Early procurement of scarlet macaws and the emergence of social complexity in Chaco Canyon, NM

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High-precision accelerator mass spectrometer (AMS) ^{14}C dates of scarlet macaw (*Ara macao*) skeletal remains provide the first direct evidence from Chaco Canyon in northwestern New Mexico that these Neotropical birds were procured from Mesoamerica by Pueblo people as early as ∼A.D. 900–975. Chaco was a prominent prehistoric Pueblo center with a dense concentration of multistoried great houses constructed from the 9th through early 12th centuries. At the best known great house of Pueblo Bonito, unusual burial crypts and significant quantities of exotic and symbolically important materials, including scarlet macaws, turquoise, marine shell, and cacao, suggest societal complexity unprecedented elsewhere in the Puebloan world. Scarlet macaws are known markers of social and political status among the Pueblos. New AMS ^{14}C-dated scarlet macaw remains from Pueblo Bonito demonstrate that these birds were acquired persistently from Mesoamerica between A.D. 900 and 1150. Most of the macaws date before the hypothesized apogeal Chacoan period (A.D. 1040–1110) to which they are commonly attributed. The 10th century acquisition of these birds is consistent with the hypothesis that more formalized status hierarchies developed with significant connections to Mesoamerica before the post-A.D. 1040 architectural florescence in Chaco Canyon.

sociopolitical complexity | Chaco Canyon | scarlet macaws | archaeology

Archaeologists have known for more than a century that the prehispanic Pueblo people of the American Southwest (hereafter SW) acquired goods from Mesoamerica. Such items included marine shell from the Gulf of California, raw copper and crafted copper bells from West Mexico (1–3), cacao from the Neotropics (4), and tropical birds such as scarlet and military macaws whose feathers were important in ritual (5, 6).

Scarlet macaws (*Ara macao*; Fig. 1*A*) are the most exotic birds recovered by archaeologists excavating settlements in the SW from southern Utah and Colorado to northern Mexico. Along with cacao, shell, and copper, these birds signal the type of long-distance transport of goods often argued to have been an important dimension of emergent sociopolitical complexity in prehistoric societies. Like cacao, to which access was probably restricted to high-status individuals or groups (7), the acquisition and control of scarlet macaws was likely the province of social and religious elites.

The skeletal remains of more than 400 scarlet macaws have been recovered from the SW, with most concentrated in Chaco Canyon (n = 35 macaws), the Mimbres region of southwestern New Mexico ($n \geq 10$), the Mogollon Rim area of east-central Arizona ($n \geq 27$), Wupatki in north-central Arizona (n = 22), and Paquimé (n = 322) in northern Mexico (5, 6) (Fig. 1*C*). The range of scarlet macaws is restricted to humid forests in tropical America (8, 9), primarily the Gulf Coast region of Mexico, Central America, and northern sections of South America (Fig. 1*B*). The northernmost populations (Mexico to Nicaragua) have been recognized as a distinct subspecies, *Ara macao cyanoptera*, and inhabit more open habitats, including deciduous, mixed pine–broadleaf, and gallery forests (10).

The acquisition of scarlet macaws likely required lengthy trips between the northern SW and the lowland tropical forests of Mesoamerica (11). These birds historically lived as far north as the Gulf Coast state of Tamaulipas near Tampico, ∼1,800 km from Chaco, until the late 19th century (12). The northern limit of this species along the Pacific coast was southern Oaxaca, even more distant (∼2,500 km) from Chaco. We know from historic accounts that such long-distance travel by Pueblo people was common, with Pueblo people exchanging turquoise and hides for macaws or their brilliantly colored feathers (13, 14). We also should note, however, the possibility that scarlet macaws were procured from more proximate, earlier Mesoamerican settlements, similar to the large 13th- to 15th-century prehispanic center of Paquimé, where scarlet macaws were bred (15).

The chronology of Pueblo–Mesoamerican relations has been based exclusively on the presence of items such as macaw remains in SW archaeological contexts dated by dendrochronology or temporal changes in ceramic styles. Such indirect dating has led most scholars to conclude that these long-distance acquisition networks developed in the northern SW after A.D. 1030–1040 and were largely a result of the evolution of social complexity and hierarchy, rather than a key causal factor in the emergence of such complexity.

