[Supplementary material]

Neolithic pathways in East Asia: early sedentism on the Mongolian Plateau

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Site descriptions

West Liao River Valley

Baiyinchanghan is located in Linxi county on the slopes of a southern extension of the Great Khingan range (Figure 1:1). An area of 7264.3m^2 has currently been excavated. Archaeological deposits belong to five different cultural phases, namely (from earliest to latest): Xiaohexi, Xinglongwa, Zhaobaogou, Hongshan and Xiaoheyan. All periods contain evidence of pit dwellings, except Xiaoheyan, for which only midden deposits were recovered. Xiaohexi cultural deposits represent the earliest phase of occupation. No radiocarbon dating samples were found from the Xiaohexi deposit of the Baiyinchanghan site. Chinese archaeologists estimate that Xiaohexi cultural period ranges between 8.5–8.2 ka cal BP based on the observation that it is earlier than Xionglongwa culture, which thrived in this region after 8.2 ka cal BP (Zhao *et al.* 2014), although recent excavations and direct dates for the Xiaohexi site Jiajiagou indicate that the site was occupied at 7.9–7.75 ka cal BP (Shelach-Lavi *et al.* 2019). Three houses and two middens from this period were excavated from west part of Zone B. From the Xiaohexi to Xinglongwa phases, there is expansion of the settlement and an increase in population. Only Xinglongwa-period dwellings are extensively distributed across the site area and they are distinct in their well-planned layout and dense distribution. The associated cultural remains are richer compared to later periods, indicating that the settlement was most intensively used during the

Xinglongwa phase. Only two radiocarbon samples from this phase have been dated (Table S1). Based on regional comparisons of dates across multiple sites, it is estimated that Baiyingchanghan was occupied between 8.2 and 5.0 ka cal BP (Neimenggu 2004).

Houses are distributed in two adjacent settlements which are surrounded by trenches, juxtaposed on the same slope with two separate cemeteries located on the hilltop (Neimenggu 2004). Rectangular semi-subterranean houses are laid out in neat rows within the settlement. Fifty-six houses were excavated, including all houses from Zone A and most of the houses in the west and southwest portions of Zone B (Figure 3A). Most of the houses had one hearth in the middle surrounded by stone slabs (Figure 3B). The living floors were typically lined in clay and fired to create a hard layer. Seven houses had empty indoor pits thought to have been used for storage. Nine midden structures are located outside the houses, four of which are illustrated in Figure 2. Lithic assemblages (Figure 5) reveal the persistence (though low-level use) of microblade core reduction strategies. The site is more notable for an emphasis on heavy duty equipment, much of which can be associated with plant exploitation, including hoes and grinding stones (hand stones, grinding slabs, and pestles) (Table S2). Pottery was sand-tempered, low-fired, and friable. Most were handmade using the coiling method. Vessels are simple but with a greater variety of forms and decorations than during the Xiaohexi phase (Figure 7). The increased emphasis on manufacture and sophisticated decoration highlight increasing investment and variety in pottery-making. The prevalence of hoes and grinding equipment suggests that farming could have been an important part of local subsistence practices at Baiyinchanghan. This is indirectly supported by potential evidence for millet starch on grinding stones from this (Tao *et al*. 2011) and other contemporary sites (Liu *et al.* 2015a) , as well as the presence of wild and/or early domesticated millet at other Xinglongwa-period sites in the Liao River valley (Liu *et al*. 2015b; Shelach-Lavi *et al.* 2019), and evidence for domesticated millet in the Yellow River valley at 8.0–7.6 ka cal BP (Zhao 2011).

Although charred plant remains were not recovered, starch grain analysis suggests that grinding stones were used to process both millet and acorns (Tao *et al.* 2011). The importance of such plant foods is attested by the rich assemblage of milling stones at Baiyinchanghan which make up 33.60 per cent of the lithic assemblage (Table 2). Likewise, stone hoes comprise 27.67 per cent of the lithic assemblage and have been found in 22 of the 41 houses where artefacts were left on the living floor (Neimenggu, 2004). All animal remains were from wild individuals, although the pig (*Sus scrofa*) had already undergone domestication in North China (Neimenggu 2004; Cucchi *et al*. 2011). Deer comprise 87.20 per cent NISP of the assemblage (*Cervus elaphus*, *Cervus nippon*, *Capreolus pygargus*), complimented by aurochs, boar, and wild carnivores (bear, wolf, fox) (Table 1). Evidence of millet and acorn in starch profiles of grinding stones suggests a fall or winter occupation (Tao *et al.* 2011), while red deer (*Cervus elaphus*) skull fragments with shed antlers suggests site use in late winter to early spring (Neimenggu 2004). This does not exclude the possibility of year-round occupation.

