

REVIEW ARTICLE

The Paleolithic in the Nihewan Basin, China: Evolutionary history of an Early to Late Pleistocene record in Eastern Asia

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Abstract

The Nihewan Basin of China preserves one of the most important successions of Paleolithic archeological sites in Eurasia. Stratified archeological sites and mammalian fossils, first reported in the 1920s, continue to be recovered in large-scale excavation projects. Here, we review key findings from archeological excavations in the Nihewan Basin ranging from ~1.66 Ma to 11.7 ka. We place particular emphasis on changes in stone tool technology over the long term. Though Pleistocene lithic industries from East Asia are often described as simple in character, re-evaluation of the stone tool evidence from the Nihewan Basin demonstrates significant, though periodic, innovations and variability in manufacturing techniques through time, indicating adaptive and technological flexibility on the part of hominins. Synthesis of paleoenvironmental and archeological data indicate changes in hominin occupation frequency in the Nihewan Basin, with chronological gaps suggesting that continuous presence in high, seasonal latitudes was not possible prior to the Late Pleistocene.

KEYWORDS

Eastern Asia, Nihewan Basin, Paleolithic, Pleistocene, stone tool technology

1 | INTRODUCTION

The Nihewan Basin, located in northern China, contains well-known mammalian faunas and lithic artifacts in long sequences of fluvio-lacustrine sediments, making the region an attractive setting for geological, paleontological, and archeological exploration and

research. The fluvio-lacustrine sediments in the basin were first investigated in the 1920s by influential scholars, including George Brown Barbour and Emile Licent and colleagues.^{1–3} The well-developed “Late Cenozoic strata” were found to contain rich mammalian fossils, then thought to correspond to the Villafranchian fauna of Europe.²

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TABLE 1 Summary of Paleolithic sites in the Nihewan Basin

Period	Site name	Age	Dating method	Excavation size (m ²)	No. of lithics	Key references
EP	Majuangou III	1.66 Ma	Paleomagnetism	85	443	4,5
	Majuangou II	1.64 Ma	Paleomagnetism	36	226	4,5
	Majuangou I	1.55 Ma	Paleomagnetism	50	215	4,5
	Dachangliang	1.36 Ma	Paleomagnetism	7	33	4,6
	Xiaochangliang	1.36 Ma+	Paleomagnetism	16+? ^a	2,963	4,7
	Banshan	1.32 Ma	Paleomagnetism	2	95	4,5
	Feiliang	1.2 Ma	Paleomagnetism	82	983	8,9
	Madigou	1.2 Ma	Paleomagnetism	177	1868	4,10
	Donggutuo	1.1 Ma	Paleomagnetism	~47	2,315	4,11,12
	Cenjiawan	1.1 Ma	Paleomagnetism	40	1,625	4,13
	Huojiadi	1.0 Ma	Paleomagnetism	6	60	14
	Maliang (site group)	~0.8 Ma	Paleomagnetism	38	318	4,15
MP	Hougou	395 ka	Paleomagnetism	16	301	16,17
	Dongpo	321 ± 15 ka	ESR	4	32	18
	Motianling	315 ± 13 ka	OSL	53	50	4,19
	Jijiazhuang ^b	In progress	OSL	76	190	20
	Que'ergou	268 ± 13 ka	OSL	16	40	4,19
LP	Xujiayao	125–104 ka++	U-series	460	13,650	4,21
	Banjingzi	86 ± 4 ka	OSL	9	3,383	4,19
	Xibaimaying	46 ± 3 ka	U-series/OSL	76	1,546	4,22
	Shiyu	39–31 ka	Radiocarbon	? ^a	Ca. 15,000	23–25
	Youfang	29–26 ka	OSL/radiocarbon	28	Ca. 3,000	4,26
	Erdaoliang	18 ka	Radiocarbon	31	1915	4,27
	Yujiagou	16–8.4 ka	Radiocarbon	120	11,982	4,28,29
	Ma'anshan	13 ka	Radiocarbon	50	Ca. 18,000	4

Notes: + indicates ages for Xiaochangliang all fall in the Early Pleistocene, but owing to different estimates of rates of sedimentation, discrepant dates have been reported (see text for details).++ indicates Middle Pleistocene ages of Xujiayao have been reported, though the U-series ages are considered the most accurate here (see text for details).

^aThe size of the excavation is not clearly recorded in the report.

^bJijiazhuang is a newly reported site and the dating is in process. The age of the site is probably Middle Pleistocene based on its stratigraphic position.

The last three decades have witnessed increasing archeological excavations in the Nihewan Basin, resulting in the identification of numerous sites over the long term (Table 1). Excavations have usually targeted artifact finds emanating from long stratigraphies, leading to small trench excavations (e.g., 2 m² at Banshan) or larger horizontal excavations across archeological horizons (e.g., 460 m² at Xujiayao). In some cases, well-preserved surfaces with demonstrable traces of hominin activities have been uncovered (e.g., Cenjiawan), though in other examples, lithics and fossils have been hydraulically modified (e.g., Xiaochangliang). Multidisciplinary archeological teams from research institutions have been involved in archeological work in the Nihewan Basin, primarily drawn from the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) (Chinese Academy of Sciences), the Hebei Provincial Institute of Cultural Relics (HPICR), and universities including Peking University and Hebei Normal University.⁴ Alongside continuous academic research on the recovered materials,^{8,11,30} archeologists from the HPICR have been conducting large-scale excavations though these remain largely unpublished. As

regularly noted by Chinese and international scholars, the Nihewan Basin provides one of the best opportunities for understanding the evolution of hominin cultural behavior in Eastern Asia over the long term.^{4,31,32}

Dating to ~1.66 Ma, the Majuangou-III site of the Nihewan Basin is so far the oldest well-dated site in northern China.⁵ However, as recently reported in *Nature*, the earliest evidence for the presence of hominins in China is now dated to ~2.1 Ma at the Shangchen site, located in the southern Loess Plateau,³³ suggesting the possibility for earlier sites in the Nihewan Basin. Though other early archeological sites have been reported in southern and northern China, such as Longgupo, Renzidong, and Yuanmou, significant questions remain about their stratigraphy, chronology, and artifact authenticity.^{34–37} In contrast, the Nihewan Basin contains a rich quantity of fossils and stone artifacts in good depositional contexts and with a sound relative chronology throughout the course of the Pleistocene.^{5,7,38–41} Moreover, dating of sedimentary sequences from the Pleistocene to the Holocene, using magnetostratigraphy, as well as electron spin resonance (ESR), luminescence, and radiocarbon methods, for example, has proven to be reliable for ascertaining relative site

ages.^{5,7,19,26,39–41} Indeed, paleoenvironmental studies in and around the Nihewan Basin have been initiated, providing information on the ecology of the region.^{6,42–45} The well-dated environmental data, together with fossil and archeological information, provide unparalleled information about the interplay between environmental change and hominin behavioral evolution and adaptation.

The aim of this article is to review and synthesize paleoenvironmental and archeological information from Early, Middle, and Late Pleistocene contexts in the Nihewan Basin. By doing so, we assess long-term continuity and change in hominin occupation history of the basin. We place particular emphasis on documenting changes in stone tool technology through time, thereby providing a fresh assessment of the technological abilities of hominins across a period extending for almost 1.7 million years. The long chronological sequence, together with the abundance of stone artifacts, provides a unique opportunity to reframe the narratives about the evolution of technology in Eastern Asia.⁴⁶

2 | GEOLOGICAL BACKGROUND AND CHRONOLOGY

The Nihewan Basin (Figures 1a and 2a) is located in the transition zone between the North China Plain and the Inner Mongolia Plateau. The basin is part of the Fen Wei Graben system, a NE–SW trending, elongate rift system bounded by a series of NNE–ENE normal faults basins, an important geological unit in northern China.⁴⁷ Fossil localities and archeological sites are present across these basins and occur in the hundreds, including the well-known Nihewan site group and the Dingcun site group.^{4,48,49} The Nihewan site group is spread over the generalized “Nihewan Basin,” which contains the Datong Basin, the Yangyuan Basin, and the Yuxian Basin (Figure 1b). The northeastern portion of the Nihewan Basin contains dense concentrations of Pleistocene sites, though a few sites outside this area occur, which will also briefly be highlighted here (Figure 1c).

