}C_{ca}$. These results can be interpreted in terms of the C_3/C_4 ratio for the diet as showing a significant variability. In other regions, such as the Great Basin and the American Southwest, the carbon isotopic collagen value for great maize consumers range between −9.5 and −7.0‰ [10]. These authors propose three categories that represent real but not strictly categorical differences in diets: a) those who subsisted on diets high in C_3 foods (<−17‰); b) individuals who consumed diets relatively high in C_4 foods (> −14‰); and c) those subsisting on mixed diets (−17 to −14‰). The central–southern Mendoza isotopic values are significantly different from each other, but the average $\delta^{13}C_{co}$ values (−16‰) show a mixed diet with medium to low or indirect consumption of C_4. In our study, most individuals are in the third category, the first group is the second most abundant, and only one individual shows a high C_4 foods diet.

There are some differences in the isotopic values between lowland and highland piedmont regions. The $\delta^{13}C_{co}$ values are more enriched in lowland samples (avg. = −15.3‰) than in highland piedmont samples (avg. = −17.4‰), but there is no significant variation in $\delta^{13}C_{ca}$. The diet in highland piedmont areas was basically composed of more C_3 resources in the protein fraction than in the lowland region, whereas the whole diet values are similar. This can be the result of more C_4 protein in the diet, perhaps from more enriched guanaco in the lowlands than in the highlands, and/or by some C_4 plant in diets poor in protein (the C_4 plant probably more consumed is *Zea mays*).

The lack of correlation between $\delta^{13}C_{co}$ and $\delta^{15}N$ suggest that the $\delta^{13}C_{co}$ variation is due to direct or indirect C_4 consumption (Figure 15-2). The human $\delta^{15}N$ values are higher than the fauna tested and can indicate both arid–semiarid stress and the importance of meat consumption. There is no significant difference in $\delta^{15}N$ values between lowland and highland piedmont samples, but there is an unexpectedly low highland outlier (sample AF-2038) that is difficult to explain.

There is a modest correlation ($r^2 = 0.42$) between $\delta^{13}C_{co}$ and $\delta^{13}C_{ca}$, but there must have been some variation in the protein portion of the diet (Figure 15-3). It could be the result of diets with low animal consumption or the consumption of animals with enriched $\delta^{13}C$, such as the lowland guanacos [15]. It is significant to explore the difference between $\delta^{13}C_{co}$ and $\delta^{13}C_{ca}$ ($\delta^{13}C_{ca-co}$) as shown in Table 15-5, where an important range is observed in human samples with values between 3.9 and 7.6. Controlled feeding experiments demonstrated some meaning to these differences [2]. When $\delta^{13}C_{ca-co}$ is greater than 4.4, a diet of C_4 carbohydrates and C_3 protein is suggested. In contrast, if $\delta^{13}C_{ca-co}$ is less than 4.4, dietary protein is more enriched than that of whole diet. In general, the southern Mendoza human samples have $\delta^{13}C_{ca-co}$ greater than 4.4. This trend in $\delta^{13}C_{ca-co}$ is accepted as a pattern consistent with a situation where C_4 plants (e.g., maize) are introduced into a C_3 diet [24]. Only some lowland samples have $\delta^{13}C_{ca-co}$ less than 4.4, but they are near 4.4.

In Figure 15-4 the relationship between $\delta^{13}C_{co}$ and chronology is shown. The samples have been grouped each 1000 years and differentiation between highland piedmont and lowland regions is indicated. For the chronological definition, direct radiocarbon data, associated dated samples, and relative chronology have been used. There does not appear to be continuous enrichment in $\delta^{13}C_{co}$ through time as would be expected from continuous incorporation of corn in the diet, as in other regions of the Americas (e.g., [10]). The highest average $\delta^{13}C_{co}$ values are recorded between 3000 and 1000 BP (−14‰) basically centered in human samples from lowland sites dated 2800–1800 BP. For post-1000 BP, there is a slight average decline to more negative $\delta^{13}C_{co}$ (Figure 15-4), but there is greater variability within each temporal unit. Similar trends can be observed in the carbonate fraction of $\delta^{13}C$. It appears that consumption of the C_4 resources starts around third millennium BP (sample GIRA70) at Gruta del Indio and that more enrichment of $\delta^{13}C_{co}$ values come from lowland sites.

In Figures 15-5 and 15-6 any chronological trends are analyzed only with human samples with direct radiometric data (i.e., those with direct chronology plus directly associated samples from the same archaeological site). In general these figures show no consistent trend to increase the isotopic value through time, with significant variability within each period. The specific locality from which samples were obtained, and the need for more samples from certain periods, may be limiting our interpretation.

LATE HOLOCENE HUMAN DIET AND THE USE OF MAIZE

Recently the role of maize in diets of this region has been analyzed from different archaeological indicators [21, 46, 47]. The oldest macrobotanical remains of *Zea mays* in

TABLE 15-5 Human samples with isotopic information ($\delta^{13}C$ and $\delta^{15}N$)

