The world's oldest promontory fort - Amnya and the acceleration of hunter-gatherer diversity in Siberia 8000 years ago

Supporting Information (SI)

1. Background

1.1. Periodization and terminology

Surveys and rescue excavations over the last decades have revealed an array of new sites across the Transurals and Western Siberia that document the pre-pottery Mesolithic and the transition towards the local Neolithic. According to Russian terminology, the Neolithic is defined as pottery-using hunter-gatherer societies (Chairkina et al. 2017; Pogodin 2006; Zhilin et al. 2018), hence, it is here unconnected to agriculture and animal husbandry, which reached these regions millennia later, or not at all in the northernmost parts of the study region (Piezonka 2017; Nordqvist 2018). In Western archaeological tradition, this period would be labelled the pottery Mesolithic. In the archaeological periodization in the study region, the Neolithic period is followed by the Eneolithic (ca. 4000-2500 cal BC) which is succeeded by the Bronze Age.

1.2. The Mesolithic settlement of the Transurals and Western Siberia

In the study region, the Mesolithic encompasses the period between the end of the Late Glacial and the advent of pottery; it ranges from c. 10,000 cal BC to the mid to late 7th millennium cal BC (Chairkina et al. 2017). The density of known sites across the region is very heterogeneous (Figure S1A). Mesolithic sites are concentrated on both sides of the Urals and along the southern fringes of the forest belt (Pogodin 2006). It is especially the peatbog sites on the eastern slopes of the Ural Mountains, with excellent preservation of organic materials, that have revealed detailed information on the Early Holocene population's mobile lifeways, hunting strategies and ritual behaviour (Zhilin et al. 2020). These include such spectacular finds as the Shigir idol, a 5 m high anthropomorphic wooden sculpture presumably dating to the Preboreal period (Zhilin et al. 2018). Another area with dense evidence of Mesolithic occupation is the catchment of the Konda river, a left tributary to the Ob', in the middle Trans-Urals. The sites are all located close to water bodies. Among them are large settlements with various types of dwellings, both lighter, ground level structures as well as substantial two-chambered houses with sunken floors and complex wooden wall and roof constructions (Pogodin 2006; Koksharov & Pogodin 2000). Further east and north in the taiga zone of the Western Siberian basin, only very few settlement sites with ground-level dwelling structures are currently known, all dating to the later part of the Mesolithic, as far as this can be judged from the sparse chronological information available. They are thought to reflect a mobile foraging lifestyle with seasonal movements and temporary camps (Konovalenko et al., 2017; Pogodin 2006).

The material culture of the Mesolithic in the study region encompasses lithics and at sites with organic preservation, also bone, antler and wooden artefacts (Koksharov & Pogodin 2000; Pogodin 2006). Lithic raw materials are mainly local, including flint of various qualities from the moraines and also quartz, quartzite and other materials.

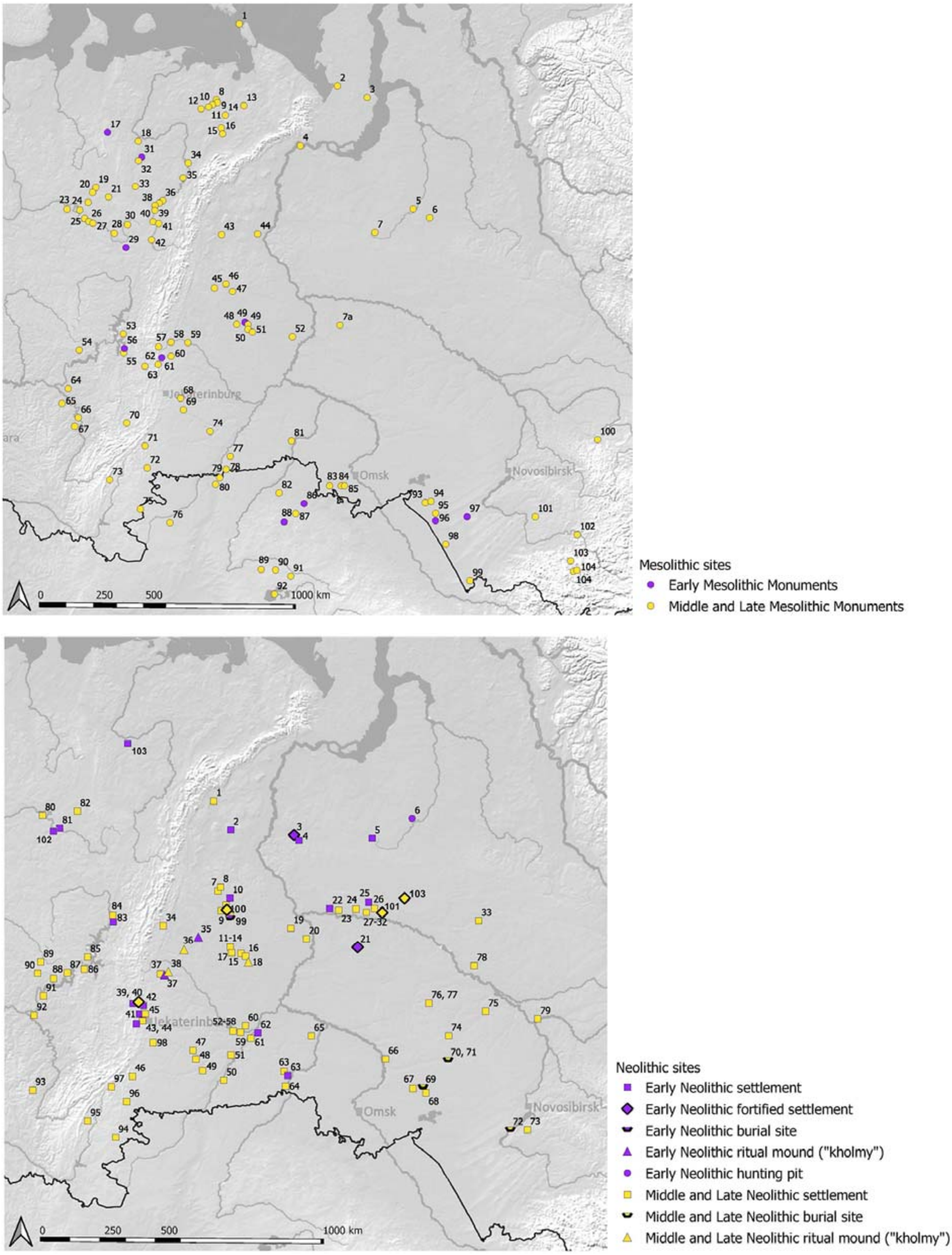

Figure S1: Mesolithic and Neolithic sites in the Urals and adjacent regions of Northeast Europe and West Siberia. **A: Mesolithic sites.** *European North-East:* 1 – Litosalia; 2 – Iuribei I; 3 – Nulmaiakha; 4 – Korchagi I-B; 5 – Ton-iakha; 6 – Kharampur 4; 7 – Piamali-iakha IV; 7a – B. Salym 4; 8 – Kolva-vis 13; 9 – Kolva-vis 14; 10 – Kolva-vis 16; 11 – Kolva-vis 30; 12 – Sandibei-iu 1,3-5; 13 – Adz'va 13; 14 – Kolva-vis 20; 15 – Adz'va I; 16 – Adak I-III; 17 – Pizhma II; 18 – Kel'chiiur I; 19 – Evdino II; 20 – Vet'iu II; 21 – Visskii I torfianik; 22 – Lial'skii Bor; 23 – Rev'iu II; 24 – Ydzhyd-ty; 25 – En'ty III; 26 – Kur'iador I,II; 27 – Pezmog; 28 – Ul'ianovo; 29 – Parch I-III; 30 – Kuz'vomyn; 31 – Lek-Lesa I; 32 – Turun-Niur; 33 – Ust'-Ukhta; 34 – Topyd-niur V, VIIa; 35 – Cherepan'ka-di; 36 – Deminskaia, Sherdinskaia; 37 – Van-pi;

