ARCHAEOLOGY

The earliest human occupation of the high-altitude Tibetan Plateau 40 thousand to 30 thousand years ago

X. L. Zhang[1,2], B. B. Ha[3], S. J. Wang[1,2], Z. J. Chen[3], J. Y. Ge[1,2,4]*, H. Long[5], W. He[3], W. Da[6], X. M. Nian[7], M. J. Yi[8], X. Y. Zhou[1,2,4], P. Q. Zhang[1,2,4], Y. S. Jin[1,2,4], O. Bar-Yosef[9], J. W. Olsen[10,11], X. Gao[1,2,4]*

The Tibetan Plateau is the highest and one of the most demanding environments ever inhabited by humans. We investigated the timing and mechanisms of its initial colonization at the Nwya Devu site, located nearly 4600 meters above sea level. This site, dating from 40,000 to 30,000 years ago, is the highest Paleolithic archaeological site yet identified globally. Nwya Devu has yielded an abundant blade tool assemblage, indicating hitherto-unknown capacities for the survival of modern humans who camped in this environment. This site deepens the history of the peopling of the "roof of the world" and the antiquity of human high-altitude occupations more generally.

The Tibetan Plateau (TP) is the highest and one of the most challenging environments inhabited by humans because of its perennial cold temperatures, low biomass productivity, and the dangers of hypoxia. As one of the last terrestrial environments occupied by humans (*1*), the timing and mechanisms of its colonization are of great interest. To date, there has been no concrete evidence of humans inhabiting the interior of the plateau before the Holocene, and only a few Paleolithic sites have been discovered around its margins (*2*–*8*) (fig. S1 and table S1).

Here, we report on our investigation of the Nwya Devu (ND) site located 4600 m above sea level (masl) in central Tibet and dated to at least 30 thousand years (ka) ago, making it the highest Pleistocene-age site yet identified (*9*). This discovery deepens considerably the history of human occupation of the TP and the antiquity of human high-altitude (>4000 masl) adaptations and encourages further investigation of the possibility that Denisovan-related DNA may have played a role in enabling Tibetans to live on the high plateau (*10*).

The ND site was discovered in 2013 during archaeological investigation of the eastern Changtang region in northern Tibet, which averages 5000 masl. The site is situated south of Siling Co and Co Ngoin lakes, ~300 km northwest of the Tibet Autonomous Region capital, Lhasa (Fig. 1), encompassing an area of ~1 km east-west by 2 km north-south. Thousands of stone artifacts made of black slate lie on the surface. In 2013 and 2016 to 2018, we carried out archaeological excavations and geological sampling to explore the site's taphonomy and the distribution of subsurface artifacts (materials and methods 2).

The ~170-cm-thick ND sedimentary sequence is situated on a terrace of Co Ngoin Lake, which has a surface elevation of ~4600 masl. This sequence can be divided into three layers from top to bottom (Fig. 2A). The 10- to 30-cm uppermost layer is composed of pebbly silt and fine sand. Many stone artifacts and some brecciated sediments were discovered on its surface. A 50- to 80-cm-thick stratum of well-sorted fine sands containing some angular gravel lies unconformably beneath Layer 1. In this horizon, a few channels filled with clast-supported boulders with a sandy matrix were observed, indicating temporary and swiftly flowing water. Additional features include periglacial involution, wind-eroded potholes, and pebbles densely distributed on the unconformity between Layers 1 and 2, suggesting long-term erosion under cold climatic conditions. Layer 3 comprises a sequence of alluvial deposits that consist mainly of sandy gravels enclosing shells of freshwater mollusks. Here, interlaced scouring channels developed extensively and were filled with highly weathered, silty, fine sands containing breccia, indicating strong erosion caused by high-energy water flow due to markedly warmer and more-humid conditions. A weathered and undulating unconformity capping Level 3 also indicates robust erosion associated with a wetter climate.