Sample	Site	Area	Age and sex	USF	C:N	$\delta^{15}N$	$\delta^{13}C_{co}$	USF	$\delta^{13}C_{ca}$	USF	$\delta^{13}C_{en}$	$\delta^{13}C_{ca-co}$	Lab Code	^{14}C	±	Temporal
AF-2036	India embarzada	highland	Female 16–20	6206	3.3	9.7	−17.5	6207	−10.1	6208	−10.8	7.4	AA-54672	2576	61	3
AF-2038	El Desecho	highland	Female 39–49	6217	3.4	6.4	−18.8	6218	−11.2	—	—	7.6	AA-54671	5502	60	6
AF-508	Cerro Mesa	pedemont	Male 38–49	6209	3.3	10.8	−17.9	6210	−12.2	6211	—	5.7	—	—	—	1
AF-510		piedmont	Female +50	7329	—	10.9	−17.9	7330	−13.0	7331	−12.7	4.9	—	—	—	1
AF-2025	Tierras Blancas	piedmont	Male 30–48	7332	—	9.5	−15.5	7333	−8.2	7334	−10.8	7.3	LP-890	200	—	1
AF-2022	Ojo de Agua	piedmont	Male 15–18	6194	3.3	10.5	−18.5	6195	—	6196	−11.9	—	LP-921	1280	50	2
Ent 3	El Chacay	piedmont	Male 25–30	7341	—	7.9	−16.2	7342	−9.2	7343	−10.2	7.0	AA-59591	2321	66	3
AF-673	El Manzano	piedmont	Male 35–43	7335	—	10.2	−17.2	7336	−12.5	7337	−12.8	4.7	—	—	—	-
AF-1082	Agua del Toro	lowland	Female 35–49	6212	3.3	12.9	−16.5	6213	−11.3	—	—	5.2	LP-1368	210	60	1
ENT-2	Capiz Alto	lowland	Female	6226	3.4	11.7	−14.9	6227	−10.6	6228	−9.6	4.3	LP-1381	1120	60	1
AF-505	La Matancilla	lowland	Male 45–50	6197	3.3	11.9	−16.0	6198	−10.1	—	—	5.9	LP-1379	470	50	1
CS-10001	Cañada Seca	lowland	Male 30–45	6199	3.3	11.6	−15.7	6200	−9.0	—	—	6.7	LP-1374	1420	60	2
AF-2019		lowland	Male +50	7349	—	10.4	−14.5	7350	−10.1	7351	−8.8	4.4	—	—	—	2
AF-2018		lowland	Male 30–40	7354	—	11.5	−14.3	7355	−9.8	7356	−9.0	4.5	—	—	—	2