A recent study (16), however, has demonstrated not only that such indirect dating may be inaccurate, particularly at settlements

Significance

New accelerator mass spectrometer (AMS) ^{14}C dates of scarlet macaw (*Ara macao*) skeletons from Chaco Canyon in northwestern New Mexico reveal the earliest (A.D. 900–975) direct evidence for procurement of this Neotropical species by Pueblo people from Mesoamerica. By directly dating the macaws, we demonstrate the existence of long-distance acquisition networks throughout much (A.D. 900–1150) of Chaco's history. In contrast to models of societal evolution that attribute procurement of macaws to the 11th-century peak of Chacoan influence and architectural expansion, most ^{14}C dates significantly predate this period. We propose that access to and control of these important status markers from Mesoamerica before A.D. 1040 was thus linked to the early formalization of social hierarchy in Chaco.

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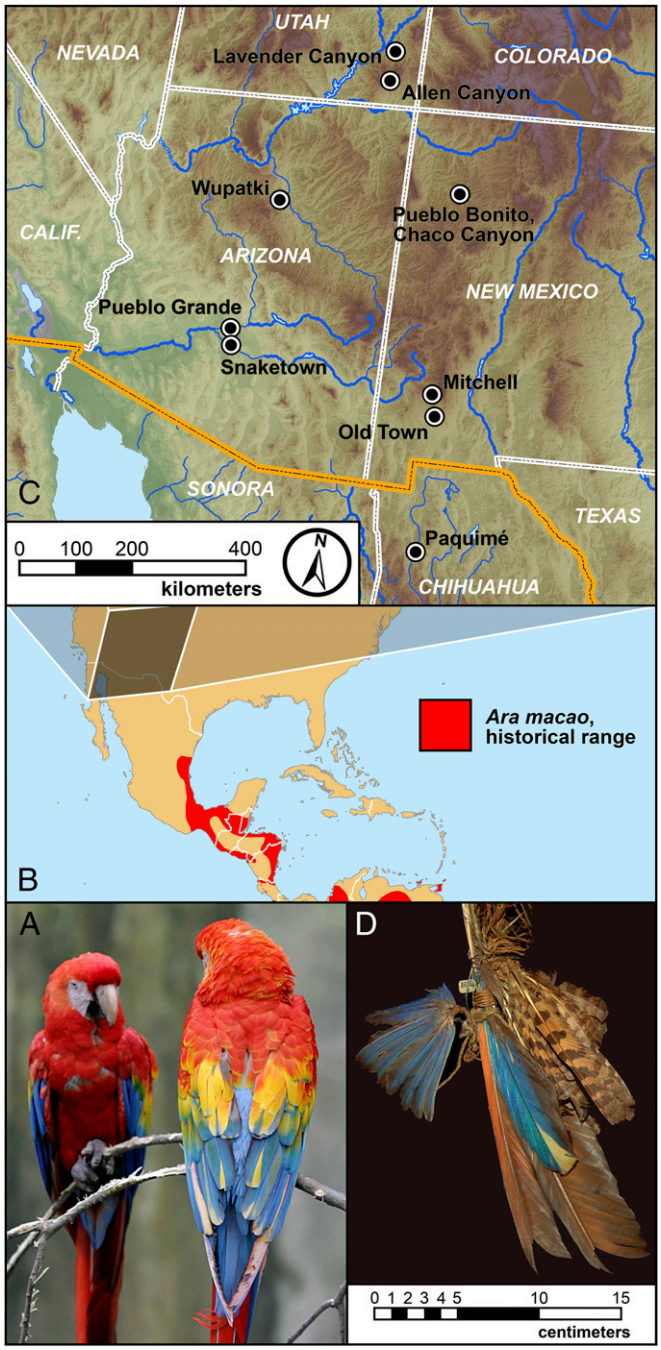

Fig. 1. (*A*) Scarlet macaws, (*B*) the historic range of scarlet macaws, (*C*) locations of sites cited in text or with larger concentrations of macaws in the SW, and (*D*) a prehistoric feather bundle (H/13338) from Allen Canyon in Grand Gulch.

occupied for centuries, but also that an incipient form of social complexity and hierarchy developed in Chaco Canyon as early as the ninth century. As Chaco is one of the locations where scarlet macaws are concentrated, we directly accelerator mass spectrometer (AMS) ^{14}C dated the available skeletal remains of 14 birds to reevaluate the chronology of Pueblo–Mesoamerican acquisition networks and the process by which social complexity emerged in Chaco.

