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Short Communication

The peopling of the hinterland of the Tibetan Plateau during the late MIS 3

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Reaching the Tibetan Plateau is notoriously challenging due to its high elevations and the surrounding mountain ranges. Considering environmental pressures such as low temperatures and precipitations, patchy resources, and especially hypoxia, continued survival in the region requires both biological and behavioral adaptations. This is probably why for a long time the Plateau was considered among the last regions occupied by human beings. Coping with such a harsh environment was once viewed as a behavior unique to *Homo sapiens* (modern humans) [1]. New discoveries have challenged these ideas, suggesting archaic hominins such as Denisovans arrived as early as the Marine Isotope Stage 6 (MIS 6) [2]. In terms of the hinterland, the site of Nwya Devu (ND) offers evidence for human activities extended back to late MIS 3 [3]. The archaeological record of this highland contains multiple occupation episodes by archaic human populations and modern humans in the Plateau from late Pleistocene to Holocene [4,5]. However, current evidence of early human occupations remains sparse and fragmented to fully address questions regarding the timing, frequency, and process of high-altitude adaptations.

From an archaeological perspective, full-scale excavations are critical to understand how humans adapted their behaviors to the extreme environment in high altitudes. High-resolution archaeological data are needed to discuss the issues such as subsistence strategy, settlement patterns, and technological evolution of hunter-gatherers in the highland. However, to date most Pleistocene sites in the region are known only from survey/test-pits [4]. ND is one of the a few exceptions, with a large lithic assemblage which was systematically excavated and dated [3]. Located in the highland hinterland, it reflects human occupation of the region had reached the elevation of 4600 m above sea level (m asl) starting from as early as 40 ka, which was once thought to only occur much later in the Holocene [4,5]. Another unique feature of ND is the appearance of a blade technology, which is rarely found in East Asia but well documented in the Eurasian Steppe during the MIS 3 (Fig. 1) [1,6,7]. As a result, this site plays a pivotal role in studying human adaptations to high altitudes and in investigating the population movements and the spread of blade technology in eastern Asia of the period.

In Europe and West Asia, the dispersal of *H. sapiens* corresponds to a suite of behavioral changes observed in the archaeological record during the MIS 3 [1]. Along with widespread use of formal bone tools, personal ornaments, art, and socio-economic changes, the technological shift to systematic blade/bladelet productions adds to the behavior package that is associated with the appearance of our species in Eurasia [1]. While not all these innovations occur in East Asia, stone tool traditions seem to follow a different evolutionary pathway. Although we found blade assemblages at ND and another excavated site, Shuidonggou (SDG) [8], MIS 3 assemblages in China are generally described as a "core and flake" industry, lacking formal retouched tools and a genuine blade/bladelet production [7]. Therefore, instead of a local origin, blade assemblages at ND and SDG may be related to the Steppe in the north, where a concentration of the specific blade assemblages known as the Initial Upper Paleolithic (IUP) industry and consecutive laminar technologies are found [6,9]. The IUP assemblages and contemporaneous *H. sapiens* remains are considered evidence for an early inland northern route of modern human dispersal into eastern Asia [10]. The blade assemblage at ND is consistent with this dispersal process, considering its age and location. Therefore,

