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Timothy A. Kohler
Matt Pier Glaude
Jean-Pierre Bocquet-Appel
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Timothy A. Kohler, Department of Anthropology, Washington State University, Pullman, WA 99164-4910, Crow Canyon Archaeological Center, and Santa Fe Institute (tako@wsu.edu)

Matt Pier Glaude, Department of Anthropology, Washington State University, Pullman, WA 99164-4910 (matt_glaude@pch.gc.ca)

Jean-Pierre Bocquet-Appel, CNRS, EP 2147 44, rue de l Amiral Mouchez 75014 Paris, France (bocquet-appel@evolhum.cnrs.fr)

Brian M. Kemp, Department of Anthropology and School of Biological Sciences, Washington State University, Pullman, WA 99164-4910 (bmkemp@wsu.edu)

Abstract: Maize agriculture was practiced in the U.S. Southwest slightly before 2000 B.C., but had a negligible impact on population growth rates until the development or introduction of more productive landraces; the ability to successfully cultivate maize under a greater variety of conditions, with dry farming especially important; the addition of beans, squash, and eventually turkey to the diet; increased sedentism; and what we infer to be the remapping of exchange networks and the development of efficient exchange strategies in first-millenium-A.D. villages. Our estimates of birthrates and growth rates are derived from the proportions of immature individuals among human remains. These proportions are somewhat affected by warfare in our region, and perhaps also by climate. Nevertheless, there is a strong identifiable Neolithic Demographic Transition signal in the U.S. Southwest in about the mid-first-millennium A.D. in most subregions, visible a few hundred years after the introduction of well-fired ceramic containers, and more or less contemporaneous with the first appearance of villages. Independent genetic data derived from the mitochondrial genomes of present-day indigenous populations of the Southwest are also consistent with the hypothesis that a major demographic expansion occurred 1500-2000 years ago in the Southwest.

Résumé: La culture du maïs se pratiquait dans le sud-ouest des Etats-Unis avant 2000 B.C., mais eut un impact négligeable sur le taux d'accroissement de la population jusqu'au développement ou l'introduction des variétés cultivées plus productifs; la capacité de cultiver du maïs avec succès sous une grande variété de conditions, avec la culture sèche particulièrement importante; l'addition de haricots, de courges, et éventuellement de dindes à la nourriture; l'accroissement de la sédentarité; et ce que l'on inféré relativement à la recomposition géographique des réseaux d'échanges et le développement de stratégies d'échange efficientes dans les villages du 1er millénaire A.D. Nos estimations de taux de natalité et de taux d'accroissement dérivent des proportions d'individus immatures dans les restes humains. Ces proportions sont quelque peu affectées par les guerres dans notre région, et peut être aussi, par le climat. Néanmoins, il y a le signal fort d'une Transition démographique néolithique dans le sud-ouest des Etats-Unis vers la première moitié du 1er millénaire A.D. dans la plupart des sous-régions, signal visible quelques centaines d'années après l'introduction de containers en céramique cuite, et approximativement contemporaine avec la première apparition de villages. Des données génétiques indépendantes provenant de génomes mitochondriaux de populations indigènes du sud-ouest aujourd'hui, sont aussi consistantes avec l'hypothèse qu'une expansion démographique majeure se produisit là il y a 1500-2000 ans.

Despite the deep hominid evolutionary history of foraging, several independent zones of agricultural invention appeared almost simultaneously on the planet during the Holocene, in a chronological window from 11-3.5 ka B.P. These were located in the Near East (wheat and barley), East Asia (rice and millet), Sub-Saharan Africa (including poorly dated plants of three major complexes [Harlan 2006]), South America (where three complexes of species emerged at differing elevations [Pearsall 2006]), Mesoamerica (maize, beans, gourds and squash), and eastern North America (squash, sunflower, and the other members of the Eastern Agricultural Complex). When agricultural crops or farmers from these primary zones appear in "secondary" neighboring regions, such as the

North American Southwest, the processes by which this transfer takes place—and its consequences—are always of great interest.

In this paper we concentrate on the demographic consequences of the introduction of Neolithic economies (more conventionally called Formative economies in the New World; Willey and Phillips 1958) to the U.S. Southwest. Demographic responses over time integrate effects from technology, economy, and social relations and cultural norms, including narrowly demographic considerations such as age at weaning, post-partum sexual taboos, etc. These responses therefore provide raw materials for inferences concerning health, carrying capacity, and sociopolitical organization—in short, the methods, and their socionatural contexts, by which populations nourished additional mouths and managed the social tensions and entrepreneurial activities arising in an increasingly numerous population in intensifiable habitats (Clarke and Blake 1994).

Our understanding of the demographic consequences of shifting to an agricultural economy has improved with two recent methodological innovations. The first of these is the development of a non-conventional demographic indicator for use on sets of human remains, most directly as an estimator of the birth rate, but secondarily, if death rates are approximately constant, as an estimator for the growth rate. The second is the development of a non-standard chronological frame that makes it possible to gather information that is dispersed over time and space to highlight otherwise undetectable demographic patterns underlying archaeological data (Bocquet-Appel 2002). These techniques have allowed Bocquet-Appel (2002) to detect a major demographic shift in a paleoanthropological database of Mesolithic and Neolithic sites in Europe and North Africa. This shift has been named the Neolithic Demographic Transition (NDT) (Bocquet-Appel 2002; Bocquet-Appel and Paz de Miguel Ibanez 2002). The indicator is calculated as the proportion of immature skeletons (5-19 years of age) to all human remains ≥5 years of age, abbreviated as ${}_{15}p_5$, in each site, or in groups of proximate, penecontemporaneous sites. In a growing population, the proportion of immature individuals (alive or dead) is high, while in a decreasing population, it is low (Johansson and Horowitz 1986; McCaa 2000; Sattenspiel and Harpending 1983). This corresponds, respectively, to a population age pyramid with a wide or narrow base, recording a high or low birthrate respectively and, underlying this, an increase or decrease in fertility and growth rates.

The assumed cause of the unprecedented rise in human fertility during the NDT is increased sedentism associated with the shift from a forager to a producer economy and the subsequent chain of effects that shortened the duration of the reproductive cycle via a reduction in the relative metabolic load for the mothers (Bocquet-Appel 2008; Valeggia and Ellison 2004). This paleodemographic indicator provides direct evidence of the demographic process that generated the relevant archaeological remains. Since it was detected in Europe and North Africa, an NDT signal has been identified in several regions of North America (Bandy et al. 2008; Bocquet-Appel and Naji 2006; Warrick 2006) Mesoamerica and South America (Bandy 2005) and the Levant (Guerrero et al. 2008). This NDT initiated the demographic regime of preindustrial populations, with their high birth and mortality rates (Bocquet-Appel and Naji 2006), and its biocultural consequences are only beginning to be explored (Bandy 2005; Bocquet-Appel and Bar Yosef 2008).

The purpose of this article is twofold. First we hope to make these methods more widely known to American archaeologists by way of their application to the U.S. Southwest. Furthermore we hope to resolve long-standing debates in this region—not so much about the timing of the introduction of maize, which finally seems to be well understood, but about the impact of early maize agriculture on the degree of sedentism achieved by these societies, or at the very least, the demographic consequences of this early agriculture. Quite some time ago, in an article that is still widely cited, Cowgill (1975:505) urged archaeologists not to assume that "a pervasive and powerful factor in human history has been the strong tendency of human populations to increase up to the point where serious shortages of important resources are in the offing." This has often been read to imply that humans generally regulate their fertility efficiently, and indeed, Cowgill himself (e.g., 1975:508) seems to doubt the usual existence of rapid increases in population growth following "important innovations in food production or colonization by people with a more intensive technology." What are the facts of the matter, so far as we can presently tell, for the U.S. Southwest?

Early Maize in the U.S. Southwest

Following its domestication in southern Mexico more than 6300 years ago, maize arrived in the southern portions of the U.S. Southwest slightly before 2000 B.C.[1] (Diehl and Waters 2006; Huber 2005; L. Huckell 2006). The earliest presently known maize sites in the American Southwest (Figure 1) do not form a strong south-to-north chronological gradient (Blake 2006; Huber 2005:Fig. 36.11; Smiley 1994). For example, maize reached northeastern Arizona by 1940 B.C. (Smiley 1994), which is almost as early as the southern Arizona dates. More lag can be seen in its subsequent east-west spread—for example, it reached the Northern Rio Grande in New Mexico by about 1200 B.C. (Vierra and Ford 2006:505)—and in its later spread into the northern reaches of the Colorado Plateau in Utah, around A.D. 600 (Barlow 2006) (Figure 2). The pattern of diffusion in Figure 2 resembles the so-called "leapfrog process" (Zvelebil 2000) from one favorable locality to another, with dissemination occurring outwards from each location rather than as a continuous front. While the core cultigens of the Mesoamerican agricultural adaptation also included beans and squash, their entrance into the Southwest is later and less distinct. Macrobotanical evidence for these plants is much less abundant than is evidence for maize throughout southwestern prehistory, and first occurrences of each are generally in the first millennium B.C. (Smith 2001a).

So familiar is the concept of the Neolithic wave-of-advance defined for Europe by Ammerman and Cavalli-Sforza (1973) that archaeologists tend to assume that this model will work elsewhere. This model, which seeks to explain important cultural and demographic change through the demic diffusion of agriculturalists, has also been used to explain the distribution of major language families (Bellwood 2005; Bellwood and Renfrew, eds., 2002; Renfrew 1987), and is consequently important to understanding the genetic and linguistic prehistory of the Southwest (Matson 2002). In Southwest Asia it appears that a highly productive package of domesticates, including animals and ceramic vessels for cooking and storage, was "assembled" early and was then able to spread rapidly from east to west into and through Europe within zones of relatively similar climate and biota. By contrast, from its probable homeland in the tropical deciduous forests or thorn forests of the Balsas depression in Mexico to the U.S. Southwest, the spread of maize was largely from south to north, demanding selection for domesticates able to thrive under novel combinations of heat units, day lengths, and precipitation regimes (Adams et al. 2006).

The spread of maize was accompanied and to some extent made possible by development of new cultivation strategies. Early maize husbandry in the Southwest apparently emphasized water-table and overbank flood farming, although irrigation systems are now recognized from both southern Arizona and the southern Colorado Plateau by only 500-1,000 years after the earliest appearances of maize in those areas (Damp et al. 2002; Doolittle and Mabry 2006). Presumably irrigation reduced the risk of crop failure (Huckell et al. 2002), allowing for a more sustainable and reliable use of maize. Dry farming—essential to opening up large and highly productive mesa tops in the northern Southwest—was added last of all, ca. A.D. 300 (Doolittle and Mabry 2006; Kohler 1993; Matson 1991).

Except in the northernmost portions of the Southwest a considerable lag exists between the first appearance of maize and the development of well-fired ceramic vessels, which regionally varies between about A.D. 1 and 500. Moreover, Southwestern domesticated animals (dog and turkey) never rivaled in dietary contribution the ovicaprids, cattle, and pigs that yielded so much protein to European Neolithic diets. Turkey, which has the greater dietary importance, is relatively unimportant in diets before the A.D. 1100s in many portions of the Southwest.