Several contemporaneous village-like settlements have been found with similar dwelling structures and linear arrangement of houses: some are larger in scale, but most are of a similar or smaller scale (Zhao 2006). Most Xinglongwa-period sites are found in the hilly land of the West Liao river drainage, within the ecological transition zone between the Mongolian Plateau and the Northeast China Plain. Baiyinchanghan represents the best excavated example this deep in the Mongolian Plateau. The dual-settlement layout and the public cemeteries are unique features, with indoor burials more typical of Xinglongwa sites (Chen 2013). This difference may be chronological, as the one set of dates comes from the end of the Xinglongwa phase (Zhao 2006).

Hulunbuir Steppe

Hag is located on a river terrace close to the west bank of Hailar River and is surrounded by water in three directions (Figure 1:2). A total of 296m^2 have been excavated to reveal cultural deposits from three different periods. Layer 7 is the lowest cultural layer with dates falling between 8.5 and 8.0 ka cal BP (Table 1). The site was only used intermittently in later periods with all overlaying layers post-dating ~1.8 ka cal BP (Zhongguo *et al*. 2010) (Table S1). These later components are few and simple with dispersed scatters of artefacts and fauna and only two pit structures (from layers 6 and 4) (Zhongguo *et al*. 2010). Layer 7 has a much more complex site structure and more abundant remains. The one pit house excavated was 56.08m^2 (Figure 2A) with thirteen postholes distributed around the interior perimeter. A layer of shells >0.16m thick, found beneath the living floor, may have served to keep the floors dry and provide insulation. Twelve smaller pit structures, possibly middens or storage pits were found: one within the house and seven surrounding it. All pit features contained lithics, pottery sherds, and animal bones, except for one (H2), which one large stone slab. H14, located at the northwest of the house, was especially large and contained rich amount of bone, particularly fish (Zhongguo *et al*. 2010).

Tamsagbulag is located in Dornod province, Mongolia, 30–40km from the border of Inner Mongolia along the high southern bank of a former tributary of Buir Lake (Figure 1.3), just west of the extant three-headed spring (*bulag*) for which the site was named. In 1968 another rectangular pit dwelling was excavated at Ovoot, about 9km west of Choibalsan on the north bank of the Kherlen River (Figure 1:4) (Dorj 1971). These sites are the only Neolithic ones known in Mongolia with clear evidence for substantial site architecture (Janz *et al.* 2017). The numerous radiocarbon dates for Tamsagbulag indicate that the site was used 8.4–6.0 ka cal BP, and most intensively at 7.8–7.5 ka cal BP (Table S1).

Four rectangular semi-subterranean dwellings, one surface-dwelling feature, two burials, and several other features have been excavated. House 1 (7.6 × 5.6m) was the best preserved and like Hag has deep post-holes around the perimeter walls, lacks a doorway, and has substantial interior pit structures (Dorj 1971). The house floor was surrounded by a foundation trench 0.50–80m deep within which one row of posts was set as a structural complement to a second cluster of posts in the centre of the living floor (Figure 2B); these would have served as support for a pyramidal roof. Four large rectangular household pits over a metre long and up to 0.40m deep were filled with darker soils, flaking debitage, and bone. The burial of a young woman was found seated in a sub-floor pit at the north end of House 1 (Figure 4B) (Dorj 1971; Derevianko & Dorj 1992).

Deposits up 1m deep of highly organic soils within and outside houses suggest intensive site use. Dates from deposit TB9, excavated in 2018, indicate accumulation within about a century (Table S1). A surface-dwelling feature (TB1) excavated in 2018, less than a kilometre from the pit-dwellings, may indicate year-round site use with different types of structures related to warm and cool season occupations. This interpretation is supported by variation in faunal assemblages: small ungulates dominating TB1 while aurochs dominated around pit-dwellings. A similar pattern of house structure variation occurs in Osipovka-type sites (13 000–10 000 BP) in the Lower Amur River region (Tabarev 2014). Year-round use is also possible for Hag based on the association of both migratory heron (April–October) and foxes (winter for fur) (Zhongguo *et al*. 2010).

