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| A red circle with a white letterDescription automatically generated | Supplementary material for  Shelach-Lavi, G., C. Amartuvshin, D. Heimberg, D. Wolin, G. Angaragdulguun, T. Rogovski, J. Chen, O. Fenigstein, T. Steiner & W. Honeychurch. 2025. **Life along the medieval frontier: archaeological investigations of the south-eastern long wall of Mongolia.** *Antiquity* 99.  Author for correspondence ✉ Gideon.shelach@mail.huji.ac.il |

1. **Radiocarbon dates** (Supplementary A–D by William Honeychurch)

**Table S1. AMS 14C analysis of samples excavated from burials in and around MA03 (OxCal 4.4, IntCal20, Bronk Ramsey 2021; Reimer et al. 2020).**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **ID - Context** | **Lab No.** | **Sample label & type** | **14C age (BP)** | **Error** | **2 sigma (BC/AD)** |
| Grave 1 | UCIAMS 288504 | Human bone | 1965 | 20 | 28-18 BC (02.4%)  7-121 AD (93.1%) |
| Grave 2 | UGAMS 68005 | Animal bone | 1740 | 25 | 246-401 AD (95.4%) |
| Grave 3 | UGAMS 98006 | Human bone | 450 | 25 | 1422-1471 AD (95.4%) |
| Grave 3 | UCIAMS 288243 | Wood | 465 | 15 | 1425-1450 AD (95.4%) |
| Grave 3 | UCIAMS 288244 | Wood | 440 | 20 | 1430-1470 AD (95.4%) |
| Grave 5 | UCIAMS 288255 | Bone (charred) | 230 | 15 | 1643-1670 AD (55.1%)  1780-1799 AD (40.3%) |

**Table S2. AMS 14C analysis of excavated samples from MA-03 (OxCal 4.4.4, IntCal20, Bronk Ramsey 2021; Reimer et al. 2020).**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **ID - Context** | **Lab No.** | **Sample type** | **14C age (BP)** | **Error** | **2 sigma (AD)** |
| Area D ashpit | UCIAMS 288245 | Charcoal | 895 | 20 | 1047-1084 (25.4%)  1128-1140 (02.3%)  1148-1219 (67.8% |
| Area D ashpit | UCIAMS 288242 | Wood | 895 | 20 | 1047-1084 (25.4%)  1128-1140 (02.3%)  1148-1219 (67.8% |
| Area C under stones of heating system | UGAMS 68008 | Charcoal | 890 | 25 | 1046-1085 (21.6%)  1095-1103 (01.1%)  1124-1222 (72.7% |
| Area C east channel of heating system | UGAMS 68009 | Charcoal | 860 | 25 | 1054-1062 (01.3%)  1156-1234 (89.5%)  1239-1260 (04.6%) |
| Area D ashpit | UCIAMS 288246 | Charcoal | 850 | 15 | 1164-1228 (95.4%) |
| Area C north channel of heating system | UGAMS 68007 | Charcoal | 840 | 25 | 1166-1263 (95.4%) |
| Area C above stone feature | UCIAMS 288241 | Bark | 835 | 15 | 1176-1264 (95.4%) |
| Area D ashpit | UGAMS 68010 | Charcoal | 820 | 20 | 1179-1190 (03.1%)  1207-1270 (92.3%) |
| Area D near large wood fragment | UGAMS 68011 | Charcoal | 820 | 25 | 1177-1193 (06.7%)  1202-1272 (88.7%) |

**(B) Stratigraphic Information**

(1) UPPERMOST CONTEXT

ID-4, Area C, Accumulation above stone feature; represents final use or post-use abandonment phase.

UCIAMS 288241, Bark, 835±15

(2) USE PHASE CONTEXT

No clear stratigraphic relations between these series of contexts including the channels of the heating system and the ashpit (Areas C and D).

UGAMS 68009, Charcoal, 860±25

UGAMS 68007, Charcoal, 840±25

UCIAMS 288245, Charcoal, 895±20

UCIAMS 288242, Wood, 895±20

UCIAMS 288246, Charcoal, 850±15

UGAMS 68010, Charcoal, 820±20

UGAMS 68011, Charcoal, 820±25

(3) LOWEST CONTEXT

ID-1, Area C, fill under stones of the heating system; represents a construction phase, but not necessarily the beginning of occupation.