Finally, recent research has helped to trace changes in the nutritional value of maize, which has important implications for its role in prehistoric diets (Benz 2006; Iltis 2006). Although it is not currently possible to accurately assess the yield of Early Agricultural period (roughly, the last two millennia B.C.) maize, it does not seem to have been particularly productive. Morphological observations underscore its very small size, with cupule size increasing very slowly through the 2000-year Early Agricultural period and then more rapidly in the first millennium AD (Diehl 2005). Adams (1994:Table 16.9; L. Huckell 2006) recounts the prehistory of maize landraces in the Southwest as it is currently understood, demonstrating important additions to the maize repertoire at ca. 100 B.C., A.D. 500, and A.D. 1000.

In short, the inhabitants of the ancient U.S. Southwest spent some 3000 years assembling their Neolithic package; it was not given to them at the outset. Considering this history, it is highly uncertain whether a specific threshold that resembles the Neolithic Demographic Transition identified in Europe by Bocquet-Appel (2002) and in the Levant (Guerrero et al. 2008) can be identified in the human remains of the Southwest.

Indeed, as discussed by Wills (1988), the dietary and social importance of earliest maize use in the Southwest has been debated for decades. Those debates have not been entirely resolved by discoveries at Early Agricultural sites in the Tucson Basin such as Milagro (Huckell et al. 1995; ca. 1100-800 B.C.), Las Capas (Mabry 1999; ca. 800-400 B.C.) and Santa Cruz Bend (Mabry 1998; ca. 800-100 BC) even though extensive excavation showed use of irrigation canals at Las Capas and 730 features covering a total over 1.2 ha of excavations at Santa Cruz Bend, which is thought to represent only 15 percent of the total site (Bellwood 2005:172). These sites are near streams and contain pit structures, probable storage pits, and large quantities of maize. The presence of multiseasonal residences is suggested, as is a reliance on storage for winter months.

Nevertheless, the extent to which use of maize affected other aspects of those societies adapting it during the Early Agricultural period remains an open question. In part, this reflects a lack of consensus as to how productive early maize was, as well as how dependent early populations were on agriculture. Some researchers (e.g., B. Huckell 1995:127-133) argue that such usage was relatively intensive and precipitated significant increases in sedentism. A program of fluoride dating on one of the latest of these sites, Los Pozos, however, suggests that what looks like a large settlement with many contemporaneous households, from the perspective of the chronological resolution available from ^{14}C dating, is more likely a series of small settlements containing shortlived structures occupying a favored locale over several centuries (Schurr and Gregory 2002). Based on decreases in diet breadth from ca. 1200 B.C. to the local onset of the Early Ceramic period ca. A.D. 150 in southern Arizona, Diehl and Waters (2006) have argued that floodplain agricultural intensified markedly early in the first millennium A.D. with the appearance of high-quality ceramic containers that may have significantly reduced maize seed storage losses.

Further north, on the Rainbow Plateau in northeastern Arizona and in Grand Gulch, Utah, Geib and Spurr (2002) consider the earliest evidence of intensive agriculture to date to approximately 300 B.C. Gumerman and Dean (1989:111) use ca. 600 B.C. as the date by which they consider use of domesticates to be common on neighboring Black Mesa, Arizona. Both of these dates lag first appearance of maize in northeastern Arizona by well over a thousand years. Matson and Chisholm (1991) used stable isotope analyses of Basketmaker II human remains and analysis of pollen and macrofossil concentrations in rockshelter middens and coprolites in SE Utah to suggest fairly intensive use of maize by ca. A.D. 1. Coltrain et al. (2007) have now pushed this date back to ca. 400 B.C. for adjacent portions of NE Arizona by a comprehensive program of radio- and stable-isotope analysis of Basketmaker II human remains. Some archaeologists, however, have worried that these stable isotope determinations are affected by other sources of C4 or CAM plants on the landscape (Wills 1992:159), and it is also possible that this apparent intensive usage is somehow embedded in rather mobile settlement strategies.

In overview, although we know much more now than we did 25 years ago about the time of the arrival of maize in most areas of the Southwest, much about the importance and impact of preceramic maize cultivation in the U.S. Southwest remains contested. Researchers in various areas, basing their interpretations on various combinations of evidence from architecture, settlement patterns, floral and faunal remains, ceramic materials, and stable isotopes from human bone have drawn differing conclusions as to the importance and consequences of maize agriculture.

In this paper we use Bocquet-Appel's (2002) method for determining population growth rates directly from age distributions of human skeletal remains. This adds a new and fundamental perspective on the importance of agriculture, and employs a single proxy that can be applied consistently across sites and regions. We will contribute to understanding the processes by which farming became central to agriculturalists in the U.S. Southwest by answering the following questions:

- Was there a Neolithic Demographic Transition (NDT) in this region that can be recognized with existing data?
- If so, does it coincide with the earliest appearance of Mesoamerican domesticates, or was it triggered only by later, presumably more intensive use—and if so, when?
- If a regional NDT exists, does it differ from that suggested for Europe by Bocquet-Appel (2002)? In what ways, and why?

Investigating the NDT in the US Southwest

NDT theory predicts a relatively abrupt increase in the proportions of immature individuals (ages 5-19) among all individuals aged ≥5 years old, for some 500-700 years following the local onset of the Neolithic. This paleodemographic indicator—abbreviated as ${}_{15}p_5$ by demographers—is highly correlated with both the crude birthrate ($r^2 \geq 0.96$) and with the growth rate ($r^2 \geq 0.875$) (Bocquet-Appel and Naji 2006:342; Bocquet-Appel 2002:643) in a sample of preindustrial populations under the stable demographic population model. Therefore increases in ${}_{15}p_5$ reflect increases in crude birth rate, via a fertility increase, probably because of decreased birth spacing accompanying sedentism (Bocquet-Appel and Naji 2006:349), rather than a decrease in mortality (see also Ammerman and Cavalli-Sforza 1984:63-66). Eventually, though, this increase in birth rates is offset by an increase in mortality due, Bocquet-Appel and Naji (2006:349) suggest, to the emergence of new pathogens, especially zoonoses, with aggregation.

Data Collection and Methods

To determine whether an NDT exists in the US Southwest, we have compiled data for as many relatively large, well-dated assemblages of human remains as we could find. We began with compilations by Kramer (2002) and Bocquet-Appel and Naji (2006:349).[2] To these we added the other assemblages in Tables 1 and 2. Our sample is not comprehensive, though it is more complete for the eastern Pueblo areas (central and northern New Mexico and Southwest Colorado) than for the remainder of the Southwest. We follow Bocquet-Appel's (2002; see especially on-line supplemental materials) methods for quantifying the proportions of individuals aged 5-19 in these assemblages. For example, these proportions are calculated against a total that excludes individuals below the age of 5. We excluded assemblages obviously affected by massacres or extreme perimortem processing possibly indicating cannibalism. In cases where counts of individuals had to be reapportioned from age categories that crosscut those used here, we used rules from Boquet-Appel (2002:on-line supplemental materials) or followed advice from Stephan Naji (personal communication 2006).

Because it does not allow comparisons of associations between farming and demographic events occurring at different dates, the usual absolute (historical) chronology has been abandoned.[3] Absolute chronology masks temporally distant statistical regularities that need to be compared in attempting to detect the signature of a global population process that occurs according to a local time scale in disparate locations. Consider for example the contemporary demographic transition, which began at the end of the eighteenth century in regions as distant as New England in North America and Normandy in France, and spread from region to region, at different times and speeds, reaching Southeast Asia in the 1970s (Bocquet-Appel and Jakobi 1998; Bocquet-Appel, Rajan, et al. 2002). How can this transition, representing a transcultural demographic process, be linked with data like those mentioned above, to facilitate its recognition as a single demographic process highly dispersed over space and time? As indicated, we replace the absolute chronology with a chronology relative to the duration that elapsed locally from the start of a major cultural shift up to the date of the demographic indicator, or the dates of other relevant cultural changes such as, for example, the appearance of public spaces (Bocquet-Appel and Dubouloz 2003, 2004), of a social hierarchy, of a defined size of village unit, of ceramic containers, etc. The change to a relative chronology makes it possible to gather information that is dispersed over space and time and to position it within a common temporal frame. This interpretation of the relative chronology has been discussed elsewhere (Bocquet-Appel 2002, 2005; Bocquet-Appel and Dubouloz 2004; Bocquet-Appel and Paz de Miguel Ibanez 2002).

Also following Bocquet-Appel, we use a method of fitting the bivariate relationship between ${}_{15}p_5$ and years dt that is unfamiliar to most archaeologists. Because we expect the relationship between these two variables to change across the span of years dt, and because statistical inference is less important to us than is characterizing that relationship, we use loess fitting (*lo*cal regr*ess*ion). This nonparametric procedure fits parametric functions "locally in the space of the predictors [here, years dt] using weighted least squares in a moving fashion similar to the way a time series is smoothed by moving averages" (Cleveland and Grosse 1991:47). Our statistical procedure and sampling did depart from Bocquet-Appel's analysis routine in one way. Because the assemblages we used ranged greatly in size, from 5 to 551 individuals, we weighted assemblages according to their sample sizes in the loess algorithm. This limits the influence of the sampling errors that are unavoidable in small assemblages on the fits obtained. Practically speaking, this also makes it unnecessary to aggregate small samples that are close in space and time. In producing the loess graphs discussed below, except where otherwise noted we allowed our fitting routine[4] to determine the size of the window used (Bocquet-Appel's α), within a permissible range of 0.3-0.6, so as to minimize the AIC_c value (Hurvich et al. 1998).

Results

To examine the relationship of this paleodemographic indicator to the first arrival of maize, we use the estimates for the first use of by maize in each site's region or subregion, as reported in Table 1, to set the zero point for the dt time scale. Figure 3 thus graphs, on its x-axis, the difference between the midpoint date for each assemblage of human remains and the date for the introduction of maize to that subregion, against the proportion of individuals from each site aged 5-19 on the y-axis. The horizontal dashed line represents an estimate for the location of a growth rate (*r*) of zero, based on simulations on 45 reference life tables as explained by Bocquet-Appel (2002:639-640). The dt=0 point marks the location of the time- and space-transgressive first appearances of maize as presently understood.

It is immediately apparent that we have no sites with enough human remains to graph that are within 500 years of the first local introduction of maize. Given the density of excavation in the U.S. Southwest, this seems to imply that for almost 500 years following first local appearance of maize, populations remained low, and perhaps relatively mobile (see, e.g., Coltrain et al. 2007; Diehl and Waters 2006; Simmons 1986). Figure 3 suggests that population growth rates began to increase some 1500 years after the first appearance of maize, and that growth rates peaked some two millennia after the local introduction of maize, declined over the next 700 years, and then increased once more. Both the first increase, and the decline, are interpretable in terms of NDT theory, though this first increase comes almost 1500 years later than expected. The second increase is somewhat unexpected, and we return to it below.

