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The Relevance of Maize Pollen for Assessing the Extent of Maize Production in Chaco Canyon

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The Relevance of Maize Pollen for Assessing the Extent of Maize Production in Chaco Canyon

Phil R. Geib and Carrie C. Heitman

Opinion is hardly unanimous, but many authors endorse the idea that Chaco Canyon is and was a marginal place for growing corn (*Zea mays*), a chief source of food energy for Puebloan groups in the Southwest. Poor soils with "toxic" levels of salts, inadequate and unpredictable precipitation, and a short growing season have all been identified as contributing to the agricultural marginality of the place (Benson 2011a; Bryan 1954; Force et al. 2002; Judd 1954:59–61). Benson has been the most vocal proponent of this view of late, and his research has culminated in the conclusion that "the San Juan Basin, including Chaco Canyon, appears to be the least promising area for dryland farming; that is, it is too dry and its soils are N-poor, saline and too basic (high pH values) for the production of maize" (Benson 2011a:49–50; Benson 2011b). The Chaco Project's experimental maize fields in the late 1970s seem to bear out this statement: "Chaco, under modern conditions, is indeed marginal as a corn growing environment" (Toll et al. 1985:124). If Chaco Canyon is as marginal for farming as many claim, then the cultural achievements of the Puebloans that lived there are all the more remarkable, and this marginality has figured prominently in many interpretations about how and why Chaco Canyon developed as it did (Judge 1979, 1989; Schelberg 1981, 1982; Sebastian 1983, 1991, 1992; Vivian 1984, 1990). Chacoans had to import not only beams for building, pottery for cooking and storage, and stone for flaked tools but also even the staff of life—corn. And when you add in such exotics as turquoise, parrots, copper bells, and cacao, the potential "trade" deficit looms large. If Chaco Canyon did not provide even enough food for basic sustenance, what was it that made the place so special in the first place? More importantly, what literally fueled the obvious cultural fluorescence of Chaco Canyon and ts massive labor-intensive construction projects? Wills and Dorshow (2012:138) observe that "the popular perspective that Chaco was mysterious or enigmatic is largely a response to this view of the canyon as agriculturally marginal."

Yet, how do we know what the agricultural potential of the canyon was during the Bonito phase (ca. A.D. 850–1140) or that Chacoans could not provide for themselves? Perhaps the pendulum has swung too far toward a pessimistic assessment of the maize farming in and around the canyon. Certainly, Navajo farmers with considerable traditional knowledge and a real stake in the outcome successfully grew corn within Chaco Canyon (Judd 1954:52–59), and in 1898, George Pepper photographed Navajo fields on the floodplain of Chaco Canyon proper that produced a bountiful corn harvest (Figure 1a). Since photo documentation is not anecdotal, it seems a sufficient counter to assertions that farming of the Chaco floodplain was impossible because of high salinity. Judd's records of Navajo maize harvests evidently come from a time of more favorable precipitation and growing-season length, but this, too, could have characterized much of the Bonito phase. Figure 1b shows another Navajo field on the main floodplain at harvest time. Navajo farmers clearly experienced agricultural risk (Huntington 1914:81), but evidently the canyon proved a sufficient attraction to entice early settlement by them (Brugge 1986), perhaps precisely because of its productive potential. Farming potential was likely the prime motivation for initial Basketmaker settlement, a time when supplemental extra-local sources of maize were improbable. Since everything is relative, Chaco Canyon may have seemed like a small Eden in the context of the vast "dreary wastes" (Huntington 1914:81) of the San Juan Basin at large.

To his credit, Benson, like others before, has collected soil samples and processed meteorological and proxy climate data to demonstrate the marginality of Chaco for farming. He has also worked to chemically fingerprint the geographic sources of maize found at Chaco and elsewhere in the San Juan Basin (Benson 2011c; Benson et al. 2003, 2006, 2008, 2009). This research grew out of previous speculations that corn and other staples may have been imported into Chaco Canyon (Altschul 1978; Cordell 1979; Cordell and Plog 1979; Judge 1979; Lyons and Hitchcock 1977) and an exploratory study using concentrations of elements in corn and soils for