Chaco Culture National Historical Park

Located in northwest New Mexico (Fig. 1*C*), the World Heritage Site of Chaco Canyon witnessed an extraordinary coalescence and transformation of dispersed farming communities over the course of more than three centuries (A.D. 800–1120). The unique nature of Chaco is manifested by a dense concentration of more than a dozen multistoried masonry great houses with unusual architecture (17), complex irrigation systems (18), thriving long-distance procurement networks (3, 4, 19, 20), dozens of roads (most 1–5 km, but others 40–50 km in length), and scores of outlying settlements distributed over several hundred square miles that mimicked Chacoan architectural style (21). The hierarchical sociopolitical structure evident in Chaco Canyon is one of the most widely cited cases of emergent societal complexity in prehispanic North America.

Establishment of at least three large Chacoan pueblos in the Canyon began no later than the early ninth century. These pueblos are referred to as great houses because of their multistory, monumental construction that required skilled masons and the acquisition of tens of thousands of wooden beams from distant forests and hundreds of tons of quarried stone. Throughout much, if not most, of the era from A.D. 800 to A.D. 1120, the cluster of large 50- to 650-room pueblos in Chaco Canyon served as a key node in social, political, and religious interaction across a broad swath of the northern SW.

Pueblo Bonito, the largest of the Chacoan great houses (~650 rooms; Fig. 2), was constructed in multiple building episodes and inhabited throughout the rise and decline of the canyon's prominence in the region. The pueblo contains two unusual burial crypts. A single small structure, room 33 in one of the crypts located in the oldest part of the Pueblo, contained 14 human interments associated with large quantities of symbolically important items such as turquoise, shell, and flutes. Two individuals (nos. 13 and 14) from the room were buried below a rare floor of wooden planks and were associated with rich assemblages of grave goods. Once assumed by most to postdate A.D. 1040 (22–24), these two burials recently have been directly AMS ^{14}C dated to no later than A.D. 775–875 (16), suggesting that hierarchical sociopolitical structures evolved earlier in Chaco than previously assumed.

Excavations in Chaco in the last 125 y have recovered quantities of marine shell, copper bells, and scarlet macaws that are orders of magnitude greater than in most sections of the northern SW. Marine shell ornaments from Chaco number in the thousands, and approximately two dozen copper bells or pieces of raw copper have been excavated (2, 25). Cacao residue also has been discovered in distinctive ceramic vessels found only in Chaco and resembling Mesoamerican chocolate pots (4). In addition, 35 scarlet macaw skeletons have been recovered in Chaco, with 30 from Pueblo Bonito (5, 26).

Two alternative interpretations have been proposed for how these Mesoamerican goods were procured. Some have concluded that the frequencies of Mesoamerican material are minimal enough that they could have been obtained through a limited number of acquisition trips and without the involvement of many people or a sophisticated system of procurement. These scholars often propose that scarlet macaws could have been acquired through simple down-the-line exchange in which they were moved from one nearby group to another, ultimately ending up hundreds of miles from their source (e.g., refs. 27, 28).

Others, however, have concluded that down-the-line exchange of scarlet macaws is unlikely because of the difficulties in raising and transporting newly fledged macaws. Of the 34 macaws (of the total of 35) recovered from Pueblo Bonito and other sites in Chaco Canyon studied by Hargrave (5), only one has been classified as aged, the remainder being immature (4–11 mo of age; $n = 1$), newly fledged (11–12 mo; $n = 24$), or adolescent (1–3 y; $n = 8$). This age distribution is typical of scarlet macaws recovered from other parts of the northern SW (5). Acquisition of such juvenile birds was a formidable task, requiring the removal of nestlings within the first few months of their birth, along with specialized knowledge, perhaps by trained aviculturists (whether Mesoamericans