Perhaps we would see a better fit between the Southwestern data presented here and the NDT graphs of Bocquet-Appel (2002) for Europe and Bocquet-Appel and Naji (2006) for North America (where they include a few sites from the Southwest) if we examined the relationship between the proportion of 5-19-year-olds and an estimate for the earliest *intensive* use of maize. Bocquet-Appel and Naji (2006, Table 1) use A.D. 200 as the date for the introduction of maize throughout the Southwest except for Casas Grandes (Paquimé) where they use a date of A.D. 700. These dates are much more in line with the local appearance of ceramics than they are with the first appearance of maize (Table 1).

Crown and Wills (1995) and Diehl and Waters (2006) give both local reasons, and theory-based arguments, to suspect that earliest well-fired ceramic containers coincide with increasingly intensive use of cultivated plants and markedly increased sedentism. On the other hand, Coltrain et al. (2007) provide much new evidence based on stable carbon isotopes that maize was a staple for Basketmaker II populations in the Four Corners area by 400 B.C., some 700 years before the first local appearance of ceramic containers (see also Chisholm and Matson 1994; Matson and Chisholm 1991). These determinations may be somehow affected by other sources of C4 plants on the landscape, though, and in any case we do not presently have enough samples of stable-carbon isotopic data throughout the Southwest to draw exclusively on that line of very direct evidence. Finally, it is possible that this apparent intensive usage was somehow embedded in rather mobile settlement strategies. Therefore, in a second analysis we use the local first appearance of well-fired ceramic vessels as a surrogate for the first local intensive use of maize among relatively sedentary populations. Here we will set the value of dt=0 as the time of the local introduction or development of efficient ceramic containers.

Figure 4 shows the relationship between ${}_{15}p_5$ and the earliest local intensive use of maize as proxied from the appearance of ceramic containers. This graph indeed resembles that produced by Bocquet-Appel for Europe (2002:Figure 4) more than did our Figure 3. Seven data points, all with relatively small assemblages, predate the intensive use of maize estimated in this way. Of these, five have low ${}_{15}p_5$ values relatively near the estimate for $r = 0$. As a group the pre-dt=0 proportions are quite variable, which contributes to the wide 80 percent confidence intervals. Some of this variability is undoubtedly due to small samples sizes, but there is also a suggestion in the data that, for some reason, early maize agriculture was more successful in the central portions and on the northeastern margins of the Colorado Plateau than it was further south or west. Unlike the European case, however, the ${}_{15}p_5$ values (and presumably the underlying growth rates r) appear to begin to increase markedly not around dt 0, but rather some 300 years after the first local use of ceramic containers. Of course, the dearth of data between about dt –300 and almost 300 weakens this suggestion considerably. If this *is* correct, though, it would suggest that intensive maize use (as proxied by first ceramic containers) perhaps slightly increased population growth rates, but that some other factor, generally occurring later, was even more important. Comparison of figures 3 and 4 suggests that birth rates increased—but very slowly—following the first use of maize into the period of intensive maize use, and then increased rapidly in local sequences some 300 years after intensive use is established.

Interestingly, the loess lines in both of our figures peak at a ${}_{15}p_5$ value slightly over 0.3, quite similar to the maximum plotted by Bocquet-Appel (2002:Figure 2) for the Near Eastern and European Neolithic data. It is somewhat surprising to us that growth rates as high as those seen in the Near East and Europe, with their mixed farming that included several domesticated animals, could be achieved in the Southwest, with no significant domesticated source of protein and fat during the period of maximum growth.

The decline in the ${}_{15}p_5$ values beginning about dt 900 until about dt 1200 in Figure 4 seems to be associated with the period of the retrenchment of population from the Northern San Juan and the San Juan Basin into the Northern Rio Grande at sites like Pecos, Gran Quivira, and into some portions of the Mogollon area, for example Point of Pines. There appears to have been great variability in ${}_{15}p_5$ values in sites in these destination areas, though, and some large, late assemblages with high ${}_{15}p_5$ values—for example San Cristobal, Hawikku, and Grasshopper—raise the fitted curve unexpectedly, on the eve of the Spanish entrance to the Southwest in 1540.

In Figure 5 we experiment with applying different values for the smoothing parameter α to the data graphed in Figure 4. The major features discussed above are also apparent in the other smoothings, indicating that our interpretations are not sensitive to the α parameter chosen. For comparison Bocquet-Appel (2002) used α values ranging from 0.3 (Figure 4) to 0.5 (Figure 2).

Discussion

The first marked increase in the ${}_{15}p_5$ values, beginning around dt 400 (Figure 4), corresponds in a general way to the first pulse of aggregation in the Southwest, where it is perhaps most striking in the Northern San Juan Pueblo I villages (Wilshusen 1999b; Wilshusen and Perry 2006). This coincidence could be due to some advantages of economic efficiency among early aggregates. Alternatively, or additionally, it could reflect growth induced through competitive processes, including aggrandizement, in these milieus, which provided increasingly important arenas for social advancement. Of course, these villages were also undergoing the pithouse-to-pueblo transition, which ethnographically tends to mark a more permanent (across years), less mobile (across seasons within a year) settlement system (Gilman 1987). This rapid demographic expansion also generally corresponds to the first appearances of Maís Blando and Harinosa de Ocho (Maís de Ocho) ca. A.D. 500-700 (Adams 1994), and follows shortly on both the opening of a vast new agricultural niche with the development of successful dry-farming strategies, and the introduction of the bow and arrow. The growth rates towards the top of the peak may also be underwritten by increased use of turkey for protein ca. A.D. 1100 (Cowan et al. 2006).

Warfare Inflates the ${}_{15}p_5$ Proportion

Of course, we expect the ${}_{15}p_5$ measure to be noisy for a variety of reasons relating to the archaeological and analytical contexts, including but not limited to possible variability through time and space in mortuary practices and preservation for children and adolescents vs. adults; differences in analytic standards for (and expertise in) determining ages for human remains; changes through time in how these decisions are made by bioarchaeologists; sampling error; and so forth. To the extent that these are random errors they will weaken, but not bias, the fitted relationship between the ${}_{15}p_5$ value and time relative to agricultural innovation.

There are as well processes in the systemic context that may tend to bias the signal, and these are of somewhat greater importance. The first of these is worthy of mention but possibly not of great concern in itself, since while it may lead to local anomalies in ${}_{15}p_5$, these should be balanced out in the regional datasets compiled in Table 1. This is the recent argument by Kohler and Turner (2006; Kramer 2002) that Chacoan centers, in at least the eleventh and thirteenth centuries, seem to be importing women from outlying regions, possibly through raiding activities.

Although this effect per se might not bias our results when these are averaged over large enough spaces, the warfare that probably underlies these patterns might cause biases. Warfare differentially affects young adults, and could therefore, in principle at least, raise the ${}_{15}p_5$ values in some of the assemblages considered here by depressing the denominators for these proportions.[5]

Kramer (2002) constructed life tables for many of the composite samples reported in Table 1, and compared the tables she constructed for each century in each region with a composite table constructed from all the samples in that region, aggregated through time. Specifically, she compared the cumulative proportions of numbers of individuals in each category, after smoothing as outlined by Weiss (1973), between each temporally specific subsample and the entire population from that region, including that subsample, using a Kolmogorov-Smirnov test. This approach is obviously conservative because the sample from each century also contributes to the regional distribution with which it is being compared, and also, to a smaller extent, because of the smoothing before the test.

In the San Juan Basin region, only one century, the 1200s, is anomalous on this measure, with significantly more individuals in the 6-25-year-old age groups than in the regional sample pooled by period, and as a result, fewer individuals in the 36-55-year-old age categories (Kramer 2002:67). Indeed, we can see in Figures 3 and 4 that this sample (SJ1250) has one of the highest ${}_{15}p_5$ values in our entire dataset, although since the sample size is relatively small its effect on the fitted line is not large.

A similar though slightly weaker effect is seen in the contemporaneous assemblages from the Northern San Juan region to the north. In the 1200s, all age categories between 3- and 25-years-old are over-represented relative to the assemblage representing all *other* periods from that region (Kramer 2002:91). This effect is no longer statistically significant, though, if the assemblages from the 1200s are included in the composite assemblage with which the 1200s are being compared. It is not surprising, then, to see that the data point for this century (NSJ1250) is slightly above the fitted line in both Figures 3 and 4, though it is not among the highest proportions in the dataset.

Taken together, we conclude that the ${}_{15}p_5$ proportions are at least somewhat affected by warfare-related processes in the Southwest, conflating as they do high values for these proportions due to depressed denominators reflecting high warfare-induced mortality in young adults, with the high values due to high numerators for the proportions that the index is intended to measure.

Climate Plays a Role in Limiting Southwest Growth Rates

Maize agriculture was surprisingly slow to reach some of the higher, better-watered, northern portions of the US Southwest. In the Central Mesa Verde region, for example, there are relatively few Basketmaker II habitations, and Basketmaker III sites become common only after AD 580 or 590 (Lipe 1999; Wilshusen 1999a). Because agriculture in this area seems to have been highly productive during most of the A.D. 600 to 1300 span, apparently supporting considerable immigration to the area (Varien et al. 2007), an earlier arrival of intensive agriculture might have led to an earlier NDT signal in our data.

However, this appears to have been impossible given the prevailing climatic conditions in the first half of the first millenium A.D. Recent well dated pollen cores from Beef Pasture in the La Plata Mountains in southwestern Colorado, analyzed and reported by Aaron Wright (2006), reveal a low-frequency increase in the Ponderosa-pine-to-spruce pollen ratios from historically low values ca. 100 B.C. through around A.D. 700, when they again decline, only to increase again slightly before AD 1000. Wright argues that these ratios are sensitive to annual temperature and to winter precipitation, so that low values indicate cold and/or winter-dry conditions. When interpreted in conjunction with contemporaneous low-frequency trends in sedge-to-Cheno-Am pollen ratios, in which increases are believed to reflect increases in winter precipitation, the period between A.D. 300 and almost 600 appears to be both cold and dry. These data strongly suggest the prevalence of cold conditions in the northern San Juan from at least 100 B.C. (when this record begins) to almost A.D. 600—excepting a short period with average conditions around A.D. 300.

Charles and Cole (2006:167-216) have recently tabulated all the known tree-ring and ${}^{14}C$ dates for Basketmaker II sites. Their tabulation reveals a distinct clustering of dates between about A.D. 100 and 300, except in the southernmost site groups (Chuska/Lukachukai, in northeastern Arizona and extreme northwestern New Mexico, and Black Mesa, in northeastern Arizona), in which the central tendencies for dates are somewhat earlier. This suggests that short growing seasons limited farming expansion to productive northern uplands throughout much of the first half of the first millennium A.D. This in turn may have slightly retarded the expression of the NDT in the Southwest.