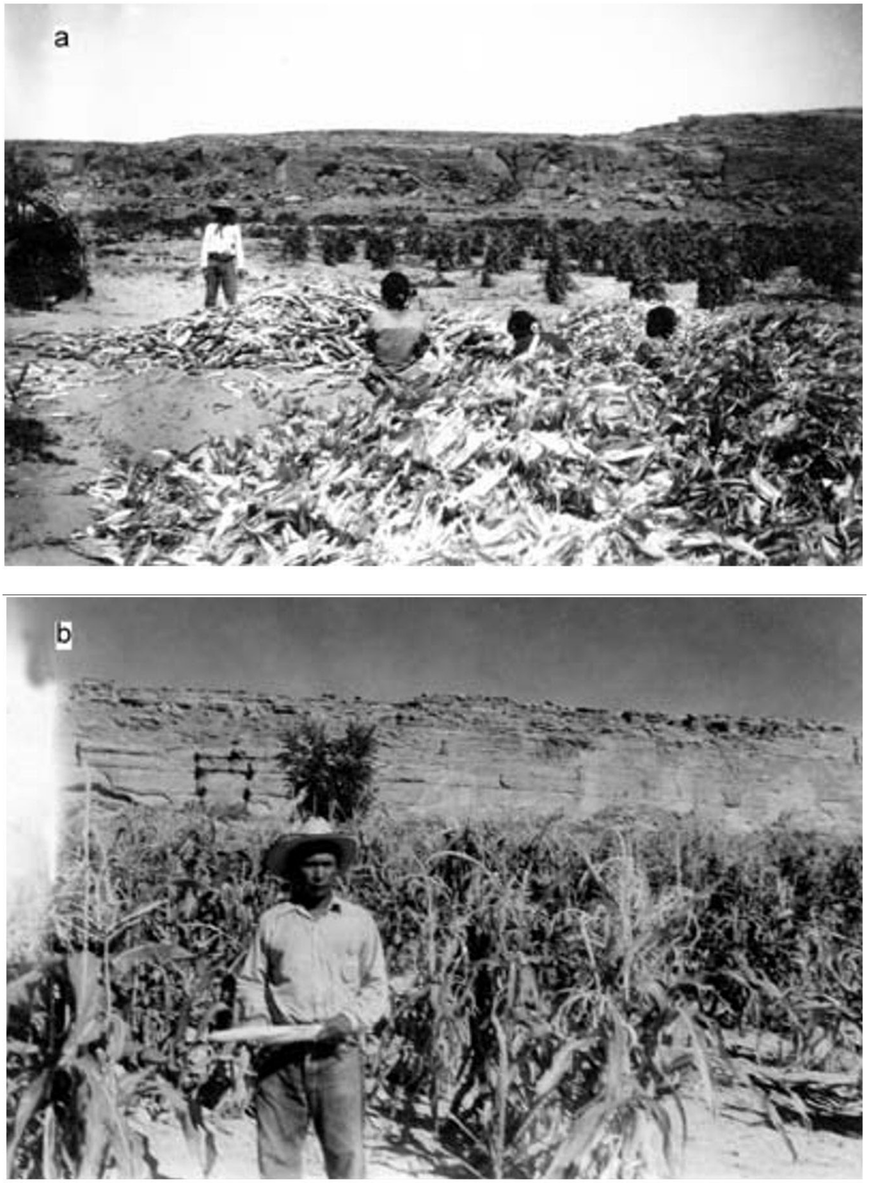

Figure 1. Navajo cornfields in Chaco Canyon: (a) field on the margin of the main floodplain at harvest time in 1898 (note the pile of husks in the foreground, with corn ears in a heap next to the standing individual) (Courtesy Maxwell Museum of Anthropology, University of New Mexico, Neg. No. 88.41.16); (b) Roy Newton in his cornfield on the floodplain of Chaco Wash at the intersection with Escavada Wash. (Courtesy Chaco Culture National Historical Park Museum Collection, chacoarchive.org, Neg. No. 78146

isolating potential source areas (Cordell et al. 2001, 2008). Corn sourcing is certainly an interesting approach, but one with many complexities and confounding issues yet to be resolved (Cordell et al. 2008). Troubling, too, is that Athabaskan-age cobs from Chaco (Gallo Cliff Dwelling) are also identified as coming from non-local sources: the Totah, Lobo Mesa, and Dinetah regions (Benson et al. 2009:403). Given the documentation of Navajo farming in Chaco Canyon, a local origin for most historic cobs from the canyon is expected. If locally grown Navajo corn is potentially misidentified as non-local, then what about the prehistoric specimens?

In the face of findings and claims as to the marginality of Chaco for farming purposes, it is certainly worth considering other evidence that bears upon the extent to which maize and other crops were grown there. Our main objective is to consider how corn pollen at Chacoan sites might inform about agricultural practices. This involves placing the pollen data generated by the Chaco Project (Cully 1985, 1988) within a regional context and incorporating the findings of experimental research with pollen washes from various portions of maize ears (Geib and Smith 2008). The latter have important implications for understanding how corn pollen might enter the archaeological record and the probabilities behind various behavioral interpretations of pollen counts. Equally significant is the Puebloan ethnographic record concerning the harvesting and processing of corn and the ceremonial use of corn pollen and plants. We discuss four different aspects, including (1) the pollen ecology of maize, (2) a brief review of experimental maize pollen washes and the implications for behavioral interpretations, (3) a review of the Puebloan ethnographic record pertaining to the use of maize and how this may relate to the patterns seen in pollen spectra, and (4) a summary of the available maize data for Chaco Canyon and how it compares on a regional scale.

Pollen Ecology of Maize and Experimental Washes

A useful starting point is to consider how corn pollen might enter the archaeological record, which requires a brief review of maize pollination. *Zea mays* is monoecious, having separate male and female flowering parts on a single plant; the tassels are the male or pollinating flowers, with the female flowering structures in the ears tightly enclosed by husks. Flowering generally occurs in two stages with close synchrony: pollen shed then silking. Male function preceding female function (protandry) helps limit self-pollination. Pollen dispersal usually begins two to three days prior to silk emergence and continues for five to eight days (Aldrich et al. 1986). As a wind-pollinated plant (anemophilous), corn, like all grasses, produces abundant pollen, with each tassel containing two to f ive million pollen grains borne in anthers, and an average-sized plant is estimated to produce between fifteen and fifty million grains (Miller 1982). As anthers open, the pollen grains pour out, to be carried away by breezes and to settle by gravity. Compared to other wind-pollinated species, maize pollen is relatively large and heavy, with the spherical grains falling rapidly (settling speed of 17–31 cm/second depending on degree of dehydration [Aylor 2002]), which generally limits dispersal. Although capable of being carried moderate distances by strong winds, especially with updrafts like dust devils, most corn pollen settles within 15 m of the plant, as estimated by cross-breeding studies or counts on surfaces (e.g., Bannert and Stamp 2007; Bannert et al. 2008; Pleasants et al. 2001). Much of the pollen falls directly on the broad hairy surfaces of the corn plant and adheres to the fine sticky hairs (trichomes) of the silks, which serve to catch and anchor the pollen grains. Silks are the functional stigmas of the female flowers, and each must be pollinated in order for an ovule to be fertilized and develop into a kernel. The tight outer wrapping of the ears protects the developing kernels and precludes the deposition of any corn pollen upon them.

The nature of maize pollination holds at least two important implications for inferences drawn from corn pollen recovered from archaeological sites. First, maize pollen is unlikely to end up at a site through natural processes like other wind-pollinated plants such as pine or other grasses unless that site is located within or quite close to a cornfield, especially on the downwind side. Even then, corn pollen deposition is likely to be minimal relative to other environmental pollen rain, so proportionally swamped. Although each corn plant produces millions of pollen grains, many other plants produce far more, at least in aggregate, including other grasses and even some entomophilous plants, with counts for some pines at more than 1,000 million grains per plant (Khanduri and Sharma 2002). In modern maize fields, Martin and Byers (1965) report that the amount of corn pollen present is often no greater than around 1 percent, and Dean (1995:Table 22.2) reports values between 0 percent and 11 percent with a mean of 4 percent for modern plowed and irrigated cornfields. The overall low proportion reflects the proportional swamping of corn pollen by that from other taxa.