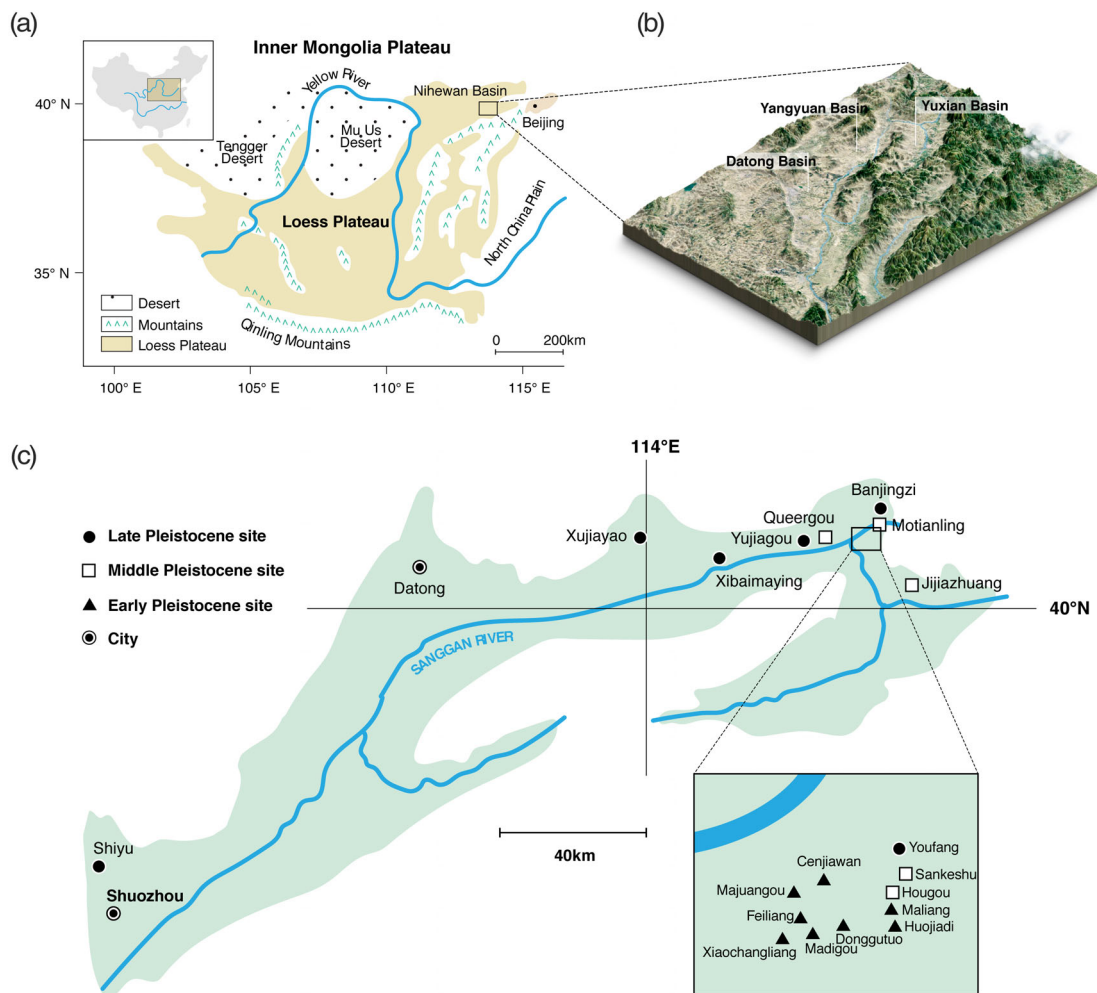


FIGURE 1 Setting and main archeological localities in the Nihewan Basin. (a) the location of the Nihewan Basin in North China, with major physiogeographic and environmental features, including the Mu Us Desert, the Tengger Desert, and the Loess Plateau. The North China Plain is to the west, the Inner Mongolia Plateau is to the north, and the Qinling Mountains are to the south. (b) Three-dimensional topographical map of Nihewan Basin showing sub-basins (Datong Basin, Yangyuan Basin, Yuxian Basin). (c) The main archeological localities in the Nihewan Basin. Note that the Early Pleistocene sites are primarily in the central basin whereas later sites appear in the western portions of the basin [Color figure can be viewed at wileyonlinelibrary.com]

Today, the Sanggan River meanders throughout the basin and flows in a northeasterly direction (Figure 1b,c). The Nihewan Basin contains up to about 150 m of exposed deposits that accumulated in and around a semi-deep to shallow paleolake dating from the Late Pliocene to the Middle Pleistocene, at ca. 420–260 ka,^{1,39,40,50–54} when the water body finally dried up. Later environments are primarily fluvial sediments deposited by the ancient courses of the Sanggan River. The entire fluvio-lacustrine sedimentary sequence is known as the Nihewan Beds.¹ The Nihewan Beds consist of the Upper Pliocene Daodi Formation, the Lower Pleistocene Nihewan Formation, the Middle Pleistocene Xiaodukou Formation, and the Upper Pleistocene Xujiayao Formation.^{40,55,56} The Nihewan Formation, which represents the type section of the Early Pleistocene in North China,⁵⁴ was initially restricted to the lower portion of the Nihewan Beds.

Magnetostratigraphic dating of the fluvio-lacustrine sequence in the Nihewan Basin has been a significant undertaking, permitting evaluation of the timing of basin infilling and dating of associated mammalian faunas and archeological sites.^{1,31,51,57} Magnetostratigraphic dating of long stratigraphic sequences requires assumptions about sedimentation rates, hence anchoring of age estimates is always best achieved through the application of multiple chronometric methods. Though debated and subject to change, the magnetochronological findings indicate that the earliest archeological sites of the fluvio-lacustrine Nihewan Beds date from the post-Olduvai Matuyama chron (~1.66 Ma for MJG-III) to the middle Brunhes chron (ca. 395 ka for Hougou). The Nihewan Beds were capped by the last glacial loess (the Malan Loess) and/or by last interglacial or Holocene sediments.^{5,16} Key Early Pleistocene sites include Majuangou I–III, Xiaochangliang, Banshan, Feiliang, Donggutuo, Cenjiawan, Huojiadi, and Maliang. Late Middle Pleistocene and Late Pleistocene sites have more recently been dated by luminescence and radiocarbon techniques, demonstrating hominin occupation from ca. 300 ka to the terminal Pleistocene. Key sites of this period include Motianling, Que'ergou, Banjingzi, Youfang, and Yujiagou.^{4,19,26} The dating of the Early to Late Pleistocene deposits provides the basis for a comprehensive chronological sequence for lithic assemblages.

3 | CLIMATE, VEGETATION, AND FAUNA

The Nihewan Basin is located at the northeastern edge of the Loess Plateau, and at the transition zone between the North China Plain and the Inner Mongolia Plateau (Figure 1a). Significant changes in climate, vegetation, and fauna are recorded in the Loess Plateau, the North China Plain, and the Mu Us Desert of the south edge of the Inner Mongolian Plateau, providing insights into understanding the environments inhabited in the Nihewan Basin.^{42,43,57,58}

The paleoclimatic records indicate that the regions immediately adjacent to the Nihewan Basin were affected by fluctuations in the Eastern Asian monsoon.^{42–44} Four instances of stepwise weakening of the Eastern Asian summer monsoon have been recorded during the last 3.5 Ma, occurring at ca. 2.6, 1.2, 0.7, and 0.2 Ma.⁴³ The ~1.2 Ma summer monsoon weakening corresponds to the Mid-Pleistocene

climate transition (MPT), occurring at ca. 1.25–0.8 Ma.^{43,59,60} During this interval, climate records indicate changes in the length and intensity of glacial–interglacial cycles, with the dominant periodicity of high-latitude climate oscillations changing from 41 ka to 100 ka cycles.^{59,60} The MPT represents a key change in climate, and several sites in the Nihewan Basin date to this transition, such as Feiliang, Donggutuo, Cenjiawan, and Huojiadi.^{9,12–14} After the MPT, complex environmental fluctuations included the weakening of the Eastern Asian summer monsoon, increasing aridification in the Asian interior, shifts of vegetation from forest steppe to open forest and steppe, and then to steppe in the Chinese Loess Plateau.^{6,43,44} The loess–paleosol record in northeastern China, and around the Nihewan Basin, indicates a long-term drying trend since ca. 1.0 Ma, punctuated by two significant abrupt drying events at ~0.65 and ~0.3 Ma.^{61,62} During the Late Pleistocene, a warm and humid period was present from ca. 125 to 115 ka, coinciding with the initial phase of paleosol S1 in the Chinese Loess Plateau.^{42,63} During the Late Pleistocene, two cold periods peaked at ca. 65 and 18 ka.⁴² In the terminal Late Pleistocene, prominent climatic phases are recognized, such as the Bølling–Allerød warm period, the Younger Dryas cold event, and the Heinrich cold events, which have been widely recorded in sediments in northern China and around the Nihewan Basin.^{64,65}

Vegetation and faunal changes have been documented in the Nihewan Basin and keyed to climate fluctuations in northern China.^{58,66} A recent study has shown close linkages between climatic fluctuations of the MPT and changes in paleovegetation patterns and large mammal communities.⁵⁸ Before 1.2 Ma, vegetation was mainly composed of alternating warm temperate forests and temperate forests; and after 1.2 Ma, vegetation was mainly characterized by alternations in forests and grasslands.⁵⁸ The Mu Us Desert to the west of the Nihewan Basin also shows an episode of expansion at about 1.2 Ma, with aridification further intensifying after 0.7 Ma.^{43,67} Up until the Late Pleistocene, the region is characterized by a warm coniferous–broadleaf mixed forest with woody grassland, as well as an increase in the extent of wetlands.⁵⁸ Pollen studies of the Nihewan Basin indicate that a relatively dry and cold desert grassland environment was present early on, as shown in the Nangou section from 2.5 to 2.0 Ma.⁶⁸ A well-developed forest was present until the transition to the MPT, with pollen evidence indicating the existence of subtropical plants.⁶⁹ During the MPT, at ca. 1.2–1.0 Ma, and especially notable in the Donggutuo section,⁷⁰ a stepwise intensification of aridification is recorded by the presence of grasses and herbs.^{69–71}