AF-2020		lowland	Male 35–49	7357	—	11.3	−14.3	7358	−9.5	7359	−8.7	4.8	LP-1184	1790	50	2
JP/J4	Jaime Prats	lowland	Male (?) 35–49	7346	—	9.8	−17.4	7347	−13.5	7348	−13.5	3.9	AA-59590	1887	42	2
JP-1155		lowland	Female 20–24	6219	3.4	10.6	−16.8	6220	−10.2	6221	−8.6	6.6	—	—	—	2
JP-1352		lowland	34–49	7338	—	9.9	−16.3	7339	−10.6	7340	−11.2	5.7	AA-59589	1880	49	2
JP1155		lowland		7344	—	10.9	−16.0	7345	−9.3	—	—	6.7	—	—	—	2
AF-503	Rncon del Atuel	lowland	Male 34–45	6203	—	—	—	6204	−7.9	6205	−9.9	—	—	—	—	2
AF-500		lowland	Male >50	6222	—	—	—	6223	−8.1	—	—	—	LP-1370	1760	70	2
AF-500		lowland	Male +50	7365	—	9.5	−15.2	—	—	—	—	—	—	—	—	2
AF-503		lowland	Female 35–45	7366	—	9.2	−13.9	—	—	—	—	—	—	—	—	2
Gira-70	Gruta del Indio	lowland	Adult	6201	3.3	10.8	−14.0	6202	−9.8	—	—	4.2	AA-54670	2879	37	3
GIRA-831		lowland	25–49	7363	—	—	—	7364	−10.5	—	—	—	AA-59588	3944	46	4
GIRA-27		lowland	Adult	6224	—	—	—	6225	−11.9	—	—	—	—	—	—	—
AF-13894		lowland	perinatal	7352	—	9.8	−15.0	7353	−10.1	—	—	4.9	—	—	—	—
AF-681	Medano Puesto Diaz	lowland	Female 40–45	7360	—	8.7	−15.6	7361	−10.2	7362	−10.7	5.4	AA-59587	2865	52	3
MGA-1	RQ-1	lowland	—	6214	3.3	10.9	−14.2	6215	−8.9	6216	−8.7	5.3	—	—	—	—
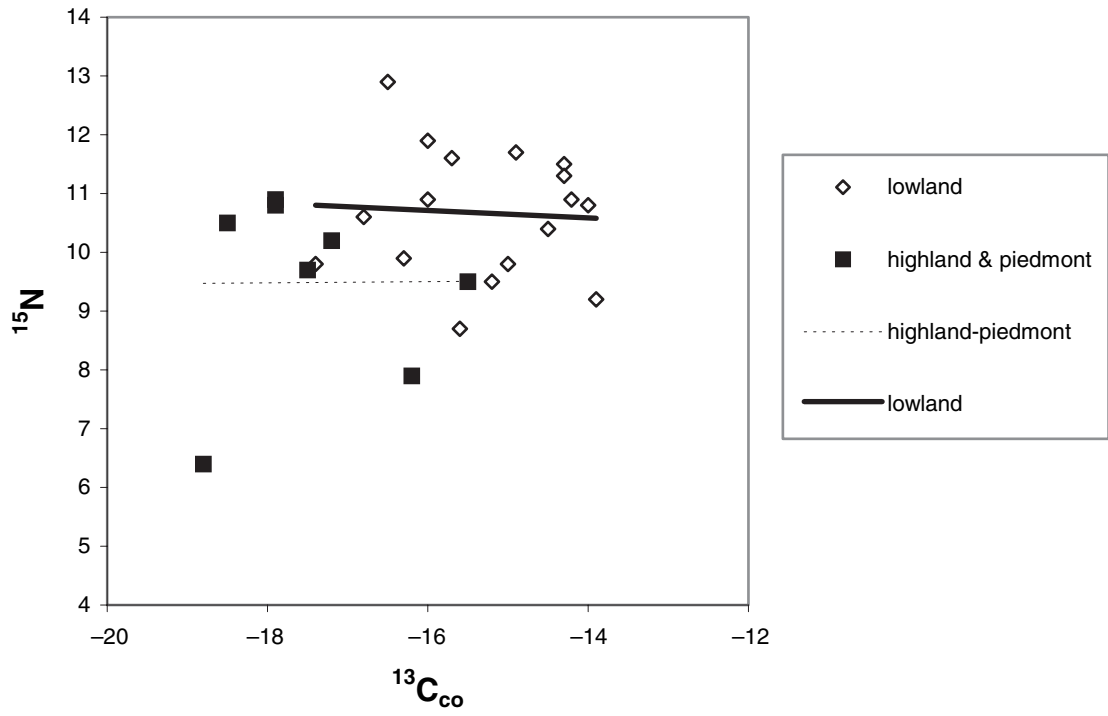
FIGURE 15-2 Correlation $^{15}N/^{13}C_{co}$.
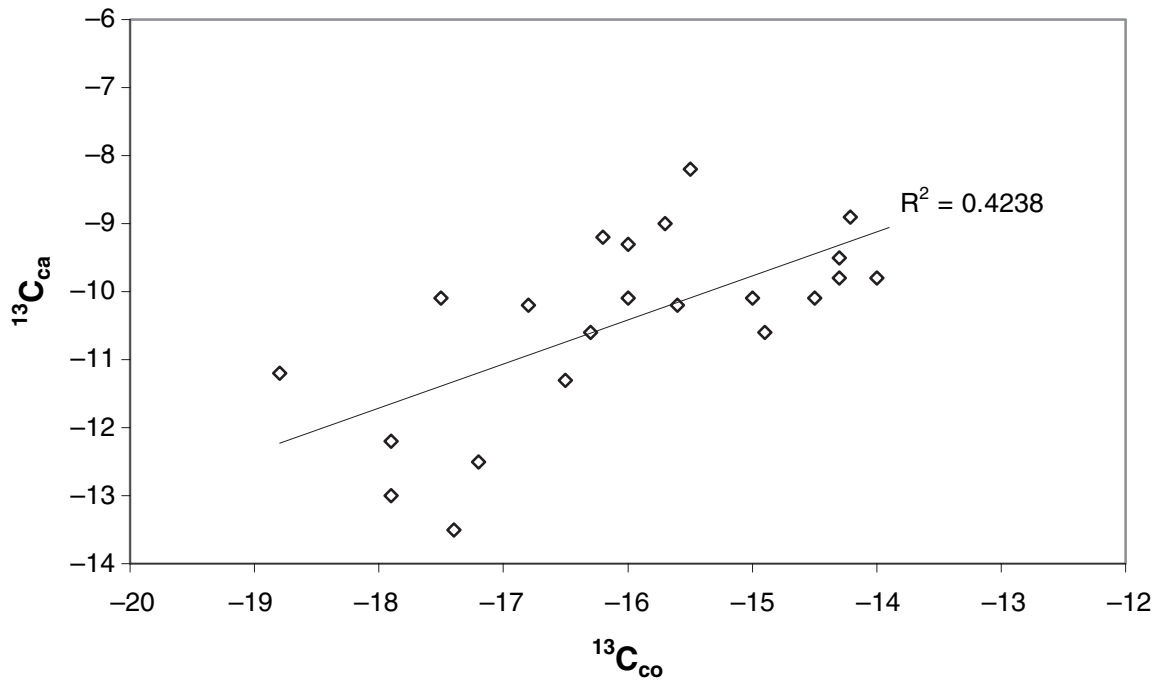
FIGURE 15-3 Correlation $^{13}C_{co}/^{13}C_{ca}$.
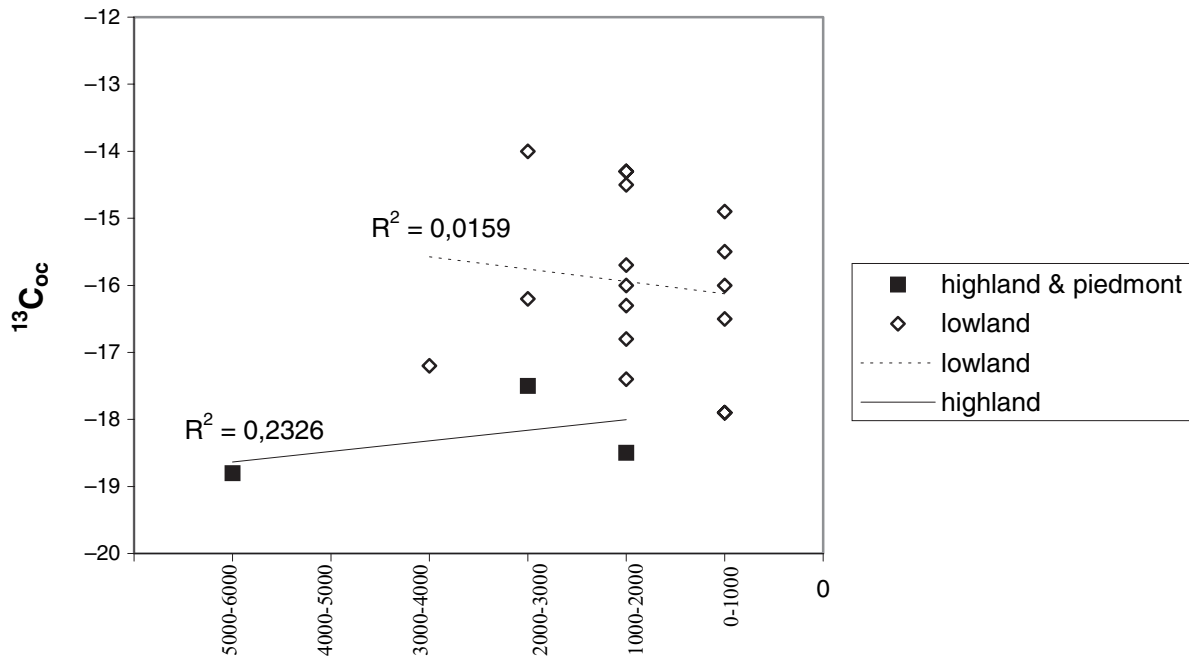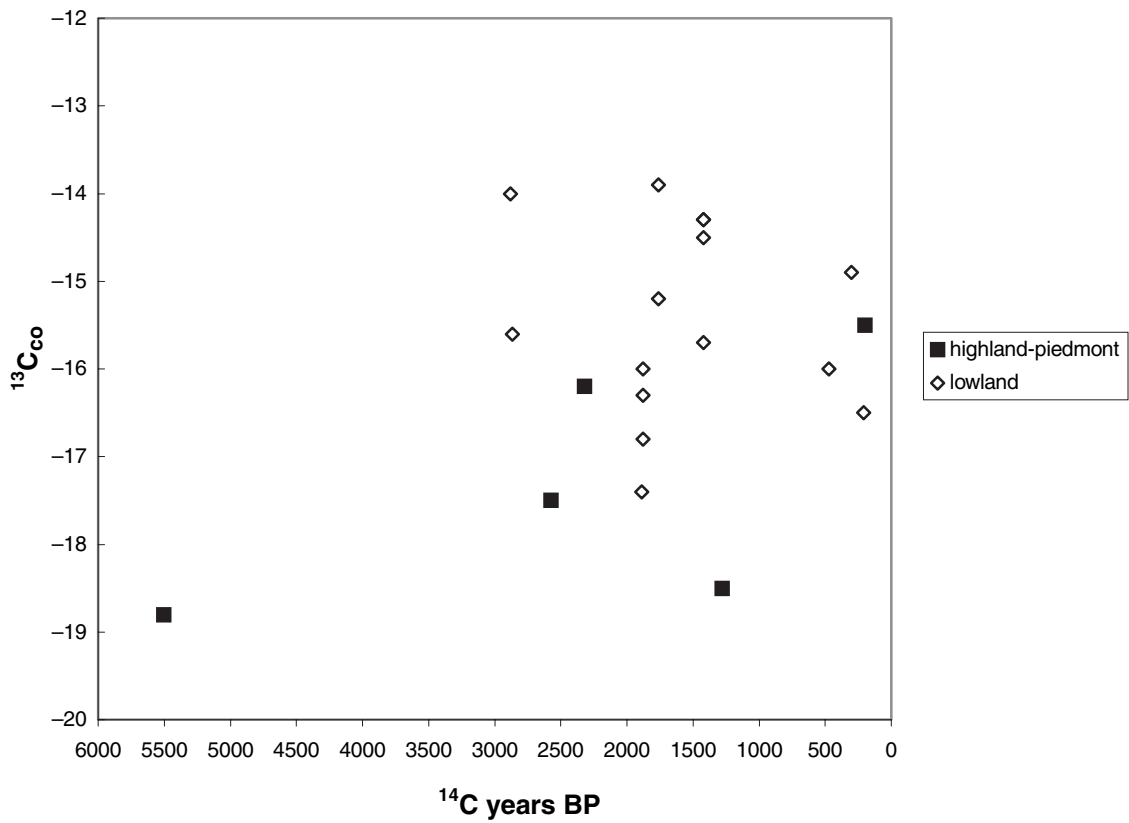
FIGURE 15-4   Temporal trends $^{13}C_{co}$.