The second implication is that storing or processing shucked corn ears or kernels is unlikely to deposit corn pollen in any significant quantities within the archaeological record. This claim was verified by experimental pollen washes of 26 maize samples, including kernels, silks, and husks (Geib and Smith 2008). Pollen of any type was rare in all of the maize washes: 23 (88 percent) produced counts of 11 or less total pollen grains, and the material on the slides was extremely clean. The pollen washes of separate portions of 3 corn ears revealed a dramatic reduction in corn pollen after removal of the outer husks (Figure 2). Indeed, except for the outer husks, nearly no corn pollen was recovered from the other portions of the maize ears, and none came from the husked ears. Although husking removed all of the maize pollen in a controlled experiment, prehistoric people probably husked corn less carefully, and handling could transfer

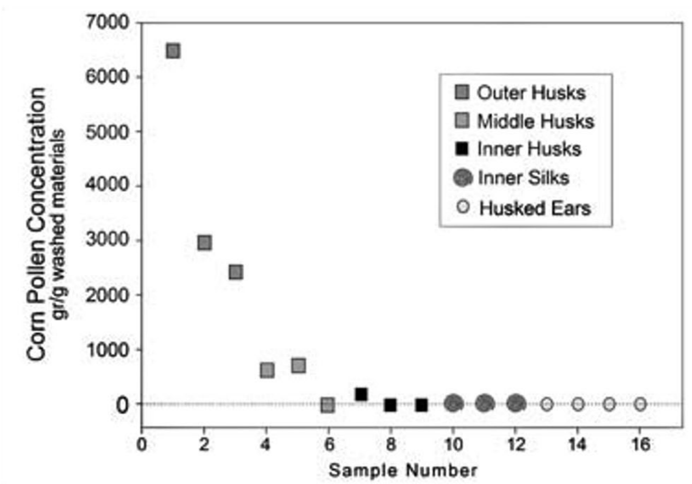

Figure 2. Concentration of corn pollen (grains/gram washed materials) from husked ears, inner silks, and husks removed sequentially from outside to inside (n=16) (Geib and Smith 2008:Figure 6). Maize pollen aggregates were totally absent from these samples, even the outer husks.

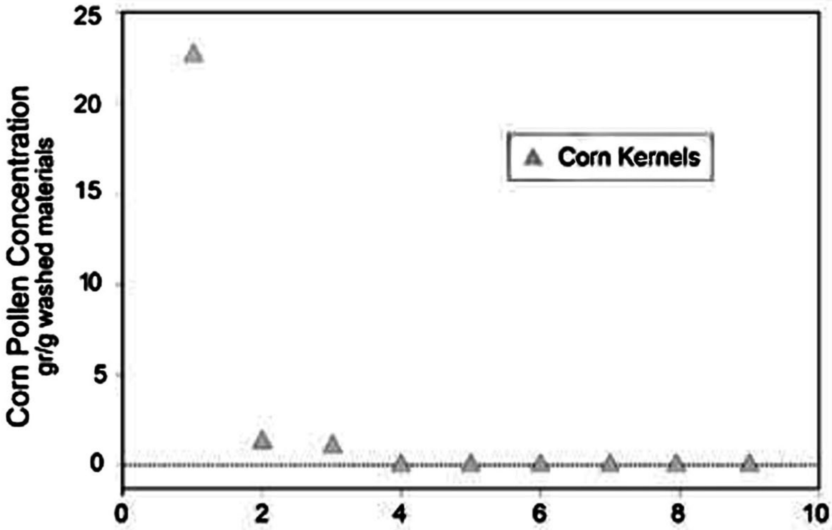

Figure 3. Concentration of corn pollen (grains/gram washed materials) from corn kernels removed from cobs in traditional manner (n=9).

pollen from the outer husks to kernels. To test this possibility, Geib and Smith (2008) also made pollen washes of 9 samples of kernels from corn ears husked and shelled following traditional practices. These washes also revealed a largely similar absence of maize pollen (Figure 3), with just 3 of the 9 samples containing any maize grains. The maximum was just 7 grains in one sample for a concentration value of 23 grains per gram; another sample had 3 grains and the third a single grain for concentration values of less than 2 grains per gram.

The basic finding of the experimental washes is that maize pollen is generally absent or exceedingly rare on kernels or shucked ears, the items that archaeologists are most interested in making inferences about. With little or no maize pollen actually present on kernels or shucked ears, it seems unlikely that storing or processing this resource would produce a directly related pollen signature, or one detectable relative to other pollen taxa in a standard archaeological sample. Maize ears or kernels not grown locally but imported from some distant agricultural f ields are even less likely to produce anything but trace amounts of pollen in a standard archaeological sample.

Corn pollen will be most abundant where outer corn husks or other plant portions, especially male flowers and leaves, are deposited. As such, harvesting practices become critical. Was husking done in the f ield or adjacent field house with shucked ears transported back to the residential site? Alternatively, were whole ears brought back to the settlement for husking there? Ethnographies demonstrate that Puebloans did both in the recent past, with field husking common among the Hopi (e.g., Stephen 1969 [1936]:940–941, 953) and Zuni (Cushing 1920:211), but with unhusked ears brought back to such villages as Cochiti, San Ildefonso, and Santa Clara (Goldfrank 1927; Robbins et al. 1916) where the husking was done communally in plaza spaces. Since wagons and draft animals were used at the Rio Grande pueblos (and at Zuni), it is difficult to know the time depth for settlement husking. Figure 1a demonstrates a probable common practice for Navajos in Chaco, that of removing husks in the field. Since this eliminates extraneous weight, it might have been the preferred method in prehistory unless maize f ields were very close to a residence. Field husking and drying would further reduce weight, and field drying is a documented practice, with the ears left in the field for many weeks (Hough 1918). Field husking would also leave organic debris to rot in the field, thereby returning much-needed nutrients to the soil. Corn husks and even whole plants could enter sites for ceremonial and other purposes; thus, it is to this aspect that we now turn.