The Nihewan Basin has long been famous for its Early Pleistocene mammalian faunas and several important and well-known fossil sites have been reported, such as at Dongyaozitou, Shanshenmiaozi, and Danangou.^{72–75} The Early Pleistocene fauna in the basin has been referred to as the Nihewan fauna, which is taken as representative of mammals in northeast Asia.^{66,76} During the MPT, there were rapid and significant responses of the mammalian fauna and associated environmental changes. Faunal analysis at Shanshenmiaozi and Donggutuo indicated that, at ca. 1.2–1.1 Ma, the number of grassland mammalian fauna increased, whereas warm and humid adapted species became extinct, such as *Leptobos stenometopon* and *Hesperotherium*.^{75–77}

In the Middle Pleistocene, changes in fauna were obvious, as *Megaloceros sangganhoensis*, *Coelodonta antiquitatis*, *Equus* sp., and *Struthio* sp. are recorded, demonstrating a relatively dry and cold environment in comparison to the Early Pleistocene.⁴⁵ The Late Pleistocene is characterized by a mixture of cold-adapted forms (e.g., *C. antiquitatis*) with some other species present in the same period (e.g., *Equus przewalskii*, *Equus hemionus*).^{66,78}

4 | THE PLEISTOCENE ARCHEOLOGICAL RECORD

4.1 | The Early Pleistocene

The Nihewan Basin preserves a series of Early Pleistocene archaeological sites ranging between ~1.66 to 0.8 Ma. The majority of the key sites are distributed in a restricted range in the eastern part of the basin (Figure 1c). Archeological horizons associate with lacustrine deposits. Early sites are generally rich in artifacts, with some localities containing one thousand or more lithics from excavated contexts (Table 1). Together with lithic artifacts, mammal fossils have been recovered in site excavations, though most fossils are highly fragmented and taxonomically unidentifiable. Only a few sites contain well-preserved faunal remains, such as at Majuangou III, where cutmarks have been reported on the large mammal long bones (e.g., *Mammuthus trogontherii*).^{4,5} Based on evidence presented in the published report, the cutmarks and percussion marks on the mammalian fauna appear to be genuine, but due caution is required in the absence of detailed taphonomic assessment to discriminate natural from cultural marks, and for determining the role of scavenging and hunting in hominin meat acquisition.

Most of the Early Pleistocene sites contain relatively small lithic artifacts, with maximum flake lengths at several sites averaging to only ca. 20–30 mm.^{11,30} These small artifact finds are interpreted as the root of the “small lithic artifact tradition” of North China.^{30,73} Recent studies of the Xiaochangliang and Donggutuo sites have shown that the small artifacts relate to the exploitation of small clasts of local raw materials, such as chert, siliceous dolomite, quartz, and volcanic breccia.³⁰ Among these raw materials, chert predominates, representing more than 90% of the artifacts at Xiaochangliang, Donggutuo, and Huojiadi, and more than 60% at Maliang, Cenjiawan, and Feiliang. Chert breccias from Jurassic pyroclastic rocks were commonly used for lithic manufacture. The chert breccias occur as outcrops of bedrock in the basin, where weathered clasts can be found. The chert breccias occurring at the outcrops are small and highly fractured clasts, showing internal flaws throughout the pieces. Chert artifacts in archaeological sites were of various qualities, including generally small fine-grained pieces and those which showed abundant internal flaws with retention of a significant amount of interstitial material.^{30,79} Though discrimination of cultural versus natural clasts can sometimes be difficult, many on-site lithic artifacts show typical technological attributes (e.g., striking platforms, bulbs of percussion), which make them readily identifiable as knapping products. Our unpublished stone

tool knapping experiments using bipolar and hard hammer percussion methods show close correspondence with archeological examples.

Majuangou is one of the most famous archeological sites in the Nihewan Basin, as it is one of the oldest paleoanthropological occurrences in Eastern Asia (Figure 2b). Lithic artifacts have been excavated from three layers, that is, MJG-I (thickness = 0.5 m, ca. 1.55 Ma), MJG-II (thickness = 0.4 m, ca. 1.64 Ma), and MJG-III (thickness = 0.5 m, ca. 1.66 Ma).⁵ Nearly 1,000 lithic artifacts were recovered from the three layers, including cores, flakes, retouched pieces, and chunks.^{8,80} The flake production system has been described as being relatively simple, showing few multiplatform flake removals on cores. Hard hammer percussion appears to be the dominant flaking method given the pattern of negative flake scars on the cores and distinct percussion platforms and bulbs of percussion on flakes (Figure 3 in Box 1). A large number of fossils were recovered from the three archaeological layers, primarily represented by *Equus* sp. and *M. trogontherii*.^{4,81} In MJG-II, 66 elephant footprints were reported (Figure 2c), measurements showing that they were mostly nearly round (400–500 mm in diameter) and between 100 and 200 mm in depth.⁴ Given the presence of a low-energy lake shore environment at MJG-III, good preservation conditions were reported, further demonstrated by the fresh condition of lithic artifacts and the clear fossil bone surfaces, with some showing signs of animal trampling and percussion.^{4,5}

Dating to between 1.4 and 1.2 Ma, several key sites have been found and excavated in the Nihewan Basin, including Dachangliang, Xiaochangliang, Bانشan, Feiliang, and Madigou.^{4,8,10} Xiaochangliang was one of the first Early Pleistocene occurrences identified in the Nihewan Basin and in China itself, leading to its excavation in the 1970s. The dating of Xiaochangliang illustrates some of the ongoing problems in estimating age, as magnetostratigraphy on-site placed hominin occupation to ~1.36 Ma,⁷ whereas other stratigraphic correlations place it to between ca. 1.67 and 1.26 Ma.^{82–84} Nearly 6,000 lithic artifacts were recovered from these sites, with the highest numbers recovered from Madigou, Xiaochangliang, and Feiliang. Recent and detailed technological analyses demonstrated that hominins used both freehand and bipolar reduction techniques to manufacture small flakes from variable raw materials, with some byproducts showing retouch (Figure 3 in Box 1).^{8,23,30,85} The retouched pieces are generally small and dominated by those that may be typed as scrapers. Bipolar reduction methods were frequently used at Xiaochangliang, whereas at Feiliang, freehand percussion was used more commonly, indicating a flexible approach in the utilization of raw materials during this period.³⁰ Though fossils were recovered at both Xiaochangliang and Feiliang, most were small fragments and unidentifiable though determinations include *Pachycrocuta licent*, *Bison palaeosinensis*, *Equus sanmeniensis*, and *Palaeoloxodon* sp.^{4,8,23,85} Taphonomic study of a small sample of the Xiaochangliang fauna indicated the absence of any clear signs of hominin interactions, and instead showed signs of carnivore modifications and abrasion from hydraulic processes.⁸⁶

Between 1.1 and 1.0 Ma, significant developments in core–flake reduction methods and tool production techniques are evidenced,¹¹ including at Donggutuo, Cenjiawan, and Huojiadi. Donggutuo and Cenjiawan each contained a large number of excavated lithic artifacts

(Table 1) and refitted pieces, allowing for detailed assessments of technological behaviors.^{11,15,87} At Donggutuo, small flakes ($n = 584$) were recovered with some showing platform preparation.¹¹ One of the key innovations applied by the toolmakers at Donggutuo was the production of small, blade-like flakes by wedge-shaped preparatory core methods (originally called the “Donggutuo Core” by Hou¹⁵) (Figure 3 in Box 1).^{11,15} Though these wedge-shaped cores are unlikely to be related to much younger microblade cores, as argued by Hou,¹⁵ it does appear that small blade-like blanks were intended knapping products.¹¹ Some small flakes were retouched into various types of tools, and likely used in a range of tasks such as scraping, cutting, and boring (Figure 3 in Box 1).¹¹ The relatively high percentage of refitted pieces in the Cenjiawan assemblage illustrate the development of controlled knapping methods, fixed planning in the knapping process, and increased tool production skills (Figure 3 in Box 1).¹⁵ Donggutuo contains a large number of fragmentary fossils, some

identified as *E. sanmeniensis* and *C. antiquitatis*. Although most of the fossil fragments are not in good condition, 1.2% of these pieces reportedly display cutmarks.⁴

Toward the end of the Early Pleistocene, at ca. 0.9–0.78 Ma, fewer sites have so far been identified in the Nihewan Basin.¹² The Maliang site was first excavated in 1985, and 121 artifacts and some faunal remains were recovered from an area measuring ca. 20 m² in horizontal dimension.¹⁷ Of the 121 lithic artifacts, most were flakes and flaking debris, with only four retouched items.¹⁷ In recent years, additional sites have been reported near Maliang, and given their similar stratigraphic setting, they have been referred to as part of the Maliang site group.⁸⁸ Maliang Locality 10 yielded 1,500 animal fossils and 197 lithic artifacts, including cores, flakes, tools, pebbles, blocks, angular fragments, and shatter.⁸⁸ Flaking was by direct hard hammer percussion without any sign of core preparation. Most tools were described as scrapers with the application of casual retouch.⁸⁸ Raw



