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THE CHRONOLOGY OF CORDED WARE CULTURE IN FINLAND – REVIEWING NEW DATA

Abstract
This paper reviews radiocarbon dates from the Late Neolithic Corded Ware Culture (CWC) contexts in Finland. The authors have recently published new CWC radiocarbon dates as a part of their multi-site geochemical provenance investigation of CWC pottery recovered from archaeological contexts in Finland, Sweden, and Estonia. In this paper, the new and old radiocarbon dates are modelled using a Bayesian phase model to identify outliers in the data set and elaborate the new dates within the wider picture of the CWC absolute chronology of the study area. Timeframe 2900–2200 calBC is suggested for the CWC in Finland.

Keywords: Bayesian modelling, Corded Ware Culture, Finland, Late Neolithic, radiocarbon dates

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INTRODUCTION

Until recently, the chronology of the Corded Ware Culture (henceforth the CWC) in Finland has not been based on absolute chronology and radiocarbon dates. Even today, only a few radiocarbon dates are available for the CWC in the region of Finland, and although quantitatively inadequate for in-depth interpretation, these few dates have largely dominated the perception of the timing and succession of the CWC chronology in the sequence of archaeological cultures of Finland. Traditionally, the beginning of the CWC in this region has been placed at 3200 calBC, i.e. at the end of the Middle Neolithic period (e.g. Carpelan 1999; Pesonen & Leskinen 2011), but recently this view has been challenged with reference to the Central European chronology. From this perspective, the CWC phenomenon has now been labelled as Late Neolithic, thus beginning in Finland only c 2900–2800 calBC (Mökkönen 2011; Nordqvist 2016; Nordqvist & Mökkönen 2016). The Finnish CWC is characterised by settlement sites, burial sites and stray finds of battle axes as well as four-sided work axes. Corded Ware pottery is present both in the settlement sites and burials as well (e.g. Nordqvist & Häkälä 2014).

During a project investigating the geochemical compositions of Corded Ware pots and grog temper, we found that the pots were drifting across the Baltic Sea, probably along with their manufacturer groups, and we also acquired several new radiocarbon dates from CWC contexts in Finland, derived from burnt bones and charred crusts on the pots (Holmqvist et al. 2018). This new material provides an opportunity to re-evaluate the chronology of the whole CWC complex in Finland. Importantly, there is now enough material to perform a Bayesian OxCal phase model on the old and new radiocarbon data related to CWC contexts. In this study, we present the

Fig. 1. Radiocarbon-dated CWC sites in Finland; 1) Vantaa Jönsas, 2) Lieto Kukkarkoski I, 3) Seinäjoki Isosaari, 4) Teuva Kortesnevankorpi, 5) Porvoo Böle, 6) Kirkkonummi Tengo Nyåker, 7) Salo (Halikko) Urheilutie 15, 8) Vantaa Vanha Nurmijärventie, 9) Vantaa Hommas, 10) Tammela Uusi-Markkula, 11) Porvoo Forsberg, 12) Virolahti Mattilan VPK, 13) Espoo Mäntymäki, 14) Virolahti Meskäärtty. The dotted line marks the approximate northern limit of CWC in the area. Illustration: P. Pesonen.

relevant radiocarbon data, evaluated and modelled using the OxCal programme (Bronk Ramsey 2009). The results indicate that there is one probable outlier in the radiocarbon data, which has strongly affected the interpretation of the timing of the beginning of the CWC in Finland. There are also younger outliers among the CWC dates, but these are more problematic and their rejection should be treated with caution. This is largely because there are indications of the continuation of the CWC tradition even until the advent of the Bronze Age in the Baltic States and the eastern part of the Gulf of Finland, and this continuum could be reflected in the late CWC dates from Finland (cf. Nordqvist 2016). If the single radiocarbon date considered too early is, indeed, rejected as we propose here, the chronology of the CWC in Finland fits better within the consensus of the CWC chronology in the pan-European context: to c 2900–2000 calBC.