Puebloan Use of Maize Pollen

Puebloan ethnographies document many other ways for corn pollen to enter the archaeological record at settlements, primarily because offerings of corn pollen (or a corn meal/pollen mix) is an ever-present component of Pueblo ritual practice (Table 1). Contexts for such offerings range from the habitual daily routine of an individual offering corn pollen to the rising sun, to more restricted ceremonial contexts involving ritual specialists. According to Parsons, “It seems probable that anciently every Pueblo sprinkled corn meal or pollen at sunrise and said a prayer. Elders and ceremonialists still do so” (Parsons 1939:179). This practice is repeatedly described in myth (e.g., Acoma: Stirling 1942:3, 5, 7, 13) and songs (Santo Domingo: White 1935:97–99). In the origin myth of Acoma, Stirling

Table 1. Summary of Contexts and Occasions when Puebloans Sprinkle Corn Meal/Pollen.

Use Category	Specific Context	Page References from Parsons (1939)
On people		
	Initiates	672
	Newborns	46
	The deceased	70, 73, 293
	Racers	311, 816
	Dancers	563, 634, 685, 816, 831, 836
	Kachinas	174, 318, 381, 461, 468, 472, 567, 569, 570, 579, 735, 742, 748, 749, 753, 755, 757n., 761, 772, 773, 778, 785, 787, 801, 1099
	Warriors	648
On ritual paraphernalia/features		
	Fetishes	654, 701–792
	Masks	294, 755, 850
	Scalps	645
	Prayer sticks & feathers	283, 284, 292, 315, 558, 567, 581, 775, 816, 955
	Kiva sipapu	383
	Kiva foot drum	512, 631, 667
	Medicine bowl	360–361, 375, 689, 704
	Staffs	327, 491n., 577, 606, 703
As part of a ceremony		
	To mark a ritual position	294, 366, 373, 512–513, 674n., 687, 700, 704,711, 755, 759, 839, 867n.
	Sprinkled down a kiva hatch	293, 295n., 362, 568, 574, 607, 617
	Offered to the sacred directions	260, 558, 827
	To create a meal road	18, 362, 693, 697, 706, 834
	In front of a line of dancers	616, 620
	To create a ground painting	294

(*continued*)

Table 1. Summary of Contexts and Occasions when Puebloans Sprinkle Corn Meal/Pollen (*continued*)

Use Category	Specific Context	Page References from Parsons (1939)
On plants and animals		
	Snakes	244, 293, 512
	Deer or rabbit	293, 304, 540, 760, 847
	Ants	293, 714
	Crops	547
	Plants and trees	277, 293, 785
	Eagles	296–297
To the heavens		
	Sun	36, 139, 179–180, 212, 218, 292, 311, 468, 517, 544, 557, 562, 583, 584, 593, 606, 672, 695, 703, 747, 775, 816, 904, 1079n.
	Moon or stars	583
At sacred places		
	Springs or rivers	375, 558, 584, 587, 788
	On altar or shrine	358, 361, 603, 633, 634, 635, 667, 677, 680, 690, 704, 714, 741, 769, 818, 819

From a survey of Parsons's *Pueblo Indian Religion* (1939).

(1942:5) describes how the two sisters first taught the people how to gather corn pollen and, with corn meal, offer it to the rising sun each morning.

Admittedly there is a great deal of overlap or conflation in the use of both corn pollen and corn meal as "prayer meal" across the Pueblo Southwest. Working at Isleta, Parsons notes that her informant used these terms indiscriminately and warns the reader to bear this lack of distinction in mind when reading ceremonial accounts (1932:275; see also 1939:296). Goldfrank (1927:68) notes the same lack of native differentiation at Cochiti but that shamans specifically keep corn pollen in a small clay bowl called a "pollen basket." Corn pollen may be used alone or mixed with ground shell and turquoise, or with micaceous hematite, or combined with pollen from other plants (Parsons 1939:296). Similarly, corn meal may also be used alone or added to such mixtures. Space limitations preclude an exhaustive listing of the host of contexts and occasions in which corn pollen/meal is sprinkled; suffice it to say that they are numerous and varied and many occur daily.

Corn pollen can also enter the record in other ceremonial ways that involve the use of corn plants, especially the upper portions of stalks that include the male tassels after pollination. Examples include ceremonies at Walpi where corn plants are set up in clay pedestals to create a mock cornfield, with plants subsequently being knocked over and distributed to women and children (Fewkes 1900:608–609, 617) or the common practice at Nima'n ceremonies of handing out gifts tied to a corn stalk to young children. Also at Nima'n, the Hemis Katsinas enter the plaza carrying armloads of freshly cut green corn, ears still on the stalks (also for the Lalakon dance [Stephen 1969 [1936]:936–937]). Ceremonies like this could introduce quantities of maize pollen to a settlement, and although these specific ones may lack sufficient time depth, similar practices might date back to the Basketmaker period. Ritual can even introduce corn pollen to granaries: at Cochiti four unhusked ears of corn, referred to as "the mothers," are saved and placed in the four corners of a corn storage room and the husked ears are piled on top of them, whereas at Laguna, an entire corn stalk is placed in each corner of a granary (Goldfrank 1927:92).

There are many examples of corn husks being used for various purposes such as wrappers around ceremonial items, for r olling tobacco or other ceremonial or medicinal plants, in food preparation, or even for artifacts. Nonetheless, the husks selected for this are likely to be fresh ones from the interior of cobs rather than the weathered ones on the exterior, and examination of ethnographic and prehistoric items in museums that include maize husks supports this claim. As the maize ear pollen wash study demonstrated, corn pollen occurs in abundance on the outer husks but with little to none on interior leaves. As such, use of corn husks at sites is unlikely to be a major contributor of maize pollen to the archaeological record. This is also true if husks were saved for fuel, something that might have occurred in wood-deprived Chaco during the Bonito phase, since hot fire destroys pollen (Ruhl 1986), and husks would have burned quickly and been reduced to ash.

The Chaco Canyon Pollen Record

With the forgoing as context, we turn to the pollen data for Chaco Canyon proper, which is limited compared to the large amount of excavation that has occurred. Cully (1985, 1988) reports pollen counts from 4 sites: 2 small sites (29SJ627 and 29SJ629, hereinafter 627 and 629) and select rooms of Pueblo Alto and Kin Nahasbas. The last site has just 5 samples, which might be poorly representative of the site as a whole. Clary (1987) provides pollen counts for 4 additional samples from Pueblo Alto, 3 from mealing bins of Room 110 and 1 from wall niche 9, also in this room. The total number of samples reported from this effort is 93, and more than half (62.8 percent) of these produced adequate counts, which means a minimum of 200 grains following Barkley (1934; see Rull 1987). A 200 grain count provides about a 75 –85 percent accurate representation for common pollen types (Dimbleby 1985; Martin and Byers 1963). Twenty-nine of the samples (31.2 percent) have pollen proportions calculated on counts of less than 200 grains, with 91 grains the lowest. Fifteen samples were essentially "sterile," with no count given, but evidently listed to record the observation of corn pollen (and cactus in one instance); one of these sterile samples is for mealing bin 6 at Pueblo Alto, which produced a count of just 17 grains.