38 – Kodach-di, Rogodinskaia, Mitrofan Dikost; 39 – Petrushinskaia, Nizhne-Petrushinskaia; 40 – Zaton I, Zarechenskaia, Martiushevskaia III, IV; 41 – Kas'ian-El'; 42 – Tyb'iu; *Middle Trans-Urals and the Konda River Basin:* 43 – Khulimsunt 1; 44 – Smolianoi Sor I; 45 – Atym'ia IV; 46 – Geologicheskoe III; 47 – Arantur; 48 – Kanda; 49 – Satyga XVIIa, XVIa, XV; 50 – Iagodnyi; 51 – Leushi III, IX, XIII, XIV; 52 – Kondinskoe I, II, III; 53 – Nizhnee-Adishchevskaia, Novozhilovskaia, Ogurdino; 54 – Barskaia Pristan'; 55 – Gornaia Talitsa; 56 – Pen'ki; 57 – Ural'skie Zori I, III, Garevaia II; 58 – Vyika II; 59 – Koksharovsko-Iur'inskaia; 60 – Golyi Kamen'; 61 – Evstiunikha III; 61a – Beregovaia II; 62 – Krutiaki I, II; 63 – Peshchera na Kamne Dyrovatom; *South Trans-Urals:* 64 – Staraia Mushta II; 65 – Kholodnyi Kliuch, Siun' II; 66 – Il'murzino; 67 – Romanovka II, Mikhailovskaia, Davlekanovo I; 68 – Shigirskii torfianik; 69 – Sukhrino I; 70 – Dolgii El'nik II; 71 – Chebarkul' XVII; 72 – Streletskaia II-IV; 73 – Iangel'skaia, Iakty-Kul' I; 74 – Tashkovo IV; 75 – Andreevka III; 76 – Evgen'evka I; 77 – Kamyshnoe I; 78 – Verkhniaia Alabuga; 79 – Zverinogolovskaia VI; 80 – Ubagan III, V, VII, VIII; *South of Western Siberia and North Kazakhstan:* 81 – Katen'ka; 82 – Iavlenka II; 83 – Gvozdevka I; 84 – Shcherbakul'; 85 – Bol'shoi Ashchikul' II; 86 – Vinogradovka II; 87 – Vinogradovka XII; 88 – Kuropatkino I; 89 – Tel'mana VII; 90 - Tel'mana VIIIa; 91 – Tel'mana IXa; 92 – Tel'mana XIVa; 93 – Novorossiika-1; 94 – Sukhoe ozero-1; 95 – Melkoe I; 96 – Kaban'ia; 97 – Ust'-Kur'ia; 98 – Alekseevka; 99 – Pavlovka; 100 – Bol'shoi Berchikul'; 101 – Barnaul'skii kovsh'; 102 – Kameshok; 103 – Ust'-Sema; 104 – Tytkesken' 2, 3. **B: Neolithic sites**. *North of Western Siberia:* 1 – Ches-Tyi-Iag; 2 – Sartynya I; 3 – Amnya I&II; 4 – Kirip-Vis-Iugan 2; 5 – Et-to I; 6 – Vora-iakha 1. *Middle Trans-Urals and the Konda River Basin:* 7 – Geologicheskoe VII; 8 – Geologicheskoe XVI; 9 – Enyia 12; 10 – Shoushma 10; 11-14 – Sumpanya II, III, IV, VI; 15 – Leushi VII; 16 – Leushi I; 17 – Kanda; 18 – Chertova Gora; 19 – Starikov Mys 1a; 20 – Chilimka V; 99 - Bol'shaia Umytya 100 (mogil'nik); 100 - Bol'shaia Umyt'ia 2, 8, 9, 57, 100, 109. *Surgutskoe Priob'e:* 21 – Kayukovo 1&2; 22 – Mikishkino 5; 23 – Kushnikovo 1, 2, 8; 24 – Bystryi Kul'egan 66; 25 – Chernaia 3; 26 – Pykhty I; 27- 32 – Barsova Gora II/8, I/8a, II/16a, II/17, IV/5, II/10; 33 – Bol'shoi Lar'iak II, III; 101 – Nekh-urii 3.1, 3.2, 3.4. *Trans-Urals:* 34 – Nizhnee Ozero 3; 35 – Ust'-Vagil'skii kholm; 36 – Makhtyl'skii kholm; 103 – Imnegan 2.1; 37 – Koksharovskii kholm; 38 – Koksharovsko-Iur'inskaia stoianka; 39 – Evstiunikha, 40 – Poludenka 1; 41 – Varga 2; 42 – Beregovaia 2 (peat); 43 – Isetskoe Pravoberezhnoe 1; 44 – Palatki 1; 45 – Shaidurikhinskoe 5. *South Trans-Urals and Tobol River basin:* 46 – Chebarkul' 1; 47 – Boborykino 2; 48 – Tashkovo 1,3; 49 – Kochegarovo 1; 50 – Pikushka; 51 – Koshkino 5; 52 - Chepkul' 21a; 53 – Kar'er 2; 54 – Andreevskoe ozero, 8-i punkt; 55-58 – Iuzhnyi bereg Andreevskogo ozera 5, 9, 12, 13a; 59 – Duvan 5; 60 – Bairyk 1D; 61 – Uk 6; 62 – Iurtobor 3; 93 – Mullino; 94 – Ust'-Utiaganskaia; 95 – stoianki na oz. Karabalykty, i Sabakty, 96 – Putilovskaia Zaimka, Krasnosel'skaia, Krasnokamenka; 97 – Uchalinskaia, Karagaily 1; 98 – Abseliamovskaia. *Ishim River basin:* 63 – Mergen' 3, 6, 7; 64 - Serebrianka 1; 65 – Kokui 1. *Barabinsk forest-steppe, middle reaches of the Irtysh River:* 66 – Ekaterininskaia, Ust'-Tara XXVIII, XXXII; 67 – Vengerovo 2; 68 – Kozlovka; 69 – mog. Sopka 2; 70,71 – mog. Protoka, Korchugan; 104 – Tartas-1, Ust'-Tartas, Avtodrom-2, Staryi Moskovskii trakt V. *Upper and middle reaches of the Ob River:* 72 – Ordynskoe 1; 73 – Zav'ialovo 2, 8; 74 – Lavrovka; 75 – Malget; 76,77 – Tukh-Sigat 8, Tukh-emtor 4; 78 – pos. Mogil'naia; 79 – Igrekovo 1, 2. European North-East: 80 – Kochmas A, B; 81 - Pezmog 4; 82 – Vis 2; 102 – En'ty I; 103 – Chernoborskaia III. Kama region: 83 – Chashinskoe Ozero 6,8; 84 – Khutorskaia; 85 – Borovoe Ozero 1; 86 – Mokino, Levshinskaia; 87 – Kriazhskaia; 88 – Chernashka; 89 – Kyilud 3; 90 - Kochurovskoe 4; 91 – Ust'-Bukorok; 92 – Ziarat (compiled and supplemented by L. Kosinskaya & E. Dubovtseva on the basis of Besprozvannyi 1997; Besprozvannyi & Mosin 1996; Bobrov 1983; Vereshchagina 1973; Volokitin 1997; Zaibert & Potemkina 1981; Zakh 1999; Ivanov 1993; Ivashchenko & Tolpeko 2006; Kungurov 1993; Kuibyshev 1977; Molodin 1985; Pogodin 2000; Serikov 1997, 2000; Shirokov et al. 2005; Balueva & Konovalenko 2016).