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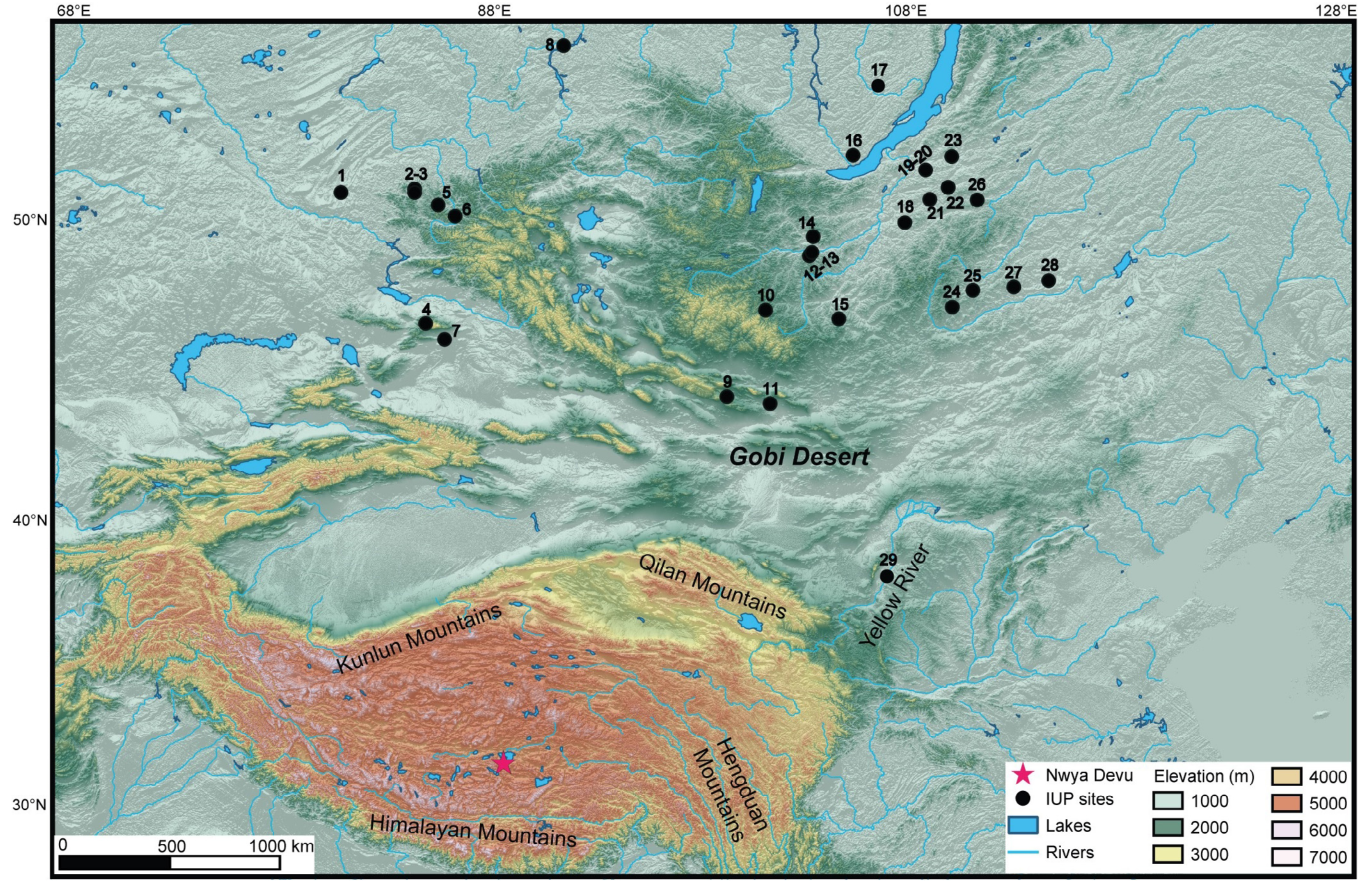

Fig. 1. The distribution of Nwya Devu and IUP sites. 1, Kara-Tenesh; 2, Denisova Cave; 3, Ust'Karakol; 4, Ushbulak; 5, Kara-Bom; 6, Luotuoshi; 7, Malo Yaloman Cave; 8, Kurtak 4; 9, Chikhen 2; 10, Tsatsyn Ereg; 11, Tsagaan Agui; 12, Tolbor 16; 13, Tolbor 4; 14, Egiin-Gol; 15, Moyl'tynam; 16, Arembovski; 17, Makarovo 4; 18, Podzvonkaya; 19, Kamenka A; 20, Kandabaevo; 21, Vavarina Gora; 22, Tolbaga; 23, Khotyk; 24, Khanzat-1; 25, Rashaan Khad; 26, Barun-Alan; 27, Khavsgayt (and Salkhit); 28, Otson Tsokhio 16–18; 29, Shuidonggou site.

in broad anthropological terms, an analysis of ND assemblage could shed light on the human occupation history of the Tibetan Plateau. It is also relevant to understand large-scale population movements, such as the expansion of our species, in eastern part of Asia.

Here, we analyzed a sample size of 3683 stone artifacts from ND site, including flakes, blades, bladelets, cores, tools, and chunks that were unearthed from three sediment layers, and the primary deposition of Layer 3 is dated back to 40–30 ka BP by Optically Stimulated Luminescence dating [3] (Text S1 and Table S1 online). Based on the analysis (Text S1 and Tables S1–S4 online), we note that except for a smaller average size of artifacts in Layer 1, lithic productions at ND are relatively consistent across layers. First, stone artifacts at site are all made from the local fine-grain slate located nearby, and the reduction sequence reflects two production modalities at site: laminar productions (mostly blades and a very small portion of bladelets) and flake productions (Table S2 online). The former is clearly dominant, with up to 70% cores associated with the laminar reduction. Second, according to scar patterns, unidirectional removal is the most common blank reduction method, with additional observations of other patterns, such as bidirectional, perpendicular, multi-direction removals (Fig. S1: 1–8 online). There is a proportion of blade production at site that takes the advantage of natural ridges or narrow-shaped sides to guide removals producing naturally elongated blades (Fig. S1: 1 online). Third, tool modification at site is about 2.7% (N = 99) (Fig. S1: 21–27 online), including mainly sidescrapers and a small number of notches, end scrapers, perforators, denticulates, burins, and retouched pieces. These tools overall show a low retouch intensity and low-angled retouch scars. Additionally, although core management is not common, the occasional use of crests, debordant removals, and core tablets suggests a controlled production of blades (Fig. S1: 9–14, 18, 19 online), which represents a genuine example of blade production with the Upper Paleolithic features.