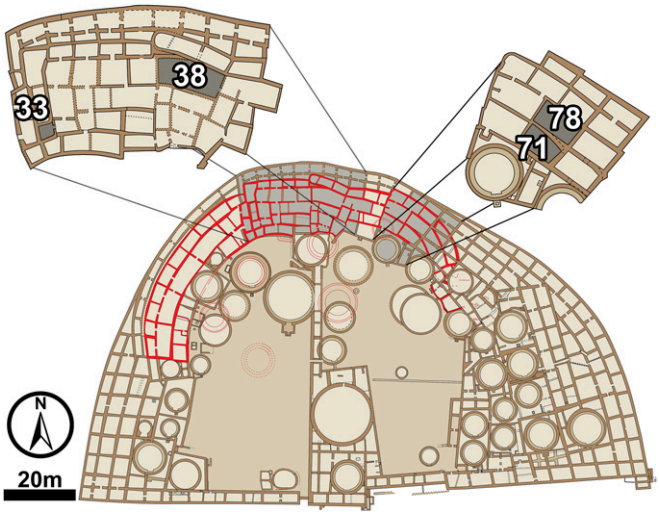

Fig. 2. Plan view of Pueblo Bonito with the earliest construction highlighted in red. The locations of the elite burial crypt, room 33, and the three rooms with dated macaw samples are highlighted.

or Puebloans), who could keep young scarlet macaws alive during long trips (6, 11, 29, 30).

An intermediate explanation between direct acquisition and down-the-line exchange suggests that Chacoans obtained scarlet macaws from the Mimbres people approximately 350 km distant in southwestern New Mexico, where another concentration of scarlet macaw remains has been found. The height of Mimbres culture, A.D. 1000–1130, coincides with the most intensive era of massive great house construction in Chaco Canyon (3, 20, 30–32).

Scarlet macaws and their feathers are of particular significance in Pueblo cosmology and ritual today, and they almost certainly were in the Chacoan era. In addition to the remains of scarlet macaws (skeletons and feathers), representations of these birds and their feathers occur in a variety of media (e.g., refs. 33, 34). Historical accounts also demonstrate the presence of scarlet macaws at pueblos in the Rio Grande Valley from the 16th (33) to the 20th centuries (35). A caged macaw observed at Zuni in the 1930s uttered Zuni words and knew the names of several people (36)—surely a significant clue to the value of macaws in general, beyond their iridescent and colorful feathers, as a symbolic vehicle bearing multiple, quasi-human qualities.

Ethnographically, macaw feathers are highly prized for ceremonial and cosmological purposes (13, 37). Macaws are a primary species marking directional association by color (red/orange) that correlates with other red material such as shell and tends to designate southern and/or nadir positions in Pueblo cosmological systems (38). Ritual use of macaw feathers on prayer-sticks, costumes, and masks to communicate prayers to deities is recorded for most pueblos (13, 36–39). Birds are a part of nature, but they are also agents with magical properties that can be put to human use; hence, the flight or just the appearance of certain birds or the use of their feathers is believed to motivate the fall of rain or snow, as well as the seasons, the sunshine, and the heat (37, 39).

In Pueblo society, religion and sociopolitical relations were (and are) closely intertwined. Religious power is thus strongly associated with sociopolitical power (38, 40). Those who controlled key cosmological knowledge and symbols also had significant influence over social, economic, and political relations.

Dating the Procurement of Macaws

The first comprehensive study of scarlet macaws from the SW concluded that groups initially acquired these birds at approximately A.D. 1100 (5), with the earliest examples in Chaco Canyon and the Mimbres region. More recently, most have concluded that Chacoan people first procured Mesoamerican goods in the decades after A.D. 1030–1050, when the construction of massive great houses expanded exponentially (1, 19, 20, 28, 41–43), an era that has been referred to as Chaco's "golden century" or the Chaco "florescence" (44, 45). These conclusions, however, were based on indirect associations of scarlet macaw remains with tree-ring-dated contexts. Many also posit that it was during the Chaco florescence when sociopolitical elites first evolved: individuals who had enough power to orchestrate the labor required to expand or build new Chacoan great houses and acquire exotic goods from distant regions (e.g., refs. 20, 41).

AMS ^{14}C dates of human skeletal remains from Pueblo Bonito (16), however, indicate that tree-ring dating alone is insufficient to identify the age of all prehistoric activities within great houses. These dates revealed that burials 13 and 14 from room 33, suggestive of elite status, were interred between the late eighth and the mid-ninth centuries, 200 y earlier than the post-A.D. 1040 date commonly proposed. This discovery demonstrates that Chaco archaeologists have been overly reliant on tree-ring dating and ceramic type frequencies for dating materials deposited in great house rooms. Pueblo Bonito was occupied for at least 300 y, and tree-ring dates for individual rooms are rarely sufficient to date the complex depositional sequences typical of most rooms. This problem is particularly acute in the earliest set of rooms constructed in the northern portion of the pueblo (Fig. 2). Considerable evidence, including the persistent use of room 33 as a burial crypt for 200–250 y, suggests that the northern section of Pueblo Bonito was central to much of the ritual activity throughout the long occupation of the great house (23, 46).