FIGURE 15-5   Temporal $^{13}C_{co}$ radiocarbon.

central–southern Mendoza are recorded ca. 2000 BP in the Atuel Valley, but are more ubiquitous after 1000 years BP [21]. Novellino and colleagues [47] analyzed the latitudinal variation in dental caries in central–western Argentina. They observed no correlation between $\delta^{13}C_{co}$ value and caries frequency but a light latitudinal decrease in caries frequency that could indicate a relationship with the use of maize and other cariogenic resources (*Prosopis* ssp.?). In a recent paper it was proposed that $\delta^{13}C_{co}$ of human samples from central–southern Mendoza have significant variation, from −20.2 to −14.1‰ [21]. No chronological change was observed in values of that paper's collagen samples, which dated between ca. 2200 and 200 BP, a period in which there is a record of corn in the region. In this research there is now isotopic information on resources and $\delta^{13}C_{co}$, $\delta^{13}C_{ca}$, $\delta^{13}C_{en}$, and $\delta^{15}N$ information from human remains recorded in the past ca. 5500 years BP, that were not previously available. These isotopic values confirm the significant range of variation of the diet and add some significant knowledge. First, in the highland and piedmont regions the C_4 resources were not generally significant in human diets. Second, in the lowland the human diet was highly variable between individuals with little C_4 diet and others with moderate C_4 diet. The more positive carbon isotopes values are grouped in the mid Atuel Valley, basically in Rincón del Atuel, Gruta del Indio, and Cañada Seca, but at the same time other close archaeological sites (e.g., Jaime Prats), have more negative isotopic values. In Jaime Prats, and between contemporary human samples, there is a wide range of variation in the $\delta^{13}C$ values (Table 15-5). It exemplifies the high variability that characterizes the ratio of C_3/C_4 resources on the diet. Third, in reference to the temporal trends, these values show some individuals where the carbon isotope ratios are higher before 1000 years BP. It contrasts with the macrobotanical evidence for *Zea mays,* which shows a more ubiquitous record after 1000 years BP. The first record of *Zea mays* is later than the enriched $\delta^{13}C$ samples from Gruta del Indio (Gira-70). Fourth, if the incorporation of *Zea mays* were an adaptive change, it would be expected to result in a continuous enrichment of $\delta^{13}C$, but that is not observed. Fifth, another important aspect to mention is that C_4 resources never were uniformly used by the late Holocene human population in southern Mendoza. Instead, a high variability is observed for all times but especially in the lowlands.

