Supporting Information

Barton et al. 10.1073/pnas.0809960106

SI Text

Domestication. Domestication is both a process and a resultant state (1). The process is one of adaptation to a novel environment defined by the interactions between people, plants, and/or animals. Construction of this relationship is the very beginning of agricultural origins, and the intensification of it is a hyperselective coevolutionary regime. The resultant state is the condition of numerous interacting organisms each with novel physical or behavioral attributes specific to their adaptive history. In plants it includes things like larger seeds or simultaneous ripening (2), facial neotony or docility in animals (3), and even a reduction in total size, stature, and bone structure in humans (4). The attributes comprise the "adaptive syndrome of domestication" used to distinguish domesticated plants or animals from their wild or feral relatives.

The lag between the development of the initial relationship and the appearance of these morphological or genetic features is variable (5, 6). Not all symbiotic relationships between humans and other taxa result in domestication, but when they do they can take thousands of years, or they can happen within 20–50 years (7–10). Furthermore, domestication is a continuum of change dictated by the strength of selection, the genetic architecture of change, and the environmental parameters of both (11, 12). Because no single attribute in any one taxon constitutes domestication, prehistoric domestication is difficult to identify, which makes it difficult to talk about origins. If domestication is a process, and that process entails the evolutionary ratchet of symbiotic interaction, our attention should be trained on identifying, measuring, and explaining these interactions.

The Archaeological Identity of Domestication. Domestication is often gauged by the degree to which plants or animals have been modified from their wild type. Presumably, these changes tell us about the strength of human selection on a resource population and about the importance of this resource to human survival.

Plant domestication is typically viewed through a combination of morphology and genetics. Efforts to determine the identity of charred or desiccated remains of plants from archaeological contexts depend largely on interpretation of the adaptive syndrome of domestication, and expectations for how the morphological attributes of plants should evolve under selection (2, 13). Grain size, for example has long been used to identify domesticated plants from archaeological sites (14). However, overlapping variation across the plastic continuum of wild types, feral weeds, and crop varieties in a single plant species makes early domestication difficult to identify using morphology alone. Furthermore, the symbioses of domestication may exist without morphological change, and some of the traits we attribute to it may also appear without domestication.

Molecular analysis tells us about population history, the regions of the chromosome that control attributes affected by domestication, and the effects of domestication on genomewide variation (15). Additionally, if we opt to define domestication as genetic change itself (10), then molecular analysis should help us to see it. But because the genetic marker is actually a result of the domestic relationship, on its own the marker adds little to our understanding of process, nor does it explain how the genetic change occurred. Furthermore, many of these molecular evaluations rely on a comparison between different populations of the same plant, including the wild type, the weed, and the crop. If the wild type is unknown (as it currently is in *Panicum miliaceum*, the plant under inspection in northern China) then the power of the analysis is low.

As with plants, animals can be studied with morphology and genetics, and the limitations of documenting the domestic relationship are similar (16). Animals have their own analog to the wild-weed–crop continuum, and the plasticity of both their physical attributes and their population structure makes the domestic relationship difficult to identify. Intentional burial of animals or coburial of animals with people (17, 18) also imply a domestic relationship, but these occurrences are relatively uncommon, and there is no reason to believe that people could not bury or be buried with totally wild animals. Quantitative age and sex profiles of archaeological fauna provide sound evidence for human harvesting, interference, and management of animal populations (19–21). These demographic patterns precede the phenotypic and genetic markers of domestication and track the early construction of the domestic niche. But this, too, has its limitations as it can be difficult to distinguish mutual benefit from intensive predation.

Last, mutual dependence can be established from dietary patterns, and stable isotope chemistry has been used to establish mutualisms between various combinations of people, plants, pigs, and dogs (22–28). Yet none of these studies evaluate the change in diet during the initial formation of the domestic niche.

The Evidence for Domestication in China. Humans in the Yangzi Drainage may have harvested wild rice (*Oryza* sp.) as early as 12,000 BP (29) but the earliest morphological evidence for its domestication varies in age from 10,000 to 6,000 BP (5, 29–32). The issue is unresolved, but we know far more about rice in the south than we do about millets in the north. The best data allude to domestic forms of broomcorn millet (*Panicum* sp.) and foxtail millet (*Setaria* sp.) by ≈7700 BP at Xinglonggou in the far northeast (33), broomcorn millet between 7900 and 7500 BP at Dadiwan on the western Loess Plateau (34–36), and both millets and rice at Yuezhuang along the lower reaches of the Yellow River by 8000 BP (37). The evidence for millet domestication in China is entirely based on the morphology of carbonized seeds.

Documenting domestication is also problematic for pigs (38, 39) and dogs (17, 40). Genetic data suggest pigs were domesticated independently in China (41) and a combination of morphological and demographic data suggest domestication by 8500–8000 BP at Cishan north of the Yellow River (42). Other early claims for pig domestication are unconfirmed but could represent multiple independent processes over a very large area (43, 44). The mere presence of *Canis* sp. bone suggests domestication at Nanzhuangtou between 12,000 and 10,700 BP (45), and at several sites throughout the Yellow River drainage, 8,000–7,000 BP (43, 46). Yet the strength of the relationship between humans and dogs has not been demonstrated for any of these places because it is difficult to infer from skeletal morphology alone. Although the deliberate burial of dogs in Siberia by ≈10,600 BP (17) suggests a long history of human–dog mutualism in northeast Asia, the earliest dog burials in northern China appear during the Yangshao Neolithic (34), well after agricultural expansion. During this time pig mandibles also become a common feature of human interments in northern China (47).