Given these problems with the existing chronology, as well as debate regarding the significance of Mesoamerican interaction in understanding sociopolitical organization and change in Chaco Canyon (20, 41, 47, 48), we requested permission from the American Museum of Natural History (AMNH) to sample 14 scarlet macaws for AMS ^{14}C dating. The macaws sampled were discovered during AMNH-sponsored excavations of Pueblo Bonito between 1896 and 1901 (49). To provide a preliminary test of the hypotheses that Chacoans obtained macaws via the Mimbres region or traded feathers to its hinterland (33) to build alliances, we also dated four scarlet macaws from the Mimbres region and a scarlet macaw feather and associated cordage (H/13338; Fig. 1*D*) discovered in cave 31 in Allen Canyon in the Grand Gulch region of southeastern Utah (50) (Fig. 1*C*).

AMS ^{14}C Sampling. The macaws dated were recovered from three rooms—rooms 38, 71, and 78—in Pueblo Bonito (49) (Fig. 2). Room 38 was constructed in the ninth century and is the largest room in the northern section. The room contained a remarkable number of objects that likely had ritual significance. These included the skeletons of 12 scarlet macaws imbedded in a 25-cm-thick layer of bird guano. Two additional macaws were buried in hollows dug in the southeastern and southwestern corners of the floor. Subsequent faunal analysis confirms a minimum number of individuals (MNI) of 14 scarlet macaws from the room. Eleven were sampled for this study (Table 1 and Table S1).

The large number of macaws in a single room and the layer of guano are unparalleled in the northern SW, but faunal analysts have concluded that macaws were not bred at Pueblo Bonito or elsewhere in the northern SW (5, 29). Of the 34 scarlet macaws from Chaco analyzed by Hargrave (5), only a single macaw may have reached breeding age, and no nestlings or juveniles (<4 mo) were found. These age groups should be well-represented in a breeding population. Moreover, no evidence of breeding pens or macaw eggshells has been reported from Bonito. In contrast, at Paquimé in northern Mexico, 630 km south of Chaco, 322 scarlet macaws were recovered, along with pens and eggshells that demonstrate a breeding program (15), a conclusion supported by

Table 1. Penn State and AMS laboratory numbers, site, provenience, and AMS (^{14}C and calibrated 2σ) dates

PSU no.	UCIAMS no.	Provenience	Material dated	^{14}C age, BP	95.4% cal range	C:N ratio
Chaco Canyon, Pueblo Bonito						
6279	148197	Room 38	Right humerus	970 ± 20	A.D. 1015–1155	3.25
6201	145204	Room 38	Right humerus	1,005 ± 15	A.D. 990–1035	3.20
5961	137927	Room 38	Right humerus	1,025 ± 20	A.D. 985–1030	3.23
5960	137926	Room 38	Right humerus	1,030 ± 20	A.D. 980–1030	3.25
5958	137924	Room 38	Right humerus	1,045 ± 20	A.D. 970–1025	3.25
6196	145199	Room 38	Right humerus	1,055 ± 15	A.D. 970–1020	3.27
6197	145200	Room 38	Right humerus	1,060 ± 15	A.D. 905–1020	3.24
6199	145202	Room 38	Right humerus	1,105 ± 20	A.D. 890–990	3.27
5959	137925	Room 38	Right humerus	1,115 ± 20	A.D. 890–985	3.25
6200	145203	Room 38	Right humerus	1,120 ± 15	A.D. 885–975	3.24
6198	145201	Room 38	Right humerus	1,130 ± 15	A.D. 885–975	3.28
6202	145205	Room 71	Right humerus	945 ± 15	A.D. 1025–1155	3.20
6203	145206	Room 78	Right humerus	1,095 ± 15	A.D. 895–990	3.23
6204	145207	Room 78	Right humerus	1,140 ± 15	A.D. 780–975	3.26
Mimbres						
6278	148196	Old Town	Tibiotarsus	945 ± 15	A.D. 1025–1155	3.23
6434	155971	Old Town	Humerus	965 ± 15	A.D. 1020–1155	3.31
6277	148195	Old Town	Tibiotarsus	975 ± 15	A.D. 1015–1150	3.19
6415	154709	Mitchell	Left humerus	1,075 ± 20	A.D. 895–1020	3.36
Grand Gulch, Allen Canyon						
6037	140287	Cave 31	Feather	980 ± 20	A.D. 1015–1155	NA
6038	140288	Cave 31	Cordage	995 ± 20	A.D. 990–1150	NA