Fish (18.20% NISP) and birds (16.10% NISP) comprise a significant proportion of the Hag assemblage (seeTable 3), but Tamsagbulag shows an overwhelming emphasis on aurochs (*Bos primigenius*), complimented by khulan (*Equus hemionus hemionus*), horse (*Equus ferus*), boar

(*Sus scrofa*), gazelle, and hare (*Lepus tolai*). Large freshwater mussel shells (Unionidae) were distributed in low densities, and were used for ornaments and pottery temper. All body parts, whether high or low utility, are represented for large game, indicating that the animals were either slaughtered near camp or that all body parts were transported to habitation sites. This has important implications for understanding resource use, but requires additional quantitative analysis, which is ongoing. Neither charcoal nor other botanical remains have been recovered from Hulunbuir sites, despite the fact that approximately 100L of soil was floated from Tamsgabulag deposits in 2018.

The lithic assemblages from Hag and Tamsagbulag (Figure 6) contain many more light duty tools than Baiyinchanghan, including an emphasis on microblades, highly curated arrowheads, scrapers, drills, and burins (Zhongguo *et al*. 2010). Microblades are a hallmark of hunter-gatherer technological assemblages in Northeast Asia. They are used as insets for projectile points and composite bone knifes and therefore correlated with hunting and butchering activities (Shelach 2006; Chen 2008). The high proportions of such tools imply that animal resource procurement and processing were important subsistence activities. Many digging weights were also found at Tamsagbulag, but probably tied to construction of dwellings, pits, and trenches. Low numbers of ball-headed rollers, grinding slab fragments, and heavy-duty scrapers made on coarse-grained materials were also recovered. The relative lack of milling equipment at Hag (Table S2) emphasises a very different emphasis on subsistence tasks than at Baiyinchanghan.

Sherds at both sites are sand-tempered and low-fired, and undecorated, incised, or cord-marked (Figure 7). They are more comparable to Xiaohexi- than Xinglongwa-period levels at Baiyinchanghan. Pottery at Tamsagbulag was sand- or shell-tempered and built using the slab method (Iizuka *et al*. 2018). As at other Early Neolithic Mongolian sites, some sherds are high-fired and durable. Most were too small to discern individual vessel forms, but diagnostic sherds from Hag Layer 7 indicate the use of both oval and flat-bottomed vessels. One rim sherd from Tamsagbulag indicates a very large vessel that was not likely to have been transported (Figure 7B).

Current data suggests a much lower level of community planning and occupation intensity than in the West Liao river valley. This is further reflected in burial traditions: Tamsagbulag burials are rare and unmarked, characterised by individuals (Dorj 1971; Cybiktarov 2002); at Hag they are characterised by the lack of burial pits or individuals in unmarked secondary inhumations

(Figure 4A) (Zhongguo *et al*. 2010). There are several other known Early Neolithic sites with pit-dwelling structures, including Ovoot (Dorj 1971) and Huiheshuiba (8.5–8.4 ka cal BP; about 44km south-west of Hag; Figure 1) (Liu *et al*. 2008), but most sites across the region are small microblade-dominated lithic assemblages distributed along rivers and around sand dunes (Dorj 1971; Zhao 2001; Guo & Liu 2007). The observed pattern of both significant population nucleation and dispersed land-use could be related to seasonal differentiation, variation in mobility strategies between groups, or simply change over time. The current lack of chronological control limits our understanding of these relationships.

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Table S1. Radiocarbon dates from Baiyinchanghan, Hag, and Tamsagbulag. All dates were calibrated using OxCal version 4.3 (Bronk Ramsey 2009) and the IntCal13 calibration curve (Reimer *et al.* 2013), dates from previously published sites were recalibrated from reported conventional dates.