Anthropogenic stone artifacts have been recovered from the upper 138 cm of the sequence, including 3124 artifacts in Layer 1, 223 in Layer 2, and 336 from Layer 3. The Layer 2 artifacts were found mainly in channels but were almost absent in the fine sands that constitute the main body of this layer. No obvious typological, technological, or morphological differences can be detected among artifacts from these three discrete layers (tables S2 and S3), though more small pieces were discovered in Layer 1. We conclude that all artifacts discovered in the excavation

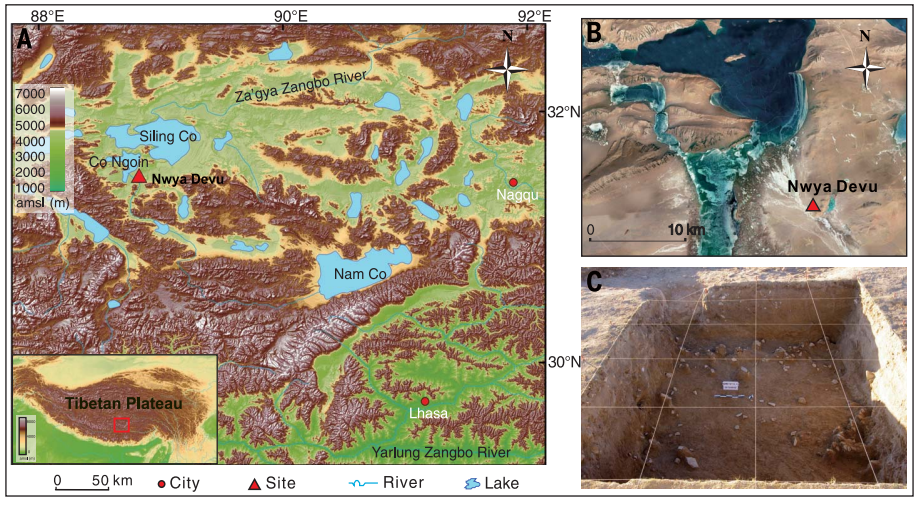

Fig. 1. The location of the ND site and excavation unit. (**A**) Regional map showing the location of the site. (**B**) Location of the site in relation to Co Ngoin and other large lakes. (**C**) Artifact distribution in Layer 3. Digital elevation model data for (A) from http://vterrain.org/Elevation/global.html. Satellite imagery for (B) courtesy of Google Earth.

[1]Key Laboratory of Vertebrate Evolution and Human Origins, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China. [2]CAS Center for Excellence in Life and Paleoenvironment, Beijing 100044, China. [3]Tibetan Cultural Relics Conservation Institute, Lhasa 850000, Tibet Autonomous Region, China. [4]University of the Chinese Academy of Sciences, Beijing 100049, China. [5]State Key Laboratory of Lake Science and Environment, Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, Nanjing 210008, China. [6]Nagqu Prefecture Cultural Relics Bureau, Nagqu 852000, Tibet Autonomous Region, China. [7]State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai 200062, China. [8]School of History, Renmin University of China, Beijing 100872, China. [9]Department of Anthropology, Harvard University, Cambridge, MA 02138, USA. [10]School of Anthropology, University of Arizona, Tucson, AZ 85721, USA. [11]Institute of Archaeology and Ethnography, Siberian Branch, Russian Academy of Sciences, Novosibirsk 630090, Russian Federation.
***Corresponding author. Email: gaoxing@ivpp.ac.cn (X.G.); gejunyi@ivpp.ac.cn (J.Y.G.)**

constitute a single assemblage, and Layer 3 is the primary cultural horizon. Artifacts found in the upper two layers are likely the result of reworking during the postoccupational formation of the site.

Because of the paucity of organic remains suitable for radiocarbon dating, the site's chronology was constructed mainly using optically stimulated luminescence (OSL) techniques (*11*). A total of 24 OSL dates for samples from three sections in the excavation unit (Fig. 2A) provide bracketing ages for the artifacts (table S4 and materials and methods 4.2).