Explanation of Radiocarbon Dating at Dadiwan. The radiocarbon dates contributing to Fig. 4 and appearing in Table S3 are the product of several different research programs beginning with the earliest excavations at Dadiwan in 1978 (34, 48–51). Shortcomings in these original data include inconsistent reporting of dates from the early excavation, and incomplete information (such as laboratory numbers, dating material, etc). We view these shortcomings as inconsequential here, primarily because Fig. 4 is merely a succinct way to illustrate archaeological interpretations with radiocarbon data. The summed probability distribution of all calibrated radiocarbon dates reported from Dadiwan, compiled with the CalPal software package (52) and the INTCAL04 calibration curve (53) illustrates abundance and preservation of charcoal from different time periods, a method repeatedly used to infer occupation intensity (53, 54) and population change (55) through time. Although taphonomy and sampling surely compromise the efficacy of this method for reconstructing prehistoric demography (56), we suggest its use here is sound. The 81 Holocene radiocarbon dates presented here come from nearly 14,800 m^2 of excavation. If anything, the later portion of the phase 2 occupation of the site is underrepresented in this distribution of radiocarbon dates thereby reflecting a sampling strategy that biases the earlier, more cryptic occupation. Furthermore, local environmental proxies (57–59) provide no indication of Holocene depositional regimes that might favor preservation of one cultural horizon over another. The summed probability distribution is provided here as an illustration of occupation intensity and should not be misinterpreted as a rigorous presentation of population history.

Unique to the isotopic data reported here are the radiocarbon estimates on human and animal bone. Bone samples were selected from collections at the Gansu Museum (all excavations between 1978 and 1984) (34, 35, 60–62), and Lanzhou University (for excavations of 2004 and 2006) (50, 51), all of which had cultural affiliations assigned by the excavators. The vast majority of the original cultural affiliations were determined by stratigraphic position and/or association with pottery. In several cases, direct dates on bone from the present study point to errors in the original cultural assignments, implying stratigraphic mixing, interpretive error, or fundamental problems with the cultural sequence. For this study, direct radiocarbon dates on bone were used to assign samples to either phase 1 or phase 2. Where direct dates were not available, the original cultural affiliation was used.

Phase 1 and Phase 2 designations for this study should not be confused with the stratigraphic age sequence derived from the original excavations at Dadiwan (34, 35): Dadiwan I (Dadiwan, Laoguantai, or pre-Yangshao, 7800–7300 calBP), Dadiwan II (Late Banpo or Early Yangshao, 6500–5900 calBP), Dadiwan III (Miaodigou or Middle Yangshao, 5900–5500 calBP), Dadiwan IV (Late Yangshao, 5500–4900 calBP), and Dadiwan V (Lower Changshan 4900–4800 calBP). Although we did sample one pig (LM-104) dating to the Lower Changshan (assigned originally to Late Yangshao), our analysis does not address this period. Instead, our study compares samples from the phase 1 pre-Yangshao culture (which includes Dadiwan I), to those of the phase 2 Yangshao culture (which includes Dadiwan II, III, and IV). The purpose of this 2-part division was to evaluate change in subsistence systems during the time when agriculture is thought to evolve and spread. Because of the new, calibrated, direct dates on human and animal bone provided by this study, calendar ages for the 2 phases reported here differ slightly from the determinations published elsewhere (34, 35): including 2σ ranges, phase 1 now dates from 7950–7160 (ca. 7900–7200 calBP); phase 2 from 6470–4890 (ca. 6500–4900 calBP).

Several points emerge from the revised dating presented here. First, although we do find a single, isotopically domestic dog (LM-096) predating the earliest recorded Yangshao presence at Dadiwan (CAMS 134426, 6471–6315 calBP 2σ), very few radiocarbon dates from the site fall within this interval. This may represent an isolated, short-term occupation of the Dadiwan site by mobile hunter–gatherers, quite similar to those during phase 1. Second, although the excavators assigned many of the faunal remains tested here to the Late Banpo phase, most were in fact much younger. Together, these points suggest that the site was little occupied during the time of the Late Banpo florescence further east, but was instead occupied later as the bearers of this tradition moved west. It seems that the Late Banpo (or early Yangshao) tradition manifests later and persists longer at the Dadiwan site than it does in the east at sites like Beishouling, Jiangzhai, or Banpo itself. The full complement of direct dates on domesticated dog (LM-087, CAMS 134425), pig (LM-038, CAMS 134371) and millet (CAMS 128457) does not appear at Dadiwan until ≈5800 calBP. Although it is possible all of these domesticates were present at Dadiwan during the early years of phase 2, the radiocarbon distribution suggests otherwise.