It is also possible that the downturn in growth rates that began about 850 years after the local introduction of ceramic containers (Figure 4) is influenced by deteriorating climates. In the Pueblo area, this decline in ${}_{15}p_5$ values began around A.D. 1200 in absolute dates. Low-frequency declines in winter temperature and precipitation began in the mid-1100s and continued until the late 1300s (temperature) and beyond 1400 for precipitation (Wright 2006). Meanwhile, high-frequency maize production conditions in southwestern Colorado, reconstructed from tree rings (Kohler et al. 2008) were unfavorable throughout nearly the entire 1200s. We suggest that these trends caused the "closing of the frontier" for continued expansion of the farming way of life in the northern Southwest well before its complete depopulation in the late-A.D. 1200s, with predictable effects on desired family sizes as excess population became impossible to export. At the same time, less-productive conditions throughout the 1200s may have played an independent role in reducing fertility, at least in those portions of the northern San Juan where these climatic reconstructions are most directly applicable.

Population Growth Patterns Form the Southwestern Region

There appear to be other signals in Figures 3 and 4 of interest to regional specialists. We note, for example, that the ${}_{15}p_5$ values tend to decline through time at Pecos (at the far eastern edge of the Pueblo world); and that the Gallina subregion of the Northern Rio Grande, which lies at the northeastern edge of the Pueblo world, tends to also have low growth rates (see the points for NRG950 and NRG1150, which are composite samples from the Gallina subregion). Indeed, some of the highest growth rates, as proxied by ${}_{15}p_5$ values, tend to be in regions that lie towards the center of the Southwest, perhaps suggesting that the reason they were at the center is that they were able to export population in various directions. Peripheral areas generally supported lower growth rates, contributing to their peripherality. This would seem to be almost too obvious to mention, except that it has not, to our knowledge, previously been demonstrated.

The second increase in the fitted line, in both Figures 3 and 4, is not anticipated by the NDT model itself, though it has a possible analog in the second bump seen in Figure 4 of Bocquet-Appel (2002:645) that appears to correspond, in general, to Chalcolithic sites with a megalithic aspect, that are often considered to reflect a more hierarchical form of sociopolitical organization than present in the earlier Neolithic sites. In our sample, following the logic of the NDT model, the highly aggregated nature of late sites such as Hawikku, San Cristobal, Grasshopper, and Paquimé would lead us to anticipate *low* values for the ${}_{15}p_5$ measure, but in fact their values are generally high, and in conjunction with their large samples, cause the second increase in our fitted lines. We are not certain what (if any) economic or social organizational factors contribute to the apparently high growth rates in such sites,[6] but this model throws them into relief as worthy of explanation. It is also possible that high rates of migration into these sites, in conjunction with the process of aggregation and regional demographic shifts, swamp the signal that the ${}_{15}p_5$ measure is designed to measure. This could happen if, for example, immigrant ages were biased towards pre-adult years. Alternatively, if the female bias in immigrant households that Lowell (2007) suggests for Grasshopper is a general phenomenon related to sex imbalance in immigrant populations due to warfare, such biases could in turn soon generate higher birth rates than would be expected in populations of that size with an even sex distribution.

Independent Corroboration for a late Southwestern NDT

Recently, Kemp (2006) characterized the mitochondrial DNA (mtDNA) of 897 individuals from 13 populations in Mesoamerica and the American Southwest to test for an ancient migration of Uto-Aztecan speakers from the former region to the latter, a prediction of the farming/language dispersal hypothesis (Bellwood 2005; Hill 2001). Surprisingly, few close genetic connections were found between the two regions and, in particular, Uto-Aztecan populations in each region were more closely related to their respective linguistically unrelated neighbors than they were to each other. These data should not necessarily cause us to reject the idea that the Uto-Aztecan language family and maize agriculture spread northward together, as suggested by Matson (2002) and Hill (2001), but they do seem to imply that if this happened, it was not a major population expansion. Moreover, recent investigation of Y-chromosome variation exhibited by some of these same populations—which directly tracks male prehistory and movement—provides no support for close genetic connections between southwestern and Mesoamerican Uto-Aztecan populations (Kemp et al. 2008).

Instead, Kemp detected a very clear signature of an in situ population expansion (a "star-like" phylogeny; see Kemp 2006:71) in the Southwest. This expansion was seen specifically in mitochondrial haplogroup B, the most common mitochondrial haplogroup among present-day populations of the region, with the highest frequencies occurring in Pueblo-affiliated populations ("Anasazi" [Carlyle et al. 2000], *n*=25, 60 percent B; Jemez, *n*=71, 86 percent B; Zuni, *n*=50, 76 percent B; but by contrast, e.g., Akimel O'odham, *n*=146, 47 percent B; Aztecs, *n*=37, 16 percent B).

In particular, the expansion began from a form of haplogroup B that exhibits two particular mutations (transitions at positions 16111 and 16483 of the mitochondrial genome) that today are only found in the Southwestern populations, and are conspicuously absent in Mesoamerican populations. The Cora and Huichol, who exhibit this form of haplogroup B, are here considered part of the "Greater Southwest" following Beals (1974). This was truly a pan-Southwest expansion as all major linguistic divisions sampled thus far in the region (Uto-Aztecan, Yuman, Kiowa-Tanoan, and Zuni) exhibit the expansion type at rather high frequencies (on average 29 percent of all matrilines in the Southwest are of this type). Kemp (2006) calculates that the expansion of this clade dates to 2105 BP (99.5 percent CI ± 1,273-3,773 BP).[7] This confidence interval encompasses the mid-first-millennium-AD date reported here for marked increase in growth rates accompanying the NDT in the Southwest.

Since this study by Kemp (2006) was completed, additional evidence of this expansion has been detected in populations of Uto-Aztecans and Yumans from southern California[8] (Johnson and Lorenz 2006) as well as in additional Yuman-speaking populations from the Southwest (Monroe and Kemp 2008). Interestingly, this type is not found in Yuman-speaking groups residing in Baja California, suggesting that it occurred after the major Yuman language families split approximately 1750-2500 years ago (Monroe and Kemp 2008), a date also in accord with the NDT expansion described here.

More traditional archaeological data also suggest a late NDT. Dean, Doelle, and Orcutt (1994:73-76) attempted to make pan-Southwestern population estimates using data from the archaeological literature available in the early 1990s. These measures ultimately depend on site counts and sizes by phase, and not on ancient human remains or contemporary DNA. Their tabulation begins at A.D. 100 and ends at 1600. They reconstruct a rapid population increase beginning around A.D. 550, with population peaking around 1000, remaining high until 1200, and then declining irregularly until the end of the period they plot. The sharp mid-first millennium A.D. increase, however, cannot be taken completely at face value, since as they point out it is influenced by the first availability of Hohokam-region population estimates at A.D. 600. If it were possible to control for that effect, they suggest, the increase would be more gradual, ramping up more slowly in the first half of the first-millennium A.D., but with, likely, a significant increase remaining at that time.

Conclusions

A Neolithic Demographic Transition is visible in the U.S. Southwest, but appears much later than the regional debut of maize slightly before 2000 B.C., providing an independent piece of evidence that the earliest maize supplements a hunter-gatherer lifestyle without fundamentally altering it. Somewhat more surprisingly, the NDT also lags the earliest intensive use of maize, measured here by the appearance of ceramic containers in this region at ca. A.D. 300, though by a much shorter period.

The Neolithic Demographic Transition, when it finally arrives, builds on the prior development of ceramic containers and on the introduction of the bow and arrow, on recently arrived (or newly developed) races of maize that help make it possible to dry-farm many new areas, including extensive and productive mesa tops in portions of the Northern San Juan region, and on increasingly permanent habitations that may facilitate, or reflect, reductions in inter-birth spacing. But before the upland dry-farming niche can be fully developed, given the higher risk of dry farming relative to earlier forms of water-managed maize production, a way of efficiently storing and exchanging agricultural surpluses must be found. The explosive growth in places like the central Mesa Verde portions of the Northern San Juan region (Varien et al. 2007) and its accompanying Pueblo I villages (Wilshusen and Perry 2006) are the most obvious result, though less obvious population growth in other portions of the Southwest benefiting from dry farming is also probable. That these early villages appear when and where they do is logical if, as Kohler and Van West (1996) argue, such villages make possible for the first time durable patterns of efficient exchange of relatively bulky goods such as maize among non-kin.

Prior to the development of these villages, habitation sites, usually referred to as hamlets, appear to have been composed of a single kin group which probably practiced internally a form of generalized reciprocal exchange. Villages, on the other hand, contain several hamlet-scale roomblock units. We infer that exchange among households across roomblocks was important in the success of these villages, and that such exchanges would have been structured through balanced reciprocity. This may have greatly increased the role of such exchanges in these societies, ultimately allowing more efficient allocation of production among all households in the village, but also providing new opportunities for ambitious actors to create dependencies (Kohler et al. 2000:204) and to construct social networks in which they were quite literally well connected. Agent-based modeling exercises on virtual landscapes resembling those used by these early villages (Kobti et al. 2006; Kohler et al. 2007) are investigating the effects of various exchange practices on population size, aggregation, degree of settlement permanence, storage accumulations, and network characteristics.

Although the measure of the Neolithic Demographic Transition developed by Bocquet-Appel for Europe is not without some problems, it gives us a new and powerful way of looking directly at the degree of reproductive success of populations participating in the new Neolithic (or Formative) way of life in the U.S. Southwest. This way of life developed slowly over twenty-five hundred years, rather than spreading dramatically at the expense of foragers at its earliest appearance. This view has been corroborated by the pattern of mitochondrial variation found in populations of the Southwest and Mesoamerican, one that provides no evidence that Mesoamerican farmers came to dominate, at least biologically, foragers in the Southwest (Kemp 2006).

Nevertheless, by midway through the first millennium A.D., a threshold was reached allowing much more rapid growth. For the next 600 years or so, southwestern societies explored new sociopolitical arrangements allowing them to cope with, and exploit the competitive advantages of, the larger group sizes resulting from this growth. A feature of these periods, known in the Pueblo area as the Pueblo I and Pueblo II periods, is that their innovations focused more on competitive success of social groups in this new sociopolitical environment, and on innovations in obtaining protein from meat, than they did on innovations in getting more calories from cultigens. These are, we believe, among those rare periods in human history where populations found themselves for a time at least generally below the carrying capacities of their economic systems in their natural environments.

Summary and Afterthoughts

The long dawn of the Formative in the U.S. Southwest reminds us that the line between foraging and agriculture is not fine and clearly drawn but should be conceptualized, especially here, as encompassing a diverse set of societies practicing various degrees of low-level food production or protoagriculture (Keeley 1995; Smith 2001b) in a variety of settings, using different strategies. One usual benchmark for agricultural societies—domestication—was passed very early in much of the Southwest. As we saw in the first part of this article, though, archaeologists have held conflicting ideas about the importance and effects of domesticated plants in societies predating the late prehistoric periods.