The technology is based on prismatic, conical and wedge-shaped cores for the production of blades and microblades, which have been used e.g. for insets of composite tools comprising slotted bone artefacts. Apart from the blade-based lithics, stone artefacts also encompass scrapers, spear heads and axe-like tools. The rich bone industry preserved in the Transuralian peat bogs includes arrowheads, harpoons, daggers and knives, artefacts made from beaver mandibles, and ornaments (Savchenko 2014). Wooden artefacts are represented by darts made of whole thin tree trunks, by fragments of arrow shafts, arrowheads and spearheads, by an oar blade, a fire-drilling stick and numerous fragments with manufacturing traces. At Beregovaya II, Middle Mesolithic stakes driven vertically into the ground have been recorded as well as worked wooden planks in the Late Mesolithic sediments, representing the remains of a trackway (Zhilin et al. 2020).

Compared to the patchy and in many regions very sparse settlement evidence of the Mesolithic, the Neolithic period starting with the onset of pottery production around 6000 cal BC is characterized by a steep rise in the number of sites also in areas that were previously more or less empty, such as the low-lying parts of the north of the Western Siberian basin (Kosinskaya 2013) (Figure S1B). The socio-economic processes that characterize this horizon of transformation and intensification are the topic of the main article.

2. Re-investigating Amnya I & II: Materials, Methods and Results

2.1. Research programme

In order to explain what is specific in Western Siberia to have led to the unique deep history of socio-economic complexity in hunter-gatherer-fisher societies from the end of the 7th millennium cal BC onwards, our Russian-German research programme has pursued four main objectives:

(1) To systematically document settlement and fortification structures and material culture of the early enclosed sites;

(2) To generate reliable and precise radiocarbon chronologies by dating various organic and inorganic materials and by evaluating potential aquatic reservoir effects;

(3) To investigate human-environment interaction, ecology and economy by palaeolandscape and palaeoclimate analysis, and through the reconstruction of subsistence strategies and seasonality;

(4) To interpret the data together with evidence from further site types within wider archaeological and anthropological frameworks, also integrating Western Siberian ethnohistoric information on indigenous fortifications.

After initial work devoted to radiocarbon dating of key Stone Age complexes since 2010 (Piezonka et al. 2020), fieldwork within this programme started in 2017, with an initial photogrammetric and geophysical survey at the forest steppe site of Mergen 6, and has continued since 2018 at sites such as Amnya, Kayukovo and Imnegan in the taiga (Dubovtseva et al. 2020; Kardash et al. 2020) (see Figure 10). With its location far north in the transition zone between taiga and tundra, with its early dates and with its clear evidence substantial settlement features and fortification lines, the Amnya complex is a key point of reference in these inquiries.

2.2. The Amnya complex: Topography and settlement structures

Between 1987 and 2000, five house pits (1, 2, 3, 4, 9) and several sections of the banks, ditches and palisades were partly or completely excavated at Amnya I, and two house pits (1, 2) were investigated at Amnya II (Morozov & Stefanov 1993; Stefanov 2001; Stefanov & Borzunov 2008) (Figures 2 below, S2-4).

Connected to the new research project reported here, four excavation trenches from fieldwork between 1989 and 1993 were re-opened in 2019: trenches 2, 4 and 6 cutting through the inner and outer fortification lines at Amnya I and through the structures no. 2, 4, 8, and a fourth trench at Amnya II, cutting dwelling no. 2. Furthermore, two previously unknown house pit depressions 5.0 x 4.5 and 3.5 x 2.2 m in size and 0.3–0.5 m in depth were recognized in the surface relief outside the fortification lines at Amnya I and recorded in the new topographic plan of the settlement (structures no. 11 and 12) (Figure 2 below).

At excavation trench no. 2, ditch I and the overlying building structure 2 as well as the palisade trench between ditches I and II were investigated. Ditch I is ca. 1.5 m wide, has a flat base and steep walls. Its fill consists of two sedimentary units, indicating a re-cutting, with a more v-shaped profile of the second ditch phase. The boundary between the upper and lower ditch layers as well as its botanical contents indicate that the ditch was partially filled and vegetation had started to grow on its surface before the construction of structure 2 (see chapter S2.4 and Table S2).

Its fill includes two podzol layers, which were separated by a thin layer of gray podzolized sand. Botanical macro remains from the podzols, which contained burnt parts of various plants and seeds of *Arctostaphylos uva-ursi* (bearberry), confirm that these layers represent old surfaces that stood open for some time (see chapter S2.4 and Table S2). The upper filling of ditch I was possibly formed during the levelling of the surface for the construction of building structure no. 2. Sample no. 21 for which archaeobotanical analysis attested bearberry seeds as well as coniferous needles, derived from the layers that formed before this second ditch phase (layers 5, 6 and 7 in Figure 5; Table S2).

Building structure 2 consists of a rectangular pit up to 0.6 m deep. Its fill consists of dark reddish-brown cultural layers with intense traces of burning and contains remains of a hearth (layer 12 in Figure 5). These cultural deposits were rich in finds, among them small fragments of pottery with comb ornamentation (15 items), pieces of burnt clay, quartz flakes, granite pebbles and calcined bone chips as well as the fragment of a bone tool, possibly an arrowhead. Granite pebbles were located in the hearth, possibly connected to heat-related practices. Grit of a similar composition to the granite pebbles was found in the temper of the ceramic vessels.

The northern profile of excavation trench 2 also captured the space between the two inner ditches (I and II). The section revealed a wedge-shaped groove, steep at the western side and more shallow at the eastern side, facing ditch II. It is interpreted as the remnants of a palisade, dug into the top of a rampart. The palisade trench was 0.4 m deep, its width at the top was 0.5–0.65 m. No finds were observed, but samples for three radiocarbon dates were taken, two from charcoal of the palisade trench itself, and on of organic material from the associated cultural layer (see below, Chapter S2.3. and Figure 6).

The re-opening of excavation trench no. 6 aimed at the clarification of the stratigraphy of dwelling 8 and its relationship to the outer fortification line with ditch III and the associated bank and palisade (see also Figure S3). Dwelling 8 was a deep sunken-floor house of 1.3 m depth. Only its south-eastern corner was located in the trench; the rest of the house remains unexcavated (Figures 2 below, S5). Material from charcoal lenses in the lower part of the pit was taken for dating. The stratigraphy of the pit indicates that the third line of fortification in the form of a rampart with a palisade and ditch III was erected when dwelling 8 was no longer in use, as the palisade cuts through the cultural layers of the house. In the lower layers of dwelling 8, a small fragment of pottery without ornamentation was found. Its temper is similar to the pottery previously found in dwelling 1 in Amnya I, in terms of thickness and composition.