For north Mendoza there are few isotopic values available [16, 47]. The three samples come from the western mountain region and range over the past 2000 years. The $\delta^{13}C$ data show an enrichment trend from −14 to −12‰; these values are higher than central–southern Mendoza but more isotopic values are requested to study the temporal variability in this part. For San Juan the first isotopic results are emerging and may show more temporal enrichment and spatial variability [56]. Preliminarily the general enrichment observed for San Juan and north Mendoza human samples

is not visible in central and southern Mendoza human samples.

THE *ZEA MAYS* FRONTIER ADOPTION MODEL

Central–southern Mendoza is the South American frontier of Pre-Hispanic maize expansion [19, 21, 39]. The ethnographic descriptions present hunter–gatherers living with neighbors farming to the north and probably to the west in modern Chile [11, 50]. The chronicles describe an exchange pattern between the hunter–gatherers, called **Puelches,** and their transcordillerean farming neighbors. Maize was one of the products obtained by these hunter–gatherers [7, 45]. In historic times, maize was obtained in this form, but it needs to be explored if it happened before. If so, the meaning of social life and subsistence need to be analyzed in greater depth. In contrast, the significance of maize in the diet and its role in these groups needs to be studied.

It is difficult to evaluate the significance of maize as a dietary staple if it were obtained by exchange [20, 21], in concordance with $\delta^{13}C$ values for human samples recorded in the past 1000 years. In general, C_4 resources were more important in the lowlands than in the highland piedmont areas, and in general less important than in north Mendoza and San Juan [47, 56]. The temporal trends of C_4 plant consumption was as important—and variable—between 2800 and 1800 years BP as it was later. This point is interesting because maize was recorded archaeologically more abundant and regionally spread in the past 1000 years than before. This can be interpreted as a variation in the significance of C_4 (maize?) in the diet. This high variability shows an economic or "adaptive" diversity, as also proposed for the Great Basin Freemont by Simms [57, 58]. This human strategy can be expected as a response to harsh environments where the cost of cultivating maize, and the adaptive risk and uncertainty, makes it highly unreliable within both a social and natural context.

The data from the southern periphery show at least three periods of corn use. In the first period, when maize was incorporated in the lowlands, it was a medium to low component of diet. This occurred some time between 3000 and 2000 years BP if we consider the human samples chronology and their associated isotopic values. In central–southern Mendoza there is only one site with corn from this time, Gruta del Indio. Probably this strategy is what Lagiglia [39] calls "incipient farming exploration and colonization." In later times, $\delta^{13}C_{ca}$ is higher (Figure 15-6) and shows a bigger difference than $\delta^{13}C_{co}$ (Figure 15-5). Low-protein plant foods (e.g., maize) are reflected in carbonate when consumed in small quantities and are reflected in collagen only when consumed in sizeable proportions [24]. Some individ-
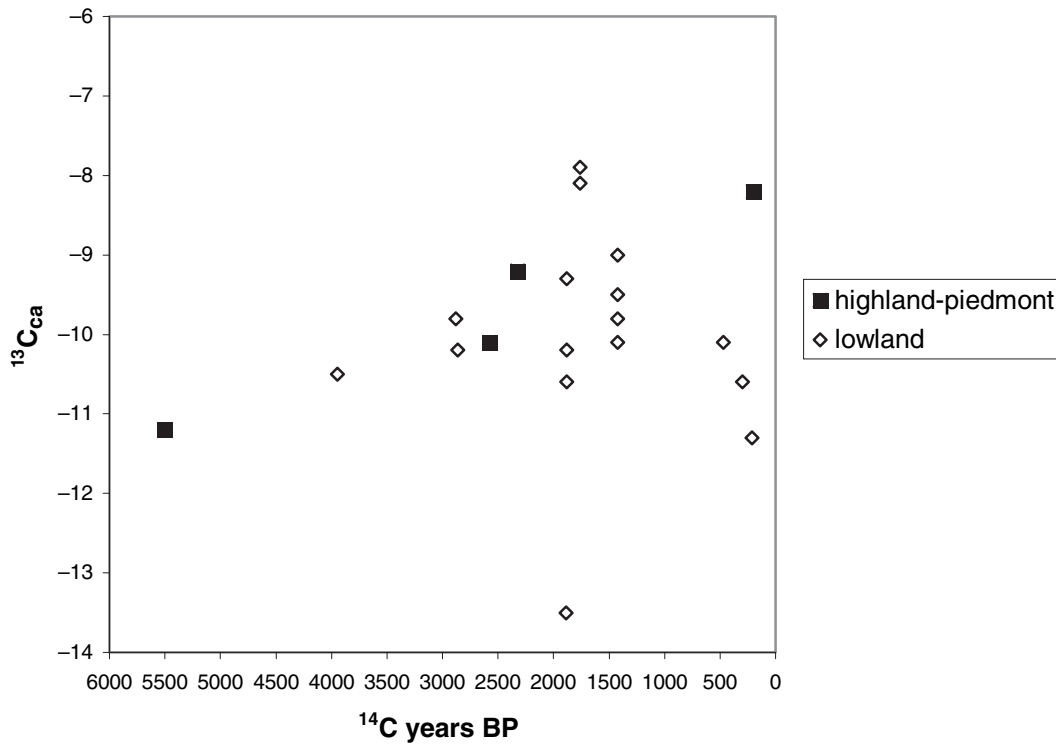
FIGURE 15-6 Temporal $^{13}C_{ca}$ radiocarbon.

uals consumed medium amounts of C_4 in their diets whereas others did not significantly consume these resources. At present, there are no maize samples attributed to the earlier dates, although around 2000 BP an **intensification process** appears to have started as a response to resource–human demography unbalance that could have affected the rest of central–southern Mendoza [41, 42]. Other authors, in relationship to this intensification process, propose farming pressure as a demographic growth from the north [13], but the relationship between intensification and farming expansion remains to be studied. Finally, the group of samples from the past 1000 years shows a lesser dependence on maize. There are maize samples to the south of Gruta del Indio, and they are more ubiquitous, with a wide geographic distribution. The oldest corn is recorded at the highland site of El Indígeno. The explanation for the decrease in isotopic $\delta^{13}C$ value, or its lack of increase through time, is a point that needs to be considered but is consistent with historic information that does not describe maize use in this region by local societies.