The discovery of ND reveals that the peopling of the hinterland of the Plateau, up to the elevation of about 4600 m asl, is as old as the late MIS 3 and much earlier than previous believed [4]. Further detail studies about site function and technological organization of ND assemblages are important to better understand the adaptive process that how the human groups coped with the harsh high elevation condition. The blades appear to be brought up by hunter-gatherer groups to the highland during a climate alleviation, because studies show that late MIS 3 is relatively warm and humid period [11]. This might be one of the major reasons that enables the early hunter-gatherers to reach the interior area of the high-altitude Plateau. However, being the only blade site that has been excavated in the Plateau and without other comparable assemblages, there is no evidence to support a "transition" or a local origin of the technology within the highland. This absence of local antecedent for blade technology points towards an exotic origin from lowlands. In adjacent lowlands, blade assemblages of similar age are also extremely rare (Text S2 online). For instance, in Southeast Asia and the most East Asia, there is a persistence of the chopper-chopping tool industry or core and flake technology during the Pleistocene [7]. To the north of the Plateau, Taklamakan Desert lacks evidence for Pleistocene human activities. Therefore, the blade technology documented at ND not only is unique in the highland, but also remains rare in most of the neighboring lowlands.

Geographically and technologically, the closest analogue of the blade technology at ND is SDG in North China. The exceptional presence of such material at SDG is commonly accepted to be associated with the assemblages found in the steppe-taiga and intermountain landscape of south Siberia and Mongolia [6,9,10], where contemporaneous Upper Paleolithic blade sites have been widely distributed (Fig. 1). The major features of blade reduction at ND show generic Upper Paleolithic features that are in line with some key features of the blade assemblages at SDG and in the Steppe. Thereby, we highlight a technological association between the laminar traditions from ND, SDG, and sites of North Asia. While we also acknowledge that there are still some unresolved questions for this association. The connection of SDG and the IUP of the Steppe in the strict sense is still under testing, and these assemblages may differ in some details of lithic productions [12]. There are also concerns regarding inconsistencies for the definitions used to describe the IUP [9]. In some regions, a succession of laminar traditions with different reduction methods occurs between 48 and 30 cal ka BP [13]. Therefore, it is possible that several migrations may have happened between these regions during the period. Even though we propose to narrow down geographic origins of the blades at to the north, it appears premature to conclude an exact ancestor for it at this point.

In this study, we focus on the well-recorded IUP assemblages which are currently the earliest volumetric blade productions in North Asia. Although the resolution of chronological data is coarse with different methods and labs involved, we note a chronological trend for the blade assemblages dated between 48 and 30 cal ka BP from the Siberian Altai and North Mongolia to East Asia (Tables S5 and S6 online; Fig. 2a). As such, there seems to be a directional spread of the blade technology with the appearance of the blades in North Asia as early as 48 to 45 cal ka BP, to North China around 41 cal ka BP, and then to the Tibetan Plateau about 40–30 ka BP, during a relative warm and humid interglacial in the MIS 3 [11]. Furthermore, Upper Paleolithic blade technology is considered an archaeological proxy for *H. sapiens* dispersal because of its critical role in a widespread human behavioral package during the MIS 3 in Eurasia [1,10]. In addition, the *EPAS1* gene, which has a strong positive selection signal in present-day Tibetans, has been identified highly similar to the haplotype of the Altai Denisovan and was suggested to be transmitted to East Asian ancestors in lowland around 48 ka [14]. All in all, multiple lines of evidence converge towards a compelling, yet hypothetical scenario. The blade assemblages of SDG and ND were potentially made by *H. sapiens* populations and brought to East Asia during the expansion from the Steppe zone around 48–30 ka; the *EPAS1* haplotype was also passed to early East Asians along the movements. We cautiously suggest that directional dispersals from the Steppe to the Tibetan