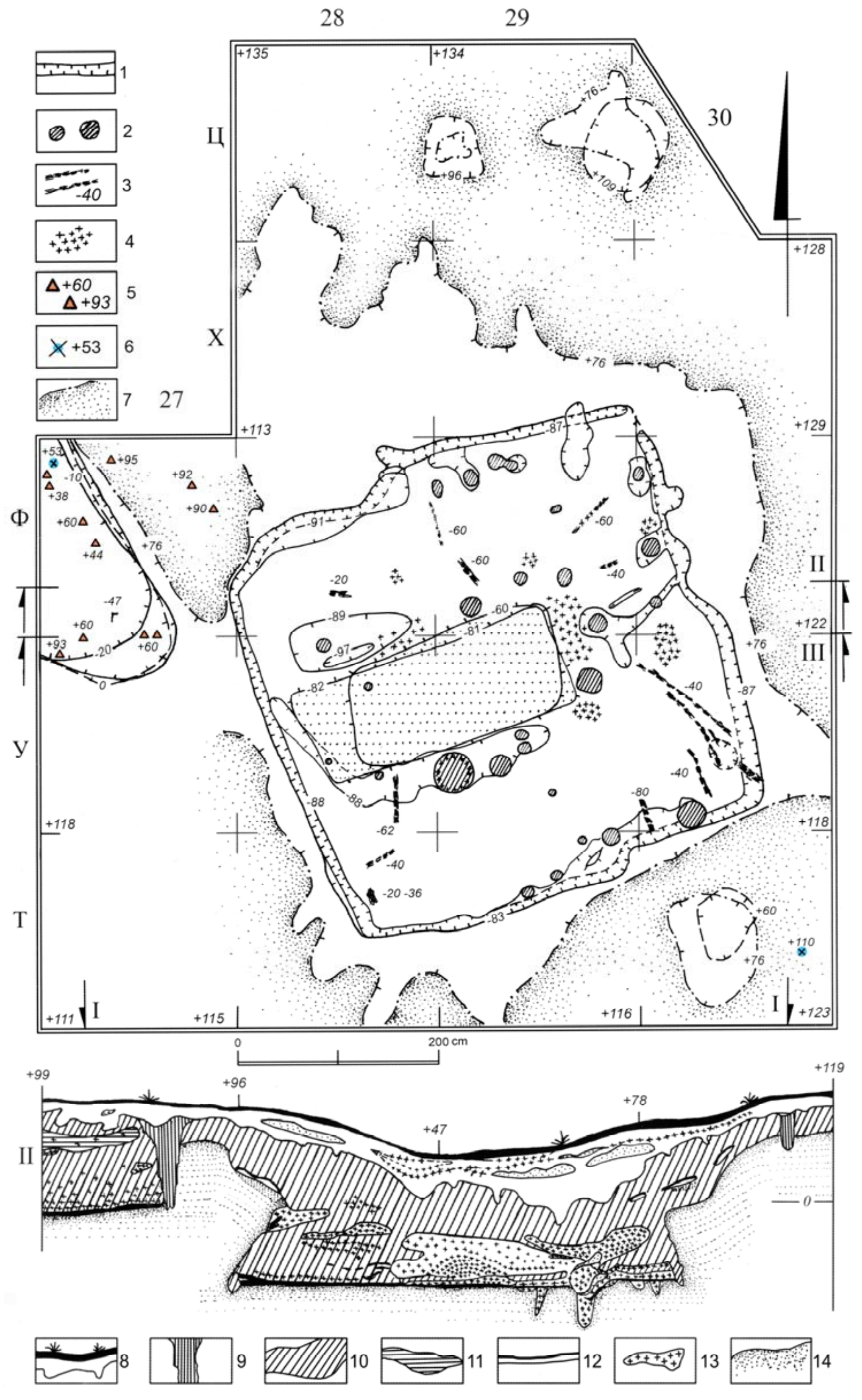

Figure S2: Amnya I, pit house 9 excavated during field work between 1987 and 2000, top – plan, bottom – profile along line II. 1 – channel, 2 – post and stake holes, 3 – charred construction timbers, 4 – charcoal, 5 – pottery fragments, 6 – lithic artefacts, 7 – subsoil (sand), 8 – forest floor and podzol, 9 – sand with iron agglomerations, 10 – mixed yellow sand, 11 – grey-brown sand, 12 – buried podzol, 13 – charcoal concentration, subsoil (sand) (after Stefanov & Borzunov 2008, with modifications).