1. Rindos D (1984) *The Origins of Agriculture: An Evolutionary Perspective* (Academic, Orlando, FL).
2. Harlan JR, de Wet JMJ, Price EG (1973) Comparative evolution of cereals. *Evolution* 27:311–325.
3. Price EO (1984) Behavioral aspects of animal domestication. *Q Rev Biol* 59:1–33.
4. Leach HM (2003) Human domestication reconsidered. *Curr Anthropol* 44:349–368.
5. Fuller DQ, Harvey E, Qin L (2007) Presumed domestication? Evidence for wild rice cultivation and domestication in the fifth millennium BC of the Lower Yangtze region. *Antiquity* 81:316–331.
6. Fuller DQ (2007) Contrasting patterns in crop domestication and domestication rates: recent archaeobotanical insights from the Old World. *Ann Bot* 100:903–924.
7. Hillman GC, Davies MS (1990) Measured domestication rates in wild wheats and barley under primitive cultivation, and their archaeological implications. *J World Prehistory* 4:157.
8. Trut LN (1999) Early canid domestication: The fox-farm experiment. *Am Sci* 87:160–169.
9. Ladizinsky G (1987) Pulse domestication before cultivation. *Econ Bot* 41:60–65.
10. Blumler MA, Byrne R (1991) The ecological genetics of domestication and the origins of agriculture. *Curr Anthropol* 32:23–54.
11. Gepts P (2004) Crop domestication as a long-term selection experiment. *Plant Breeding Rev* 24:1–44.
12. Harlan JR (1992) *Crops and Man* (American Society of Agronomy, Crop Science Society of America, Madison, WI).
13. Harlan JR, de Wet JMJ (1965) Some thoughts about weeds. *Econ Bot* 19:16–24.
14. Renfrew JM (1973) *Palaeoethnobotany: The Prehistoric Food Plants of the Near East and Europe* (Columbia Univ Press, New York).
15. Emshwiller E (2006) in *Documenting Domestication: New Genetic and Archaeological Paradigms*, eds Zeder MA, Bradley DG, Emshwiller E, Smith BD (Univ California Press, Berkeley), pp 99–122.
16. Zeder MA (2006) in *Documenting Domestication: New Genetic and Archaeological Paradigms*, eds Zeder MA, Bradley DG, Emshwiller E, Smith BD (Univ California Press, Berkeley), pp 171–180.
17. Morey DF (2006) Burying key evidence: The social bond between dogs and people. *J Archaeol Sci* 33:158–175.
18. Vigne J-D, Guilaine J, Debue K, Haye L, Gérard P (2004) Early taming of the cat in Cyprus. *Science* 9:259.
19. Zeder MA, Hesse B (2000) The initial domestication of goats (*Capra hircus*) in the Zagros Mountains 10,000 years ago. *Science* 287:2254–2257.
20. Zeder MA (2006) in *Documenting Domestication: New Genetic and Archaeological Paradigms*, eds Zeder MA, Bradley DG, Emshwiller E, Smith BD (Univ California Press, Berkeley), pp 181–208.
21. Whitaker AR (2008) Incipient aquaculture in prehistoric California?: Long-term productivity and sustainability vs. immediate returns for the harvest of marine invertebrates. *J Archaeol Sci* 35:1114–1123.
22. Coltrain JB, Leavitt SW (2002) Climate and diet in Fremont prehistory: Economic variability and abandonment of maize agriculture in the Great Salt Lake Basin. *Am Antiquity* 67:453–485.
23. Pechenkina EA, Ambrose SH, Ma X, Benfer Jr. RA (2005) Reconstructing northern Chinese Neolithic subsistence practices by isotopic analysis. *J Archaeol Sci* 32:1176–1189.
24. Minagawa M, Matsui A, Ishiguro N (2005) Patterns of prehistoric boar *Sus scrofa* domestication, and inter-island pig trading across the East China Sea, as determined by carbon and nitrogen isotope analysis. *Chem Geol* 218:91–102.
25. Hogue SH (2003) Corn dogs and hush puppies: diet and domestication at two protohistoric farmsteads in Oktibbeha County, Mississippi. *Southeastern Archaeol* 22:185–195.
26. Noe-Nygaard N (1988) ^{13}C values of dog bones reveal the nature of changes in man's food resources at the Mesolithic-Neolithic transition, Denmark. *Chem Geol* 73:87–96.
27. van der Merwe NJ, Vogel JC (1977) Isotopic evidence for early maize cultivation in New York state. *Am Antiquity* 42:238–242.
28. Burger RL, van der Merwe NJ (1990) Maize and the origins of highland Chavin civilization: An isotopic perspective. *Am Anthropol* 92:85–95.