FIGURE 2 The Nihewan Basin and location of key Early Pleistocene sites. (a) Terrain of the Nihewan Basin illustrating incision of the fluvio-lacustrine deposits and the location of the Xiaochangliang site. The Sanggan River and the Xionger Mountains are to the north. (b) Long fluvio-lacustrine section at the Majuangou site, with the three main layers (I–III) indicated. (c) Excavated area of Majuangou-III showing the co-occurrence of stone artifacts and elephant fossils [Color figure can be viewed at wileyonlinelibrary.com]

BOX 1 The Archeological Record of the Nihewan Basin

Free hand hammer percussion flakes recorded from the earliest cultural layer of Majuangou (Figure 3); flakes show clear striking platforms and bulbs of percussion (No. 1–2). The bipolar technique is present in the earliest sites, with especially high numbers at Xiaochangliang; typical bipolar products are noted by battering scars on two opposite ends (No. 3) and in an axial orientation (No. 4). During the MPT, increasing levels of skill are present in flake production, as evidenced at Donggutuo and Cenjiawan. Well-controlled flaking is demonstrated in small flakes (No. 5–7) and cores (No. 8). The wedge-shaped cores from Donggutuo (No. 9) show parallel flake scars and partly prepared the platforms, interpreted to indicate planning and foresight in flaking. Retouched pieces in early assemblages are present, but the tools not regular in shape, and retouch is typically confined to small areas on a single edge (No. 10). During the MPT, finely retouched tools, typable as scrapers (No. 11–12), notches (No. 13), denticulates (No. 14), and multiedged retouched tools (No. 15–16) are present.

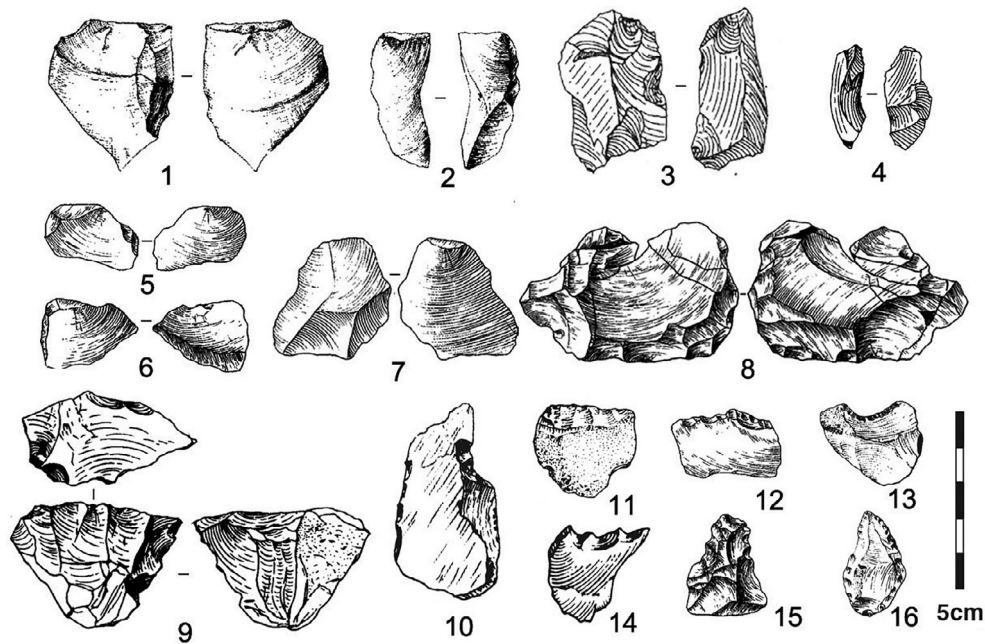


FIGURE 3 Selected Early Pleistocene artifacts^{4,79}

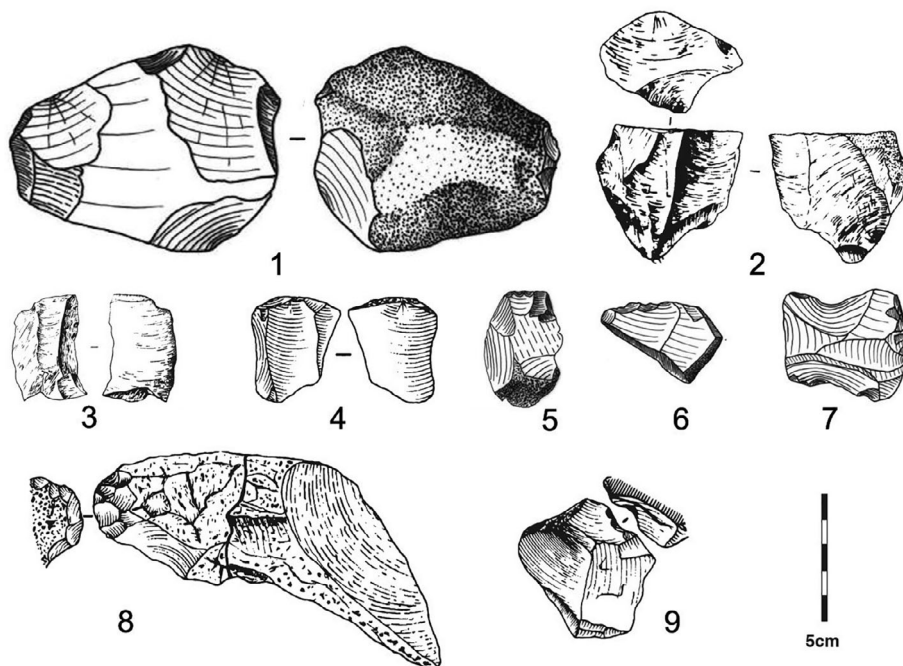


FIGURE 4 Selected Middle Pleistocene artifacts^{4,83,84}

During the Middle Pleistocene, there are changes in the relative shapes and sizes of lithic artifacts in comparison to the Early Pleistocene assemblages (Figure 4). A larger range of raw materials were exploited (e.g., siliceous dolomite, andesite, and trachyte). Cobbles were frequently used, though not heavily flaked as shown by remnant cortex (No. 1, 8). Freehand percussion predominates, and some cores show multidirectional flaking, though with limited flake scars (No. 1, 2). Most flakes have plain platforms (No. 3), though some examples show retouched platforms (No. 4). Retouch is not regular and frequently confined to a single edge (No. 5, 6, 8, 9), though scrapers (No. 5, 6, 8) and notches (No. 7, 9) can be identified.

Stone tool manufacturing methods advanced significantly during the Late Pleistocene as shown by the variety of flaking methods employed and tool types produced (Figure 5). Elongated protoblade cores (No. 1) and disk cores (No. 5) are present at the early stages of the Late Pleistocene, such as at Xujiayao. At ca. 60–40 ka, smaller regular cores appeared at Xibaimaying and Shiyu, cores showing small and elongated negative flake scars (No. 2, 6). At ca. 29–26 ka, the microblade technique is found throughout the basin, with wedge-shaped cores (No. 3) and cylindrical cores (No. 4) and as the common types. Retouch became more standardized and includes a large variety of tool types, including scrapers (No. 7, 8) borers (No. 9), denticulates (No. 10), burins (No. 11), and a projectile point from Shiyu (No. 12). After the emergence of the microblade technique, tools skills become highly standardized tools, and include end scrapers (No. 13, 14), backed tools (No. 15), triangular points (No. 16), and burins (No. 17, 18). The appearance of personal ornaments (No. 19) and bone tools (No. 20) signals important social and behavioral changes.

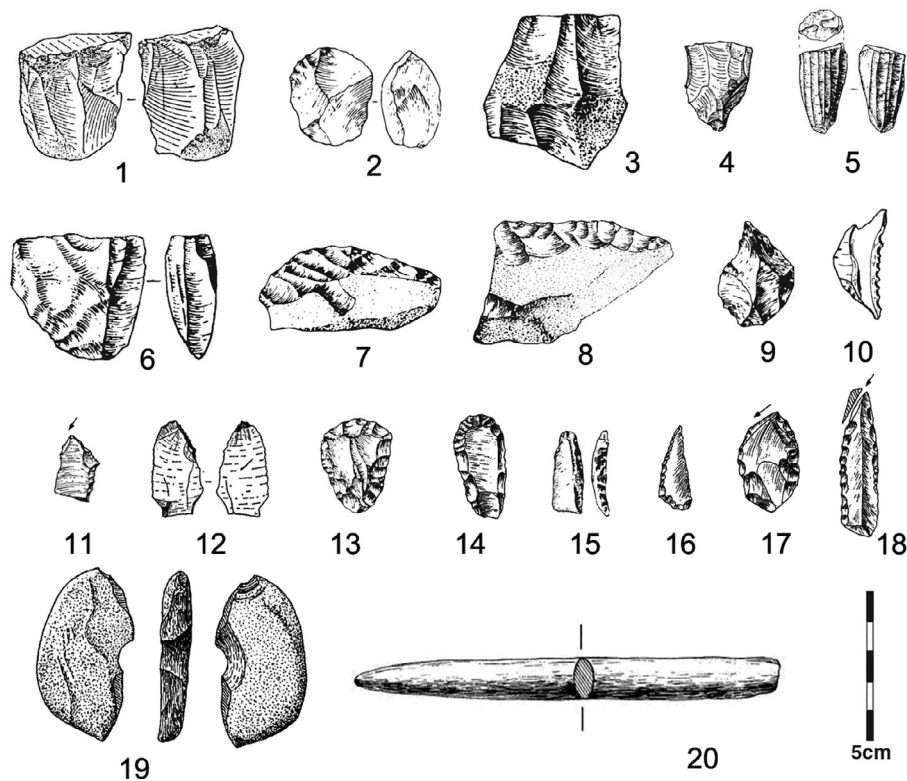


FIGURE 5 Selected Late Pleistocene artifacts^{4,73,99}

material exploitation patterns began to change at this time, and though chert was still used, its presence dropped to about half of the stone assemblage, with quartz, sandstone, and dolomite forming a higher percentage. In comparison with earlier sites, knapping techniques at Maliang Locality 10 were relatively simple, exemplified by the presence of only a few shallow flake scars on cores, accounting for ca. 13% of the lithic assemblage.⁸⁸