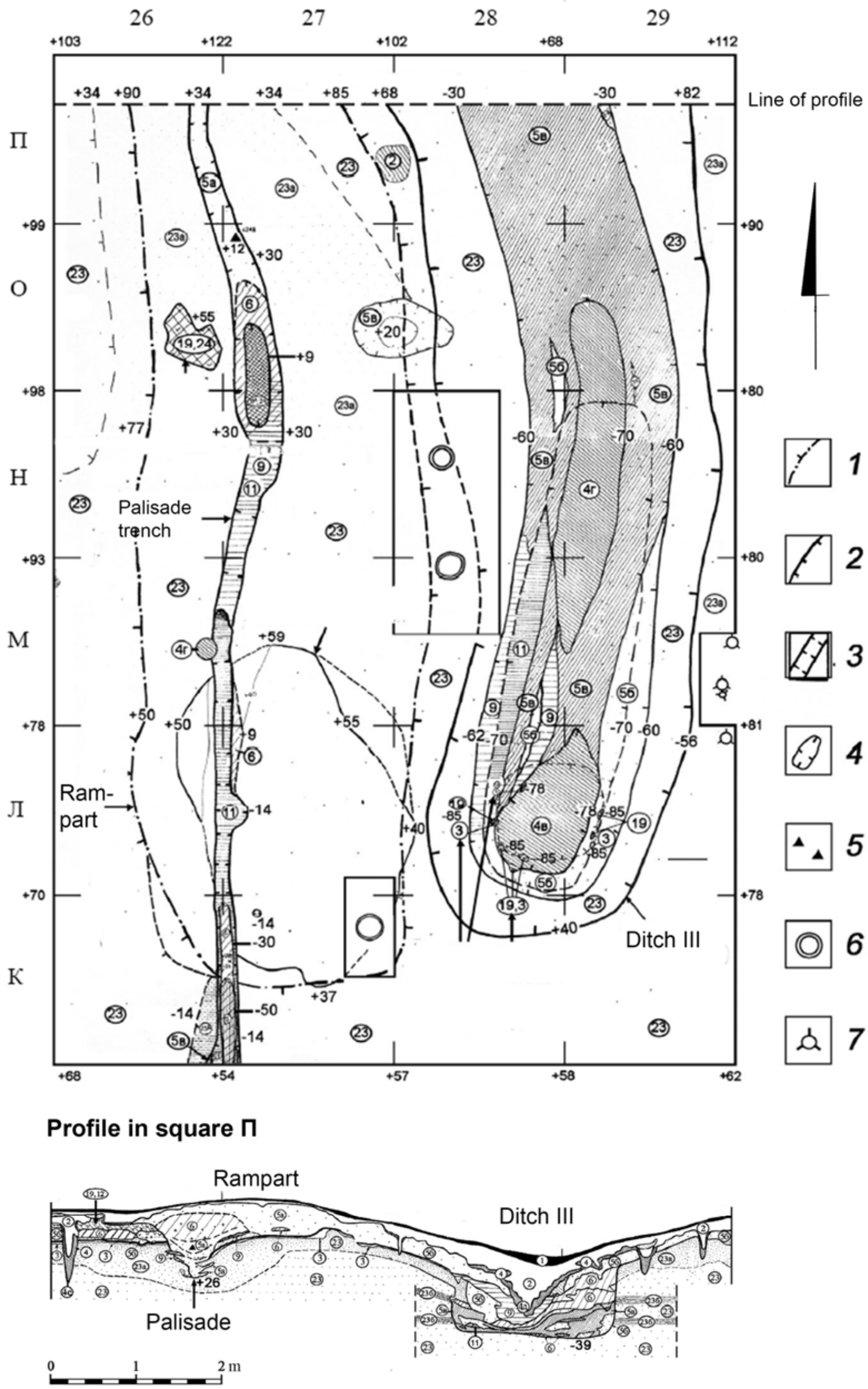

Figure S3: Amnya I, ditch III with associated rampart and palisade excavated during field work between 1987 and 2000, top – plan, bottom – profile across squares 26-29/П. 1 – limit of rampart, 2 – limit of ditch, 3 – palisade trench, 4 – pit, 5 – pottery fragments, 6 – pine, 7 – measurement point (after Borzunov 2020, with modifications).

Figure S4: Amnya I, reconstruction of one of the pit houses, Museum of Nature and Man, Khanty-Mansiisk, Russia (model by V.M. Morozov, V.I. Stefanov, D.N. Melikhov).

At the settlement of Amnya II, a trench was re-opened following the 1993 excavation trench that cut through the edge of house depression 2 (Figure S6). This house was 1.1–1.2 m deep, thus differing from the nearby Eneolithic house 1, which was smaller and only reached a depth of 0.65–0.7 m (Stefanov 2001: 35). The basal fill of house 2 consisted of charcoal-rich layers which were sampled for radiocarbon dating and botanical analysis (see Chapters 2.3 and 2.4). A buried podzol sealing the layers of the collapsed and filled-in pit house shows that the former dwelling stood open in this state for a while before further sedimentation took place, indicating several phases of occupation and re-use. From the interlayer of buried podzol, which marks the old surface, samples were also taken for radiocarbon dating. No artefacts were recovered during the re-investigation of this profile.

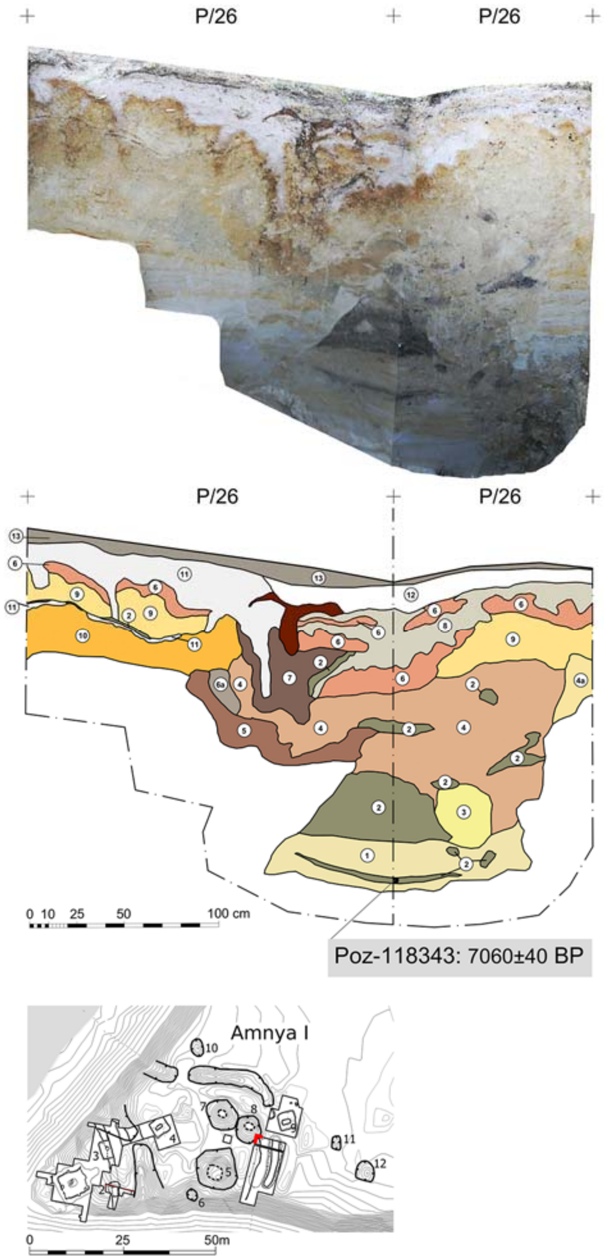

Figure S5: Amnya I; section through the southeastern corner of house 8. Rectified profile photo (top) and drawing with interpretation and position of AMS dating sample (bottom) (illustration: H. Piezonka, E. Dubovtseva, N. Golovanov, S. Juncker).

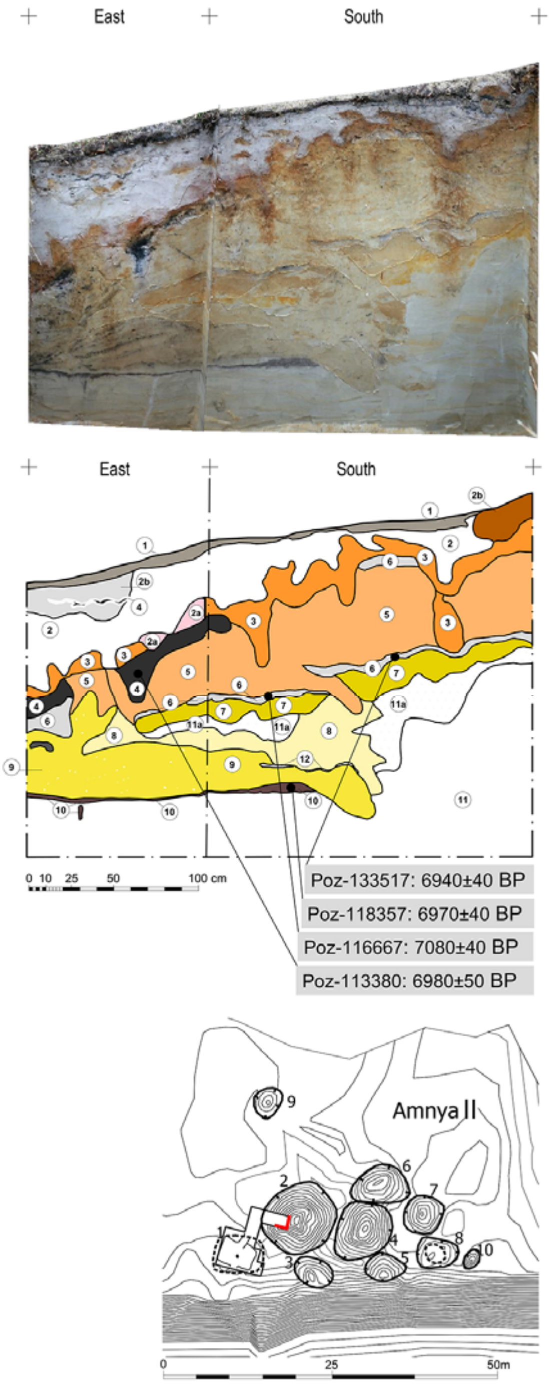

Figure S6: Amnya II, section through house 2. Rectified profile photo (top) and drawing with interpretation and position of AMS dated samples (bottom) (illustration: E. Dubovtseva, L. Kosinskaya, N. Golovanov, S. Juncker).