UGAMS 68008, Charcoal, 890±25

**(C) Bayesian model rationale**

The chronological model for the walled settlement is informed by prior historical information as well as stratigraphic relationships between sample contexts, all of which have been incorporated into a Bayesian model. Stratigraphic relationships for the dated samples consist of a date prior to the construction of the heating system, several dates for the use period of Areas C and D, and a date marking either the final use or abandonment phase of the settlement (see Supplementary Section above). We delimited a lower chronological boundary for the model based on evidence suggesting that the southeastern wall line is associated with the Jurchen Jin Empire and therefore would be expected to post-date the collapse of the Kitan Empire at 1125 AD. During most of the 12th century AD this frontier area was subject to Jurchen Jin influence, but histories indicate that by ca. AD 1200-1204 the expanding Mongol state became the primary political power in the area. Based on this, we might expect that a Jurchen Jin frontier establishment, such as MA03, would have been occupied and supported up to the beginning of the 13th century, but thereafter experienced diminishing use. To model this dynamic, we replace a uniform prior with a sigma prior which assumes that the group of events characterizing settlement occupation is distributed with higher probability of occurrence in an initial phase followed by a tailed drop off in probability.

The best way to explain the difference this choice makes is to consider (**A**) our objective, (**B**) our radiocarbon sample of dated events from MA03, and (**C**) how different distributions of probability (uniform or sigma) help us apply our dated sample to better understand the full sequence of events at MA03. We do this by illustrating these three steps using a modification of the discussion given by Bronk Ramsey (2009: 345–47). Our ultimate goal (**A**) is to understand an ordered sequence of events in time that pertained to the use of the MA03 settlement. The settlement sequence of events includes all of the human activity in and around the site. This can be characterised schematically in terms of a start date, a startup period, a use period, a wind down phase and an end date. Initially, we have no information whatsoever about the timing or extent of these phases of use and are unable to situate these settlement events in time.

By analyzing deposited materials using radiocarbon we sampled the sequence of events pertinent to the use of MA03 (**B**) and we wish to use this rather small sample of dated events to answer larger questions about the entire sequence of events – for example, we would like to know what the likely start date for MA03 might have been. Our sample of dated events begins to orient the use of MA03 in time, but it is difficult to know to what part of the use sequence these dated events pertain. Our earliest dated event "might" pertain to the initial start date, but it also "might" pertain to the primary use period or the wind down phase. Without additional information, we cannot know to what part of the entire MA03 sequence our dated events pertain.

In OxCal, this “no additional information” approach is the default, and it supposes that every radiocarbon dated event has an equal likelihood of pertaining to any part of the sequence of events at MA03. Having no extra contextualizing information to delimit where within the entire sequence our dated events fall is one possible format of "prior" information, although it is unfortunately non-informative. This condition is modelled by a uniform distribution (the uniform prior) as shown below in the figure modified from Figure 4 in Bronk Ramsey (2009: 346). In other words, the likelihood that any one dated event pertains to a specific region within the gray zone is uniform and equally probable throughout – our dated event could fall anywhere within that sequence.

Here we argue that in fact we DO have additional information that helps to clarify where dated events have a higher likelihood of falling within the entire sequence (**C**). As specified above, historical sources provide the following additional information by which to build a more informative prior model:

(1) evidence suggests that the southeastern wall line is associated with the Jurchen Jin Empire and therefore would be expected to post-date the collapse of the Kitan Empire at 1125 AD;

(2) during most of the 12th century AD this frontier area was subject to Jurchen Jin influence, but histories indicate that by ca. AD 1200-1204 the expanding Mongol state became the primary political power in the area;

(3) therefore, we might expect that a Jurchen Jin frontier establishment, such as MA03, would have been occupied and supported up to the beginning of the 13th century, but thereafter would have experienced diminishing use.

Given this additional information, and noting that this model is of course a hypothesis, any dated event from MA03 would have a higher likelihood of pertaining to the initial high-use phase occurring sometime between 1125 and 1204 AD. In turn, any dated event would have less likelihood of pertaining to the diminishing wind down phase post-1204 AD. Moreover, we expect that when Mongol control of this border area was established, the settlement may have been rapidly abandoned by its occupants contributing to a rather sharp decline in the use-likelihood curve. We also know from historical sources that Jin frontier sites were temporarily and episodically re-occupied by the Mongols during the early 13th century and therefore we would not expect a sharp break in use-likelihood but rather a gradually diminishing tail of probability. The “shape” of probability of use at MA03, based on this historical information, is best modeled as a sigma distribution as shown below. Given this sigma-shaped prior information, our earlier dated events have a higher likelihood of pertaining to the startup and primary use phase of the settlement and our later dates have a higher likelihood of pertaining to the wind down phases at MA03. Our dated events are therefore used to inform and characterise those respective phases of the larger sequence.