In sum, the Early Pleistocene archeological record is well represented in the Nihewan Basin. The earliest inhabitants of the basin

utilized lacustrine environments, producing archeological sites with stone tools and animal remains. To date, no hominin fossils in the Early Pleistocene have been recovered, though it is assumed that *Homo erectus* may be present, as demonstrated in other regions, such as Lantian.⁸⁹ Stone tool evidence across a 0.9 Ma period indicates changes in lithic technology through the Early Pleistocene. At 1.1–1.0 Ma, artifact density increased, with clear evidence for improvements in lithic manufacturing techniques.¹¹ At ca. 0.9–0.8 Ma, there was a decline in site and artifact densities in the basin.

4.2 | The Middle Pleistocene

The Middle Pleistocene archeological record of the Nihewan Basin is not as abundant in comparison to the Early Pleistocene situation. The majority of the Middle Pleistocene sites occur at the edge of Yangyuan Basin or further into the Yuxian Basin in the south,²⁰ likely signaling a shift in hominin landscape activities away from the central area of the basin (Figure 1c). Most of the reported Middle Pleistocene sites (e.g., Hougou, Motianling, Que'ergou) date to a restricted time period, ca. 400–260 ka, and occur in deposits at the top of lacustrine sections.^{16,19} A significant gap in archeological sites in the Nihewan Basin therefore occurs between the Matuyama and Brunhes geomagnetic reversal (ca. 780 ka) to 400 ka.

The number of lithic artifacts and mammal fossils from Middle Pleistocene sites are not as plentiful in comparison to those recovered from Early Pleistocene localities. Moreover, there is no single site with a lithic assemblage of more than a few hundred artifacts despite large-scale excavations (Table 1). In addition, there are significant changes in raw material use in the Middle Pleistocene. Though good quality chert was still used,^{4,18,90} other types of raw materials were procured and tested, such as siliceous dolomite, andesite, and trachyte. Though limited, some lithic artifacts show some degree of planning, as demonstrated by platform preparation and fine retouching on flakes (Figure 4 in Box 1).

The Hougou site, dated to ca. 395 ka,¹⁶ was excavated in 2005, leading to the recovery of about 300 lithic artifacts and 700 fossils, primarily consisting of *Cervus* sp. and *Equus* sp.⁹⁰ The lithic artifacts were mainly manufactured using hard hammer percussion, without showing any signs of core preparation. A small number of artifacts were made by bipolar percussion. Core and flake sizes were relatively large, and the majority of flakes measure at least 20 mm larger in length in comparison to the Early Pleistocene lithic assemblages. The range of retouched tool types was limited, and dominated by scrapers (Figure 4 in Box 1), contrasting with the situation in earlier assemblages. Similar to other Middle Pleistocene sites, chert accounted for ca. 41% of the raw materials, though representing a significant decline in comparison to the Early Pleistocene sites. Two bone fragments from Hougou are said to show percussion marks, and eight unidentified bones are thought to have cutmarks.⁹⁰

Motianling and Que'ergou have been dated by optically stimulated luminescence (OSL) to 315 ± 13 ka and 268 ± 13 ka, respectively.¹⁹ The Que'ergou excavations only yielded 40 lithic artifacts in an excavated area measuring 16 m². The Motianling excavations produced 55 lithic artifacts and 146 pieces of fossil fragments in excavations measuring 53 m². Flake removals on cores were mostly applied from a single direction, and many cores do not show full exploitation (Figure 4 in Box 1).⁴ A few retouched tools were reported from the sites, and among those recovered, few showed regular retouch.⁴

A newly reported Middle Pleistocene site, excavated in 2016 and 2017, has been investigated at Jijiazhuang, in the southern part of the Nihewan Basin (Yuxian).²⁰ A total excavation area of 76 m² was exposed, recovering 190 stone artifacts and 178 fossil fragments. The lithic artifacts were mainly made by hard hammer percussion. The

dominant raw material was volcanic lava, while chert only accounted for ca. 5% of the assemblage. Flake platforms and retouched platforms were present, indicating application of preparatory techniques.²⁰ A range of retouched tools was identified and described as pointed tools, scrapers, and denticulates.²⁰ Although dating results have not been reported, it is expected that new information on hominin behavior in the Middle Pleistocene will emerge from this key site.

In sum, four Middle Pleistocene sites (Hougou, Dongpo, Motianling, and Que'ergou) have been investigated in the Nihewan Basin, all dating to between ca. 400 and 260 ka.^{18,19} So far, no Middle Pleistocene site dates to between 780 and 400 ka. The stratigraphic position of Jijiazhuang, however, indicates that the site may provide an opportunity to fill this chronological gap. In comparison with the Early Pleistocene record, fewer Middle Pleistocene sites occur in the central portion of the basin and the density of artifacts in each investigated site was relatively low. In the Middle Pleistocene, stone tool manufacture shifted from chert to the wider use of a range of raw materials. Flake reduction in the Middle Pleistocene was relatively simple, with the presence of high numbers of tested cores, similar to what was reported at Maliang at the end of Early Pleistocene.^{17,88} It is not clear whether changes in raw material types was responsible for the general lack of systematic flaking and the low frequency of retouched tools. The exception, however, was Jijiazhuang, where tool production methods show some level of increased skill in flaking on volcanic materials,²⁰ thus indicating that hominins were certainly capable of manufacturing such implements during this time period.

4.3 | The Late Pleistocene

By the beginning of the Late Pleistocene, the cultural history of the Nihewan Basin entered into a new stage,^{4,91} with significant increases in site numbers and higher numbers of artifacts within sites (Table 1). So far, the only recovered hominin fossil in the Nihewan Basin comes from Xujiayao, here considered to be Late Pleistocene in age. Many key changes are recorded in lithic flaking and tool manufacture across the Late Pleistocene, and at ca. 100–70 ka, discoid cores, blade-like cores, and finely retouched tools are recovered.⁴ Between ca. 57 and 30 ka, tool types became more standardized, and bone tools and ornaments are present for the first time.⁷⁸ At ca. 29–27 ka, microblade manufacturing methods are present, and these sites become widespread throughout the basin.²⁶

The depositional and environmental conditions of Late Pleistocene sites changed substantially in comparison to earlier periods, as there was a shift from lacustrine to alluvial settings. Late Pleistocene archeological sites are found distributed along the course of the Sanggan River and in nearby environments, thereby showing a substantial difference in comparison to earlier site distributions, which tended to be clustered in particular areas within the basin (Figure 1). With respect to stone tool acquisition, sites show the wide use of a variety of raw materials, including chert, quartzite, quartz, agate, and siliceous limestone. Although raw material frequencies differ from site to site, flake reduction and tool production skills increase

substantially, showing the presence of regular cores and standardized tools. Raw material constraints no longer appear to form a barrier in limiting stone tool production.

Xujiayao is among the key sites that is placed here at the beginning of the Late Pleistocene on the basis of the biostratigraphy of mammalian fossils and U-series dates of 125–104 ka on fauna from an archeological context.^{4,21,40,91–95} Other age estimates of Xujiayao place the site in other periods of the Middle and Late Pleistocene,^{96–99} though these dating results are discrepant, and it remains unclear how these dates relate to the archeological deposits themselves. Xujiayao was first identified and excavated in the 1970s, recovering an abundance of lithics and fossils, and importantly, hominin fossils, a first of its kind discovery in the Nihewan Basin.¹⁰⁰ The Xujiayao hominin fossils consist of 15 partial neurocranial elements, a partial maxilla with six teeth, a mandibular ramus, and three isolated molars. Morphologically, the fossil finds are described as “late archaic humans,” distinct from earlier *H. erectus* populations of Eastern Asia.^{95,101} Wu and Trinkaus⁹⁵ indicated that the fossils preserve the traits of Pleistocene archaic humans, such as Neanderthals, and Late Pleistocene modern humans in eastern Eurasia, implying an early entry of *Homo sapiens* into Eurasia.