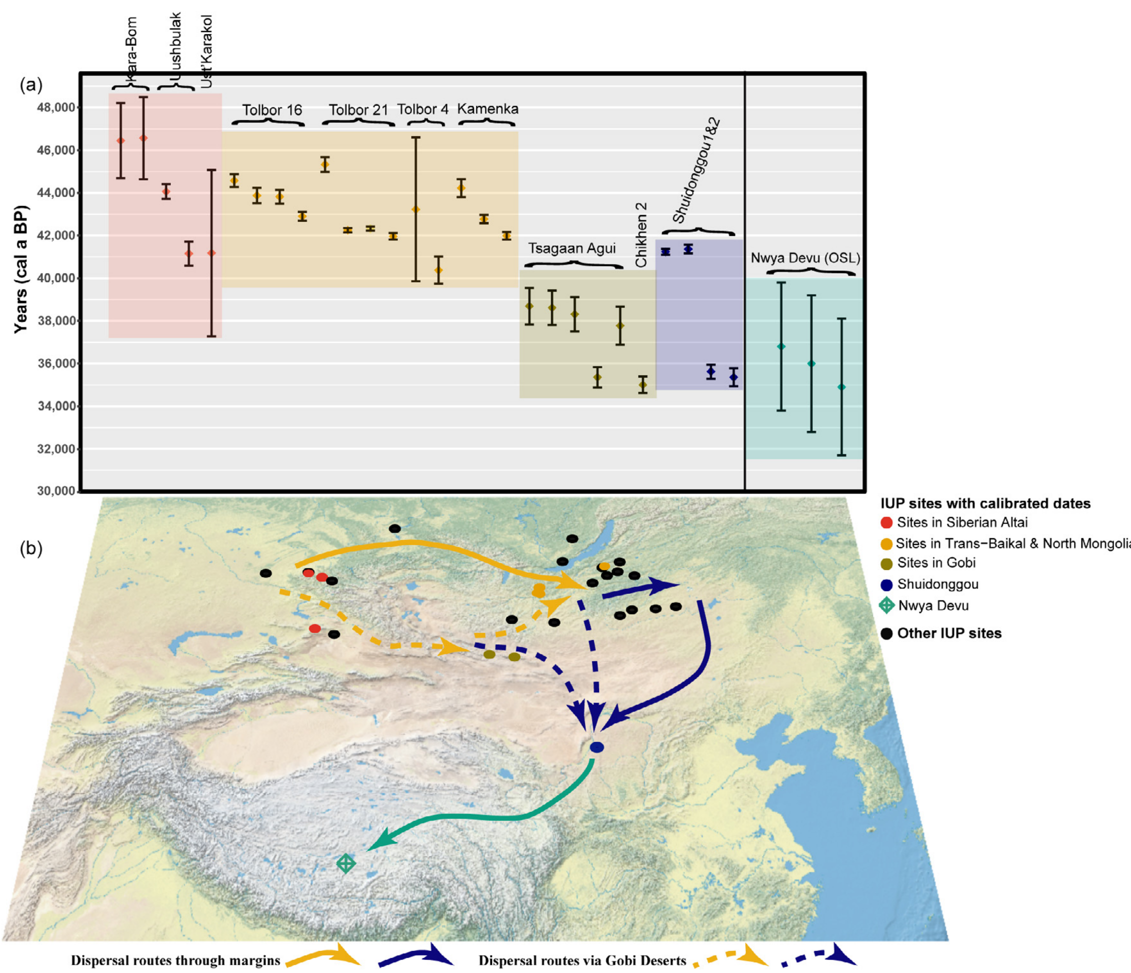

Fig. 2. The hypothetical dispersal routes of the blade technology and related human populations. (a) Chronological dates of the representative sites in this study (Tables S5 and S6 online). (b) The proposed migration routes of hunter-gatherers who was equipped with the blade technology from North Asia to North China and to the Tibetan Plateau: dotted lines are possible routes cutting through the Gobi Desert; the solid lines are possible routes bypassing the Gobi Desert moving around the margins.

Plateau is the most parsimonious way to explain the existing data regarding the appearance of the blade assemblages in eastern part of Asia.