MATERIAL

The first radiocarbon dates from CWC contexts in Finland were obtained in the 1970's. For decades, the chronology of the CWC was based only on the radiocarbon dates from three burials in southern Finland, namely from the Jönsas site in Vantaa, the Kukkarkoski site in Lieto, and the Eknäs (Forsberg) site in Porvoo. The oldest

No	Site	Lab-index	BP	±	$\delta^{13}C$ (‰)	MRE corrected date BP*	Unmodeled calBC (95.4%)	Modelled calBC (95.4%)	Material & context	Catalogue number	Reference
1	Vantaa Jönsas	Hel-1006	4520	130			3630–2900	3130–2630	Charcoal, burial		Ojonen 1983
2	Lieto Kukkarkoski I	Hel-831	4320	170			3500–2480	3070–2470	Charcoal, burial		Torvinen 1979
3	Seinäjoki Isosaari	Hela-2658	4229	47	-24.7	4184±52	2900–2620	2900–2620	Crust, pottery		This work**
4	Teuva Kortesnevankorpi	Hela-3429	4216	28	-28.0		2910–2690	2910–2690	Crust, pottery	KM 18921	Holmqvist et al. 2018
5	Porvoo Böle	Hela-3426	4210	29	-26.4		2900–2680	2900–2680	Crust, pottery	KM 22004:6006	Holmqvist et al. 2018
6	Kirkkonummi Tengo Nyåker	Hela-3461	4205	31	-25.9		2900–2670	2900–2670	Burnt bone	KM 21501:51	Holmqvist et al. 2018
7	Salo (Halikko) Urheilutie 15	Hela-3458	4192	28	-28.0		2890–2670	2890–2670	Burnt bone	KM 22008:144	Holmqvist et al. 2018
8	Vantaa Vanha Nurmijärventie	Ua-32204	4185	45	-27.0		2900–2630	2900–2630	Burnt bone		Leskinen & Pesonen 2008
9	Vantaa Hommas	Hela-1648	4165	40	-27.3		2890–2620	2890–2620	Burnt bone		Koivisto 2010
10	Tammela Uusi-Markkula	Hela-3462	4161	31	-27.6		2880–2630	2880–2630	Burnt bone	KM 37643:495	Holmqvist et al. 2018
11	Porvoo Forsberg	Sch156/ H1938-1009	4140	80			2900–2490	2900–2490	Charcoal, burial		Edgren 1992
12	Virolahti Mattilan VPK	Hela-3428	4136	29	-23.5	4050±51	2860–2460	2860–2460	Crust, pottery	KM 15329:132	Holmqvist et al. 2018
11	Porvoo Forsberg	GrN-6256	4105	55			2880–2490	2880–2490	Charcoal, burial		Edgren 1992
7	Salo (Halikko) Urheilutie 15	Hela-3457	4040	30	-26.9		2840–2470	2840–2470	Burnt bone	KM 22008:202	Holmqvist et al. 2018
13	Espoo Mäntymäki	Hela-3425	3897	29	-28.9		2470–2290	2470–2300	Crust, pottery	KM 16288:16	Holmqvist et al. 2018
14	Virolahti Meskäärtty	Hela-1614	3820	45	-25.0	3786±48	2450–2030	2460–2140	Crust, pottery		Mökkönen 2008
1	Vantaa Jönsas	Ua-32196	3790	40	-25.2	3763±42	2300–2030	2460–2130	Crust, pottery	KM 20087:264	Leskinen & Pesonen 2008

*Table 1. The CWC-related radiocarbon dates from Finland used in this study. The resulting posterior dates have been rounded by 10. Calibration with OxCal v. 4.3 (Bronk Ramsey 2009), atmospheric data (IntCal 13) by Reimer et al. 2013. * The MRE correction procedure explained in detail by Pesonen et al. (2012; Pesonen & Oinonen in press). ** With the kind permission of Päivi Kankkunen, the Finnish Heritage Agency, Finland.*