29. Zhao Z (1998) The Middle Yangtze region in China is one place where rice was domesticated: Phytolith evidence from the Diaotonghuan Cave, Northern Jiangxi. *Antiquity* 72:885–897.
30. Jiang L, Liu L (2006) New evidence for the origins of sedentism and rice domestication in the Lower Yangzi River, China. *Antiquity* 80:355–361.
31. Crawford G, Shen C (1998) The origins of rice agriculture: Recent progress in East Asia. *Antiquity* 72:858–866.
32. Zong Y, et al. (2007) Fire and flood management of coastal swamp enabled first rice paddy cultivation in east China. *Nature* 449:459–462.
33. Zhao Z (2005) Zhiwu kaoguxue jiqi xin jinzhan (Recent progress in Chinese archaeobotany). *Kaogu (Archaeology)* 7:42–49.
34. GPICRA (2006) *Qin'an Dadiwan xinshiqi shi dai yizhi fa jue baogao (Dadiwan in Qin'an: report on excavations at a Neolithic site*) (Cultural Relics Publishing House, Beijing).
35. Lang S (2003) Gansu Qin'an dadiwan yizhi juluo xingtai ji qi yanbian (Settlement pattern of the Dadiwan site in Qin'an County, Gansu, and its evolution). *Kaogu (Archaeology)* 6:83–89.
36. Liu CZ, Kong ZC, Lang SD (2004) Dadiwan yizhi nongye zhiwu yicun yu renli shengcun de huanjing tantao (Plant remains at the Dadiwan site and a discussion of human adaptation to the environment). *Zhongyuan Wenwu (Archaeology of Central China*) 4:26–30.
37. Crawford GW, Chen X, Wang J (2006) Shan dong ji nan chang qing qu yu zhuang yi zhi fa xian hou li wen hua shi qi de tan hua dao (Houli culture rice from the Yuezhuang site, Jinan). *Dong Fang Kao Gu (East Asia Archaeology*) 3:247–251.
38. Albarella U, Dobney K, Rowley-Conwy P (2006) in *Documenting Domestication: New Genetic and Archaeological Paradigms*, eds Zeder MA, Bradley DG, Emshwiller E, Smith BD (Univ California Press, Berkeley), pp 209–227.
39. Rowley-Conwy P (1995) Wild or domestic? On the evidence for the earliest domestic cattle and pigs in South Scandinavia and Iberia. *Int J Osteoarchaeol* 5:115–126.
40. Olsen SJ (1979) in *Advances in Archaeological Method and Theory 2*, ed Schiffer MB (Academic, New York), pp 175–197.
41. Larson G, et al. (2005) Worldwide phylogeography of wild boar reveals multiple centers of pig domestication. *Science* 307:1618–1621.
42. Yuan J, Flad RK (2002) Pig domestication in ancient China. *Antiquity* 76:724–732.
43. Flad RK, Yuan J, Li S (2007) in *Late Quaternary Climate Change and Human Adaptation in Arid China*, eds Madsen DB, Gao X, Chen FH (Elsevier, Amsterdam), pp 167–203.
44. Ho PT (1977) in *Origins of Agriculture*, ed Reed CA (Mouton, The Hague), pp 413–484.
45. Jin J, Xu H (1992) Qianyi Xushui Nanzhuangtou Xinshiqi Shidai Zoaqi Yicun (Opinions on the early Neolithic site of Nanzhuangtou at Xushui). *Kaogu (Archaeology*) 11:1018–1022.
46. Underhill AP (1997) Current issues in Chinese Neolithic archaeology. *J World Prehistory* 11:103–160.
47. Kim S-O (1994) Burials, pigs, and political prestige in Neolithic China. *Curr Anthropol* 35:119–141.
48. IA-CASS (1991) *Zhongguo Kaoguxue zhong Tanshisi Niandai Shujuji 1965–1991 (Radiocarbon Dates in Chinese Archaeology, 1965–1991*) (Cultural Relics Publishing House, Beijing).
49. Lu TLD (1999) *The Transition from Foraging to Farming and the Origin of Agriculture in China* (British Archaeological Reports, Oxford, UK).
50. Bettinger RL, Barton L, Brantingham PJ, Elston RG (2005) Report on 2004 Archaeological Fieldwork at the Dadiwan Site, Shao Dian Village, Gansu Province, PRC. (Pacific Rim Research Program).
51. Barton L (2009) Early food production in China's Western Loess Plateau. PhD thesis (University of California, Davis).
52. Weninger B, Jöris O, Danzeglocke U (2007) *Cologne Radiocarbon Calibration and Paleoclimate Research Package* (University of Cologne, Cologne, Germany).
53. Reimer PJ, et al. (2004) INTCAL04 terrestrial radiocarbon age calibration, 0–26 KYR BP. *Radiocarbon* 46:1029–1058.
54. Barton L, Brantingham PJ, Ji DX (2007) in *Late Quaternary Climate Change and Human Adaptation in Arid China*, eds Madsen DB, Gao X, Chen FH (Elsevier, Amsterdam), pp 105–128.
55. Gamble C, Davies W, Pettitt P, Hazelwood L, Richards M (2005) The archaeological and genetic foundations of the European population during the Late Glacial: Implications for agricultural thinking. *Cambridge Archaeol J* 15:193–223.
56. Surovell TA, Brantingham PJ (2007) A note on the use of temporal frequency distributions in studies of prehistoric demography. *J Archaeol Sci* 34:1868–1877.
57. Feng Z, An C, Tang L, Jull TA (2004) Stratigraphic evidence of a Megahumid climate between 10,000 and 4000 years B.P. in the western part of the Chinese Loess Plateau. *Global Planetary Change* 43:145–155.
58. Feng ZD, Tang L, Wang HB, Ma YZ, Liu KB (2006) Holocene vegetation variations and the associated environmental changes in the western part of the Chinese Loess Plateau. *Palaeogeogr Palaeoclimatol Palaeoecol* 241:440–456.
59. An C, Feng Z, Tang L (2004) Environmental change and cultural response between 8000 and 4000 cal. yr BP in the western Loess Plateau, northwest China. *J Quaternary Sci* 19:529–535.
60. GPICRA (2003) Gansu Qin'an dadiwan yizhi yangsho wenhua zaoqi juluo fajue jianbao (Excavation of the settlement of early Yangshao culture on the Dadiwan site in Qin'an County, Gansu). *Kaogu (Archaeology*) 6:19–31.
61. CPAM and Dadiwan Excavation Group (1982) Qin'an Dadiwan 1980 nian fajue jianbao (A brief report on the excavation of Dadiwan in Qin'an during the 1980 season). *Kaogu yu Wenwu (Archaeology and Relics*) 2:1–8.
62. CPAM, Provincial Museum of Gansu, and Dadiwan Excavation Group (1981) Gansu Qin'an Dadiwan xinshiqi shidai jiaoqi yizhi (Early Neolithic remains at Dadiwan, Qin'an Xian, Gansu). *Wenwu (Cultural Relics*) 4:1–8.