FINAL REMARKS

In the past decades, there has been an increased effort on the part of archaeologists to explain the adoption of new crops by populations or in the spread of domesticates [23].

It is difficult at this time to support the dualistic perspective where many scholars see the boundary between hunter–gatherers and agriculturalists as a continuum [62]. Maize was not used in the same way in all places and in all periods in South America [49]. The frontier of corn in the Pre-Hispanic record is a good region to evaluate the precondition, cause, and consequences of maize incorporation into the subsistence diet. Now the isotopic information shows a significant variation in C_4 resources, both spatial and temporal, and it demonstrates that C_4 resources were never a quantitatively significant part of human diets. But it is also necessary to understand isotopic variation compared with bioanthropological information about affiliation, mobility, and other indigenous resources.

Some points are emerging and some problems as well. The information on resources shows that human samples from the highland piedmont regions are more likely to have $\delta^{13}C$ values that directly reflect maize consumption, whereas the values obtained for guanaco in the lowlands make it difficult to measure direct maize consumption. Other aspects to consider include the potential of $\delta^{13}C$ and $\delta^{15}N$ values to reflect territoriality or mobility, or both, as an implication of significant variations in the isotopic structure of resources between lowland and highland piedmont regions. Another point that emerges is the relationship between the intensification process proposed to Atuel high valley, the chronology of the first corn, and the high variation on diet recorded in

the lowlands. The relationship among subsistence, technology, and land use, which could be recorded around 2000 years BP as a consequence of this process, needs to be analyzed with the domestication record and maize use. If this process is a response to macroregional change (i.e., farming expansion), it needs to be evaluated [13]. The lack of correlation between the archaeological abundance of maize and its consumption (as isotopically inferred) is a point that also needs to be explored. Variables including the role of maize in the diet, modes of obtaining it, and connections between different human populations (e.g., production vs. exchange; human migration vs. local incorporation) must be analyzed and discussed further. It is important not to confuse diet, strategies, subsistence, and technology in the discussion [62]. In the methodological aspect, the application of flotation, detailed archaeobotanical studies, and the increase of directly dated maize can confirm or deny the trends suggested here. Our data suggest that there is clear evidence of use of other C_4 resources (i.e., *Amaranthaceas*), but no detailed archaeobotancal studies are available that discuss its significance in human diet, and it could be underrepresented in the interpretation of $\delta^{13}C$ values. Finally, the ethnographic pattern of hunter–gatherers who obtained maize through exchange needs to be analyzed from a diachronic perspective to differentiate its dietary importance from those regions where it was locally cultivated and to more clearly understand its incorporation into various regional subsistence diets and its possible significance to demography, sedentism, and to complexity.

Acknowledgments

References Cited

1. M. Albeck. (2000). La vida agraria en los andes del sur. In: M. Tarragó, (Ed.), *Los Pueblos originarios y la conquista.* Buenos Aires, Argentina: Nueva Historia Argentina 1. pp. 187–228.

2. S. Ambrose, L. Norr. (1993). Experimental evidence for the relationship of the carbon isotope ratios of whole diet and dietary protein to those of bone collagen and carbonate. In: J. Lambert, G. Grupe, (Eds.), *Prehistoric human bone: Archaeology at the molecular level.* Berlin: Springer-Verlag. pp. 1–37.

3. R. Barbarena. (2003). *Los límites del mar. Isótopos estables en Patagonia Meridional.* Buenos Aires, Argentina: Sociedad Argentina de Antropología.

4. R. Bárcena. (1998). *Arqueología de Mendoza. Las Dataciones Absolutas y sus Alcances.* Mendoza, Argentina: EDIUNC, Universidad Nacional de Cuyo.

5. R. Bárcena. (2001). Prehistoria del Centro Oeste Argentino. In: E. Berberian, A. Nielsen, (Eds.), *Historia Argentina Prehispánica.* Córdoba; Argentina. pp. 561–634.

6. J. Bárcena, F. Roig, V. Roig. (1985). Aportes Arqueo-Fito-Zoológicos para la prehistoria del N.O. de la provincia de Mendoza: La excavación de Agua de la Tinaja I. *Trabajos de Prehistoria, 42,* 311–363.

7. G. Bibar. (1966) [1558]. *Crónica y Relación Copiosa y Verdadera de los Reinos de Chile MDLVIII.* Santiago, Chile: Fondo Histórico y Bibliográfico José T. Medina.

8. V. Castro, M. Tarragó. (1992). Los inicios de la producción de alimentos en el cono sur de América. *Revista de Arqueología Americana, 6,* 91–124.

9. J. Cavagnaro. (1988). Distribution of C3 and C4 grasses at different altitudes in a temperate arid region of Argentina. *Oecologia, 76,* 273–277.

10. J. Coltrain, S. Leavitt. (2002). Climate and diet in Fremont prehistory: Economic variability and abandonment of maize agriculture in the Great Salt Lake basin. *American Antiquity, 67,* 453–485.

11. L. Cornejo, L. Sanhueza. (2004). Coexistencia de Cazadores Recolectores y Horticultores Tempranos en la cordillera Andina de Chile Central. *Latin American Antiquity, 14,* 389–407.

12. H. D'Antoni. (1983). Pollen analysis of Gruta del Indio. *Quaternary of South America and Antarctic Peninsula, 1,* 83–104.

13. V. Durán. (2002). Nuevas consideraciones sobre la problemática arqueológica del valle del río Grande (Malargue, Mendoza). In: A. Gil, G. Neme, (Eds.), *Entre montañas y desiertos: Arqueología del sur de Mendoza.* Buenos Aires, Argentina: Sociedad Argentina de Antropología. pp. 85–102.