In this scenario, the blade technology was likely brought from Siberia and/or Mongolia by a long way up to the Tibetan Plateau as an intrusive element. Along this distant expansion, hunter-gatherers would have experienced diverse landscapes and many physical barriers, such as high elevation and the mountain ridges of the Plateau in particular. Therefore, investigating how hunter-gatherers overcame the constraint of the physical geography is essential to understand the process to reach the highland hinterland about 4600 m asl. The study about how humans moved on these geographic landscapes is fundamental and critical in this case. Hence, we used Least Cost Path (LCP) analysis to obtain least-cost migration routes based on terrain slope from topography and geography of these regions (Text S2 online), which are informative for studying the accessibility of the Plateau and human movements in the region. Given current studies of the technological sequences from SDG, Siberian Altai, and North Mongolia, it is unclear about the exact technological origin for ND blade technology. We ran LCP simulations to generate optimal routes to ND site from the three possible regions (Text S2 and Fig. S2a–c online). We also examined the routes leaving the Plateau from ND under conditions of 1, 8, 16 direction(s) available because it is useful to explore alternative routes if there were in the absence of known original sites and to test the consistency with those routes reaching ND site (Text S2 and Fig. S2d–f online).

According to geographic distribution of blade assemblages and the LCP results, we note SDG lays at a strategic position in the route up to the Plateau. In our model, under all possible LCP scenarios, this site connects ND with the two distant hubs of the blade technology by a route along the Yellow River from south Qaidam Basin (Fig. 2 and Fig. S2 online). Additionally, this path generally overlaps with the optimal route to leave the Tibetan Plateau from ND site (Fig. S2 online). On the other hand, the route from the north of Qaidam Basin remains highly possible since according to current archaeological data, the northeast Plateau is the earliest and most occupied area in this highland [4,5]. In a broader scale, our LCP simulations generated two shortest pathways from the possible origins in the Steppe belt (Fig. S2 online). One starts from the Siberia Altai, passing the south of Gorny-Altai mountains, to North China and finally to the Plateau. The other one connects the Tibetan Plateau and North China to the Selenga River basin of North Mongolia. Both routes would have cut through the Gobi Desert under models where only topography is considered (Fig. 2b and Fig. S2 online). However, the Gobi Desert is an extremely inhospitable environment due to the lack of water, food, and other natural resources, and therefore means stronger selective pressures on hunter gatherers than moving in other landscapes. The two shorter routes might be approachable under conditions with melting glaciers and a string of ephemeral lakes during temperate climates [15], meaning these routes might be only available in certain periods. Instead, according to the distribution of archaeological sites and previous studies (Fig. 1) [15], other options moving around the margins of the Gobi Desert could have been more attractive and accessible for the great majority of time despite of the longer travel distance (Fig. 2b). Currently the latter is also more consistent with a higher site density in the trans-Baikal, North Mongolia, and even East Mongolia than in the Gobi Desert. While there is a potential west route linking the south Central Asia with the north of Tarim Basin (south of Tianshan) to North China [15], more evidence is needed to confirm the IUP or related technologies in these regions.

To summarize, ND documents a novel technology in the Tibetan Plateau, with a generic Upper Paleolithic blade technology dated as early as 40,000 years ago. Located near raw material source, the assemblages indicate a low investment in preparation and maintenance and low reduction intensity. The lack of plausible antecedents within the highland and the most adjacent lowlands points to a scenario of exogenous origin for the technology. The peopling of the highland hinterland and the transmission of the technology may connect with the expansion of *H. sapiens* populations in lowland areas during the MIS 3. Based on archeological records, chronology, and LCP simulations, the blade technology at ND is closely associated with SDG in North China and comparable MIS 3 blade assemblages found in the Siberian Altai and North Mongolia. There are two possible scenarios for the arrival of the technology and related populations at ND from the Steppe belt. The shorter paths cut through the Gobi Desert, but which are probably only approachable during prominently temperate climates. On the other hand, the routes bypassing the Gobi Desert would have been preferred by hunter-gatherers mostly while considering the inhospitable environment of the desert. Due to limited data, these proposed routes above are all hypothetical at this point, which would be instructive to design and develop future archeological studies and paleoclimate reconstructions to validate or invalidate it. The dispersal is also worth being tested by systematic and inter-region comparisons on blade assemblages from these regions to identify a precise origin for the blade technology.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgments

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Author contributions

Peiqi Zhang and Xiaoling Zhang designed the study. Peiqi Zhang, Xiaoling Zhang, Wei He, Yingshuai Jin, Junyi Ge, Dawa, and Shejiang Wang conducted the research. Peiqi Zhang and Xiaoling Zhang wrote the manuscript. Linhui Li, Nicolas Zwyns, and Xing Gao revised the manuscript.

Appendix A. Supplementary materials

Supplementary materials to this short communication can be found online at https://doi.org/10.1016/j.scib.2022.11.008.

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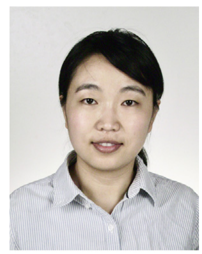

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