2.3. Site chronology and radiocarbon dating results

18 radiocarbon (^{14}C) dates are currently available for the settlement complex of Amnya I & II and the nearby unenclosed pit house settlement of Kirip-vis-Yugan (Stefanov et al. 2005) (Table S1). During investigations at Amnya from the late 1980s to the 2000s, four conventional (radiometric) ^{14}C dates were obtained for the Amnya I settlement and one for Kirip-vis-Yugan. These samples were dated by liquid scintillation counting at the Institute for the History of Material Culture, St Petersburg (Le-) and the Kyiv radiocarbon laboratory (Ki-). The bulk charcoal samples, dated at St Petersburg, would have been extracted following normal acid-base-acid protocols (Zaitseva and Popov 1994); the main interpretative challenges are whether the charcoal fragments in each sample were fully contemporaneous and associated with the archaeological events concerned. The potsherd, dated in Kyiv, would have been extracted following the protocol of Kovalyukh and Skripkin (2006) and Zaitseva et al. (2009), which aims to maximise the recovery of carbon from organic temper, soot and food remains, while minimising contamination from geological and post-depositional carbon sources. The pattern of published results from similar samples in Eastern Europe suggests that these dates are often, but not always, misleadingly old (Meadows 2020).

Within the framework of the initial Russian-German dating project on early hunter-gatherer ceramics since 2010, two samples of charred food crust on pottery from Amnya I and Kirip-vis-Yugan 2 were dated in the Poznań Radiocarbon Laboratory using AMS (Accelerator Mass Spectrometry) (Goslar et al. 2004), following normal acid-base-acid extraction. Ten further samples from Amnya have been dated by AMS at the Poznań Radiocarbon Laboratory. They include 6 charcoal samples and 4 samples of organic matter such as conifer needles. Again, samples would have been extracted following an acid-base-acid protocol, similar to that employed by the Oxford laboratory (Brock et al. 2010). For the charcoal samples, there is a significant risk that the fragment dated is either re-deposited (i.e. older than the context in which it was found) or embodies a significant wood-age offset relative to the tree-fall date.

Here we use Bayesian chronological modelling of the Amnya ^{14}C dates to compare the estimated initial date of fortification with the chronology of the so-called 8.2 ka cooling event. A synthesis of the Greenland ice-core evidence (Kobashi et al. 2007) suggests that temperatures dropped abruptly (with no real time-lag between Greenland and elsewhere in the northern hemisphere) beginning in c. 8175±30 cal BP (6255-6195 cal BC), and remained below average for c.150 years, although the first half of this period was colder than the second. Based on this study, we assume that climate amelioration began in 8090±30 cal BP (6170-6110 cal BC) and that by 8025±30 cal BP (6105-6045 cal BC) temperatures had returned to the long-term average.

Ten AMS and one radiometric ^{14}C result from plant material associated with the Neolithic occupation of Amnya are currently available, all of which correspond to calendar dates in the late 7th-early 6th millennium cal BC (Table S1; Figure S6). Four results are associated with the Amnya I palisade 1, and three with building structures 2, 8 and 9 in Amnya I; the structure 2 hearth is stratigraphically later than the palisade 1 ditch, but otherwise there is no stratigraphic evidence of the sequence of these dates. The other four dated samples are from a stratified sequence of deposits in Amnya II house 2. Although an Eneolithic date of occupation has been suggested for building 1 at this site, based on previous excavations (Stefanov 2001), the dating results confirm that structure 2 dates to the Neolithic phase, and in fact it is difficult to discern any interval between the Amnya I and II houses.

Table S1: Radiocarbon dates from Amnya I&II, Kirip-vis-Yugan (assembled from Stefanov et al. 2005: 33; Stefanov & Borzunov 2008: 109; Piezonka et al 2020: 5, Table 1; with additions of previously unpublished dates). The results have been calibrated using OxCal v4.4.2 (Bronk Ramsey 2020); using the IntCal20 calibration data (Reimer et al. 2020). The final column shows posterior density estimates of the dates of samples included in the Bayesian chronological model. No calibrated date ranges are given for food-crust and TOCC ^{14}C ages, as these are not regarded as true dates due to uncertainty about the origin of the carbon in these samples.

Lab. No	**Context**	**Dated material**	**^{14}C age BP**	**calibrated date (cal BC, 95% probability)**	**modelled date (cal BC, 95% probability)**
Amnya I					
Le-4973	Dwelling 9, filling	Charcoal	6900±90	5990-5630	6000-5730
Le-4974a	Dwelling 9, bottom layer (weighted mean)	Charcoal	8760±280	8240-7480	
Le-4974b			8630±180		
Le-4974			(8669±152)		
Ki-16028	Dwelling 1, potsherd	TOCC (total organic carbon content)	6920±90		
Poz–97648		Charred crust on pottery	7590±40		
Poz–116666	Palisade 1, layer 6	Charcoal	7390±40	6390-6080	6130-5880
Poz–120474		Charcoal (2nd fragment)	7205±35	6220-5980	6130-5880
Poz–118343	Dwelling 8, house floor layer	Charcoal	7060±40	6020-5840	6020-5810
Poz–118431	Ditch I, bottom layer, layer 1	Charcoal	7070±50	6060-5830	6040-5840
Poz–118432	Structure 2, hearth, layer 12	Charcoal	7020±50	6010-5770	5990-5770
Poz–133516	Palisade 1, assoc. cultural layer 4	Charcoal/ organics	7220±40	6230-6000	6100-5920
Amnya II					
Poz–118357	Dwelling 2, floor, layer 10	Charcoal/ organics	6970±40	5980-5740	5990-5850
Poz–116667	Dwelling 2, buried podzol, layer 6	Charcoal	7080±40	6060-5840	5980-5810
Poz–133517	Dwelling 2, buried podzol, layer 6	Charcoal/ organics	6940±40	5970-5720	5980-5780
Poz–133380	Dwelling 2, burnt layer, layer 4	Charcoal/ organics	6980±50	5990-5740	5920-5740
Kirip-vis-Yugan 2					
Le-6582	Dwelling 4	Charcoal	6880±50	5890-5660	
Poz–97649	Dwelling 1, potsherd	Charred crust on pottery	7600±40		

Our Bayesian chronological model (main text, Figure 7) was created in OxCal v.4.4 (Bronk Ramsey, 2009a). It assumes that these 11 ^{14}C results represent a single Neolithic phase of activity. Most of the results are on fragments of unidentified charcoal, with potential wood-age offsets relative to the tree-fall date. Differences in wood-age offsets may explain why two fragments from the same palisade charcoal sample gave incompatible ^{14}C ages (Poz-116666 and Poz-120474). To account for these intrinsic ages, the model applies OxCal's default Charcoal Outlier_Model function (Bronk Ramsey, 2009b), with a prior probability of 1 (100%) that each charcoal ^{14}C result is too old[1]. For the organic samples (uncharred material such as pine needles), we assume that the dated fragment does not embody a significant wood-age offset.