Cully analyzed her samples in the late 1970s for the Chaco Project, a time when palynological research in archaeology was still in its formative stages (at least in the New World). Sampling strategies, processing technique, and counting methods have continued to evolve, and even during the Chaco Project, the procedures for sampling rooms changed, such that the approach for 627 (the first site analyzed) differed from 629 and Pueblo Alto. Most analysts these days include tracer or marker grains (e.g., *Lycopodium* spores) as a "spike" to a sample prior to processing, which allows calculation of pollen concentration (PC) and pollen accumulation rate (Maher 1981; Stockmarr 1971). Marker grains also allow calculation of confidence intervals for estimates (Rull 1987) and the specification of how many grains need to be counted in order to discover rare pollen types (Dean 1995). Absolute pollen frequencies allow an estimate of the deposition of a pollen type (such as corn) that is independent of any other pollen type. Although this approach is now standard practice in the Southwest, most comparisons are still done with proportions, such that the grains of a given taxon are presented relative to the total grains counted in a sample. Since only four of the Chaco samples from the 1970s were spiked (the four samples analyzed by Clary), we mainly restrict our comparisons to proportions. Dean (2006) demonstrates that PC values can be calculated after the fact if the pollen residue from the original samples still exists, but this requires doing new counts after spiking the samples.

Not surprisingly, corn pollen is present in the Chaco samples (Table 2); indeed, Cully observed it in nearly all of them (<80 percent occurrence for the three sites with adequate sample size), even in some that did not produce adequate counts. Aside from mere presence, corn pollen is quite abundant in several of the samples, accounting for 10 percent or more of the pollen counted in more than 35 percent of the samples from each site (Figure 4). This is significant since it greatly exceeds the amount of corn pollen commonly present on modern maize f ields, which is often around 1 percent (Martin and Byers 1965; cf. Dean 1995:Table 22.2). Of course fields are open settings where environmental pollen rain from prolific producers

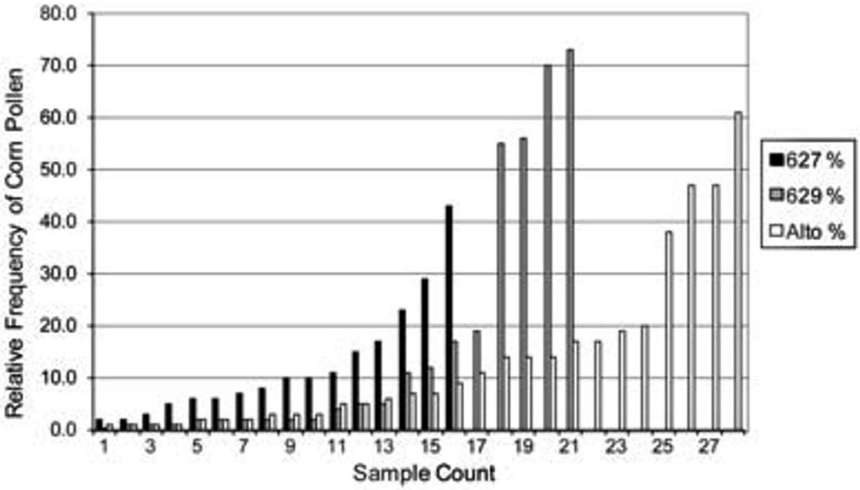

Figure 4. Relative frequency of corn pollen in samples with "adequate" counts from 29SJ627, 29SJ629, and Pueblo Alto, Chaco Canyon, New Mexico. (Data from Cully 1985)

Table 2. Summary of Corn Pollen Data from Chaco Canyon Sites.

Attribute	627	629	Alto	Nahasbas
n of samples reported	24	28	36	5
n of samples with reported counts	19	23	31	5
% of samples with reported counts	79.2	82.1	86.1	100.0
n of 200+ grain counts	9	14	21	5
% 200+ grain counts	47.4	60.9	67.7	100.0
n of counted samples with corn	16	21	29	2
% of counted samples with corn	84.2	91.3	93.5	40.0
n of total samples with corn	21	26	33	2
% of total samples with corn	87.5	92.9	91.7	40.0
n of samples with 10%+ corn	8	8	13	2
% of samples with 10%+ corn	42.1	34.8	41.9	40.0
Average corn proportion	10.4	14.9	14.9	16.2
Standard deviation	11.2	23.6	19.6	23.2
Lower quartile	2.5	1.5	2	—
Median	7.0	2	7	—
Upper quartile	13.0	14.5	17	—
Maximum	43.0	73.0	68	50.0
Total pollen grains counted	3,198	4,668	6,010	1,090
Total corn pollen grains counted	343	640	1,038	190
% corn pollen grains counted	10.7	13.7	17.3	17.4

Data from Clary 1987; Cully 1985, 1988.

can swamp the maize signal, whereas most archaeological samples come from closed environments where the pollen record is accumulated by humans to some unknown degree.