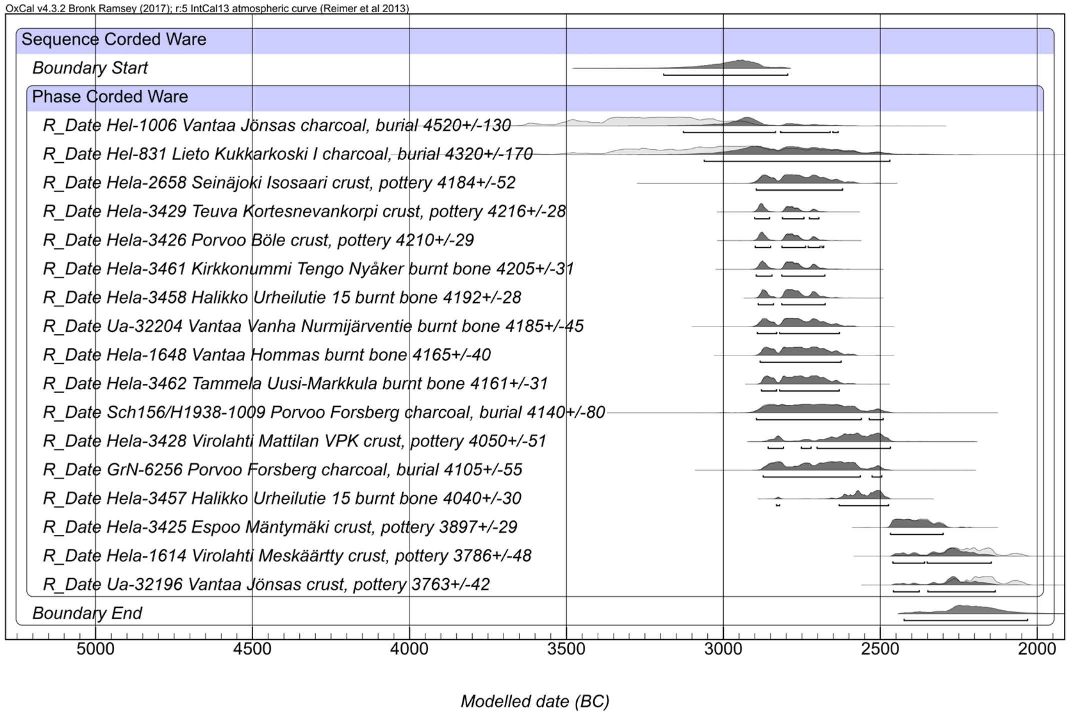

Fig. 2. An example of a Bayesian model of radiocarbon dates associated with the CWC in Finland. The modelling strongly affects the two earliest dates from Vantaa Jönsas and Lieto Kukkarkoski, and the two youngest dates from Virolahti Meskäärtty and Vantaa Jönsas. Calibration with OxCal v. 4.3 (Bronk Ramsey 2009), atmospheric data (IntCal 13) by Reimer et al. 2013.

of these radiocarbon dates, the dating acquired from Vantaa (Hel-1006; 4520±130 BP), is from a charcoal sample retrieved from the bottom of a grave (Jungner & Sonninen 1983: 32; Ojonen 1983: 7; Purhonen 1986; Edgren 1992: 92; Carpelan 1999: 48; 2004; Leskinen & Pesonen 2008). The Kukkarkoski radiocarbon date (Hel-831; 4320±170 BP) was also produced from a charcoal sample found in a burial (Torvinen 1979; Jungner & Sonninen 1983: 24; Edgren 1992: 92; Carpelan 1999: 48; 2004). The Eknäs burial in Porvoo has yielded two radiocarbon dates, which are not as old as the dates from Lieto and Vantaa. These two dates are in perfect concordance with each other (Sch-156/H1038-1009; 4140±80 BP and Grn-6256; 4105±55 BP). Both samples are charred wood, and presumably derive from the container of the deceased, or from the lining of the burial (Edgren 1959; 1970: 75–7; 1992: 92; Carpelan 1999: 48; 2004). In the European perspective, the rather old dates from Vantaa and Lieto have been problematised by Carpelan (1999: 48–9), who, however, did not find any reason to suspect e.g. old wood effecting the dates. Later on, considering the chronological evidence of the CWC from continental Europe, the early dates and the early start of the CWC in Finland have been rejected (Mökkönen 2011: 17).