In each section, OSL ages are generally consistent with stratigraphic order when taking standard deviations of age into account, and their chronostratigraphy is similar (Fig. 2B). The results show that the ages of Layer 1 range from ~13 ka to ~4 ka, suggesting a Holocene horizon. The accelerator mass spectrometry (AMS) ^{14}C dating of freshwater mollusk (*Gyraulus* sp.) shells from the bottom of Layer 1 (Fig. 2A) yielded an age of ~12.4 to 12.7 ka before the present, close to OSL dates generated from the same level (table S5), confirming the reliability of OSL dating. Chronometric ages for Layer 2 fall within a narrow range of ~25 to 18 ka, indicating deposition or reworking during the Last Glacial Maximum, which is consistent with our field observations and subsequent assessment of the prevailing climatic conditions at that time. Layer 3 yields ages of ~45 to 30 ka, in accordance with the AMS ^{14}C dating of mollusk shells (Fig. 2A, table S5, and materials and methods 4.1). On the basis of the OSL chronologies of the three sequences and two additional radiocarbon dates, the initial date of occurrence of stone artifacts at ND is estimated to be ~40 to 30 ka ago.

A total of 3683 stone artifacts were recovered from excavated layers over an area of 20 squares that measured 1 m by 1 m. The lithic assemblage includes blade cores, flake cores, blades, flakes, chunks, and tools (Fig. 3, figs. S2 to S6, table S2, and materials and methods 5). A distinctive feature of the assemblage is the production of blades and blade tools. Such blades were made from prismatic cores rather than Levallois cores, and most of the blades were detached from the cores' long, narrow faces (figs. S2 to S5 and table S6). Unidirectional flaking dominates the assemblage (72 of 91 pieces). Blade size varies considerably (table S7). Retouched tools include scrapers, awls, choppers, notches, and burins. Finely retouched formal pieces are rare, and most modification is expedient. All artifacts were produced from black slate derived from an outcrop on Nwya Devu Hill (figs. S7 and S8), ~800 m east of the excavation area. Considering the high ratio of debitage, the low number of curated tools, the size of the site, and its near proximity to the raw material source, we suggest that this site was a workshop where early Tibetans procured and knapped lithic material. No faunal remains, hearths, or structures have yet been uncovered.

ND is the first excavated stratified Paleolithic site in high-elevation Tibet. The extreme environment characterized by a pervasively cold, dry climate and atmospheric hypoxia presumably greatly constrained early human settlement in the region. The previous absence of reliably dated Paleolithic sites from the central TP (fig. S1 and table S1) led some archaeologists to propose that humans first colonized altitudes above 4000 masl only during the Holocene (*12*) or slightly before the Pleistocene-Holocene transition (*13*). Genetic studies imply different periods of human migration to the plateau, including the Neolithic and the late Paleolithic (*14*–*17*), and some genetic continuity between Tibet's initial Ice Age inhabitants and its modern indigenous population has been suggested (*15*). The age and typological characteristics of the lithic assemblage at ND indicate that modern humans bearing an advanced blade technology occupied this high-altitude area at least ~40 to 30 ka ago. This evidence establishes a record for the prehistoric conquest of this high-altitude environment, much earlier than current