One way of trying to evaluate the pollen record from the Chaco Canyon sites is to compare it against the results obtained for other sites in the greater San Juan Basin and beyond (e.g., Dean 1999; Gish 1994a, 1994b; Smith 1999; Smith et al. 1999). This can be done in many dif- ferent ways, but we take a broad-brushed approach, focusing on vari- ability in maize pollen occurrence. Rather than finely parsing the data, we examine site departures in corn pollen representation in two ways: (1) the average relative frequency of corn pollen in the samples for a given site, and (2) the average count of corn pollen relative to the total pollen sum for each site. We specifically exclude modern samples and post-occupation fill at sites and also exclude fecal specimens, such as those from Bis sa'ani (Cully 1982). Fecal pollen counts are a significant source of information about diet and other aspects of plant use (e.g., Bryant and Dean 2006; Dean 2006), but few Chacoan sites in addition to Bis sa'ani have preserved specimens, most notably Salmon Ruins (Reinhard et al. 2006a, 2006b) and Pueblo Bonito (Karl Reinhard, personal communication 2013). The contexts that we included are diverse but mostly intramural, especially structure and pit surfaces. After calculating two regional means of corn pollen representation, we computed departures therefrom (anomalies) for each site, which were then transformed to Z-scores. We recognize that this approach is insensitive to potentially important variability introduced by context, site age, sampling, processing, counting, and other details, but with suff iciently large sample sizes, both within sites and across the region as a whole, any patterns disclosed are likely to be robust, and they should have comparative heuristic value at a broad scale. Use of absolute corn frequencies could be more informative but cannot at present be done with Cully's Chaco data. As discussed below, pollen counts for Pueblo Alto and Pueblo Bonito obtained more recently by Susan Smith for the University of New Mexico allow comparison using maize pollen concentration in a summary fashion.

Our current database has over 1,200 pollen samples from 50 sites and a total pollen sum of more than 235,000 grains. Given this scale, the patterns should be telling us something about differential corn pollen accumulation at sites across the region. The plots of Z-scores (Figure 5) by the two different methods closely mirror each other; indeed, the r 2 for the correlation between the data sets is 0.98. The zero line marks the mean in these figures, which we assume represents the baseline frequency of corn pollen at habitations resulting from prehistoric Puebloan use of this domesticate. Both means are somewhat positively skewed by the few sites with high levels of corn pollen, which includes the Chaco Canyon sites. For example, the average proportion of corn pollen per sample is 3.6 compared to a median 1.5. The median value is similar to the proportion of corn pollen in modern fields where deposition s largely mediated by natural processes.

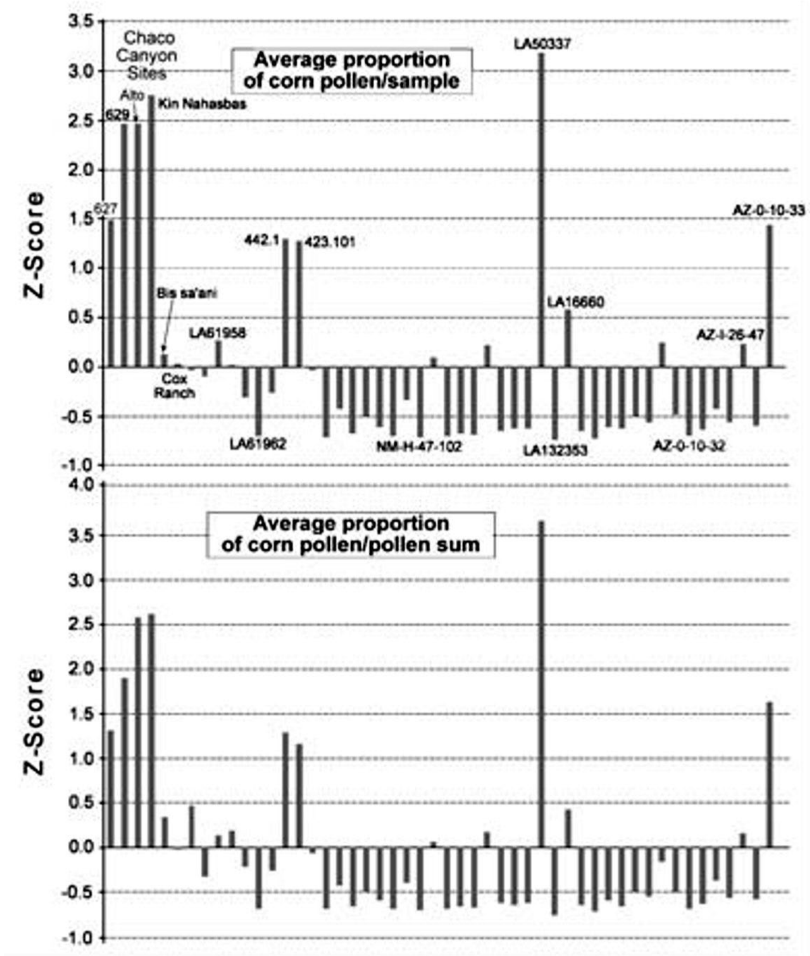

Figure 5. Plots of the anomalies from the mean of corn pollen representation calculated by two different methods; Chaco Canyon sites are shown in sequence to the far left.

Positive departures denote those sites with greater than average corn representation and vice versa for negative departures; bar height signifies the extent of departure in standard deviations. The small number of sites with positive departures include all four Chaco Canyon sites grouped on the far left: 629, Alto, and Kin Nahasbas are more than two standard deviations above the mean with 627 just less than 1.5 standard deviations above the mean. Even though the Chaco Canyon sites are a significant part of the reason for the mean being pulled higher than the median, these sites are still quite divergent; they would appear even more divergent based on the median value of corn pollen representation. Higher than average amounts of corn pollen is not true for Chacoan outliers, since Bis sa'ani and Cox Ranch have near-average values.

The only site in our database with more abundant maize pollen than the Chaco Canyon sites is LA50337 (Clary 1993), located along the La Plata River in northwestern New Mexico. Many of the samples from this site with abundant corn pollen came from plaza contexts where ears may have been husked and ceremonies performed. Situated as it is in a prime agricultural setting, one that Benson et al. (2007:301) identify as "an excellent area for maize production and exportation," a high incidence of maize pollen at LA50337 is perhaps unsurprising. Yet the Chaco Canyon sites are little different and contain far more maize pollen than other sites located in seemingly less marginal settings. If we were to plot the maize pollen departures as isopleths, there would be a peak at Chaco Canyon and another along the La Plata River, with plenty of negative space.