Before our project began, a few more dates had been obtained from CWC contexts in Finland. There are three samples from Vantaa, one charred crust from the Jönsas site, and two burnt bone dates from the Vanha Nurmijärventie and Hommas sites (Leskinen & Pesonen 2008; Koivisto 2010). In addition, there is one charred crust date from the Meskäärtty multi-room pithouse site in Virolahti (Mökkönen 2008), and one crust date from the Isosaari site located in Seinäjoki. The latter sample was analysed already in the late 2000's, but it has not been published previously.

Altogether, there are currently 17 radiocarbon dates available from Finland that can be associated with CWC materials and contexts (Fig. 1; Table 1). Eight of these are new dates and acquired as part of a project investigating the provenance of CWC pottery, published recently by the authors (Holmqvist et al. 2018; Fig. 2; Table 1). Four of the dates are charcoal from graves, eight are charred (food)crusts from pottery walls, and five are burnt bone dates from CWC settlement sites. In addition, we also dated one sherd with a carbonised crust from Rötved, Sweden, as a reference. While many of the other eastern Fennoscandian ceramic traditions link with the hunter-gatherer societies (e.g. the Comb Ware Culture), there is now convincing evidence of the connection between animal husbandry and CWC pottery. The lipid composition analysed from the Finnish Corded Ware pots is quite strictly dairy fat or ruminant carcass fat, which also applies to the Late Bronze Age and Early Iron Age ceramic finds (Cramp et al. 2014; Pääkkönen et al. 2019). The carbon stable isotope value reflects the aquatic composition of the charred crust, where the terrestrial/marine limit is set to c -26 ‰ (Fischer & Heinemeier 2003). In our samples, the highest value is -23.5 ‰ (Virolahti Mattilan VPK, Hela-3428), a bit above the limit in the marine side, as well as three other dates, ranging from -25.2 to -24.7 ‰, from the coastal regions of Finland (Seinäjoki Isosaari, Hela-2658; Virolahti Meskäärtty, Hela-1614; Vantaa Jönsas, Ua-32196; see Table 1). The marine reservoir (MRE) correction of the dates has been made according to procedure explained in detail by Pesonen et al. (2012; also Pesonen & Oinonen in press), and the current average value of MRE is estimated as 231±113 radiocarbon years (N=8, CHRONO Marine database). The correction takes into account the possible marine component arithmetically according to carbon isotope value between -19.3‰ (100% marine) and -26‰ (100% terrestrial).

However, there is a strong possibility that the burnt bone dates actually represent the age of the wood burned in the pyre (Hüls et al. 2010; Van Strydonck et al. 2010; Olsen et al. 2012). In such cases, the burnt bone dates would have the same pros and cons as traditional charcoal dates, which, in principle, should not carry any other error sources but the possible old wood effect. At

	95.4% start	95.4% end	68.2% start	68.2% end	Median start	Median end	Mean start	Mean end
Whole dataset	3040–2880	2290–2110	3200–2790	2430–2030	2970	2210	2990±100	2210±100
Hel-1006 excluded	2960–2800	2290–2110	3050–2780	2430–2040	2900	2220	2910±70	2210±90
Only crust and burnt bone dates	2960–2800	2280–2110	3050–2780	2400–2000	2900	2190	2910±70	2180±90

Table 2. Results of OxCal runs on the CWC radiocarbon dates from Finland. The calibrated dates have been rounded by 10. Calibration with OxCal v. 4.3 (Bronk Ramsey 2009), atmospheric data (IntCal 13) by Reimer et al. 2013.