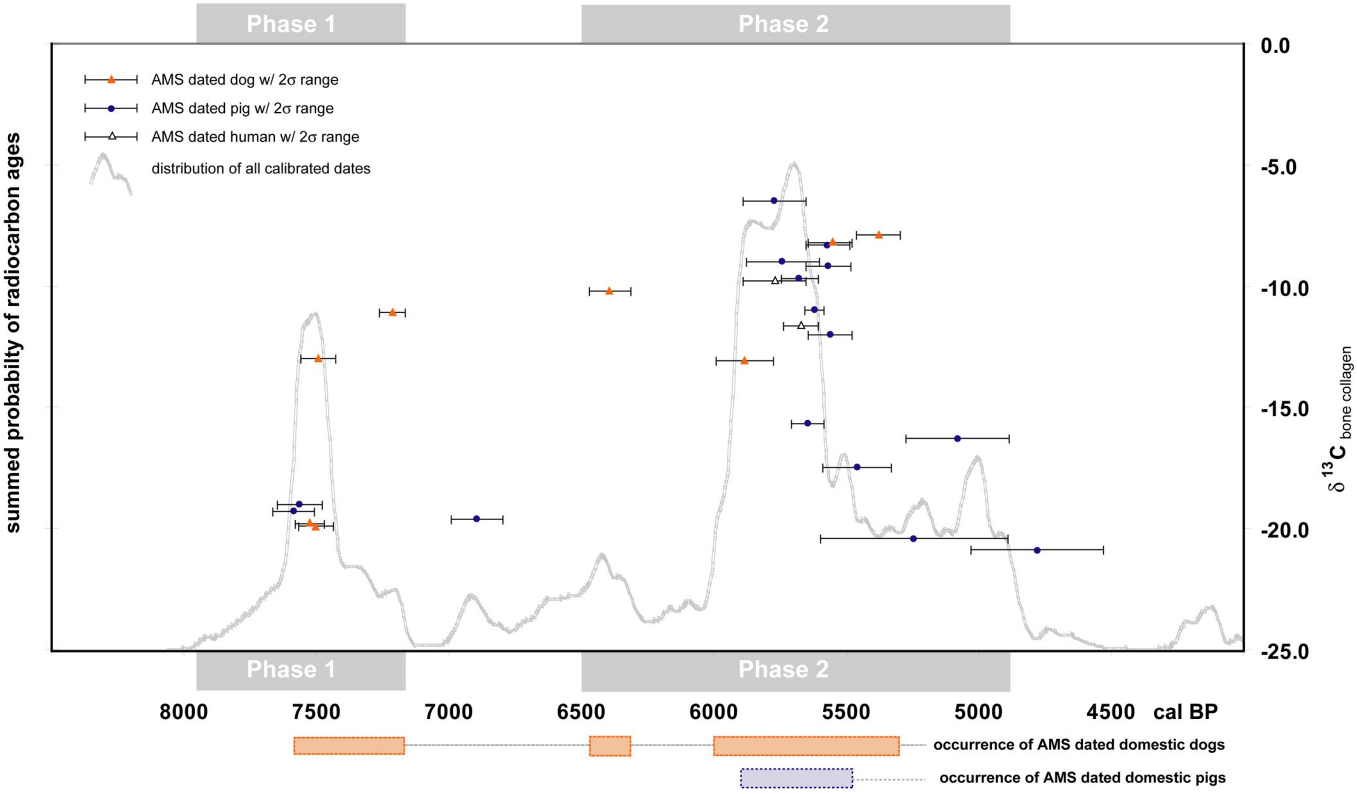

Fig. S1. A radicarbon chronology of domestication at the Dadiwan site. Here, dated samples and their 2σ calibrated ranges are plotted against their associated δ^{13}C values (right *y* axis), and superimposed on the summed probability distribution of all calibrated radiocarbon dates from the Dadiwan site (left *y* axis).

Table S1. Complete listing of samples (n = 74), taxonomic identifications, cultural affiliations and isotopic data