Together with the hominin fossils, abundant stone artifacts and some bone tools were recovered at Xujiayao.^{4,91,102} Hard hammer percussion was mainly used to produce stone tools, with investigators characterizing them as part of the “small tool tradition.”^{78,91} Lithic assemblages comprising 1,765 pieces from the 1977 excavation of Pit-U3 have been analyzed.¹⁰² The stone tools were made on quartzite (49%) and quartz (34%), with chert and agate accounting for 3% of the artifacts; in addition, sandstone, dolomites, and limestone were used in small quantities.¹⁰² The Xujiayao lithic assemblage is composed of a variety of small tools, including scrapers, points, notches, burins, borers, and denticulates (Figure 5 in Box 1). Discoid cores and blade-like cores were described in the original report⁹¹ and noted to demonstrate the development of knapping techniques. Spheroids recovered from Xujiayao represent a rather unique find in China and compose a high proportion of the formal tools (25%) (Figure 6). The spheroids are mostly made mostly on quartzite and dolomite, with weights ranging from 76.5 to 1,500 g.^{4,102} The spheroids are mostly round and sub-round in shape, and show evidence of flaking scars from multiple directions.

Xujiayao is the best studied site for taphonomic analysis in the basin, providing high-quality data and the reconstruction of hominin subsistence activities.^{93,103} The fauna at Xujiayao has been identified as *E. przewalskii* and *E. hemionus*, supporting an interpretation that the environment was relatively cold and dry.^{102,103} A large number of spheroids was found in association with horse bones, the bones of which show both percussion marks and cutmarks,¹⁰⁴ leading archeologists to refer to the Xujiayao inhabitants as the “horse hunters.”¹⁰⁵ Cementum increment analysis of the equid teeth demonstrated that hunting occurred during several seasons, and mainly during the cold interval.¹⁰³ Recent mortality profile analysis indicated that the Xujiayao inhabitants probably used both active hunting and scavenging to acquire equids.¹⁰³

Banjingzi is dated to 86 ± 4 ka by OSL.¹⁹ In the 1988 excavation, more than 3,000 lithic artifacts were recovered.⁴ The lithic assemblages are relatively advanced, showing the production of finely made scrapers and points (Figure 5 in Box 1). Some of the cores have been described as “prepared” and related to “Levalloisian methods,” although it was noted that the shapes and structure of the cores differed from classic Levallois techniques.⁴ The lithic assemblages at Banjingzi are dominated by high quality chert nodules, which were advantageous for making more refined tools. A large number of fossils was also recovered, though no detailed zooarcheological study has been carried out.⁴ Among mammal finds were *E. przewalskii*, *C. antiquitatis*, and *Cervus canadensis*, and among them, horse was the most dominant. Bone tools have been identified at Banjingzi, the published report illustrating an example that showed consecutive retouch on two convergent edges on a broken long bone.⁴ However, without detailed taphonomic assessment, it is difficult to determine the authenticity of the bone tools. Among important site features, the earliest known hearths in the basin were reported, evidenced by burned sediments and charcoal, typically measuring ca. 40 cm in diameter and ca. 2–5 cm in thickness.⁴

The site of Xibaimaying was dated to 46 ± 3 ka by OSL,²² more than 20,000 years earlier than a previous result.⁴ A large number of lithic artifacts ($n = 1,546$) and fossils were recovered from an excavated area measuring 78 m². The small (<30 mm) and slightly elongated cores from the sites are said to show microlithic traits.¹⁰⁵ The small tools were finely retouched and dominated by single- and multi-edge scrapers and denticulates (Figure 5 in Box 1). Raw materials were dominated by pyroclastic rock (36%), alongside vein quartz, agate,

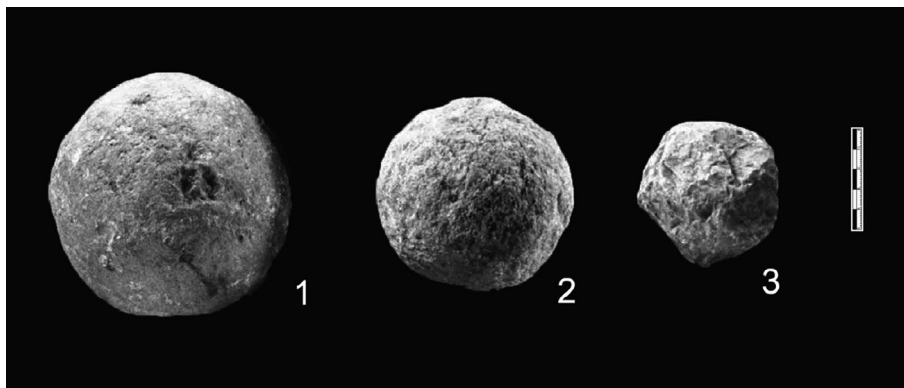


FIGURE 6 The spheroids of the Xujiayao site, illustrating their round shape and the variability in their size. Note signs of battering on their edges

siliceous limestone, and chert. A total of 31 bone tool fragments were reported by the excavators,⁴ although given the shallow and uneven retouch scars along the edges of the pieces, it is difficult to ascertain their genuine cultural production. Freshwater mollusks (*Corbicula*

fluminea, *Gyraulus convediusculus*, *Gyraulus compressus*, and *Radix auricularia*) in association with artifacts have been reported.⁴ Some avian and mammal fossils were identified, including *Struthio* sp., *E. przewalskii*, and *Bos primigenius*.⁴

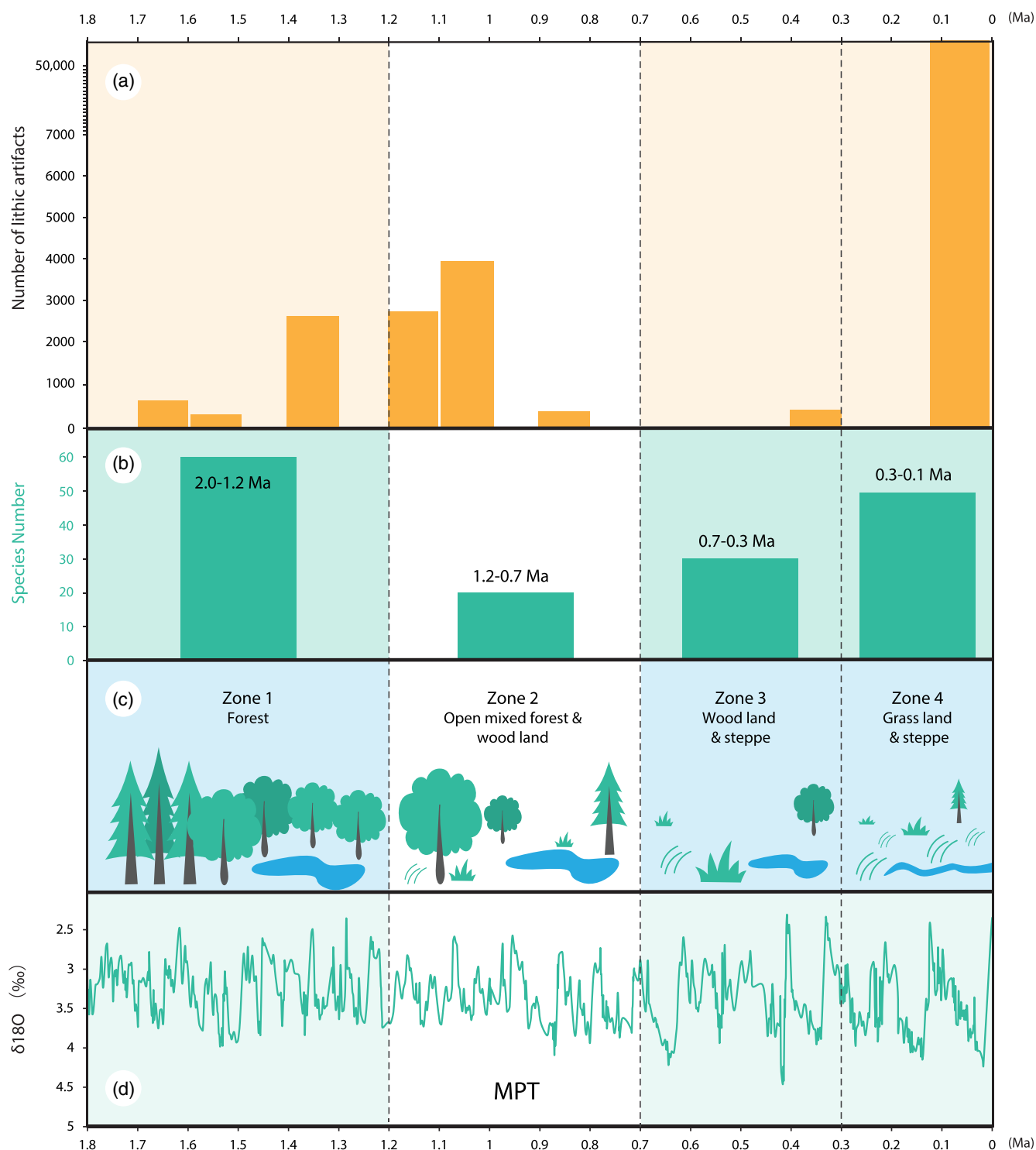


FIGURE 7 Synthesis of ecological and archeological history of the Nihewan Basin and North China from the Early to Late Pleistocene. (a) The number of lithic artifacts. (b) The number of large mammal species in North China.^{58,66} (c) Hypothetical setting and landscape of Nihewan Basin based on information from the North China Plain and previous studies in the Nihewan Basin.^{45,58} (d) global climate change based on the benthic $\delta^{18}O$ records for ODP site 1,143 in the South China Sea¹¹⁴ [Color figure can be viewed at wileyonlinelibrary.com]