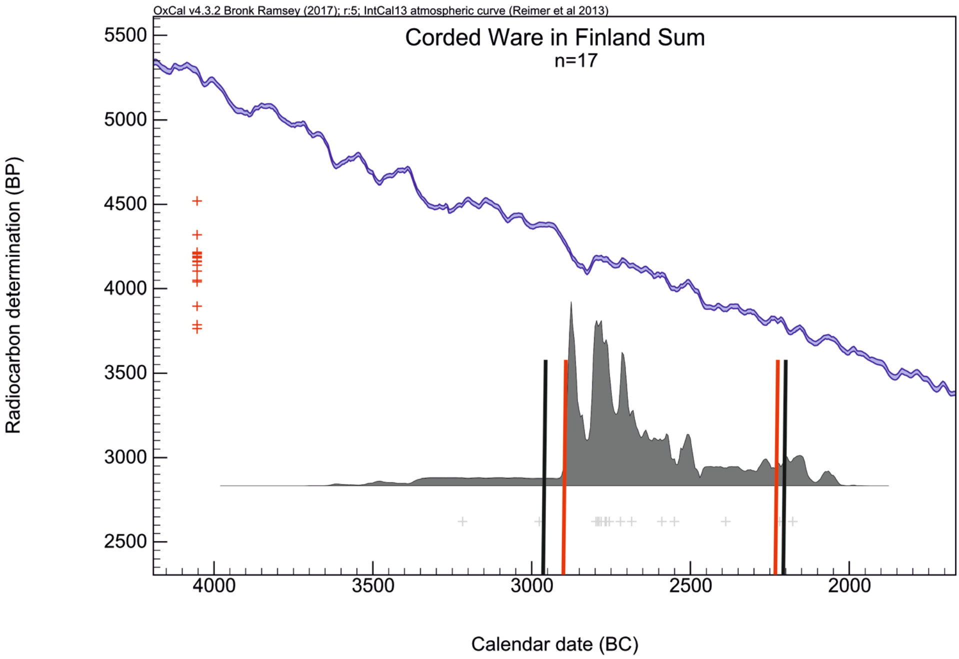

Fig. 3. Sum curve of radiocarbon dates associated with the CWC in Finland. Grey lines denote the Bayesian phase model median boundaries with all data included (2970 and 2210 calBC), and black lines with the outlier (Hel-1006) excluded (2900 and 2220 calBC). Small crosses on the y axis indicate the original radiocarbon determinations, and crosses on the x axis mark the unmodeled median value after calibration. Calibration with OxCal v. 4.3 (Bronk Ramsey 2009), atmospheric data (IntCal 13) by Reimer et al. 2013.

the same time, the 'replacement' of the animal carbon signal by the wood carbon signal would eliminate the possible reservoir effect in the burnt bone dates. For this study, the burnt bone samples were selected because of the extreme lack of datable materials in the Finnish CWC contexts, where crusted sherds, for instance, are very rare.

METHODS AND RESULTS

We suggest that the radiocarbon dates should be treated as probability distributions rather than as discrete truths as such. There are many error sources inherent to radiocarbon dating, starting with the sample selection, preparation, and the possible reservoir effect in coastal food crust dates. One cannot rule out all of the error sources, but there are analytical packages which utilise Bayesian statistics to both calibrate the radiocarbon dates and to identify possible outliers among the dates. The OxCal programme creates a model where the probabilities of the dates are recalculated, allowing statistically grounded phases being formed (Buck et al. 1991; Bayliss 2009; Bronk Ramsey 2009). In this study, a Bayesian-based OxCal model was created and then compared to the sum curve and the 'traditional' dating schemes presented in the literature. The Bayesian model is implemented in the OxCal calibration package. The method has already been applied in a number of previous chronological studies of the ceramic phases in eastern Fennoscandia (Pesonen et al. 2012; Oinonen et al. 2014; Pesonen & Oinonen in press), but it has also faced some criticism (Mökkönen & Nordqvist 2014).

In this case, a simple phase model was employed (Bronk Ramsey 2009; Fig. 3). During the analysis, the oldest date, Hel-1006 from the

Jönsas site in Vantaa, turned to agree poorly with the model. Its agreement index with the rest of the model remained 48.6%, while usually 60% is expected.