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**(D) OxCal 4.4 model code**

Plot()

{

Sequence("MA-03")

{

C\_Date("Kitan Fall",1125,10);

Boundary("Start");

R\_Date("UGAMS 68008",890,25);

Phase()

{

R\_Date("UCIAMS 288245",895,20);

R\_Date("UCIAMS 288242",895,20);

R\_Date("UCIAMS 68009",860,25);

R\_Date("UCIAMS 288246",850,15);

R\_Date("UGAMS 68007",840,25);

R\_Date("UCIAMS 68011",820,25);

R\_Date("UCIAMS 68010",820,25);

};

R\_Date("UCIAMS 288241",835,15);

Sigma\_Boundary("End");

};

Sigma=(End-Start);

Combine("Grave 3")

{

R\_Date("UCIAMS-288243",465,15);

R\_Date("UGAMS-68006",450,25);

R\_Date("UCIAMS-288244",440,20);

};

Difference("MA-03 and Burial","Grave 3","End");

};

**(E) MA03 Fauna Analysis**. (by Tikvah Steiner)

**Table S3. Body size group (BSG) categories and examples of animals in each size group.**

|  |  |
| --- | --- |
| B | Horse, cattle |
| C | Sheep, goat, deer |
| D | Gazelle, large dog |
| E | Marmot, hare, pika, eagle-sized bird, badger |
| F | Small rodents, small birds, toad |

Area D: 234 identified, 336 unidentified (UND)

**Table S4. Total numbers and percentages of NISP**

|  |  |  |
| --- | --- | --- |
| **Species** | **NISP** | **%NISP** |
| Equid | 21 | 9 |
| *BSGB* | 54 | 23 |
| Gazelle | 16 | 7 |
| Sheep | 12 | 5 |
| Sheep/Goat | 15 | 6 |
| *BSGC* | 109 | 47 |
| *BSGD* | 3 | 1 |
| *BSGE* | 4 | 2 |
| **Total** | 234 | 100 |

**Table S5. Total numbers and percentages of NISP recovered from area A**

|  |  |  |
| --- | --- | --- |
| **Species** | **NISP** | **%NISP** |
| Avifauna | 1 | 16.7 |
| *Lepus* sp. | 1 | 16.7 |
| BSGC | 3 | 50 |
| BSGF | 1 | 16.7 |
| **Total** | 6 | 100.0 |

Lepus sp. is most likely Tolai hare (*Lepus tolai*)

**Table S6. Total numbers and percentages of NISP recovered from area B**

|  |  |  |
| --- | --- | --- |
| **Species** | **NISP** | **%NISP** |
| Equid | 5 | 8.9 |
| Badger (*Meles leucurus*) | 2 | 3.6 |
| Avifauna (small) | 4 | 7.1 |
| Avifauna (large) | 1 | 1.8 |
| Toad | 7 | 12.5 |
| BSGB | 2 | 3.6 |
| BSGC | 7 | 12.5 |
| BSGE | 4 | 7.1 |
| BSGF | 24 | 42.9 |
| **Total** | 56 | 100.0 |

Toad species is most likely *Strauchbufo raddei*

**Table S7. Total numbers and percentages of NISP recovered from area C**

|  |  |  |
| --- | --- | --- |
| **Species** | **NISP** | **%NISP** |
| Equid | 5 | 7.7 |
| Sheep | 2 | 3.1 |
| Sheep/Goat | 3 | 4.6 |
| Marmot | 2 | 3.1 |
| Avifauna (large) | 3 | 4.6 |
| Avifauna (small) | 4 | 6.2 |
| BSGB | 13 | 20.0 |
| BSGC | 24 | 36.9 |
| BSGE | 7 | 10.8 |
| BSGF | 2 | 3.1 |
| **Total** | 65 | 100 |

**Table S8. Total numbers and percentages of NISP recovered from area E**

|  |  |  |
| --- | --- | --- |
| **Species** | **NISP** | **%NISP** |
| Cattle | 1 | 6.7 |
| Equid | 2 | 13.3 |
| Sheep | 5 | 33.3 |
| BSGB | 2 | 13.3 |
| BSGC | 4 | 26.7 |
| BSGD | 1 | 6.7 |
| **Total** | 15 | 100.0 |

**References**

Bronk Ramsey, C. 2009. Bayesian analysis of radiocarbon dates*. Radiocarbon* 51: 337–60. https://doi.org/10.1017/S0033822200033865

Bronk Ramsey, C. 2021. OxCal, version 4.4.4 [software]. Oxford: Oxford Radiocarbon Accelerator Unit. Available at: https://c14.arch.ox.ac.uk/oxcal.html

Reimer, P.J. *et al*. 2020. The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* 62: 725–57. https://doi.org/10.1017/RDC.2020.41