See *SI Text* for additional data. cal, calibrated; NA, not applicable; PSU, Pennsylvania State University; UCIAMS, University of California, Irvine accelerator mass spectrometer.

isotopic analysis (51). In addition, scarlet macaws classified as nestlings, juveniles, of breeding age, or aged constitute 14.0% of the Paquimé population (29), a markedly and significantly ($z = 1.82$; $P < 0.05$, one-tailed test) higher proportion than the 2.9% in Chaco.

Room 71 is east of room 38 and was constructed at approximately the same time or soon after. Excavations uncovered two scarlet macaws (MNI of 2) in the southeast corner of the structure, and one was sampled for this study. Room 78 lies north and contiguous to room 71. Both scarlet macaws (MNI of 2) found in this room were sampled.

Results and Discussion

The 14 high-precision scarlet macaw AMS ^{14}C dates have several implications for Chacoan social evolution and the timing and extent of Mesoamerican–Southwest interaction (Fig. 3 and Table 1). First, a group of six macaws, four from room 38 and two from room 78, all have 2σ (SE) ranges that fall between A.D. 885 and A.D. 990 (Fig. 3). Uncalibrated ^{14}C ages of these six specimens are consistent with a single procurement event (52) ($\chi^2 = 5.59$; df = 5; $P > 0.05$). These scarlet macaws are among the earliest known in the SW. Only scarlet macaws from sites such as Snaketown and Pueblo Grande in the Hohokam region of southern Arizona are likely to predate the Pueblo Bonito macaws (3, 6, 53). Moreover, these six dates are 50–150 y earlier than the dates for scarlet macaw procurement previously postulated by Chaco scholars.

A second cluster of six dates, all from room 38, have 2σ ranges between A.D. 970 and A.D. 1035. Along with the first cluster of dates, these samples further demonstrate that interaction between the people of Chaco Canyon and Mesoamerican groups began earlier than previously proposed and continued for many decades. The ^{14}C ages of this group are also consistent with a single procurement event ($\chi^2 = 8.98$; df = 5; $P > 0.05$).

Finally, two dates, one from room 38 and one from room 71, fall in a part of the calibration curve that generates a broad 2σ range between A.D. 1015 and 1155, but are statistically identical in uncalibrated age ($\chi^2 = 1.00$; df = 1; $P > 0.05$). These two samples could have been procured during the same era as the latest scarlet macaw in the second cluster, but they more likely date to the period when great house construction was at its height.

Based on direct AMS ^{14}C analysis of the Pueblo Bonito macaws, three separate and isolated procurement events could account for the observed temporal patterning (Fig. 4). The apparent episodic structure in the calibrated ages, however, is partly attributable to reversals and plateaus in the radiocarbon calibration curve from A.D. 900 to 1150, which cause certain date ranges to be over- or underrepresented in a random sampling (Fig. S1). Given this tendency, a model of continuous macaw procurement throughout the 10th to 12th centuries A.D. cannot be rejected. However, simulated calibrations (described in *SI Text*) indicate that, whereas the early group of macaws conforms to the effects of the calibration curve, the middle group represents more dates than expected, and the late group represents fewer individuals than predicted (Fig. S2). Therefore, even if scarlet macaw procurement was relatively continuous, the data suggest that more birds may have arrived at Pueblo Bonito between A.D. 970 and 1035 than before or after.