Site	Lab #	Material	Radiocarbon yr BP	Cal yr BP (95.4%)	Reference
Hag, layer 7	BA081790	Charcoal	7710±40	8580–8416	Neimenggu (2004)
	BA081791	Charcoal	7355±35	8306–8036	Neimenggu (2004)
Hag, layers 1–6	BA071294	Collagen	1750±35	1775–1560	Neimenggu (2004)
	BA071295	Collagen	1785±35	1817–1616	Neimenggu (2004)
Huiheshuiba	n.a	Collagen	7750±40	8595–8431	Liu *et al.* (2008)

	n.a	Collagen (human)	8555±40	9560–9475	Liu *et al.* (2008)
Baiyinchanghan	WB90-1	Charcoal	n.a.	7612–7325	Zhongguo *et al.* (2010)
	WB90-1	Charcoal	n.a	8034–7669	Zhongguo *et al.* (2010)
Tamsagbulag Area 2	PLD-20347	Collagen	6698±26 6700±25	7613–7510 7614–7510	Odsuren *et al.* (2015)
Area 2	PLD-20348	Collagen	6646±29 6646±30	7578–7475 7579–7472	Odsuren *et al.* (2015)
Area 2	PLD-23211	Collagen	6758±27 6760±25	7663–7577 7661–7579	Odsuren *et al.* (2015)
Area 2	PLD-23212	Collagen	6702±27 6760±25	7616–7510 7661–7579	Odsuren *et al.* (2015)
Area 2, TB2	UOC-9624	Collagen	6928±29	7830–7685	Reported here
Area 2, TB7	UOC-10166	Collagen	6561±51	7571–7339	Reported here
Area 2, TB9, Level 1	UOC-9630	Collagen	6799±29	7679–7590	Reported here
Area 2, TB9, Level 1	UOC-9629	Collagen	6826±29	7699–7595	Reported here

Area 2, TB9, Level 2	UOC-9627	Collagen	6854±29	7751–7616	Reported here
Area 2, trench D	Gif. 10949	Charcoal?	5590±120	6673–6030	Sériadès (2004)
Area 1, TB1 trench	UOC-9628	Collagen	6745±29	7662–7571	Reported here
Area 1, TB1 hearth	UOC-9625	Collagen	6962±29	7917–7700	Reported here
Area 1, TB1 hearth	UOC-10165	Collagen	6842±66	7825–7578	Reported here
Area 3, TB3	UOC-9623	Collagen	7178±29	8030–7945	Reported here
Area 3, TB5	UOC-9626	Collagen	7519±29	8400–8216	Reported here

Table S2. Comparison of tool assemblages between Baiyinchanghan and the Hag site.

<table>
<tr><th colspan="2" rowspan="2">Tool type</th><th colspan="3">Baiyinchanghan</th><th colspan="3">Hag</th></tr>
<tr><th colspan="2">Count</th><th>P(%)</th><th colspan="2">Count</th><th>P(%)</th></tr>
<tr><td rowspan="2">Microblade</td><td>microblade</td><td>18</td><td rowspan="2">23</td><td rowspan="2">9.09</td><td>392</td><td rowspan="2">420</td><td rowspan="2">74.73</td></tr>
<tr><td>retouched microblade</td><td>5</td><td>28</td></tr>
<tr><td rowspan="4">Light duty tools</td><td>end scraper</td><td>0</td><td rowspan="4">7</td><td rowspan="4">2.77</td><td>60</td><td rowspan="4">104</td><td rowspan="4">18.47</td></tr>
<tr><td>scraper</td><td>6</td><td>8</td></tr>
<tr><td>point/drill</td><td>1</td><td>33</td></tr>
<tr><td>burin</td><td>0</td><td>3</td></tr>
<tr><td rowspan="3">Heavy duty tools</td><td>hammer stone</td><td>3</td><td rowspan="3">27</td><td rowspan="3">10.67</td><td>0</td><td rowspan="3">4</td><td rowspan="3">0.71</td></tr>
<tr><td>chopper</td><td>0</td><td>3</td></tr>
<tr><td>stone knife</td><td>24</td><td>1</td></tr>
<tr><td rowspan="2">Woodworking</td><td>axe</td><td>19</td><td rowspan="2">27</td><td rowspan="2">10.67</td><td>0</td><td rowspan="2">1</td><td rowspan="2">0.18</td></tr>
<tr><td>adze/chisel</td><td>8</td><td>1</td></tr>
</table>

Milling stone	hand stone/stone slab	50	85	33.60	3	3	0.53
	pestle/mortar	18			0		
	round grinding tool	17			0		
Farming	stone hoe	70	70	27.67	0	0	0.00
Hunting	arrow head	0	0	0.00	16	16	2.84
Other	net sink	1	1	0.00	0	0	0.00
	stone ball	3	3	0.01	0	0	0.00
	perforated tool	2	2	0.01	1	1	0.18
	unknown	8	8	0.03	14	14	2.49