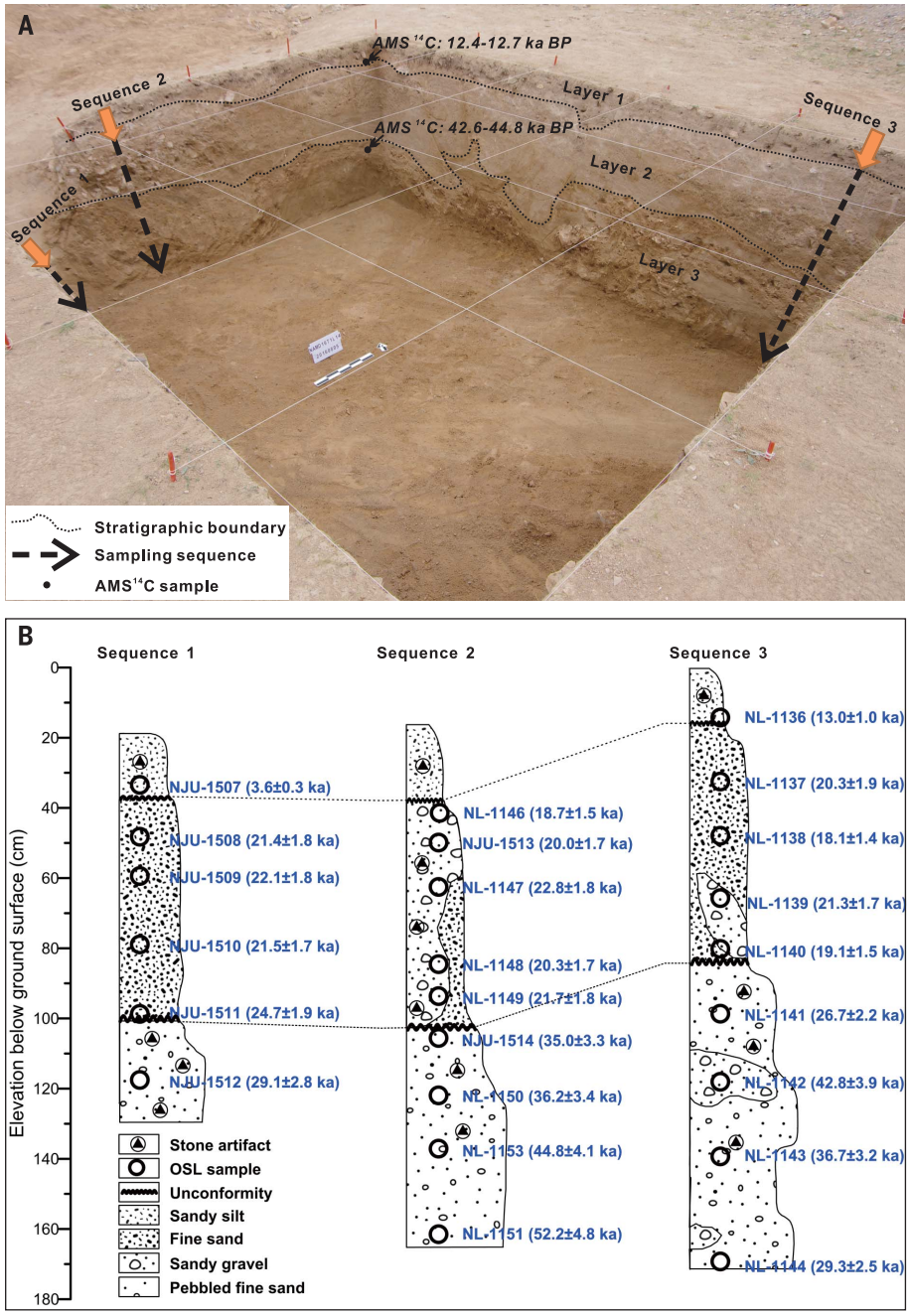

Fig. 2. Stratigraphic correlation of three sedimentary sequences and the position of OSL and AMS samples. (**A**) Diagram of sedimentary sequence and stratigraphic divisions at the site. Radiocarbon ages were determined after reservoir effect correction. (**B**) Stratigraphic correlation and OSL ages of three sequences.