Some of this ambiguity can be resolved, as we attempt to do here, by considering not just the “supply” side of the subsistence equation (e.g., domesticated plants constitute *n percent* of the diet, which is typically difficult to reconstruct), but also what we might call the demand side: what are the birth rates, and growth rates, of the populations in question? Specifically, have they undergone a Neolithic Demographic Transition, as observed in central and western Europe, and in the Levant, and as predicted for sedentary agriculturalists? Here we show how that might be assessed.

Our results, as we interpret them, do not shed much light on the demographic processes accompanying the earliest arrival of maize to the Southwest, though the current absence of populations suitable for the techniques used here implies that achieved growth rates were slow at best both prior to and immediately after its arrival. Furthermore, current mtDNA results suggest that the demic correlates of this earliest expansion of maize cultivation were slight or have been blurred by the more recent population expansion. In making these observations we acknowledge the possibility that more demographic and genetic data from populations pre-dating the appearance of agriculture, and during the Early Agricultural period, may eventually reveal modest increases in growth rates in conjunction with the earliest appearance of maize. We would be very surprised, however, if these were as dramatic as the later increases we document here. We also remind our readers that our samples are larger in the northern (Puebloan) Southwest, possibly affecting our conclusions.

As we interpret our results, there is material here to please and aggravate both the population-pressure theorist, and the aggrandizer theorist, on the "origins of agriculture" question. The very slow achieved growth rates for more than two thousand years following the introduction of maize to Southwestern economies suggest, to us, that populations were generally near their economically governed carrying capacities. We suspect that the initial adoption and slowly increased dependence on domesticated species emerged from nothing more dramatic than people seeking the least-costly means of meeting their subsistence needs in contexts of changing climates, environments, and demographic pressures. The changing environment includes the genomic changes that domesticated species were undergoing in response to the selective pressures of domestication.

It seems probable to us, though, that the NDT beginning around the mid-first-millennium A.D. coincides with an increased salience for various social and political interactions that may have the effect of allowing or even provoking population growth. We have suggested above what some of those might be, but much still remains to be convincingly unraveled. Is the burst of growth due only to a completely achieved sedentism in these contexts, or is there more? And what specifically allows, or provokes, that sedentism? Though we have answered some questions here to our satisfaction, others remain. We hope they can now be more clearly poised.

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Figure Captions

Figure 1. Location of study area and of selected sites used in the analysis.

Figure 2. Calibrated B.P. dates for earliest maize sites in the U.S. Southwest, interpolated using inverse-distance weighting.

Figure 3. Proportions of immature individuals in sites and composite samples plotted against the difference between earliest maize use in that site’s subregion, and midpoint date of site occupation. Relationship fitted using loess, a nonparametric method for estimating local regression surfaces (α [smoothing parameter]=0.56; AIC_C = 0.89; fit method = kd tree; n fitting points = 17; n observations = 51; n points in local neighborhood = 28). See note 4 for inferential test.

Figure 4. Proportions of immature individuals in sites and composite samples plotted against the difference between earliest intensive maize use in that site’s subregion, as proxied from appearance of ceramic containers, and midpoint date of site occupation.

Relationship fitted using loess, a nonparametric method for estimating local regression surfaces (α=0.52; AIC_C = 0.89; fit method = kd tree; n fitting points = 17; n observations = 51; n points in local neighborhood = 26). See note 4 for inferential test.

Figure 5. Data as in Figure 4, using scatterplot smoothing parameters from 0.3 to 0. 6 and fit method=direct.

Table 1. Sites used in analysis of Southwestern demographic data

Area/Site (Abbreviation for figures)	Subregion	Site date (A.D.)	Early Maize (A.D.)	Effective use of Maize (A.D.)	dt Early Maize	dt Effective Maize	n(5+)	5-19	19+	$_{15}p_5$	Sources
Hohokam Area											
Cienega[a]	Tucson Basin	-125	-2000	150	1875	-275	55.00	13.00	42.00	0.170	Mabry 1998:Table 16.2
Las Capas (LasCapa)	Tucson Basin	-1000	-2000	150	1000	-1150	11.00	2.75	8.25	0.250	McClelland in Diehl 2005
Matty Wash[a] (MattyWa)	Tucson Basin	-443	-2000	150	1557	-593	15.00	2.00	13.00	0.133	Huckell 1995:Table 3.5
SA Mission (SAMissi)	Tucson Basin	-385	-2000	150	1615	-535	12.00	1.80	10.20	0.150	McClelland 2008
Pueblo Grande-Early Classic (PGEC)	Phoenix Basin	1213	-2000	150	3213	1063	88.67	19.67	69.00	0.222	Sheridan in Mitchell and Brunson-Hadley 2001
Pueblo Grande-Late Classic (PGLC)	Phoenix Basin	1363	-2000	150	3363	1213	61.33	13.33	48.00	0.217	Sheridan in Mitchell and Brunson-Hadley 2001
Roosevelt Platform Mound Study-Roosevelt Phase (RPMS-RP)[a]	Tonto Basin	1300	-2000	150	3300	1150	102.50	18.50	84.00	0.180	Ravesloot & Regan 2000:62
Schoolhouse Point Mound-Gila Phase (RPMS-GP)	Tonto Basin	1400	-2000	150	3400	1250	61.00	13.00	48.00	0.213	Ravesloot & Regan 2000:62
Mogollon Area											
Casas Grandes (Paquimé)	Chihuahua	1300	-2000	1	3300	1299	550.80	220.32	330.48	0.400	Bocquet-Appel & Naji 2006:243
Galaz-Late Pithouse (GalazLP)	Mimbres	775	-2000	1	2775	774	64.75	24.42	40.34	0.377	Anyon & Leblanc 1984
Galaz-Classic Mimbres (GalazCM)	Mimbres	1075	-2000	1	3075	1074	540.75	161.69	379.06	0.299	Anyon & Leblanc 1984
Grasshopper Pueblo (Grassho)	Cibecue	1338	-2000	1	3338	1337	279.00	90.00	189.00	0.323	Bocquet-Appel & Naji 2006:243
Point of Pines (Pointof)	Black River	1275	-2000	1	3275	1274	333.00	37.00	296.00	0.111	Bocquet-Appel & Naji 2006:243
SU	Cibola	500	-2000	1	2500	499	27.00	3.00	24.00	0.111	Buzon & Grauer 2002:Table 1
Pueblo Area											
423-101	San Juan Basin	900	-980	300	1880	600	9.00	1.00	8.00	0.111	Herrmann et al. 1993:12
Arroyo Hondo[a] (ArroyoH)	Northern Rio Grande	1363	-1250	300	2613	1063	59.00	18.00	41.00	0.305	Bocquet-Appel & Naji 2006:243
Black Mesa-Early Pueblo[a] (BMEarly)	Kayenta	925	-1900	600	2825	325	35.43	10.43	25.00	0.294	Martin et al. 1991:Table 2-11
Black Mesa-Late Pueblo[a] (BMLate)	Kayenta	1100	-1900	600	3000	500	79.00	23.00	56.00	0.291	Martin et al. 1991:Table 2-11
Darkmold-5LP4991 (Darkmo)	La Plata	200	-400	500	600	-300	22.60	8.23	14.38	0.363	Charles, ed. 2000; Charles 2007
Dog Leg Site (DogLeg)	San Juan Basin	-290	-980	300	690	-590	10.50	4.85	5.65	0.462	Kearns et al. 1998
Durango[a]	La Plata	750	-400	500	1150	250	5.00	0.00	5.00	0.000	Rowen III 1980:Table 24
Duna Leyenda-42Sa8540 (DunaL)	Northern San Juan	600	-400	300	1000	300	10.00	1.50	8.50	0.150	Neily 1982:64-103
Gran Quivira-Early (GranQuE)	Northern Rio Grande	1376	-1250	300	2626	1076	22.00	3.00	19.00	0.136	Hayes 1981
Gran Quivira-Middle (GranQuM)	Northern Rio Grande	1475	-1250	300	2725	1175	49.33	13.00	36.33	0.264	Hayes 1981
Gran Quivira-Late (GranQuL)	Northern Rio Grande	1611	-1250	300	2861	1311	60.33	10.00	50.33	0.166	Hayes 1981
Hawikku LA37	Zuni	1563	-2000	300	3563	1263	147.00	44.00	103.00	0.299	Bocquet-Appel & Naji 2006:243; Stodder 1994
La Plata	La Plata	1100	-400	500	3100	60	41.00	11.00	30.00	0.268	Martin & Akins 2001
Marsh Pass[a] (MarshPa)	Kayenta	-233	-1900	600	1667	-833	21.00	2.63	18.37	0.143	Coltrain et al. 2007:Table 1
NRG - 1150[a]	Northern Rio Grande	1150	-1250	300	2400	850	17.96	2.19	15.77	0.122	Kramer 2002:Appendix D

NRG - 1250[a]	Northern Rio Grande	1250	-1250	300	2500	950	17.02	2.42	14.60	0.142	Kramer 2002:Appendix D
NSJ - 850[a]	Northern San Juan	850	-400	300	1250	550	86.14	20.74	65.40	0.241	Kramer 2002:Appendix D
NSJ - 950[a]	Northern San Juan	950	-400	300	1350	650	20.40	3.40	17.00	0.167	Kramer 2002:Appendix D
NSJ - 1050[a] + Porter-5MT1	Northern San Juan	1050	-400	300	1450	750	43.28	9.26	34.02	0.219	Kramer 2002:Appendix D & Swedlund 1966
NSJ - 1150[a] + 5MT3	Northern San Juan	1150	-400	300	1550	850	77.77	29.97	47.78	0.385	Kramer 2002:Appendix D & Swedlund 1966
NSJ - 1250[a]	Northern San Juan	1250	-400	300	1650	950	82.30	25.75	56.55	0.313	Kramer 2002:Appendix D
Pecos Pueblo-Forked Light (PecosFL)	Northern Rio Grande	1225	-1250	300	2475	925	99.33	19.33	80.00	0.195	Mobley 1980
Pecos Pueblo-Glaze/B&W (PecosBW)	Northern Rio Grande	1338	-1250	300	2588	1038	39.57	9.57	30.00	0.242	Mobley 1980
Pecos Pueblo-Glaze I (PecosG1)	Northern Rio Grande	1400	-1250	300	2650	1100	118.71	20.71	98.00	0.174	Mobley 1980
Pecos Pueblo-Glaze II (PecosG2)	Northern Rio Grande	1450	-1250	300	2700	1150	69.86	8.86	61.00	0.127	Mobley 1980
Pecos Pueblo-Glaze III (PecosG3)	Northern Rio Grande	1513	-1250	300	2763	1213	122.71	19.71	103.00	0.161	Mobley 1980
Peña Blanca-E. Devel (PBED)	Northern Rio Grande	700	-1250	300	1950	400	12.25	3.25	9.00	0.265	Akins 2008
Peña Blanca-L. Dev/Coal (PBLDEC)	Northern Rio Grande	1200	-1250	300	2450	900	8.25	3.25	5.00	0.394	Akins 2008
San Cristóbal (SanCris)	Northern Rio Grande	1503	-1250	300	2753	1203	203.00	55.00	148.00	0.271	Bocquet-Appel & Naji 2006:243
SJB - 700[a]	San Juan Basin	700	-980	300	1680	400	43.94	9.54	34.40	0.217	Kramer 2002:Appendix D
SJB - 850[a]	San Juan Basin	850	-980	300	1830	550	42.76	9.51	33.25	0.222	Kramer 2002:Appendix D
SJB - 945[a] (UpPuerc)	San Juan Basin	945	-980	300	1925	645	32.17	9.17	23.00	0.285	Herrmann et al. 1993:12-14
SJB - 950[a]	San Juan Basin	950	-980	300	1930	650	89.85	36.75	53.10	0.409	Kramer 2002:Appendix D
SJB - 1050[a]	San Juan Basin	1050	-980	300	2030	750	139.74	38.69	101.05	0.277	Kramer 2002:Appendix D
SJB - 1150[a]	San Juan Basin	1150	-980	300	2130	850	222.63	91.43	131.20	0.411	Kramer 2002:Appendix D
SJB - 1250[a]	San Juan Basin	1250	-980	300	2230	950	26.76	12.04	14.72	0.450	Kramer 2002:Appendix D
Stevenson-5MT1 (Stevens)	Northern San Juan	660	-400	300	1060	360	5.00	0.00	5.00	0.00	Swedlund 1969

[a] Composite samples; see Table 2 for additional information.