The date on a macaw feather and cordage from the feather bundle in cave 31 in Allen Canyon and a previously dated sash with macaw feathers found in Lavender Canyon (54, 55), all in Grand Gulch in southeastern Utah and with 2σ ranges between A.D. 1015 and 1155, coincide with only the two latest macaws from Pueblo Bonito. Three of the four Mimbres macaws also fall within the same period, with one dating to the middle episode of macaw acquisition in Chaco. This small sample of dates from two key areas potentially connected to Chaco suggests that (*i*) Chacoans did not acquire all of their macaws from the Mimbres region and (*ii*) if macaw feathers were traded to establish Chacoan ideology and authority outside the canyon, such trade occurred after the initial establishment of sociopolitical hierarchies in the canyon. Acquisition of the Chaco macaws via the Hohokam region is a possibility, although we have no direct dates for macaws from that

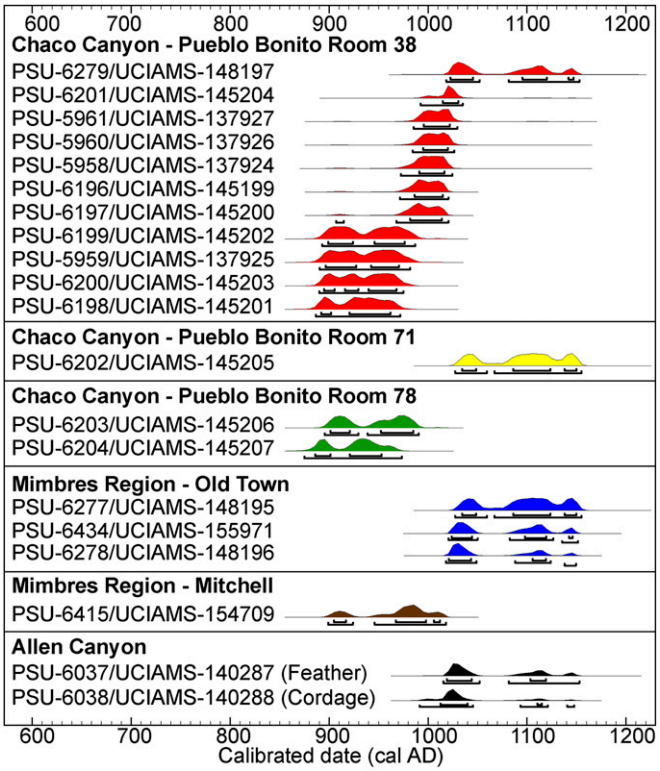

Fig. 3. Calibrated posterior probability distributions for directly AMS ^{14}C-dated macaw bones from Chaco Canyon [Pueblo Bonito rooms 38 (red), 71 (yellow), and 78 (green); Mimbres region Old Town (blue) and Mitchell (brown); and Allen Canyon in Grand Gulch (black)]. Brackets below distributions indicate 1σ and 2σ calibrated ranges.

area and it is only marginally closer than Chaco to the natural range of scarlet macaws.

We will continue testing these alternative scenarios. Sample sizes from the Mimbres region and from areas north of Chaco must be increased. We also will AMS ^{14}C date another set of scarlet macaws collected from Chaco by a National Geographic Society expedition in the 1920s (43). These macaws were recovered from rooms that are hypothesized to have been constructed later in time than rooms 38, 71, and 78; the macaws from these rooms thus could increase the number of post-A.D. 1000 dates.

Conclusions

Twelve of the 14 sampled macaws from Pueblo Bonito predate the apogee of architectural expansion (A.D. 1040–1110), a period often hypothesized to represent the peak of Chacoan interaction with Mesoamerica. These direct AMS ^{14}C dates thus contradict the long-held view that the acquisition of scarlet macaws (and potentially other Mesoamerican goods) was coincident with the major expansion of great house construction in Chaco Canyon or Chaco's expanding geographic sphere of influence in the last half of the 11th century.

These direct ^{14}C dates also are consistent with studies indicating that social hierarchy and significant sociopolitical power had evolved in Chaco by the early ninth century (16, 56). As noted earlier, previously reported AMS ^{14}C dates for the elite burials from room 33 of Pueblo Bonito place these interments in the late eighth or mid-ninth centuries A.D., and additional dates indicate continued use of the room as a burial crypt over the next few centuries (16). The thousands of pieces of turquoise and marine shell ornaments that accompanied these rich ninth-century burials served as powerful cosmological symbols in Pueblo society that signaled and sustained status differences (16, 39). These data suggest that at least one elite social group or "house" was established by the mid-ninth century and was maintained for decades (16). The early dates for macaws thus support the proposition that the Chaco florescence cannot be understood without a better understanding of culture change from the 8th through 11th centuries.