The model dates palisade 1 to the final decades of the 7th millennium cal BC, and domestic activity to the first quarter of the 6th millennium (main text, Figure 7), but palisade 2 and most of the Amnya houses are undated, and it would be premature to assume that the fortification was not accompanied by permanent dwellings. The model output (main text, Figure 7) suggests that palisade 1 was built after the coldest interval of the 8.2ka event and perhaps shortly after global temperatures had returned to the pre-8.2ka average. Even the model's slightly broader estimate of when the Neolithic phase at Amnya began is clearly later than the coldest interval of the 8.2ka event. The fact that the palisade date apparently coincides with amelioration and/or the return to normal temperatures that characterize the climatic event on a global scale provides an important insight into the potential triggers for the creation of fortified settlements. However, since the regional effects of the 8.2ka event in the north of Western Siberia are currently not well understood, further palaeoclimatic and palaeoenvironmental research is necessary (Chairkina & Piezonka 2021).

The model omits two radiometric measurements (Le-4974a and Le-4974b) of bulk charcoal from the lowest level of Amnya 1, house 9, which appear to date this material to the Mesolithic period (earlier 8th millennium cal BC), a phase currently not recognizable archaeologically in the excavated structures and materials[2]. Another radiometric result on bulk charcoal from house 9 (Le-4973, 6900±90 BP), with a much smaller uncertainty, corresponds to a calibrated date similar to those of AMS samples from other structures at Amnya I, and is used in the model. The model also omits an AMS date from charred organic crusts on pottery from Amnya I, which is 600-700 ^{14}C years older than charcoal dates from equivalent contexts, presumably due to freshwater reservoir effects (FRE) in the food ingredients (Dubovtseva et al. 2019; Piezonka et al. 2020), and a radiometric ^{14}C measurement (Ki-16028) on the total organic carbon content of a sherd fragment of one of these pots. The last result (6920±90 BP) is consistent with the charcoal dates from the occupation phase, but intrinsically less reliable than dates on visible organic fragments.

[1] Poz-116666 seems to be significantly older than the other dated fragment from the same sample and thus almost certainly embodies a wood-age offset, but we cannot a priori know whether any of the other dated fragments were significantly older than the date of deposition. The default Charcoal Outlier_Model parameters assume that most wood-age offsets are trivial.

[2] Both measurements have large uncertainties, however, suggesting low carbon yields and thus a higher risk of contamination with residual organic material. The ^{14}C results may therefore be misleading.

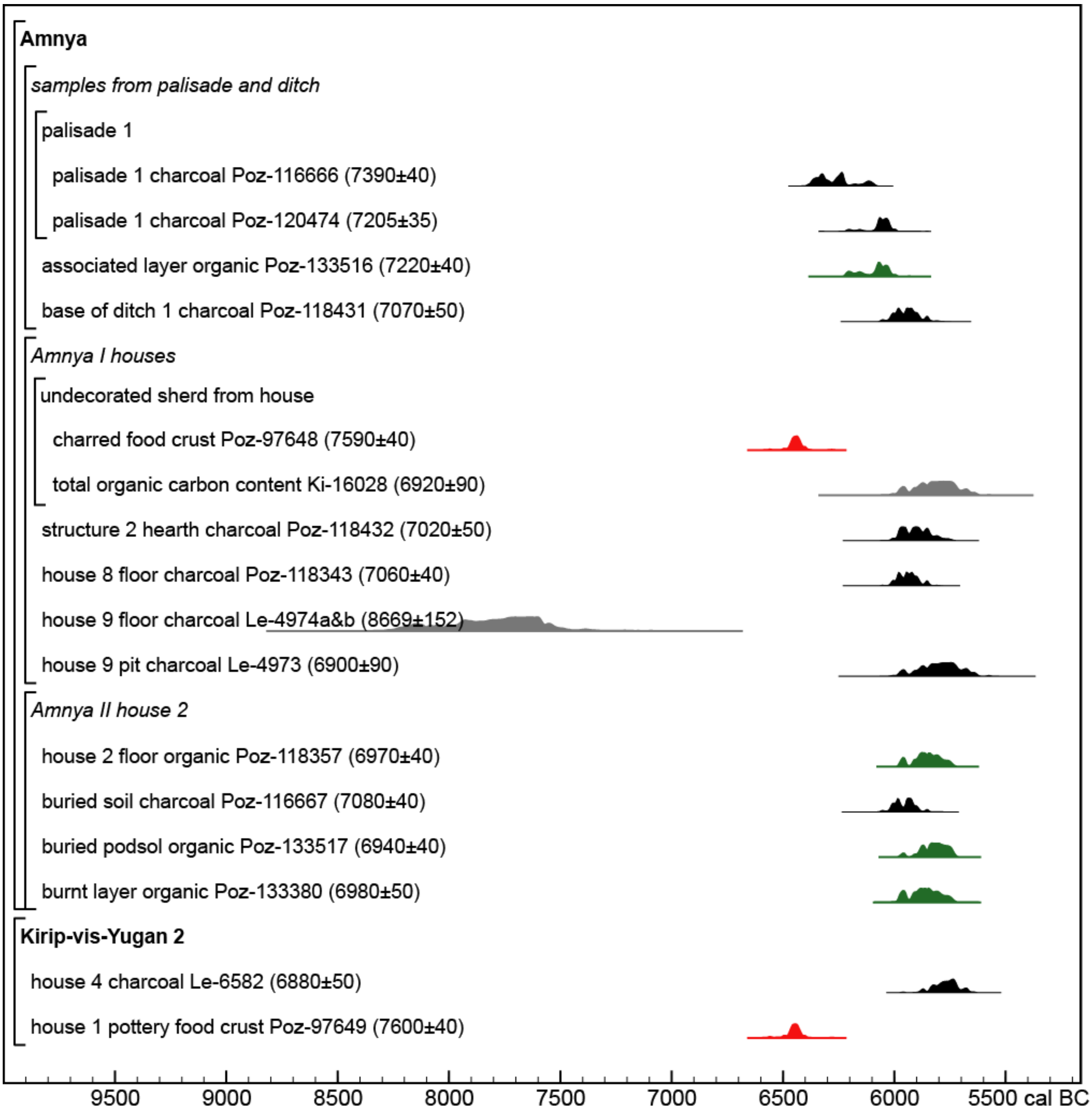

Figure S7. Simple calibration of ^{14}C results from Amnya and Kirip-vis-Yugan (Table S1). ^{14}C ages (given in labels) were calibrated using OxCal v.4.4 (Bronk Ramsey, 2020) and the IntCal20 calibration curve (Reimer et al., 2020). Legend: black – wood charcoal, no allowance for wood-age offsets; green –organic (plant) material; red – charred food crust on pottery, calibration only provides a maximum age (pottery cannot be older than this date) due to potential for ^{14}C reservoir effects; grey – radiometric ^{14}C measurements of potentially inhomogenous material.