Further support for concluding that Chacoan sites have extraordinarily high amounts of corn pollen comes from the trash mounds of Pueblo Alto and Pueblo Bonito. Susan Smith and Susan Fish have both analyzed additional samples from Pueblo Alto, specifically the trash mound, and Smith has also analyzed samples from the Pueblo Bonito trash mound. This work was done for Wirt Wills and Patricia Crown, and the data are not yet available. Some summary results presented by Susan Smith at a recent SAR symposium, however, provide a useful glimpse of the findings. These more recent pollen counts fully support the overall trend in maize pollen occurrence in Cully's samples, and Smith does this with a more robust quantification measure, that of maize PC (Fish's data is based on proportions). Susan Smith (personal communication 2010) found that maize pollen concentration (grains/ gr of sample) for both the Alto and Bonito mounds was far above other sites in the region for which she had comparative data. Whereas non-Chacoan sites had maximum values of less than 400 grains/gr and in most cases less than 200 grains/gr, samples from both Chacoan great house trash mounds had upwards of 500 maize grains per gram and most samples had more than 1,000 grains per gram. Susan Fish also found high proportions of corn pollen in most of the samples that she analyzed from the Pueblo Alto trash mound, most between 30–60 percent (Susan Smith, personal communication 2010). Wills and Dorshow (2012:147) conclude from these recent pollen counts that "Pueblo Alto shows one of the strongest signals for on-site processing of maize plants."

Given that the mean of corn pollen representation in Figure 5 represents the basic frequency of deposition deriving from prehistoric Puebloan use of this domesticate, it is worth considering how and why corn pollen entered the Chaco Canyon sites at frequencies well above the norm for the region. Maize pollen may have simply blown into archaeological contexts as part of the background pollen rain, but only if the sampled habitations were very close to agricultural fields. Even then, deposition within the relatively closed setting of structure interiors by wind or other natural processes should have been minimal. To the extent that natural processes were involved, this would suggest that agricultural fields were proximate to all sampled sites, including Pueblo Alto. Nonetheless, it seems reasonable to assume that most corn pollen at settlements results from human activity of one sort or another, with natural processes playing a minimal role. But what sort of activities? Is it the storage and processing of corn ears and kernels, as often inferred? Given the experimental results reported previously, we have to say no. Storage of ears or kernels and the processing of kernels into flour or by parching or popping are unlikely to deposit corn pollen in the archaeological record at frequencies higher than the overall mean or even at the mean. If true for locally grown maize, the produce imported from afar would be even less likely to generate such a pollen signature. The activities that are most likely to result in corn pollen deposition have little to do with corn kernels or corn ears per se regardless of where they originate.

Activities that could deposit corn pollen in the proportions seen at Chaco Canyon sites include the onsite husking of corn ears and various ceremonial activities that involve corn pollen or corn stalks. High corn pollen frequencies might be expected in plazas or open areas next to structures, where husking would be performed. Yet plazas are also important places for ceremonies, such that maize pollen could accumulate in them from these activities alone. What remains unknown is whether ceremonial deposition would produce as robust a maize pollen signature as seen in many of the Chaco samples, especially considering that few if any came from places of probable ritual activity. T he small sites of 627 and 629 are well positioned to have been locations of on-site maize ear husking, located as they are along the south side of the Chaco floodplain. Given Alto's elevated position away from the potential farmland of the canyon bottom, the site might seem an unlikely location for corn husking. Yet, Wills and Dorshow (2012:142) have recently argued that "agricultural production was integral to the Pueblo Alto community" and further that "the mesa top around Pueblo Alto is so suitable for maize and bean cultivation today that even inexperienced archaeologists can get plants to grow [there]" (2012:146). If this claim has merit, then ear husking might well have occurred at Alto as well, and this could account for the high frequency of maize pollen that all analysts have documented at the site. Nonetheless, except for the recently analyzed mound samples, the Chaco Canyon pollen record comes from structure interiors, doubtful places for husking. For sites situated in close proximity to fields, there could have been ample opportunity for maize pollen to be introduced to structure interiors on the bodies and clothing of field workers, children, or dogs. Yet by such incidental processes, the frequency of corn pollen seems more likely to be low and certainly not at the levels documented for the Chaco sites.

The mealing bin pollen data from Pueblo Alto provides an intriguing hint at a ritual activity that could partially account for some of the high maize frequencies: the preparation of ceremonial meal. Cully analyzed three samples from mealing bins one through three from Room 110, and Karen Clary analyzed the other three plus one from a wall niche in the same room. Clary spiked her samples so that these are the only reported samples from Chaco that allow calculation of pollen concentration; for maize this ranged from a low of 105 grains per gram to a high of 11,844. It is worth mentioning that the "low" value is actually quite high compared with most samples from the Southwest. The lowest relative frequency of corn pollen in the seven samples is 20 percent, with most samples containing more than 40 percent maize pollen (Figure 6). Given the experimental maize washes, the grinding of kernels alone is a highly improbable means to produce these

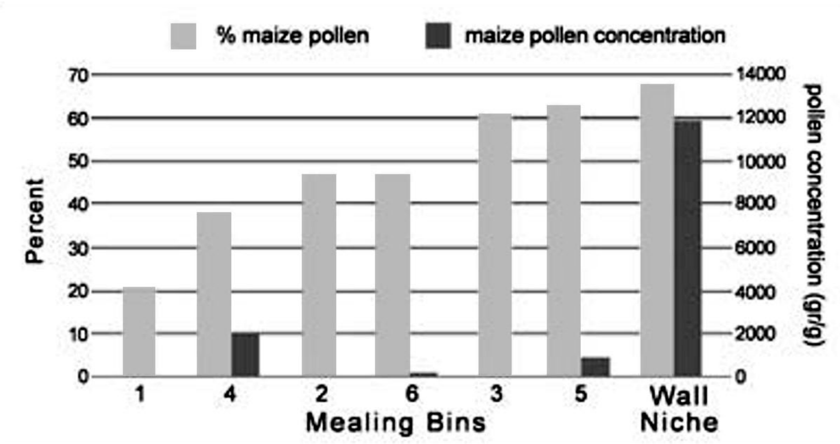

Figure 6. Bar graph of the proportion of maize pollen and maize pollen concentration for six mealing bins and a wall niche of Room 110 from Pueblo Alto (data from Clary 1987); note that mealing bin 6 only had a total pollen count of 17 grains.

frequencies of maize pollen. Not only would maize pollen rarely occur on kernels but also any that did would be proportionally swamped by the numerous other types of environmental pollen that would have settled on ears as they dried in the sun after husking. The activity that could account for the incidence of maize pollen in the mealing bin samples is the preparation of "prayer meal" as described in various ethnographies, where corn pollen or male flowers are added to kernels and ground together. The preparation of ceremonial meal, whether for public gatherings or simply as an exchange commodity (prayer meal from a sacred place) might help account for the massed (four or more) mealing bins seen at Pueblo Bonito (Rooms 90 and 291), Pueblo del Arroyo (Room 55), Pueblo Alto (Room 110), small house site Bc 51 (Room 47), and likely other Chacoan great houses.