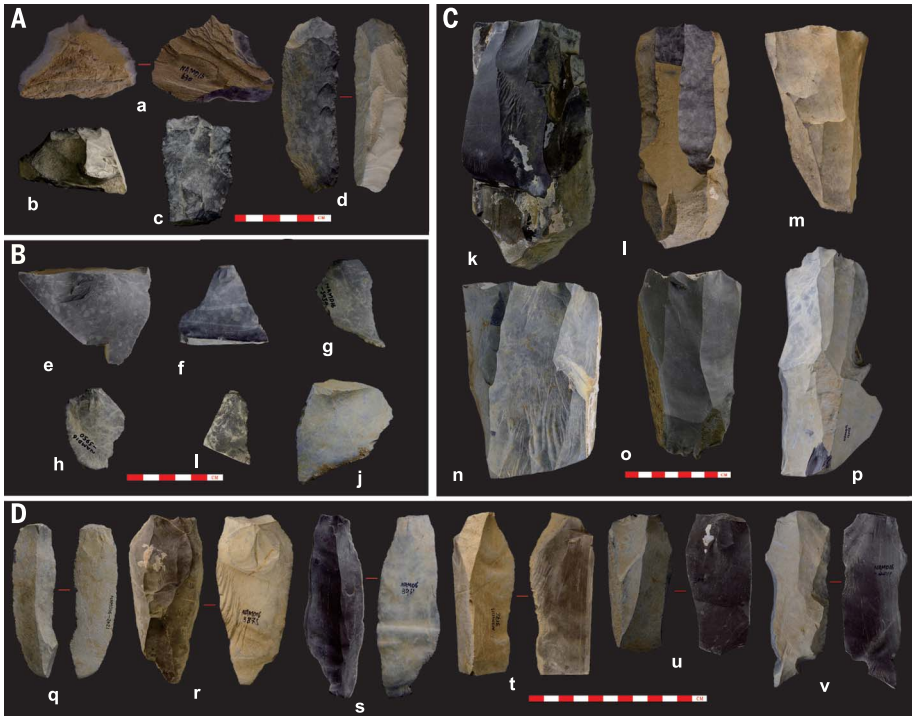

Fig. 3. Lithic artifacts unearthed at ND. (**A**) Tools. (a and b) Awl and side scraper, Layer 1; (c and d) side scrapers, Layer 3. (**B**) Flakes. (e and f) Layer 1; (g and h) Layer 2; (i and j) Layer 3. (**C**) Blade cores. (k and l) Layer 1; (m) Layer 2; (n to p) Layer 3. (**D**) Blades. (q) Layer 1; (r and s) Layer 2; (t to v) Layer 3.

evidence from the Andes for high-altitude colonization there suggests (*9*).

How did early humans respond to the combined stressors of hypoxia and scarcity of resources on the "roof of the world?" This occupation event in Tibet occurred during late marine isotope stage 3 (*18*), when ecological conditions on the high plateau were similar to or better than those today, thus allowing foragers to make repeated seasonal usage of the area for acquisition of lithic material and other resources. Meanwhile, the *EPAS1* gene region is thought to help reduce hypoxia in Tibetan populations, and the presence of this gene may be due to an infusion of DNA from Denisovan-related individuals (*10*). Hence, the environmental, genetic, and archaeological data complement one another, yielding a model for early Tibetan adaptation to the high plateau that combines biology and technology.

The abundance of prismatic blade cores at ND is nearly unique in China. Similar technocomplexes have been found at only a few sites in North China (*19*, *20*). Technologically, this lithic assemblage most closely resembles those classified as Early Upper Paleolithic in Siberia and Mongolia (*21*). On the basis of the typological similarities of the stone assemblages and hypotheses concerning the introgression of hominin ancestors, it is possible that early humans from Tibet and Siberia interacted at least 40 to 30 ka ago. Because Denisovans contributed 4 to 6% of their genetic material to the genomes of present-day Melanesians and may have been widespread in Asia during the late Pleistocene (*22*), the TP may be one region through which humans with Denisovan DNA diffused to the south, contributing an enhanced ability to adapt to the rigors of the hypoxic high-altitude environment.

The timing and dynamics of the permanent human settlement of the TP have generated much debate (*1*–*3*, *8*, *13*, *15*–*17*). Whereas some have argued that permanent occupation of the Earth's third pole was a relatively recent occurrence in which agriculture played a key role (*3*), others have suggested that biological adaptation to the plateau and its harsh environment required a much longer history and substantial period of residence (*1*, *23*), and a series of tentative trial steps must have been taken before successful adaptation was achieved (*12*). The discovery of the ND site, dated to at least 30 ka ago, has helped lift the curtain on this episode in the lengthy history of human exploration and colonization of the TP.

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SUPPLEMENTARY MATERIALS

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Materials and Methods
Figs. S1 to S18
Tables S1 to S10
References (*24*–*72*)

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Paleolithic occupation of Tibet

Human colonization of the high-altitude Tibetan Plateau has generally been thought to have been confined to the past few thousand years of the Holocene. Zhang *et al.* report an investigation of the Nwya Devu archaeological site in central Tibet, 4600 meters above sea level, with Paleolithic occupation dates of ~40 thousand to 30 thousand years ago (see the Perspective by Zhang and Dennell). The site has yielded a range of stone tools, indicating the adaptive ability of early modern humans to the harsh environment of the "roof of the world." The findings also suggest that people from Tibet and Siberia may have interacted at this time.

Science, this issue p. 1049; see also p. 992