We suggest that the acquisition of another powerful cosmological symbol, scarlet macaws, in the early 10th century further reinforced and stimulated rising social inequality. Scarlet macaws were significant not only because of the linkage to central dimensions of Pueblo cosmology, but also because they demonstrated the ability of some Chacoan individuals to access key cosmological beings and forces (57) and link with distant groups who possessed potent ritual knowledge. We propose that the control of turquoise as well as Mesoamerican acquisition networks played a seminal role in the transformation of Chacoan society during the 9th and 10th centuries. Such historical trajectories are similar to patterns identified in many other regions where social complexity and sociopolitical hierarchies developed prehistorically. Thus, although some aspects of the evolution of Chaco society were unique (e.g., great houses), other key dimensions follow patterns of socioevolutionary change that have been well documented elsewhere (e.g., refs. 57–59).

We propose that the hierarchical sociopolitical foundation of Chacoan society was established during the initial era of great house construction (no later than the mid-ninth century) and that this foundation was reinforced during the late 9th and 10th centuries by the acquisition of scarlet macaws and other cosmologically powerful agents from Mesoamerica. Sociopolitical hierarchies thus had evolved over the course of nearly two centuries before taking shape in the form of more visible architectural and iconographic manifestations of Chacoan complexity and ideology referred to as the Chaco florescence or Chaco's golden century. There was not, therefore, a sudden change in Chacoan society, but a transformation in the ways sociopolitical elites legitimized and reinforced their status. As in many parts of the world, the evolution of hierarchically organized political institutions centered upon Chaco Canyon was a long-term process rather than a brief, abrupt transformation.

Methods

Bone collagen for AMS ^{14}C was extracted and purified using the modified Longin method with ultrafiltration (60) following procedures detailed by Hoggarth et al. (61). Physically cleaned samples were demineralized and gelatinized. Crude gelatin yields were recorded and the gelatin was ultrafiltered, retaining > 30 kDa molecular weight gelatin. Carbon and nitrogen concentrations

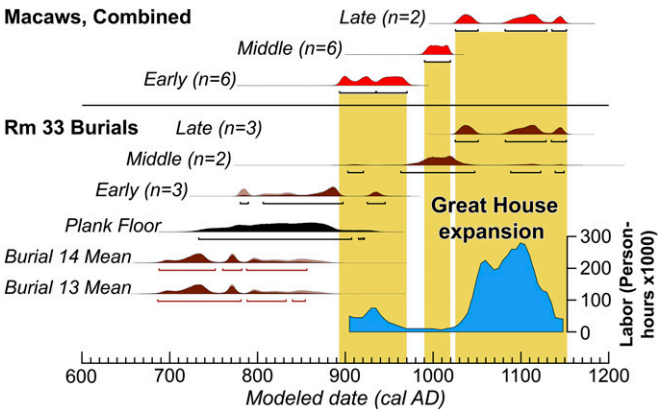

Fig. 4. Modeled distributions of AMS ^{14}C dates on Pueblo Bonito macaws as well as human burial dates and stratigraphic data (16) from room 33 relative to total construction effort (17) in Chaco Canyon. Macaws and burials were grouped and combined in OxCal based on ^{14}C ages, and stratigraphic data from room 33 was incorporated in a sequence model.

and stable isotope ratios were measured at the Yale Earth Systems Center for Stable Isotopic Studies facility with a Costech elemental analyzer (ECS 4010) and a Thermo DeltaPlus Advantage analyzer. Sample quality was evaluated by percentage crude gelatin yield, C percentage, N percentage, and C:N ratio (62). The Grand Gulch feather sample was treated with standard acid/base/acid using dilute (0.1 N) HCl and NaOH. Ultrafiltered gelatin and pretreated feather (~2.1 mg) was combusted for 3 h at 900 °C in vacuum-sealed quartz tubes with CuO and Ag wire. Graphitization and AMS ^{14}C measurements were done at the Keck Carbon Cycle Accelerator Mass Spectrometer facility. The ^{14}C ages were corrected for mass dependent fractionation with measured $\delta^{13}C$ values (63), and compared with backgrounds and known-age secondary standards. Calibrations and modeling were done in OxCal version 4.2.3 (https://C14.Arch.Ox.Ac.Uk/) using the IntCal13 curve (64).

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