The consumption of ceremonial meal consisting of a pollen flour mix would also account for the high incidence of maize pollen in some of the human feces from Chaco Canyon (Clary 1984), Salmon Ruins (Reinhard et al. 2006a, 2006b) and Pueblo Bonito (Karl Reinhard, personal communication 2013). Williams-Dean (1986:198–199; also Williams-Dean and Bryant 1975) attributed the high incidence of corn pollen in Antelope House feces as possibly resulting from the consumption of corn silks, meaning the dried ones exterior to the husks that actually received pollen rain. Whether such items were commonly consumed is an open question, though Pepper (1920) reported corn silk quids from Pueblo Bonito. However, Williams-Dean also found that some of the maize pollen in the feces appeared crushed, which was thought to represent the grinding of pollen-covered maize kernels with manos and metates (Williams-Dean 1986:199). Reinhard et al. (2006b:Tables 1 and 3) also obtained high maize counts and concentration values in the feces from Salmon Ruins along with a considerably higher incidence of crushed maize pollen than at Antelope House. They interpreted this evidence as indicating the consumption of "pollen-bearing, maize-based foods such as stews" (Reinhard et al. 2006a:103). Given the experimental wash data summarized earlier, this seem unlikely unless maize pollen was being purposefully added to the kernels during the processing, which is exactly what occurs in the preparation of ceremonial meal. This might occur not just with collected pollen but also with entire tassels. Pollen is nutritionally beneficial, and Simms (1985) has shown that cattail pollen, which was commonly consumed in the Great Basin, is the highest-ranked plant food, above even oak and pinyon nuts.

Conclusion

As with most aspects of archaeology, single data sets alone seldom provide clear answers. It is only by integrating and fully accounting for disparate lines of evidence that a more comprehensive understanding is achieved. The frequency of corn pollen in the Chaco Canyon samples appears high, well above the incidence of corn pollen in modern fields where, despite dense planting, corn pollen proportions are below many of the Chaco samples, sometimes well below. By creating a regional pollen database to look at the incidence of corn pollen at prehistoric habitations scattered across the San Juan Basin and somewhat beyond, we obtained an even better datum point for evaluating the frequency of corn pollen in the Chaco Canyon samples. The regional pollen database demonstrates quite markedly that the four Chaco Canyon sites with analyzed samples have frequencies of maize pollen well above the regional average. This finding is fully corroborated by more recently analyzed samples from the trash mounds of Pueblo Alto and Pueblo Bonito (Susan Smith, personal communication 2010).

Any interpretation of what the anomalously high maize pollen proportions might mean should factor in what we currently know from experimental pollen washes coupled with knowledge about how maize pollen could enter the archaeological record based on Puebloan ethnography. Even armed with such information, there are still inferential gaps between pollen counts and past behavior. It is obvious that pollen analysis will never be able to answer how much corn was grown in the canyon. Nonetheless, the transport of maize ears or kernels into Chaco Canyon from growing areas of the Chaco Halo or beyond cannot account for the high incidence of maize pollen at Chaco settlements unless such transport involved the highly improbable movement of corn ears in the husk or tasseled corn plants. While it is possible that some corn plants were brought to the canyon from surrounding communities for special ceremonies—a practice that could account for some of the maize pollen deposited in some samples, perhaps especially at great houses—it cannot account for the overall abundance of maize pollen across the board, especially at small sites.

The high proportions of maize pollen at Chacoan sites imply significant local production of this domesticate similar to the high proportions at the La Plata site of LA50337. The occurrence of maize husks, stalks, and silks in samples from structure interiors at small and large Chacoan sites also strongly supports significant local production and harvesting. Perhaps the best indication of this, on account of preservation, comes from Pueblo Bonito, which yielded samples of husks, stalks, corn silk quids, and tassels. The Chaco Research Archive database (http://www.chacoarchive.org/cra) lists 22 incidences of husks, 5 of stalks, 2 of silk quids, and 1 of a corn tassel from Bonito; doubtless this is just a minor fraction of what was actually present (see Pepper 1920:37, 70, 96–97, 105, 107). The alternative that we find highly unlikely is one where legions of Puebloans weighed down by maize ears in the husk trudged across the clay flats of the San Juan Basin bringing in the staple to be distributed to small and great houses alike for the requisite husking and consequent scattering of maize pollen.

Although Chaco Canyon may have been marginal for growing corn, the pollen record implies that there was significant local production of maize, as much by the Alto data as by that from the small sites of 627 and 629. Vivan and Watson (this volume) argue that diverse agricultural strategies were employed by prehistoric occupants to take full advantage of the hydrological and physiographical diversity of the Chaco Core. T he pollen record similarly indicates that we should not underestimate the productive potential of the canyon. This includes the central floodplain as well as seldom considered areas such as argued by Wills and Dorshow (2012) and Vivian and Watson (this volume). In this regard, careful pollen sampling could reveal which portions of the canyon were actually farmed, perhaps coupled with the sampling of packrat (Neotoma sp.) middens both for pollen and macroremains (e.g., Hall 2010). T he occurrence of maize remains in such contexts well away from habitations is hard to square with the maize importation model, but easily accounted for by local maize production in every suitable setting.

The abundance of maize pollen in mealing bins at Pueblo Alto strongly suggests the purposeful addition of pollen or anthers while grinding kernels to flour. This is further supported by the high incidence of maize pollen, especially broken grains, in human feces from both Salmon Ruins and Pueblo Bonito. Based on ethnographic homology this would have occurred in the preparation of ceremonial meal to be used for prayer making. Prayer meal from such a special place as Chaco Canyon and one of its illustrious great houses may have been in high demand within the region characterized by Chacoan outliers, providing one local commodity to help balance the economic and social debts of canyon residents. The practice of purposefully mixing in maize pollen or tassels during the preparation of meal can account for the high proportions of maize pollen at Chacoan sites, a behavior that was ritually salient while also being nutritionally beneficial.

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