MS-ID	Taxon	prov	exPhase	^{14}C	anPhase	[C]	[N]	C/N	$\delta^{13}C_{col}$	$\delta^{15}N_{col}$
LM-003	Homo sapiens	M311	LYS		2	47.57	17.67	2.69	−6.6	9.5
LM-004	Homo sapiens	M701	LYS		2	46.02	17.25	2.67	−6.5	10.4
LM-005	Homo sapiens	M318	LYS		2	47.98	17.80	2.70	−14.2	10.8
LM-010	Homo sapiens	H5-A37	LBP		2	48.69	17.34	2.81	−10.0	8.7
LM-011	Homo sapiens	H235-A137	LBP	*	2	46.58	16.91	2.75	−9.8	9.1
LM-012	Homo sapiens	H235-A1	LBP	*	2	47.41	17.11	2.77	−11.6	9.8
LM-020	deer (Moschus)	F229–157	LBP		2	48.88	17.62	2.77	−20.8	5.8
LM-021	deer (Moschus)	F203	LBP		2	46.58	16.91	2.76	−20.9	4.6
LM-023	deer (Moschus)	F229–152	LBP		2	42.78	14.26	2.81	−21.1	6.9
LM-024	deer (Moschus)	F229–33	LBP		2	45.94	16.81	2.73	−20.2	5.6
LM-025	Canis	F361-A3	LBP	*	2	50.20	18.14	2.77	−7.9	7.9
LM-026	Canis	F219-A2	LBP	*	2	43.52	15.85	2.75	−8.2	8.6
LM-027	Canis	F337-A10	LBP		2	44.83	16.37	2.74	−10.7	8.7
LM-028	Sus	H205-A43	LBP		2	48.40	17.50	2.77	−8.5	8.0
LM-029	Sus	F347-A3	LBP	*	2	45.24	16.22	2.79	−15.7	7.2
LM-030	Sus	H325-A78	LBP		2	49.77	18.16	2.74	−8.3	8.4
LM-031	Sus	H345-A1	LBP		2	48.80	17.94	2.72	−14.7	8.5
LM-032	Sus	F223-A1	LBP	*	2	45.11	17.01	2.65	−17.5	6.4
LM-033	Sus	H259-A6	LBP		2	49.01	17.80	2.75	−7.0	7.7
LM-034	Sus	F347-A7	LBP	*	2	43.35	15.84	2.74	−9.7	9.2
LM-035	Sus	H211-A66	LBP		2	49.38	18.04	2.74	−9.0	9.2
LM-036	Sus	F361-A6	LBP		2	49.07	17.94	2.74	−10.0	8.8
LM-037	Sus	H73-A1	LBP		2	47.32	16.69	2.83	−6.3	8.1
LM-038	Sus	F250-A35	LBP	*	2	46.06	16.92	2.72	−6.5	8.6
LM-039	Sus	H211-A46	LBP		2	50.19	18.28	2.74	−8.8	8.4
LM-041	Sus	H211-A62	LBP		2	47.94	17.15	2.79	−11.5	9.9
LM-042	Sus	H211-A68	LBP		2	48.42	17.60	2.75	−12.2	8.9
LM-043	Sus	F246-A12	LBP		2	41.56	14.07	2.95	−9.1	9.1
LM-044	Sus	H211-A14	LBP		2	49.54	18.07	2.74	−11.4	9.6
LM-045	Sus	F361-A7	LBP	*	2	36.04	12.79	2.82	−9.2	8.8
LM-046	Sus	F218-A2	LBP		2	45.74	16.57	2.76	−8.2	9.1
LM-047	Sus	F222-A29	LBP	*	2	28.77	9.95	2.89	−8.3	8.7
LM-048	Sus	H211-A67	LBP		2	45.44	16.50	2.75	−14.9	6.8
LM-049	Sus	F250-A26	LBP		2	44.10	16.08	2.74	−9.0	8.4
LM-053	Bos	H398-A290	LBP		2	28.62	9.32	3.07	−19.9	8.0
LM-058	deer (Cervus)	F250-A34	LBP		2	45.08	16.85	2.68	−21.0	6.4
LM-060	deer (Cervus)	F250-A11	LBP		2	44.58	16.32	2.73	−21.0	7.8
LM-062	Bos	H3100-A10	LBP		2	45.61	16.90	2.70	−22.1	8.1
LM-063	Sus	F382-A28	LBP	*	2	44.30	16.11	2.75	−9.0	8.6
LM-064	Sus	H5-A27	LBP		2	50.16	18.17	2.76	−7.7	7.9
LM-065	Sus	H709-A8	LBP		2	45.94	16.35	2.81	−8.3	8.9
LM-066	Sus	T347-A4	LBP		2	47.39	17.12	2.77	−9.0	8.2
LM-067	Sus	F229–19	LBP	*	2	44.84	16.63	2.70	−11.0	7.8
LM-068	Sus	H253-A12	LBP		2	48.60	17.35	2.80	−12.3	9.3
LM-069	deer (Cervus)	H363-A3	DDW		1	41.88	14.90	2.81	−20.2	7.1
LM-070	deer (Cervus)	H254-A2	DDW		1	40.40	14.67	2.75	−19.4	6.2
LM-075	deer (Cervus)	F310-A3	LBP		2	46.39	16.87	2.75	−18.9	5.6
LM-076	deer (Cervus)	H3114-A10	DDW		1	42.76	15.68	2.73	−20.0	8.1
LM-078	deer (Cervus)	H363-A30	DDW		1	38.86	14.48	2.68	−20.7	7.3
LM-081	Canis	H398-A127	DDW	*	1	48.50	17.54	2.77	−19.9	6.2
LM-082	Canis	H398-A377	DDW	*	1	46.44	17.10	2.72	−19.8	5.9
LM-083	Canis	F103–17	LBP		2	39.25	14.17	2.77	−9.3	9.0
LM-084	Canis	H398-A271	DDW		1	43.58	16.25	2.68	−10.2	7.3
LM-085	Ursus	H398-A310	DDW		1	42.11	15.11	2.79	−17.3	7.0
LM-086	Canis	M224-A1	LBP	*	1	45.45	16.24	2.80	−13.0	8.6
LM-087	Canis	M224-A1	LBP	*	2	44.08	15.77	2.79	−13.1	8.7
LM-089	Bird (possibly Gallus)	H398-A115	DDW		1	43.37	15.90	2.73	−15.6	7.4
LM-090	Bird (possibly Gallus)	F371-A11	DDW		1	44.60	16.37	2.72	−16.8	7.4
LM-091	Bird (possibly Gallus)	H393-A93	LBP		2	44.73	16.27	2.75	−16.2	7.1
LM-092	Bird (possibly Gallus)	H227-A140	LBP		2	43.09	15.84	2.72	−17.6	6.3
LM-093	Bird (possibly Gallus)	H227-A52	LBP		2	41.65	15.18	2.75	−14.2	5.9
LM-094	Bird (possibly Gallus)	H227-A50	LBP		2	43.71	15.87	2.76	−17.2	5.7
LM-095	Bird (possibly Gallus)	H227-A53	LBP		2	43.88	15.71	2.79	−16.2	6.5
LM-096	Canis	H398-A273	DDW	*	2	44.38	16.14	2.75	−10.2	7.5

MS-ID	Taxon	prov	exPhase	^{14}C	anPhase	[C]	[N]	C/N	$\delta^{13}C_{col}$	$\delta^{15}N_{col}$
LM-097	Canis	H398-A275	DDW	*	1	41.88	15.36	2.73	−11.1	7.7
LM-099	Sus	H398-A4	DDW	*	2	45.51	16.46	2.77	−12.0	8.3
LM-101	Sus	H359-A1	DDW	*	2	40.82	14.26	2.86	−16.3	6.2
LM-103	Sus	H363-A66	DDW	*	2	44.74	15.73	2.84	−20.4	5.6
LM-104	Sus	H359-A12	DDW	*	2	42.88	14.72	2.91	−20.9	7.2
LM-106	Sus	uncertain	NA	*	1	43.76	15.39	2.84	−19.6	5.2
LM-107	Sus	H363-A43	DDW	*	1	46.16	16.37	2.82	−19.3	5.3
LM-108	Sus	H398-A215	DDW		1	44.06	15.95	2.76	−19.1	7.0
LM-109	Sus	H398-A147	DDW	*	1	44.05	15.71	2.80	−19.0	5.6
LM-117	Sus	DDW02 4.2B	LBP		2	48.54	17.45	2.78	−8.3	7.6

The archaeological provenience (prov) of each sample is recorded in curatorial lots from the Gansu Museum or Lanzhou University. Because the original excavators determined the cultural affiliation of each provenience (exPhase), each sample can be assigned to a cultural tradition, and therefore has an approximate age range. However the radiocarbon results (SI Table 2) occasionally required that these affiliations be changed. The phases used for the analysis and interpretations (anPhase) reflect these changes. Asterisks identify samples dated directly by radiocarbon accelerator mass spectrometry.