Another key site in the Late Pleistocene is Shiyu, occurring in the southwest end of the basin (Figure 1c) and radiocarbon dated to ca. 39–31 ka.^{24,25} A very large number of stone artifacts ($n = 15,000$) was recovered, together with bone tools and a single ornament fragment.⁷⁸ The lithic industries were similar to Xibaimaying, as the tools are primarily well-made small tools, including points, scrapers, and burins, as well as a single projectile point (Figure 5 in Box 1). The projectile point was made on an elongated chert flake, with careful retouch on the base to form a stem.⁷⁸ Microblade core methods were not reported, although some small cores are said to have “micro-core” traits.^{78,106} The “micro-cores” are mainly made on igneous rocks, typically with one plain platform and flaked in the same direction repeatedly. The recovery over 200 individuals of horses and onagers was interpreted to be the result of specialized hunting activities.⁷⁸ A total of 39 bone tools was reported, and among these, 20 pieces showed multiple and regular retouch scars along functional edges, 9 pieces showed retouch on one edge, and the remainder showed retouch on two edges or convergent edges (tips). The investigators compared the bone tools with those gnawed by carnivores, asserting that the Shiyu finds were genuine cultural artifacts on the basis of the fact that flaking was conducted on the inner surfaces and centered on the lateral sides and at the proximal and distal ends of the bones.¹⁰⁷ The single reported ornament was a polished black broken stone bead made on graphite (Figure 5, No. 19).⁷⁸

The emergence of microblade technology in the Nihewan Basin is dated to ca. 29–26 ka, as noted at the site of Youfang.^{22,26} Together with the other sites, such as Longwangcan, Xishi, and Shizitan, Youfang is one of the oldest sites with microblade technology in north China.^{108,109} Youfang contains a rich collection of artifacts, and in the 1986 excavation, more than 3,000 stone artifacts were recovered from a trench measuring 28 m².¹¹⁰ The raw materials were mainly fine-grained flint, with well-developed microblade cores and finely retouched tools (Figure 5 in Box 1).

There are several terminal Late Pleistocene sites in the basin, such as Yujiagou (ca. 16–8.4 ka), Ma'anshan (ca. 13 ka) and Erdaoliang (ca. 18 ka).^{4,27,28} The sites contain a large amount of microblade production debris and show well-developed microblade techniques with multishaped microblade cores, including “wedge-shaped,” “boat-shaped,” “cylindrical,” and “conical” types. At Erdaoliang, “boat-shaped” cores, flakes, and blades were refit, illustrating preparatory sequences in the manufacture of microblades.²⁷ A well-made bone awl from Erdaoliang indicates the maturity of bone tool manufacturing techniques during the Last Glacial Maximum (Figure 5, No. 20).²⁷ At Yujiagou, perforated shells, ostrich eggshell beads, bone tubes, and stone beads were recovered.⁴ Recent taphonomic study of the Yujiagou fauna indicated an emphasis on antelope and horse hunting, intensive exploitation of animal resources, and possible management of juvenile horses.²⁸ The appearance of pottery and ground stone tools by ca. 13 ka in these sites denotes the beginning of the Neolithization process in the Nihewan Basin, as is also demonstrated in North and Northeast China, as well as Korea, Japan, and Siberia.^{29,109,111}

In sum, during the Late Pleistocene, several important behavioral developments were recorded in the Nihewan Basin, including changes

in site locations, which changed from a lacustrine setting to a riverine orientation. At the beginning of the Late Pleistocene, a variety of new flaking methods and tool types occur, including discoid cores, blade-like cores, and well-made retouched tools at sites such as Xujiayao and Banjingzi.^{4,78} One of the most significant discoveries in the early Late Pleistocene was the recovery of the Xujiayao hominin finds in association with abundant lithic assemblages, including spheroids and cutmarked and processed equid fossils, which have been taken as evidence for active scavenging and hunting behaviors.^{103,104} The appearance of hearths, bone tools, and personal ornaments at sites dating from ca. 40 ka indicates significant changes in the activities of the Nihewan site occupants, and likely signal the presence of *H. sapiens* in the basin. By 29–26 ka, microblade technology began to spread across the basin, becoming a common technology, and by 13 ka, significant new cultural changes are recorded with the onset of the Neolithization process.

5 | DISCUSSION

5.1 | The lithic record in wider perspective

The Nihewan Basin preserves a long and rather remarkable archeological and paleontological record ranging over a period of nearly 1.7 Ma, making it one of the most important paleoanthropological archives in Asia. Here, we described key sites and findings from the Nihewan Basin, describing novel behavioral features, while placing emphasis on describing changes in lithic technology from the Early Pleistocene to the end of the Late Pleistocene.

Our review of the long-term lithic evidence from the Nihewan Basin indicates that there was indeed a general commonality in the selection of small clasts for stone tool production, leading many investigators to discuss “small tool traditions.” However, an evaluation of lithic assemblages in the basin, particularly from the most recent studies of stone tool assemblages, indicates that there were significant changes in reduction methods and tool manufacturing techniques over time. Variability in stone assemblage formation included the periodic introduction of innovative tool-making strategies, changes in the frequency of raw material selection and use, and flexibility in the manufacture of different tool types. The application of innovative lithic tool-making strategies and changes in lithic assemblage composition over time likely reflect a range of hominin behaviors, including changes in landscape and settlement behaviors, situational responses of groups to ecological alterations, and choices of individuals during activity tasks. The dynamic formation of lithic assemblages as a product of hominin behaviors over time contrasts with the view that lithic technology was a homogenous and long-lasting tradition. The traditional view is that there were long periods of technological stasis, frequently categorized by archeologists as simple, small tool technologies, and typed under generic typologies such as “Chopper-Chopping” tool industries and Mode I.^{31,112,113} Even recently, Pei and colleagues commented that the lithic assemblage from Feiliang was a Oldowan-like or Mode I technology, the core-flake industry showing

a low degree of standardization, expedient knapping techniques, and casually retouched flakes.⁸ Owing to more detailed lithic studies in recent years,^{11,30} there has been an increased awareness that such categorization has mischaracterized the situation in the Nihewan Basin leading investigators to treat Early Pleistocene lithic assemblages as monotonous. Therefore, our evaluation of the long-term lithic evidence from the Nihewan Basin leads us to the conclusion that archeologists working in Eastern Asia should move away from a pre-occupation with broad technological typologies and instead concentrate on the distinctive characteristics that establish the stone tool record, placing emphasis on evolutionary trends and variable behaviors across the Pleistocene. That said, it is instructive to review key information from the Nihewan Basin that illustrates this point in relation to regional and global climate and environmental records (Figure 7).

5.2 | Trends in the ecology and occupation history of the Nihewan Basin

A general observation is that archeological sites dating to between ~1.66 Ma to 800 ka are well represented in the Nihewan Basin, as thousands of lithic artifacts and fossils have been excavated, representing one of the most important records for Eastern Asia over this 800 ka long interval (Figure 7a, Table 1). The Early Pleistocene sites of the Nihewan are concentrated in the central portion of the basin and associate with the paleolake.^{8,11,30} The presence of lithic assemblages in association with cutmarked bone in lacustrine settings is reminiscent of early sites in Africa and other parts of Eurasia.^{115–118} The wide availability of reliable fresh water resources, the high number and variety of mammalian faunas, and the relatively stable climate characteristics (i.e., lower amplitude fluctuations and the shorter intervals of glacial–interglacial cycles) would have provided more favorable conditions for early hominin populations (Figure 7a–d).

The earliest sites show variation in tool-making, including changes in the frequency in the use of free-hand percussion and bipolar techniques.^{8,30} The oldest site, Majuangou III, is dated to intervals between ca. 1.66 and 1.55 Ma,⁵ demonstrating that early hominins were using casually flaked, but sharp-edged implements during activities along the lakeshore. Cutmarks on bones of *Mammuthus trogontherii* and percussion marks on other mammals, such as deer- and horse-size mammals, provide evidence for meat in the diet of the earliest inhabitants. Slightly younger sites, dating to between ca. 1.36 and 1.32 Ma, show increased artifact densities at sites, especially at Xiaochangliang. Improvements in lithic manufacturing skills at Xiaochangliang are apparent, including increased numbers of well-made, retouched pieces.