Table 2. Details on composite burial assemblages.

Area/Site	Number of sites	n(5+)	Sites	Largest Contributing Site	Comment
Hohokam					
Cienega	7	55.00	Coffee Camp (AZ AA:6:19),Wetlands (AZ AA:12:90), S. Cruz Bend (AZ AA:12:746), Stone Pipe (AZ AA:12:745), Los Pozos (AZ AA:12:91), Clearwater (AZ BB:13:6), Pantano (AZ EE:2:5)	AZ AA:12:90 (Wetlands), n=21	Compilation of sites from south-central Arizona
Matty Wash	2	15.00	Donaldson Site, Los Ojitos	Los Ojitos, n=10	
Roosevelt Platform Mound Study-Roosevelt Phase	2	102.5	Schoolhouse Point Mound (U:8:24) and U:8:450	Schoolhouse Point Mound	Populations with dental traits suggesting mixed Sinagua and western Anasazi affiliations
Pueblo					
Black Mesa - Early Pueblo	13	35.43	7:98, 7:134, 7:135, 7:262, 7:234, 7:707, 7:2103,11:2023, 11:2025, 11:2030, 11:2040,11:2062, 11:2068	7:234 (n=8)	Compilation of Black Mesa sites dating to A.D. 800 - 1050
Black Mesa - Late Pueblo	39	79.00	7:11, 7:12, 7:23, 7:27, 7:102, 7:109, 7:216, 7:716, 7:719, 7:220, 7:725, 7:2001, 7:2017, 11:3, 11:12, 11:14, 11:97, 11:260, 11:265, 11:275, 11:289, 11:290, 11:300, 11:335,11:348, 11:352, 11:409, 11:425, 11:426, 11:500, 11:569, 11:666, 11:686, 11:687, 11:2013, 11:2048, 11:2068, 11:2108, 11:2155	11:500 (n=7), 11:300 (n=7)	Compilation of Black Mesa sites dating to A.D. 1050 - 1150
Durango	2	7.00	5LP110, 5LP111	5LP11 (n=3)	
Marsh Pass	4	21.00	Sayodneechee Cave, Kinboko Cyn Cave 1, White Dog Cave, Tsegi Canyon Cave 3	Sayodneechee Cave, n=9	Compilation of early Kayenta sites
NRG - 1150	4	17.96	LA649, LA6865, LA11633, LA654	LA649 (Nogales Cliffhouse), n=11	Compilation of Gallina sites dating to A.D. 1100 - 1199
NRG - 1250	9	17.02	LA11843, LA22866, LA22867, LA22868, LA22895, LA22902, LA23043, LA11850, LA11841	Even distribution of burials	Compilation of Gallina sites dating to A.D. 1200 - 1300
NSJ - 850	16	86.14	5MT2192, 5MT2848, 5MT2853, 5MT5107, 5MT2182, 5MT23, 5MT4671, 5MT4725, 5MT2320, 5MT4475, 5MT5108, 5MT4480, 5MT1604, 5MT8899, 5MT8937, 5MT3868	5MT5107 (Pueblo de las Golondrinas), n=19	Compilation of regional sites dating to A.D. 800 - 899
NSJ - 950	5	20.4	5MT4477, 5MT2525, 5MT8934, 5MV1452, 5MV875	5MV1452 (Badger House), n=11	Compilation of regional sites dating to A.D. 900 - 999
NSJ - 1050	7	31.78	5MT5501, 5MT5106, 5MT8827, 5MT2433, 5MV1452, 5MV866, 5MV1229	5MV1452 (Badger House), n=12	Compilation of regional sites dating to A.D. 1000 - 1099
NSJ - 1150	10	65.77	5MT5498, 5MT2149, 5MT2235, 5MT948, 5MT2148, 5MT2544, 5MV1595, 5MV499, 5MT7723, 5MT10207	5MV1595, n=20	Compilation of regional sites dating to A.D. 1100 - 1199

NSJ - 1250	7	82.3	5MT9735, 5MV34, 5MV1452, 5MV1200, 5MV1228, 5MV1229, 5MT10206	5MV1200 (Long House), n=28	Compilation of regional sites dating to A.D. 1200 - 1300
SJB - 700	10	43.94	LA45689, LA2507, LA8939, LA16029, LA4195, LA8662, LA80407, LA83505, LA083506, LA83507	LA4195 (Sambrito Village), n=16	Compilation of regional sites dating to A.D. 600 - 799
SJB - 850	12	42.76	LA3562, LA4487, LA3646, LA4363, LA4384, LA4151, LA4131, LA4148, LA4242, LA4198, LA80934, LA83507	LA4487, n=15	Compilation of regional sites dating to A.D. 800 - 899
SJB - 945	5	32.17	423-122, 423-124, 423-129, 423-130, 423-131	423-124, n=12.67	Upper Puerco River sites from A.D. 285-1410, dates averaged
SJB - 950	16	89.85	LA50337, LA4169, LA4298, LA4380, LA4131, LA4053, LA4086, LA4088, LA2585, LA226, LA40299, LA40626, LA40627, LA40935, LA41629, LA83506	LA4086 (Sanchez Site), n=27	Compilation of regional sites dating to A.D. 900 - 999
SJB - 1050	35	139.74	LA16660, LA104984, LA8846, LA80440, LA59497, LA2675, LA2699, LA2701, LA2937, LA5062, LA6383, LA6387, LA16254, LA8779, LA2585, LA2592, LA80377, LA40395, LA226, LA838, LA841, LA2470, LA40394, LA40396, LA40399, LA40597, LA40626, LA42385, LA83498, LA100627, LA100628, LA100629, LA83500	LA40399 (Tom Mathew's Dig), n=19	Compilation of regional sites dating to A.D. 1000 - 1099
SJB - 1150	17	222.63	LA45, LA8846, LA5057, LA226, LA2985, LA2987, LA2988, LA2470, LA40394, LA40396, LA2464, LA8978, LA40395, LA40397, LA40721, LA2592, LA40399	LA226 (Pueblo Bonito), n=62	Compilation of regional sites dating to A.D. 1100 - 1199
SJB - 1250	17	26.76	LA3292, LA45, LA8846, LA85235, LA5596, LA2714, LA4485, LA6372, LA6380, LA6400, LA35867, LA41947, LA2508, LA4050, LA40399, LA40589, LA40633	LA45 (Aztec Ruin)	Compilation of regional sites dating to A.D. 1200 - 1300

Endnotes

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[1] All dates in this paper are either general dates, tree-ring-based dates, or calibrated ^{14}C ages.

[2] We made chronological subdivisions within aggregated assemblages reported by Bocquet-Appel and Naji (2006:349) for Black Mesa and Pecos Pueblo, and we did not use their data for Mesa Verde and Pueblo Bonito, since these were included in more chronologically precise fashion in the data compiled by Kramer.

[3] Those who prefer an absolute chronology can see the Pueblo sites (only) in this analysis graphed against their absolute ages in Kohler and Varien (2009). As the areas considered become smaller, and the dates for earliest maize and ceramics subject to less spatial lag, absolute chronologies become more acceptable for our purposes.

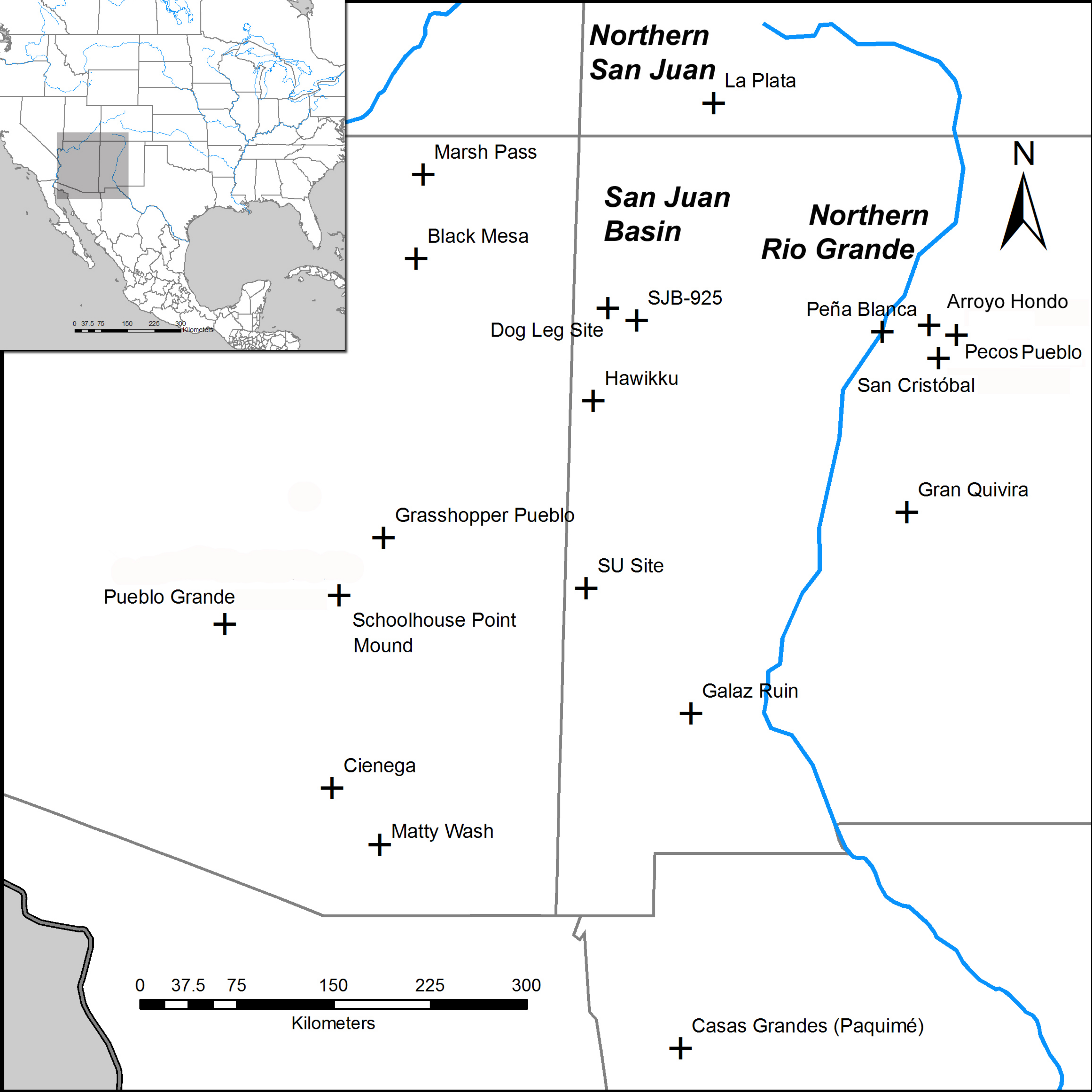
[4] SAS v. 9.1.3, PROC LOESS. Loess is fundamentally a nonparametric method for fitting a regression relationship to noisy data that frequently exhibit nonlinear relationships. Nevertheless statistical inference is possible. Following procedures outlined in Cleveland and Grosse (1991), we can compare the goodness-of-fit of the line in Figure 3, formed using a smoothing parameter of 0.56, against the straight line that would be fitted using all the points simultaneously (i.e., a smoothing parameter of 1.0). This comparison yields an $F_{(2.4,45.2)} = 3.36$, $p = 0.035$, indicating that the loess line we display is a significantly better fit than the straight-line fit would be. Using the same procedures for the loess line in Figure 4, we calculate $F_{(3.1,44)} = 4.37$, $p = 0.0004$, indicating that the loess line we display is a significantly better fit than the straight-line fit would be. Since the sample size is constant across the analyses in these two figures, we have also improved the fit relative to the loess line in Figure 3 by changing the calculation of the years DT.