14. V. Durán, J. Ferrari. (1991). El proceso de araucanización del Sur Mendocino desde una perspectiva arqueológica. *Actas del XI Congreso Nacional de Arqueología Chilena* 3. Santiago de Chile: Chile. pp. 165–188.

15. J. Fernández. (1999–2001). H. Panarello, Isótopos del carbono en la dieta de herbívoros y carnívoros de los Andes Jujeños. *Xama, 12–14,* 71–85.

16. J. Fernández, H. Panarello, J. Schobinger. (1999). The Inka mummy from Mount Aconcagua: Decoding the geographic origin of the "messenger to the deities" by mean of stable carbon, nitrogen and sulfur isotope analysis. *Geoarchaeology, 14,* 27–46.

17. M. Gambier. (2000). *Prehistoria de San Juan.* 2da Edición. San Juan, Argentina: Ansilta Editora.

18. A. García. (1992). Hacia un ordenamiento preliminar de las ocupaciones prehistóricas agrícolas precerámicas y agroalfareras en el NO de Mendoza. *Revista de Estudios Regionales, 10,* 7–34.

19. A. Gil. (1997–1998). Cultígenos prehispánicos en el sur de Mendoza. Discusión en torno al límite meridional de la agricultura andina. *Relaciones de la Sociedad Argentina de Antropología, 22–23,* 295–318.

20. A. Gil. (2000). Arqueología de La Payunia. Ph.D. Dissertation. La Plata; Buenos Aires: Facultad de Ciencias Naturales y Museo. Universidad Nacional de La Plata.

21. A. Gil. (2003). *Zea mays* on South American periphery: Chronology and dietary importance. *Current Anthropology, 44,* 295–300.

22. E. González Díaz, L. Fauqué. (1993). Geomorfología. In: V. Ramos, (Eds.), *Geología y Recursos Naturales de Mendoza.* Buenos Aires, Argentina: Relatorio XII Congreso Geológico Argentino II Congreso Exploración de Hidrocarburos, pp. 217–234.

23. K. Gremillion. (1996). Diffusion and adoption of crops in evolutionary perspective. *Journal of Anthropological Archaeology, 15,* 183–204.

24. R. G. Harrison, A. M. Katzenberg. (2003). Paleodiet studies using stable carbon isotopes from bone apatite and collagen: Examples from Southern Ontario and San Nicolas Island, California. *Journal of Anthropological Archaeology, 22,* 227–244.

25. J. Hart. (1999). Maize agriculture evolution in the Eastern Woodlands of North America: A Darwinian perspective. *Journal of Archaeological Method and Theory, 6,* 137–180.

26. C. Hastorf, S. Johannessen. (1994). Becoming corn eaters in prehistoric America. In: S. Johannessen, C. Hastorf (Eds.), *Corn and culture in the prehistoric America.* Boulder, CO: Westview Press. pp. 427–472.

27. A. Hernández. (2002). Paleoetnobotánica en el sur de Mendoza. In: A. Gil, G. Neme (Eds.), *Entre montañas y desiertos: Arqueología del sur de Mendoza*. Buenos Aires, Argentina: Sociedad Argentina de Antropología. pp. 157–180.

28. A. Hernández, H. Lagiglia, A. Gil. (1999–2000). El registro arqueobotánico en el sitio "Agua de los Caballos-1" (San Rafael, Mendoza). *Anales de Arqueología y Etnología, 54–55,* 181–203.

29. A. Hunziker, A. Planchuelo. (1971). Sobre un nuevo hallazgo de *Amaranthus caudatus* en tumbas indígenas de Argentina. *Notas del Museo* 13. Mendoza, Argentina: Museo de Historia Natural de San Rafael.

30. H. Lagiglia. (1956). La presencia del patay en una tumba indígena de San Rafael (Mendoza). En: *Notas del Museo* 1. Mendoza, Argentina: Museo de Historia Natural de San Rafael. p. 4.

31. H. Lagiglia. (1962). Presencia del *Phaseolus vulgaris.* var. Oblongus Alef. En: *las excavaciones arqueológicas del Rincón del Atuel, Departamento de San Rafael, Mendoza.* Notas del Museo 6. Mendoza, Argentina: Museo Municipal de Historia Natural de San Rafael. p. 10.

32. H. Lagiglia. (1968). Plantas cultivadas en el área centro–andina y su vinculación cultural contextual. *Actas y Memorias del XXXVII Congreso Internacional de Americanistas, 2,* 209–228.

33. H. Lagiglia. (1975). Ecosistema natural y ecosistema cultural. *Anuario de Divulgacao Científica, 2,* 167–173.

34. H. Lagiglia. (1977). Arqueología y Ambiente Natural de los Valles del Atuel y Diamante. Ph.D. Dissertation. Facultad de Ciencias Naturales y Museo. La Plata, Buenos Aires: Universidad Nacional de La Plata.

35. H. Lagiglia. (1980). El proceso de agriculturación del sur de Cuyo. La cultura del Atuel II. *Actas del V Congreso Nacional de Arqueología Argentina, 1,* 231–252.

36. H. Lagiglia. (1981). Problemática del Precerámico y del proceso de agriculturización en el Centro oeste Argentino. *Boletín del Museo de Ciencias Naturales y Antropológicas "Juan C. Moyano," 2,* 73–93.

37. H. Lagiglia. (1997). *Arqueología de Cazadores–Recolectores Cordilleranos de Altura.* Mendoza, Argentina: ICN Ediciones Ciencia y Arte.

38. H. Lagiglia. (1999). Nuevos fechados radiocarbónicos para los agricultores incipientes del Atuel. En: Cristina Diez Marín, (Ed.), *Actas del XII Congreso Nacional de Arqueología Argentina, 3,* 239–250.

39. H. Lagiglia. (2001). Los orígenes de la agricultura en la Argentina. In: E. Berberian, A. Nielsen, (Eds.), *Historia Argentina Prehispánica.* Argentina: Cordoba. pp. 41–81.