At ca. 1.2–1.0 Ma, the number of sites increased substantially over their forerunners, with elevations in artifact densities in comparison to the older sites (Figure 7a, Table 1). Following the 1.2–1.0 Ma peak in site and artifact numbers, only one site group at Maliang, dating to ~0.8 Ma, resulted in the recovery of artifacts. The high overall number of sites in this interval corresponds with MPT, the global

climatic change occurring at ca. 1.25–0.8 Ma (Figure 7d).^{114,119,120} Fossil and pollen evidence from the Nihewan Basin and the adjacent area indicates that the vegetation changed from a mixed forest to a dry and cold open grassland and mixed forest in a paleolake setting (Figure 7c). Alongside changes in vegetation, the range of large mammal species declined (Figure 7b) and pollen of *Artemisia* and *Ephedra* began to increase.^{45,75} During the MPT, one of the earliest, and perhaps most significant innovations in stone tool-making occurred at Donggutuo, with the manufacture of wedge-shaped cores to produce particular flake shapes, including small blade-like forms.^{11,15} Moreover, well-controlled and skilled core flaking strategies are apparent at Cenjiawan given observations of refitted core–flake sets, demonstrating flexible planning in the knapping process.⁸⁷ These innovations may be a response to more variable environments in the high latitudes during the MPT (Figure 7d).¹¹ Though demonstrable tool-making skills are apparent by 1 Ma, these particular stone tool manufacturing strategies are not long-lived, as by the end of the Early Pleistocene, site numbers decreased and lithic assemblages do not show the same level of planning in flaking.

In the Middle Pleistocene, some key changes in the archeological record are recorded. Of the relatively few sites recorded during this period, there is a shift in site location to the western part of the basin. This likely reflects changes in the hydrological conditions in the basin toward a fluvial system as the paleolake in the central basin dried up (Figure 7c).^{53,54} Site occupations in the Middle Pleistocene are dated to between ~400–260 ka at Hougou, Motianling, and Que'ergou (Table 1).^{4,16,19} With the exception of Hougou, artifact densities are generally low at the sites, with exceedingly few artifacts found in some site excavations (e.g., Motianling, Jijiazhuang, and Que'ergou), thus also signaling some significant changes in landscape behaviors. In contrast with the focused use of chert in the Early Pleistocene, hominins used a wider range of raw materials available across the basin.^{16,19} The lithic assemblages have been described as relatively simple, with a small number of flakes obtained from unprepared cores, though occasional finely retouched tools were also manufactured, indicating that knappers had the ability to manufacture fine implements. Little further information is available about Middle Pleistocene sites in the Nihewan, making this the least understood period of time concerning hominin activities in the basin.

In the Late Pleistocene, site counts, artifact numbers, and artifact densities increased dramatically in comparison to the earlier records. Several site excavations have yielded more than 10,000 artifacts each, thus providing detailed information on behavioral activities (Figure 7a, Table 1). At the onset of the Late Pleistocene, sites are found in grassland or steppe ecosystems and situated along the Sanggan River terraces, in stark contrast to earlier site locations in the fluvio-lacustrine Nihewan Beds (Figure 7c). The only known hominin find in the Nihewan Basin so far occurs at Xujiayao, with current dating suggesting an age of ~100 ka. The Xujiayao hominin is a particularly important fossil for Asian paleoanthropology, as it thought to preserve the traits of Pleistocene archaic humans, such as Neanderthals, and Late Pleistocene modern humans of eastern Eurasia.^{95,101} If this is the case, it suggests that early and incoming populations of *H. sapiens*

interbred with archaic populations present in the region in the early phases of the Late Pleistocene. This would be consistent with other fossil and genetic data to suggest an early entry of *H. sapiens* into Asia, though this does not discount the possibility that such populations may have also gone extinct.¹²¹

During the Late Pleistocene, the inhabitants of the basin developed new adaptive strategies, perhaps in response to unstable and harsh climates, particularly during the Last Glacial Maximum (Figure 7d).^{122,123} The Late Pleistocene record is generally characterized by a high abundance and mixture of cold-adapted mammals, and regional vegetation studies also showed relatively dry climate (Figure 7b,c).⁴ Late Pleistocene sites contain evidence for complex cultural behaviors, including highly developed lithic toolkits, bone tools, and ornaments. Between ca. 100 and 86 ka, discoid cores, blade-like cores, and finely retouched tools are present at Xujiayao and Banjingzi, indicating innovations in stone tool manufacturing methods and tool manufacture. The presence of abundant horse bones with cutmarks at Xujiayao, together with the large number of spheroids for possible marrow extraction, suggests efficient hunting and processing of game. At ca. 50–30 ka, a new set of cultural and technological innovations occur, as illustrated by the presence of an ornament at Shiyu, bone tools at Xibaimaying and Shiyu, and a series of well-produced stone tools, including denticulates and a projectile point at Shiyu. At around 46 ka, elongated cores occur at Xibaimaying and suggested to be the precursors of microblade manufacturing techniques. By ca. 29–26 ka, fully developed microblade toolkits are present throughout the Nihewan Basin, and between 20 and 11 ka, a variety of methods are present to produce microlithic tools. During Late Pleistocene, there is no clear break in the occupation history of the Nihewan Basin, though higher resolution records and accurate dates are needed.

5.3 | Gaps in the record and their meaning

Although there is no doubt that the Nihewan Basin contains an impressive set of sites over the long term, this synthesis identifies two substantial and long-term lacunae in the record, one prior to 1.66 Ma and the other between ca. 800 and 400 ka, as well as four shorter chronological gaps of 100 ka in length (i.e., 1.5–1.4 Ma, 1.3–1.2 Ma, 1–0.9 Ma, and 260–120 ka) (Figure 7a, Table 1). Thus, though the Nihewan Basin is often conceived of as a long, and continuous hominin record, considerable gaps are evident, calling into question the permanency of occupation. The reasons underlying these chronological gaps in the archeological record may be complex and multiple, including the lack of archeological research, site visibility, preservation conditions, and dating limitations. It has been pointed out that the absence of archeological sites in the Nihewan Basin during particular times, and indeed throughout portions of Eurasia, may be a consequence of highly seasonal and cold conditions in northern latitudes.^{124,125}

With respect to the earliest possible gap in the Nihewan record, the recent publication of the Shangchen site at ~2.1 Ma in Central China is of importance,³³ as it is 400 ka older than Majuangou III at

~1.66 Ma, if we assume that the paleomagnetic age estimates are correct. Based on the presence of the long lacustrine sequences in the Nihewan Basin, it is entirely possible that older archeological sites will be located, as sediments and mammal fossils extend to more than 3 Ma in the basin, and include finds of horse (*Hipparion*) and rhinoceros (*Chilotherium*).⁵² Early deposits extending to between 1.7 and 3 Ma have not been seriously investigated for archeological sites, calling attention to the need for new surveys in Late Pliocene deposits to assess if the record before 1.7 Ma is a real gap in the paleoanthropological record.

The longest gap in the Pleistocene archeological sequence occurs between ca. 780 ka, at the Matuyama–Brunhes geomagnetic reversal, and ca. 400 ka (Figure 7a). The absence of hominins in the region cannot account for this significant chronological lacuna, as sites in this time frame are found in other places in China, such as Zhoukoudian, 130 km to the southeast, and Chenjiawo (Lantian), 800 km to the southwest, where fossils of *H. erectus* have been recovered.^{126,127} The lack of archeological evidence in the Nihewan Basin has been interpreted to be the consequence of either the lack of archeological investigations or to a dry environment at the time.⁴⁵ After the MPT and into the Middle Pleistocene, the length and intensity of the glacial–interglacial cycles significantly increased, with the dominant periodicity of high-latitude climate oscillations changing from 41 ka to 100 ka (Figure 7d),^{118,119} indicating that cold and dry glacial periods became longer. As the Nihewan Basin is located in a high northern latitude, the regional and local environments were harsh and highly seasonal, which presumably influenced hominin settlement patterns.

Four shorter 100 ka-long chronological gaps occur in the Nihewan Basin, three in the Early Pleistocene and one at the transition between the Middle and Late Pleistocene. The chronological gaps in the Early Pleistocene sequence may be the result of limitations with paleomagnetic dating, as the specific ages of site occupations cannot be precisely identified. The terminus of the Middle Pleistocene occurs before the major increase in site counts in the Late Pleistocene. One explanation rests on the large-scale changes from a paleolake to an alluvial setting, though this hydrological changeover occurred at an earlier date, so it may not be the sole reason for the site gap. Another alternative is that there were substantive changes in hominin demography, with archaic populations on the decline at the end of the Middle Pleistocene, and *H. sapiens* populations on the increase in later periods.

In sum, and as frequently stated in the literature, the Nihewan Basin is an ideal setting to examine the behavioral evolution of hominin populations in Eastern Asia based on the abundance of archeological sites over the long term and the good to excellent preservation conditions of many sites. Yet, increased scrutiny needs to be paid to understanding the ecological settings of sites in the basin, to site formation and taphonomy, and changes in hominin behavior over time. And, indeed, there is a need to conduct high-precision interdisciplinary field work to understand hominin adaptations to northern latitudes and to determine how climatic fluctuations and changes in environments influenced hominin expansions, contractions, and extinctions over the long term. As hopefully demonstrated here, the

research potential of the Nihewan Basin and surrounding regions is unparalleled in Eastern Asia, allowing for an exploration of many key topics in human evolutionary studies.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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