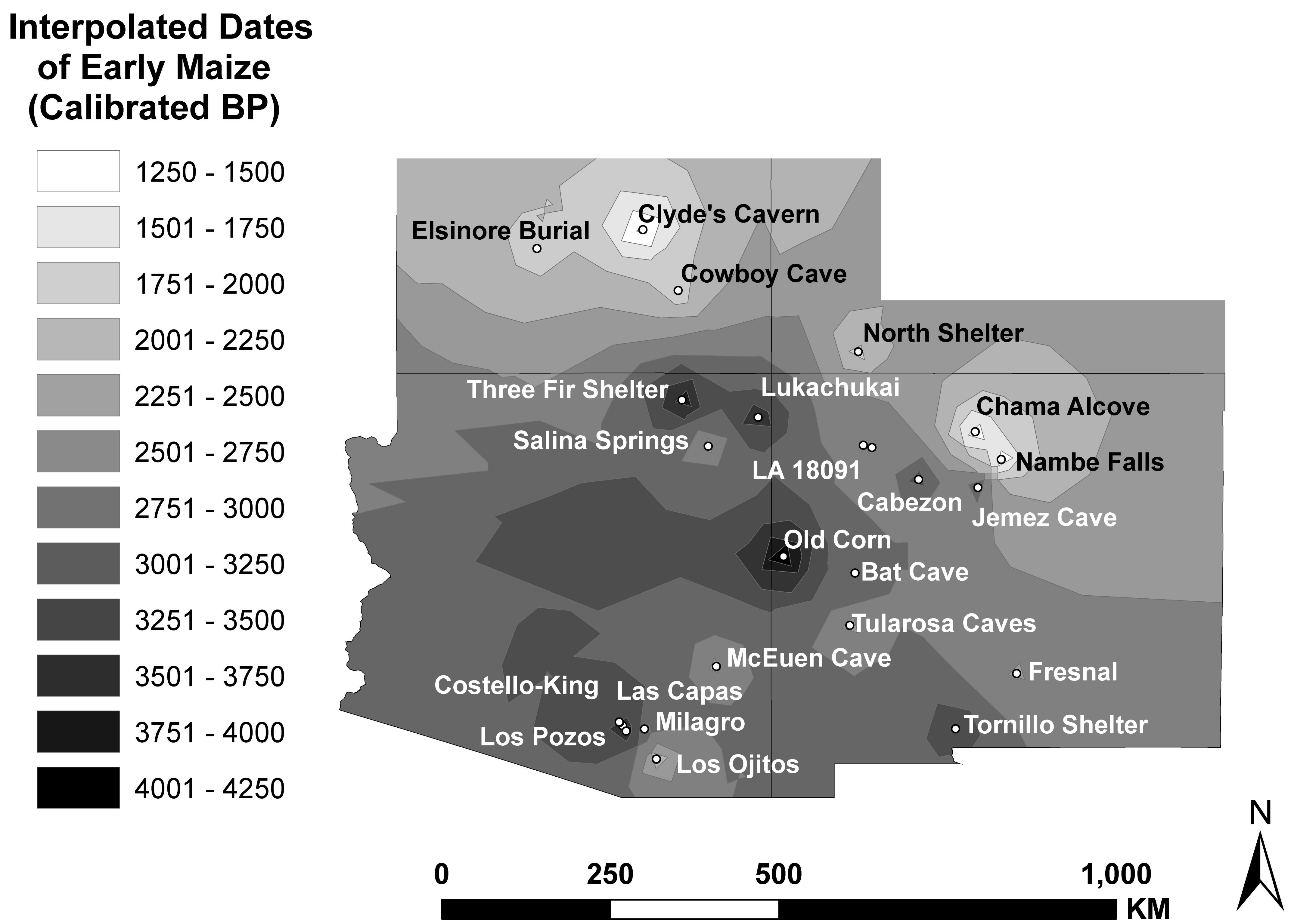
[5] This assumes that deaths due to warfare are slightly more likely in the ≥20-year-old group, that individuals dieing from warfare were as likely to enter the excavated death assemblages as were individuals dieing from other causes, and that individuals dieing from warfare in each age category were equally likely to enter the excavated death assemblages.

[6] Though we have some suspicions. Kohler et al. (2004) have pointed to the proto-market forces visible in Classic period (mid-fourteenth- through early sixteenth-century) towns in the Northern Rio Grande and suggested that this vibrant new economic organization, which is accompanied by novel forms of ceremonial organization, contributed significantly to the success of these large aggregates.

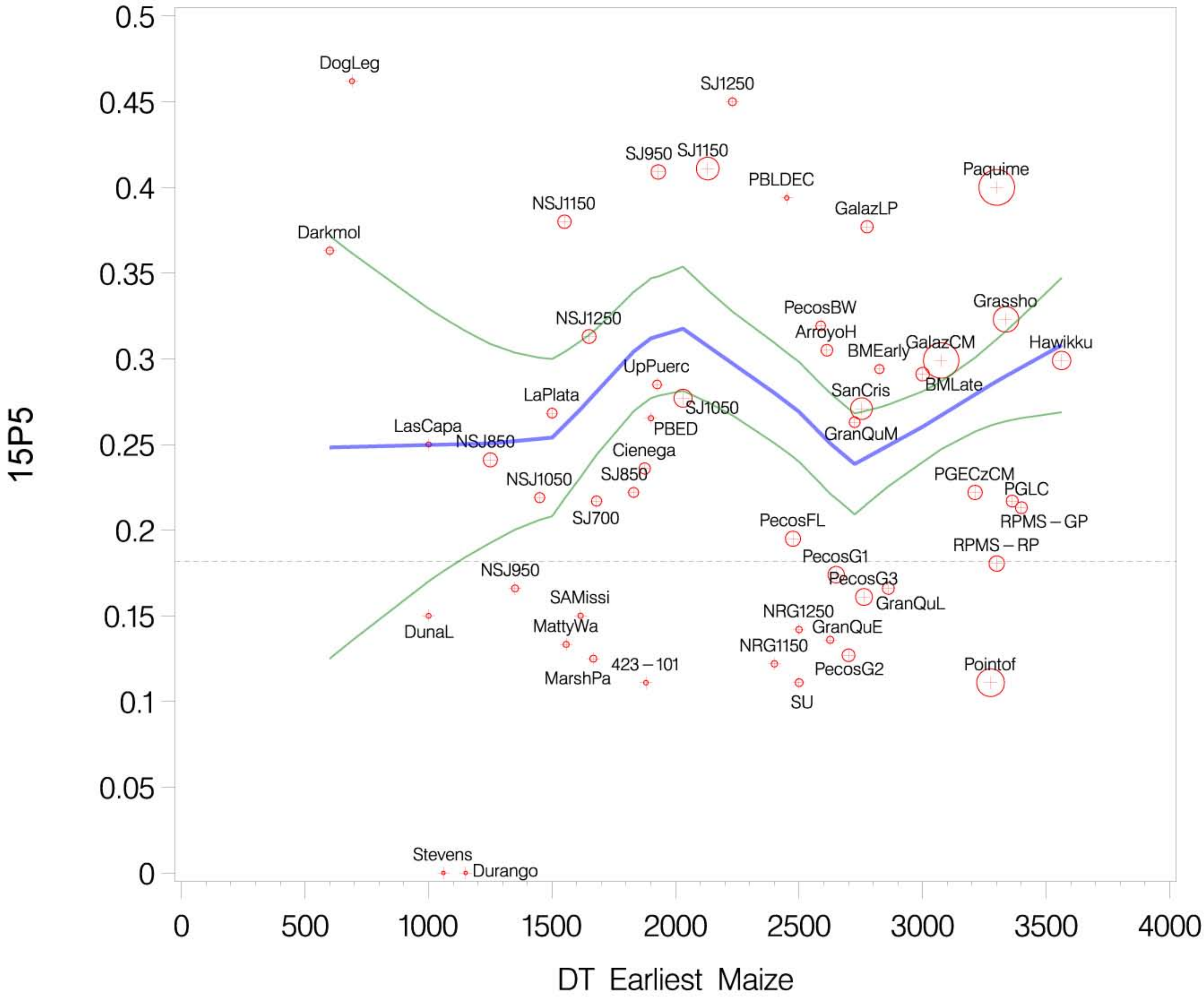
[7] This range of dates would not go uncontested by some molecular anthropologists. It is based on a mutation rate derived from pedigree studies (Howell et al. 2003), which has recently been argued by Kemp et al. (2007) to extend further back in time than previously believed. The independent data derived here from the archaeological record provide more evidence that previous estimates of mtDNA evolution are too slow (Kemp et al. 2007; Ho et al. 2005).