Table S2. New AMS radiocarbon dates on bone collagen from the Dadiwan site

Lab no.	prov	MS ID	rcybp	+/−	2σ mid	2σ +	2σ −
CAMS 134454*	M102	LM-001	1035	35	943	1055	832
CAMS 134455*	F14-A18	LM-009	4950	30	5670	5736	5605
CAMS 134456	H235-A137	LM-011	5010	35	5773	5892	5655
CAMS 134457	H235-A1	LM-012	4950	30	5670	5736	5605
CAMS 134458*	DDW05	LM-013	4955	40	5726	5855	5598
CAMS 134366	F361-A3	LM-025	4620	30	5379	5462	5297
CAMS 134367	F219-A2	LM-026	4835	30	5561	5644	5478
CAMS 134368	F347-A3	LM-029	4895	30	5646	5706	5586
CAMS 134369	F223-A1	LM-032	4760	35	5460	5589	5330
CAMS 134370	F347-A7	LM-034	4965	30	5677	5747	5608
CAMS 134371	F250-A35	LM-038	5010	35	5773	5892	5655
CAMS 134372	F361-A7	LM-045	4850	30	5568	5652	5485
CAMS 134373	F222-A29	LM-047	4855	30	5570	5654	5486
CAMS 134420	F382-A28	LM-063	4970	40	5741	5879	5603
CAMS 134421	F229–19	LM-067	4875	30	5621	5657	5585
CAMS 134422	H398-A127	LM-081	6615	35	7503	7569	7438
CAMS 134423	H398-A377	LM-082	6645	30	7524	7579	7470
CAMS 134424	M224-A1	LM-086	6580	30	7495	7560	7429
CAMS 134425	M224-A1	LM-087	5165	30	5884	5993	5775
CAMS 134426	H398-A273	LM-096	5625	30	6393	6471	6315
CAMS 134427	H398-A275	LM-097	6280	30	7214	7264	7164
CAMS 134446	H398-A4	LM-099	4835	30	5561	5644	5478
CAMS 134447	H359-A1	LM-101	4440	25	5081	5278	4885
CAMS 134448*	H363-A50	LM-102	6390	30	7342	7418	7265
CAMS 134449	H363-A66	LM-103	4620	130	5244	5598	4890
CAMS 134450	H359-A12	LM-104	4240	80	4779	5029	4529
CAMS 134451	Uncertain	LM-106	6050	35	6894	6992	6795
CAMS 134452	H363-A43	LM-107	6720	40	7587	7665	7509
CAMS 134453	H398-A147	LM-109	6690	40	7565	7650	7479

The archaeological provenience (prov) corresponds to locations named during original excavations. $\delta^{13}C$-corrected radiocarbon ages (rcybp) are based on the 5568 Libby half-life. All calibrations are with OxCal 4.0 by using the INTCAL 04 calibration curve. Asterisks denote samples removed from the interpretations presented here, either because the dates are outside our range of interest, or because the stable isotope analysis returned flawed results or no results at all. The Mass Spectrometer IDs (MS ID) correspond to samples presented in SI Table 1.