40. H. Lagiglia. (2004). *Arqueología y Arte Rupestre de las Tinajas del sur de Mendoza.* Ediciones Ciencia y Arte. Mendoza, Argentina: Instituto de Ciencias Naturales.

41. G. Neme. (2002). Arqueología del Alto Valle del Atuel (Provincia de Mendoza). Ph.D. Dissertation. Facultad de Ciencias Naturales. La Plata, Argentina: Universidad Nacional de La Plata.

42. G. Neme. (2002). Arqueología del Alto valle del río Atuel: Modelos, problemas y perspectivas en el estudio de las regiones de altura del Sur de Mendoza. En: A. Gil, G. Neme, (Eds.), *Entre montañas y desiertos: Arqueología del sur de Mendoza.* Mendoza, Argentina: Sociedad Argentina de Antropología. pp. 65–83.

43. G. Neme, A. Gil. (2002). La explotación faunística y la frecuencia de partes esqueletarias en el registro arqueológico del sur mendocino. In: A. Gil, G. Neme, (Eds.), *Entre montañas y desiertos: Arqueología del sur de Mendoza.* Mendoza, Argentina: Sociedad Argentina de Antropología. pp. 141–153.

44. G. Neme, A. Gil. (2004). *Faunal Exploitation and Agricultural transitions in the South American agricultural limit.* Report Manuscript. Departamento de Antropología. Mendoza, Argentina: Museo de Historia Natural de San Rafael.

45. G. Neme, A. Gil. (2004). *Aportes para la Discusión del Intercambio en el sur de Mendoza. Report Manuscript. Departamento de Antropología.* Mendoza, Argentina: Museo de Historia Natural de San Rafael.

46. P. Novellino, R. Guichón. (1999). Formas de subsistencias e isótopos estables en el sur de Mendoza. *Revista de la Asociación Argentina de Antropología Biológica, 2,* 323–334.

47. P. Novellino, A. Gil, G. Neme, V. Durán. (2004). El Consumo de maíz en el holoceno tardío del oeste argentino: Isótopos Estables y caries. *Revista Española de Antropología Americana, 34,* 85–110.

48. D. Pearsall. (1992). The origin of plant cultivation in South America. In: C. W. Cowan, P. J. Watson, (Eds.), *The origins of agriculture.* Washington, D.C.: Smithsonian Institution Press. pp. 173–205.

49. D. Pearsall. (1994). Issues in the analysis and interpretation of archaeological maize in South America. In: S. Johannessen, C. Hastorf, (Eds.), *Corn and culture in the prehistoric New World.* pp. 245–272.

50. M. Planella, B. Tagle. (2004). Inicios de presencia de cultígenos en la zona central de Chile, Períodos Arcaico y Agroalfarero Temprano. *Chungara, 1* volumen especial, 387–399.

51. F. Roig. (1977). Frutos y Semillas Arqueológicos de Calingasta, San Juan. In: M. Gambier, (Ed.), *La Cultura de Ansilta.* San Juan: Instituto de Investigaciones Arqueológicas y Museo. pp. 216–250.

52. C. Rusconi. (1945). El maíz en las tumbas indígenas de Mendoza. *Darwiniana, 7,* 117–119.

53. C. Rusconi. (1962). *Poblaciones pre y posthispánicas de Mendoza.* 4 volúmenes. Mendoza, Argentina: Gobierno de Mendoza.

54. J. Schobinger. (1999). Las tierras Cuyanas. *Nueva Historia de la Nación Argentina, 1,* 159–180.

55. J. Semper. (1962–1968). H. Lagiglia, Excavaciones Arqueológicas en el Rincón del Atuel (Gruta del Indio). *Revista Científica de Investigación, 1,* 89–158.

56. N. Shelnut, A. Gil, R. Tykot, G. Neme, T. Michielli. (2004). *Isótopos Estables y Dieta en el Centro Oeste Argentino: Recientes Datos Obtenidos Sobre Muestras Humanas de San Juan.* Paper presented on the 14° Congreso Nacional de Arqueología Argentina, Río Cuarto, Córdoba.

57. S. Simms. (1986). New evidence for Fremont adaptive diversity. *Journal of California and Great Basin Anthropology, 8,* 204–216.

58. S. Simms. (1990). Fremont transition. *Utah Archaeology, 6,* 1–6.

59. J. Smalley, M. Blake. (2003). Sweet beginnings. Stalk sugar and the domestication of maize. *Current Anthropology, 44,* 675–703.

60. B. Smith. (1994/1995). The origins of agriculture in the Americas. *Evolutionary Anthropology, 3,* 174–184.

61. B. Smith. (2001). The transition to food production. In: G. Feinman, D. Price, (Eds.), *Archaeology at the millennium: A sourcebook.* New York: Kluwer Academic/Plenum Publisher. pp. 199–229.

62. B. Smith. (2001). Low–level food production. *Journal of Archaeological Research, 9,* 1–43.

63. K. Spielmann, M. Schoeninger, K. Moore. (1990). Plains–Pueblo interdependence and human diet at Pecos Pueblo, New Mexico. *American Antiquity, 55,* 745–765.

64. R. H. Tykot. (2004). Stable isotopes and diet: You are what you eat. In: M. Martini, M. Milazzo, M. Piacentini, (Eds.), *Physics methods in archaeometry.* Proceedings of the International School of Physics "Enrico Fermi" Course 154. Bologna, Italy: Società Italiana di Fisica. pp. 433–444.

65. R. H. Tykot, J. Staller. (2002). The importance of early maize agriculture in Coastal Ecuador: New data from La Emerciana. *Current Anthropology, 43,* 666–677.

66. M. Zárate. (2002). Los ambientes del tardiglacial y Holoceno en Mendoza. In: A. Gil, G. Neme, (Eds.), *Entre montañas y desiertos: Arqueología del sur de Mendoza.* Buenos Aires, Argentina: Sociedad Argentina de Antropología. pp. 9–42.