[8] The Uto-Aztecan and Yuman populations of southern California, argued here to exhibit a signature of the haplogroup B expansion, all exhibit a mutation at position 16111 of the mitochondrial genome, in common with those individuals in the Southwest characterized by Kemp (2006). However, the other position (i.e., 16483) found in the expansion type of haplogroup B in the Southwest was unfortunately not screened by Johnson and Lorenz (2006). It is very likely that these individuals also exhibited a mutation at the 16483 position.

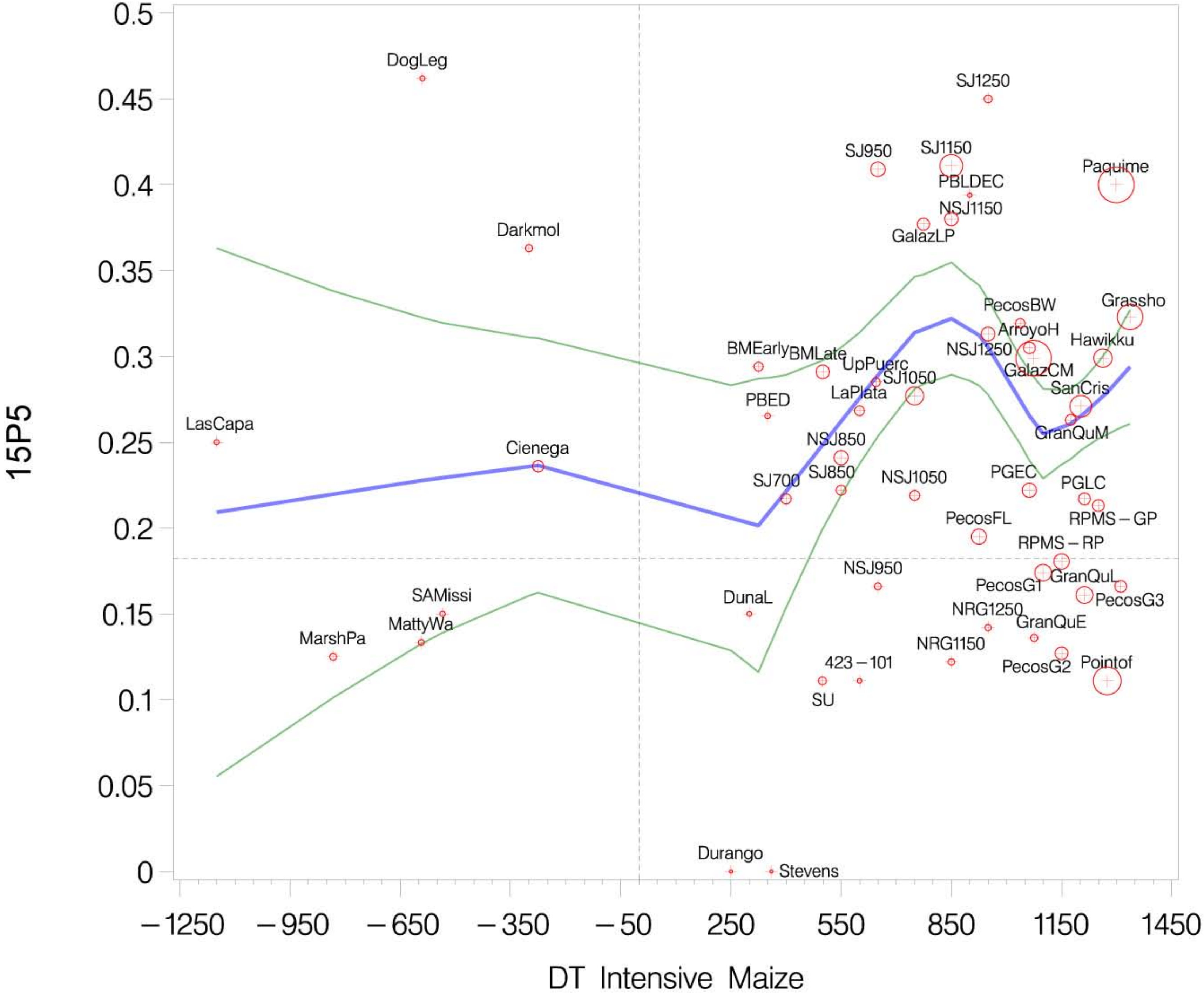

Northern San Juan
La Plata
Marsh Pass
San Juan Basin
Northern Rio Grande
N
Black Mesa
SJB-925
Dog Leg Site
Peña Blanca
Arroyo Hondo
Pecos Pueblo
San Cristóbal
Hawikku
Gran Quivira
Grasshopper Pueblo
SU Site
Pueblo Grande
Schoolhouse Point Mound
Galaz Ruin
Cienega
Matty Wash
0 37.5 75 150 225 300
Kilometers
Casas Grandes (Paquimé)



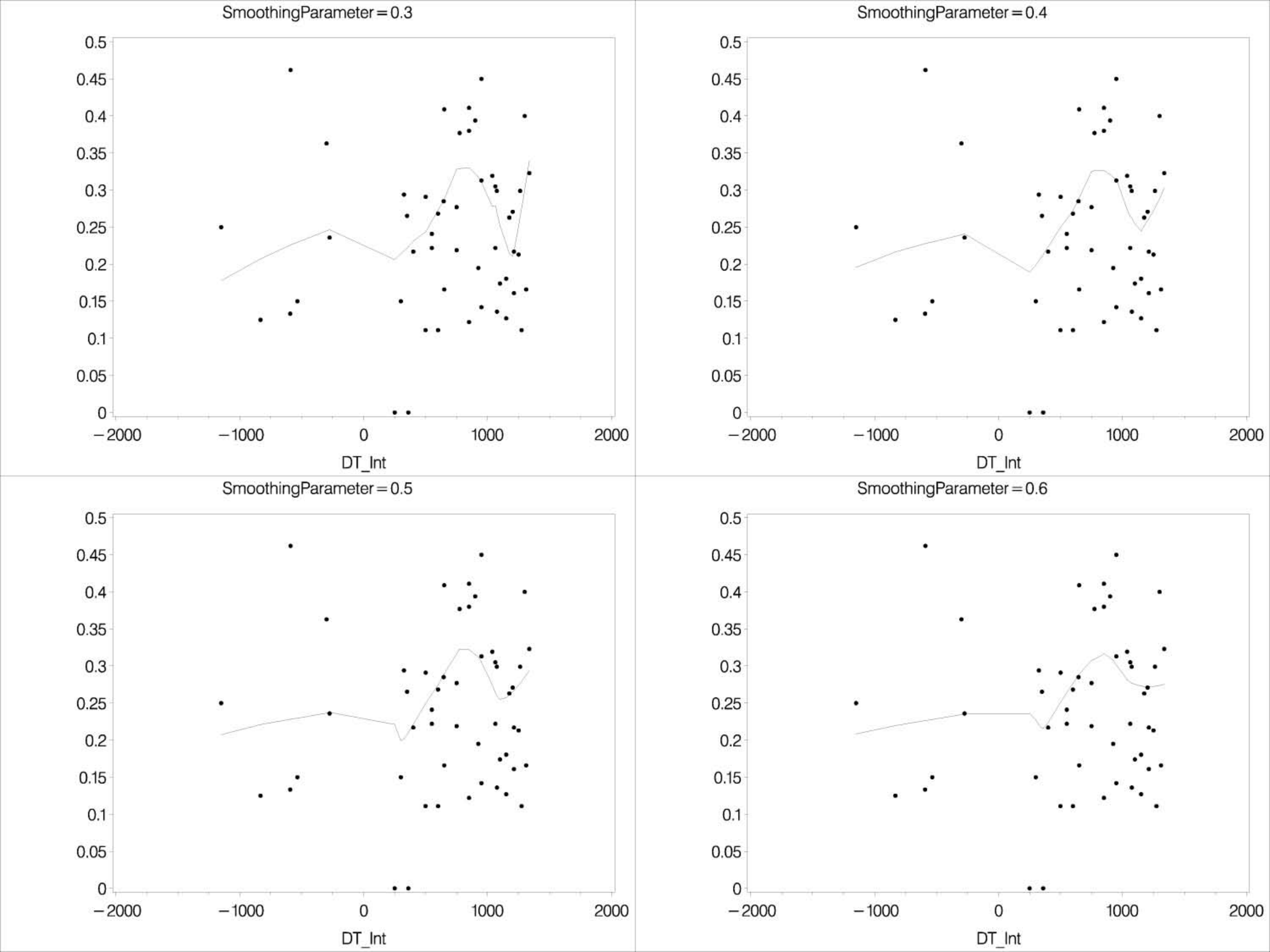
Interpolated Dates of Early Maize (Calibrated BP)
1250 - 1500
1501 - 1750
1751 - 2000
2001 - 2250
2251 - 2500
2501 - 2750
2751 - 3000
3001 - 3250
3251 - 3500
3501 - 3750
3751 - 4000
4001 - 4250
Elsinore Burial
Clyde's Cavern
Cowboy Cave
North Shelter
Three Fir Shelter
Lukachukai
Chama Alcove
Salina Springs
Nambe Falls
LA 18091
Cabezon
Jemez Cave
Old Corn
Bat Cave
Tularosa Caves
McEuen Cave
Fresnal
Costello-King
Las Capas
Milagro
Tornillo Shelter
Los Pozos
Los Ojitos
0
250
500
1,000
KM
N



15P5
DT Earliest Maize
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
500
1000
1500
2000
2500
3000
3500
4000
DogLeg
SJ1250
SJ950
SJ1150
Paquime
PBLDEC
NSJ1150
GalazLP
Darkmol
NSJ1250
PecosBW
Grassho
ArroyoH
GalazCM
Hawikku
BMEarly
BMLate
UpPuerc
LaPlata
SanCris
SJ1050
PBED
GranQuM
LasCapa
NSJ850
Cienega
SJ850
NSJ1050
SJ700
PGECzCM
PGLC
RPMS − GP
PecosFL
RPMS − RP
PecosG1
PecosG3
NSJ950
GranQuL
SAMissi
NRG1250
DunaL
GranQuE
MattyWa
NRG1150
423 − 101
MarshPa
PecosG2
Pointof
SU
Stevens
Durango



15P5
DT Intensive Maize
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
−1250
−950
−650
−350
−50
250
550
850
1150
1450
DogLeg
Darkmol
LasCapa
Cienega
SAMissi
MattyWa
MarshPa
DunaL
Durango
Stevens
SJ1250
SJ950
SJ1150
Paquime
PBLDEC
NSJ1150
GalazLP
Grassho
PecosBW
ArroyoH
NSJ1250
Hawikku
GalazCM
BMEarly
BMLate
UpPuerc
SJ1050
LaPlata
PBED
SanCris
GranQuM
NSJ850
SJ700
SJ850
NSJ1050
PGEC
PGLC
RPMS − GP
PecosFL
RPMS − RP
NSJ950
GranQuL
PecosG1
PecosG3
NRG1250
GranQuE
NRG1150
423 − 101
PecosG2
Pointof
SU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0.25
0.2
0.15
0.1
0.05
0
−2000
−1000
0
1000
2000
DT_Int