Table S3. Complete list of known radiocarbon dates from the Dadiwan site

Lab no.	Material	prov	MS ID	rcybp	+/−	2σ mid	2σ +	2σ −	Source/ref.
CAMS 134454	bone collagen	M102	LM-001	1035	35	943	1055	832	This study
CAMS 134379	charcoal	DDW03		3770	35	4117	4245	3990	50, 51
CAMS 134450	bone collagen	H359-A12	LM-104	4240	80	4779	5029	4529	This study
BK 84080	charcoal	F901		4392	100	5022	5315	4729	34
BK 81050	charcoal	F405		4392	80	5064	5288	4841	34
Beta 197628	charcoal	DDW02		4420	40	5072	5277	4867	50
BK 84081	charcoal	F901		4421	100	5075	5313	4838	34
CAMS 134447	bone collagen	H359-A1	LM-101	4440	25	5081	5278	4885	This study
BK 93177	?	F902		4499	80	5155	5436	4875	34
BK 81049	charcoal	F405		4538	80	5175	5464	4886	34
WB 80–50	charcoal	H366		4557	200	5183	5717	4650	34
CAMS 134449	bone collagen	H363-A66	LM-103	4620	130	5244	5598	4890	This study
BK 84082	charcoal	F901		4606	100	5281	5584	4978	34
CAMS 134366	bone collagen	F361-A3	LM-025	4620	30	5379	5462	5297	This study
CAMS 134369	bone collagen	F223-A1	LM-032	4760	35	5460	5589	5330	This study
BK 93180	?	F400		4757	85	5479	5644	5313	34
WB 80–52	?	F17		4761	95	5504	5709	5300	34
BK79027	charcoal	H202		4761	100	5508	5720	5296	34
CAMS 134367	bone collagen	F219-A2	LM-026	4835	30	5561	5644	5478	This study
CAMS 134446	bone collagen	H398-A4	LM-099	4835	30	5561	5644	5478	This study
CAMS 134372	bone collagen	F361-A7	LM-045	4850	30	5568	5652	5485	This study
CAMS 134373	bone collagen	F222-A29	LM-047	4855	30	5570	5654	5486	This study
WB 80–51	charcoal	F330		4854	95	5602	5881	5324	34
BK 93181	?	F411		4854	100	5604	5887	5322	34
BK 93182	?	F709		4868	90	5607	5887	5327	34
CAMS 134421	bone collagen	F229–19	LM-067	4875	30	5621	5657	5585	This study
CAMS 134368	bone collagen	F347-A3	LM-029	4895	30	5646	5706	5586	This study
CAMS 134455	bone collagen	F14-A18	LM-009	4950	30	5670	5736	5605	This study
CAMS 134457	bone collagen	H235-A1	LM-012	4950	30	5670	5736	5605	This study
CAMS 134370	bone collagen	F347-A7	LM-034	4965	30	5677	5747	5608	This study
CAMS 134458	bone collagen	DDW05	LM-013	4955	40	5726	5855	5598	This study
CAMS 128457	charcoal	JB1		4965	40	5738	5875	5601	50, 51
CAMS 134420	bone collagen	F382-A28	LM-063	4970	40	5741	5879	5603	This study
BK 93183	?	F229		4990	140	5751	6173	5330	34
BK 79024	charcoal	H201:20		4995	90	5753	5915	5590	34
WB 80–53	charcoal	F332		5000	90	5754	5917	5591	34
CAMS 134456	bone collagen	H235-A137	LM-011	5010	35	5773	5892	5655	This study
CAMS 134371	bone collagen	F250-A35	LM-038	5010	35	5773	5892	5655	This study
CAMS 128452	charcoal	LY03		5030	35	5778	5895	5662	50, 51
CAMS 128455	charcoal	DDW04		5040	35	5783	5902	5663	50, 51
CAMS 128447	charcoal	DDW03		5080	40	5826	5915	5736	50, 51
CAMS 127100	charcoal	DDW05		5080	30	5828	5910	5746	50,51
CAMS 128456	charcoal	DDW04		5095	35	5832	5917	5747	50,51
CAMS 128454	charcoal	DDW04		5105	35	5835	5921	5749	50, 51
WB 80–32	?	F229		5097	85	5854	6095	5613	34
CAMS 110291	charcoal	DDW02		5145	35	5871	5990	5753	50
CAMS 134425	bone collagen	M224-A1	LM-087	5165	30	5884	5993	5775	This study
BK 79028	charcoal	F400		5090	100	5888	6173	5602	34
WB 80–54	charcoal	F232		5106	90	5894	6174	5615	34
BK 93185	?	F246		5138	120	5901	6189	5614	34
WB 80–30	charcoal	F17		5150	85	5921	6179	5664	34
WB 80–31	charcoal	H227		5170	95	5926	6189	5664	34
BK 79025	charcoal	Y202		5170	150	5947	6277	5616	34
CAMS 110292	charcoal	DDW02		5195	40	6034	6174	5893	50
BK 93176	?	F714		5374	160	6122	6491	5753	34
ZK 0742	charcoal	Trench 301.2		5520	90	6261	6501	6020	34
CAMS 134426	bone collagen	H398-A273	LM-096	5625	30	6393	6471	6315	This study
BK 79029	charcoal	Y300		5620	80	6457	6630	6283	34
ZK 2219	plaster/ash paste	F405		5730	110	6539	6775	6302	48
ZK 2220	white ash	F415		5780	85	6593	6785	6402	48
BK 93178	?	F820		5860	150	6734	7152	6317	34
CAMS 134451	bone collagen	?	LM-106	6050	35	6894	6992	6795	This study
CAMS 134427	bone collagen	H398-A275	LM-097	6280	30	7214	7264	7164	This study
?	charcoal	H363		6474	165	7336	7665	7007	49

Lab no.	Material	prov	MS ID	rcybp	+/−	2σ mid	2σ +	2σ −	Source/ref.
CAMS 134448	bone collagen	H363-A50	LM-102	6390	30	7342	7418	7265	This study
CAMS 134375	charcoal	DDW03		6465	35	7371	7435	7308	50, 51
BK 80007	charcoal	H363		6540	90	7428	7579	7277	34
BK 81021	charcoal	H398		6579	80	7457	7592	7323	34
CAMS 127099	charcoal	DDW04		6580	30	7495	7560	7429	50, 51
CAMS 134424	bone collagen	M224-A1	LM-086	6580	30	7495	7560	7429	This study
CAMS 128453	charcoal	DDW04		6595	35	7498	7566	7431	50, 51
CAMS 128450	charcoal	DDW04		6615	40	7503	7570	7436	50, 51
CAMS 134422	bone collagen	H398-A127	LM-081	6615	35	7503	7569	7438	This study
Beta 197626	charcoal	DDW02		6650	40	7515	7587	7444	50
CAMS 134423	bone collagen	H398-A377	LM-082	6645	30	7524	7579	7470	This study
CAMS 128451	charcoal	DDW04		6685	35	7550	7612	7489	50, 51
BK 81024	charcoal	H397		6690	80	7553	7671	7435	34
CAMS 134453	bone collagen	H398-A147	LM-109	6690	40	7565	7650	7479	This study
CAMS 134452	bone collagen	H363-A43	LM-107	6720	40	7587	7665	7509	This study
BK 81022	charcoal	F371		6740	80	7587	7731	7444	34
CAMS 134374	charcoal	DDW03		6860	50	7705	7819	7592	50, 51
BK 80025	charcoal	H10		6950	90	7786	7950	7622	34

The archaeological provenience (prov) corresponds to locations named during original excavations. Radiocarbon data from the original excavations are drawn from the excavation report (34) and the radiocarbon database of the Institute of Archaeology, Chinese Academy of Social Science (48). Additional information can be found from each reference. Question marks indicate data gaps. Unreported sample types (material) are most likely charcoal. It is unclear how many of the dates from the original excavation were δ^{13}C-corrected. Though use of the 5570 half-life is standard procedure in Chinese radiocarbon labs, all radiocarbon ages (rcybp) This study reflects the 5568 Libby half-life. All calibrations are with OxCal 4.0 using the INTCAL 04 calibration curve.