A similar ^{14}C age offset is possible in an AMS date of a pottery food-crust from dwelling 1 at nearby Kirip-vis-Yugan 2 (Poz–97649, 7600±40 BP), given that the only other ^{14}C from this site (Le-6582, 6880±50 BP; dwelling 4 bulk charcoal, 5890-5660 cal BC) also suggests an early 6th millennium Neolithic occupation. Without organic residue analyses of the food crusts (to confirm that the ingredients included aquatic species) and ^{14}C measurements on known-age aquatic species from Amnya (to estimate the local freshwater ^{14}C reservoir effect), this interpretation remains speculative, but larger ^{14}C age offsets are recorded in food crusts on hunter-gatherer-fisher pottery in eastern Europe (Courel et al., 2021).

2.4. Palaeobotanical analysis

A pilot study of soil samples from the re-opened sections provides first insights into the potential of studies of plant macroremains at Amnya (Tables S2-3). Seeds of species such as bearberry and knotweed from house fill layers at Amnya I and II attest to plants collected for food and/or medicine. The presence of spruce needles in house floor sediment could be the earliest evidence of soft furnishing the dwelling floors with coniferous twigs - a practice still widespread among recent and contemporary circumpolar mobile forager groups (Moermann 2009: 398-403; Piezonka et al. 2021: 161-162).

Table S2. Amnya I, palaeobotanical determination of plant macroremains from samples retrieved during re-opening of sections through house pit 2 (x = present, n = number, g = gram).

Amnya I							
Sample no.		**6**	**9**	**20**	**21**	**22**	
Trench no.		**6**	**6**	**2**	**2**	**2**	
Section no.		**R-26**	**R-27**	**D-8**	**D-8**	**D-9**	
Object no./ context		**House 8**	**House 8**	**Structure 2**	**Ditch I**	**Ditch I**	
Layer no.		**floor**	**floor**		**5**	**5**	
Botanical taxon	Remains	n	n	n	n	n	Common name
Arctostaphylos uva-ursi	Seeds (core)				6		Bearberry
Malvaceae	Seeds						Mallows
Polygonaceae	Inner fruit		2				Knotweed
Vegetative remains							
Picea	Needle fragments		7	12			Spruce
cf. *Betula*/*Picea*/*Pinus*	Bark (half-charred)		x	x	x	x	Possibly birch/ spruce/ pine
Ind.	Halm- and stem fragment				4		Ind.
Other							
Red pebbles			x	x	x		
Bone (g)			< 0,1	26			

Table S3. Amnya II, palaeobotanical determination of plant macroremains from samples retrieved during re-opening of sections through house pit 2.

Amnya II				
Sample no.		**2**	**5**	
Trench no.		**1**	**1**	
Object no./ context		**House 2**	**House 2**	
Layer no.		**11a**	**10**	
Botanical remains (latin)	**Remains**	n	n	**Botanical remains (engl.)**
Arctostaphylos uva-ursi	Seeds (core)			Bearberry
Malvaceae	Seeds		4	Mallows
Polygonaceae	Inner fruit			Knotweed
Vegetative remains				
Picea	Needle fragments			Spruce
cf. *Betula*/*Picea*/*Pinus*	Bark (half-charred)			Possibly birch/ spruce/ pine
Ind.	Halm- and stem fragment		1	Ind.
Other				
Red pebbles				
Bone (g)				

2.5. Palaeoenvironmental pilot study of sedimentary cores adjacent to the Amnya promontory

To reconstruct the paleoclimate of northern West Siberia, the most informative source to date are peatbogs, which contain, as a rule, complete sedimentation sequences of all Holocene periods, allowing a greater degree of reliability in using scientific methods in palaeoenvironmental reconstructions.

Altogether, 18 cores were drilled in three transects across the peatland abutting the promontory Northwest, West and Southwest (main text, Figure 8). This work was executed with an Eijkelkamp Peat Sampler drill of 0.6 m width. They reached depths between 0.55 and 3.65 m. The stratigraphy of sediments including visible macro-remains in the cores was assessed and described on site. The standard profile starts with peaty clays and gyttja sediments at the bottom of the cores, followed by peat layers of various type that significantly vary in their thickness between the three transects, with peats reaching more than 2 m thickness in line 2 to the Southwest of the promontory, and maximal thicknesses of less than a metre in Line 1 to the West. The peat layers are covered by modern vegetation.

Three samples for radiocarbon dating were collected from borehole 2.3 on the southern side of the promontory from gyttja layers and from the base of the peat layer in this core (Table S4).

Table S4. Amnya. Radiocarbon results from borehole 2.3 adjacent to promontory.

Depth	Material	Laboratory number	^{14}C age (BP)	Calibrated date range (95% probability)
2.25-2.35 m	peat	Le-9711	4,740 ± 100	3770-3130 cal BC
2.35-2.45 m	gyttja	Le-9712	6,050 ± 120	5310-4690 cal BC*
3.25-3.35 m	gyttja	Le-9713	8,170 ± 280	7800-6450 cal BC*

* range regarded as a maximum age due to the potential for ^{14}C reservoir effects in aquatic organisms such as algae

The results of radiocarbon dating of the lower part of the gyttja deposits in the ancient floodplain by the settlement site of Amnya I - 8170±280 BP (Le-9713) indicate the beginning of formation of a lake stage in the hydrological regime by the promontory approximately around 7800-6450 cal BC. The beginning of peat formation took place after the upper parts of the gyttja had formed at 6,050±120 BP (Le-9712) or later (ca. 5310-4690 cal BC) and before or around the age determined for the lower part of peat samples at 4740±100 BP (Le-9711), equating to ca. 3770-3130 cal BC.

Thus, during the period when these monuments were in operation, at the end of the seventh and first quarter of the sixth millennium cal BC, open water bodies existed next to them, and the processes of paludification in these areas began later. The first results of the analysis of samples of botanical macroremains from the Amnya I promontory fort and the Amnya II settlement tentatively indicate moderately warm climatic conditions, which favoured the formation of birch-pine and pine-birch forests with spruce and fir of the southern taiga type. This is in broad accordance with the few palaeoenvironmental and archaeological data available to date, which indicate that there were generally favourable, moderately warm climatic conditions in the North of Western Siberia and the Urals in the early Atlantic period, with the lowest winter temperatures and the highest summer temperatures and lower annual precipitation totals than at present (Zaretskaya et al. 2014).

Altogether, the palaeoecological situation in Western Siberia during the 7th-6th millennia cal BC has not yet been sufficiently investigated. Questions remain open concerning the vegetation history, the position of vegetation zone boundaries and climatic conditions in the Boreal and early Atlantic periods, especially in the northern regions. For objective reconstruction of the paleoclimatic situation in which the early fortified sites such as Amnya I appeared, along with the analysis of reference cross-sections of marshlands of the middle and southern taiga zone, the study of peat and gyttja sections from wetland areas in the immediate vicinity of archaeological sites, supported by sufficient ^{14}C dating, is necessary. The extension of palynological studies to the northern regions of Western Siberia is also promising (Zakh et al. 2021).

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