The sample is charcoal from the filling of a grave, and therefore its context is a dubious one. Another run was performed for the dates, but this time with this one outlier removed from the dataset, and the third run was performed with charred crust and burnt bone dates only (Table 2). The latter two options appear to show the minimum span of the CWC in Finland, dated between c 2900–2220 calBC in the median values, while the maximum span is shown by the whole dataset run, dated to c 2970–2210 calBC in the median values. These figures differ somewhat from the sum curve of the radiocarbon dates, which shows the whole distribution of probabilities and, consequently, a much wider chronological span, in fact corresponding with the maximum span of the CWC as suggested in the Finnish archaeological literature (Fig. 3).

DISCUSSION AND CONCLUSIONS

According to the European radiocarbon dates available for CWC contexts, the early stages of the CWC phenomenon in Denmark and Central Europe can be dated to c 3000–2900 calBC, while the vast majority of the acquired dates are younger than 2800 calBC, spanning even until 2100–2000 calBC (Furholt 2003; Włodarczak 2009; Olalde et al. 2018). Some Central European dates are, however, controversial and there seems to be certain inconsistencies between laboratories (Włodarczak 2009). In the eastern Baltic region, the radiocarbon dates linked to the beginning of the CWC date somewhere between 3000–2700 calBC, and the dates allow a span until at least c 2150 calBC (Lõugas et al. 2007). Recent work in Lithuania dates whole sequence to c 2800–2400 calBC (Piličiauskas 2018), in North Germany to c 2950–2150 calBC and in North Jutland to c 2750–2250 calBC (Brozio 2018). In Scandinavia, a large amount of radiocarbon dates is available for CWC contexts. For example, in the Malmö region, southern Sweden, the majority of the CWC-related dates extend from 3000 to 2000 calBC (e.g. Brink 2009). However, it seems that the general opinion on the date of the CWC is 2800–2200 calBC (e.g. Sjögren et al. 2016). The exact beginning of the CWC is blurred by a wide plateau in calibration curve between 2880–2580 calBC (e.g. Piličiauskas 2018: 227).

In the earlier Finnish literature, the CWC is dated to c 3200–2350 calBC (Carpelan 1999: 273) or later, c 2900–2250 calBC (Mökkönen 2011: 17). In a recent study, the beginning of the CWC in both Finland and Estonia is considered to date to c 2800 calBC, while the terminal date of the CWC follows that accepted for the rest of Europe, c 2300 calBC (Nordqvist 2016). According to our new data and the modelling of the dates presented here, it appears feasible to propose that the beginning of the CWC in Finland dates to around 2900 calBC, as suggested earlier by Mökkönen (2011). It is perplexing, however, that this date is still 100 years older than the estimated beginning date in the Central European CWC chronology. In the sum curve, there is a distinct rise shortly after 2900 calBC, which does not really allow shifting the CWC start date in the Finnish context to much later than 2900 calBC, even if also the other charcoal dates (Hel-831, Sch156/H1938-1009 and GrN-6256) would be rejected from the model, in addition to the outlier (Hel-1006) discussed above. The calibration curve plateau of 2880–2580 calBC may further contribute to the problem (e.g. Piličiauskas 2018: 227) and hamper the spotting of the exact beginning in models and sum curves. However, certain Fatyanovo sites in the Moscow Region have yielded early dates pointing also to 2900 calBC beginning there (Krenke et al. 2013). Unfortunately, the number of dates in CWC and Fatyanovo contexts is still limited.

The younger end of the Finnish CWC appears to be even more controversial based on radiocarbon dates. In all cases, the model predicts the end of CWC dates to c 2200 calBC (Table 2). However, there is a group of even younger dates from the eastern part of the Gulf of Finland, which suggest that the lower end of the CWC may lie even in the beginning of the Bronze Age (cf. Nordqvist 2016). It is worth noticing, that the end of the CWC coincides roughly with the so-called 4.2 ka event which led to extremely wet weather conditions, especially between 2190 and 2100 calBC (Helama & Oinonen 2019).

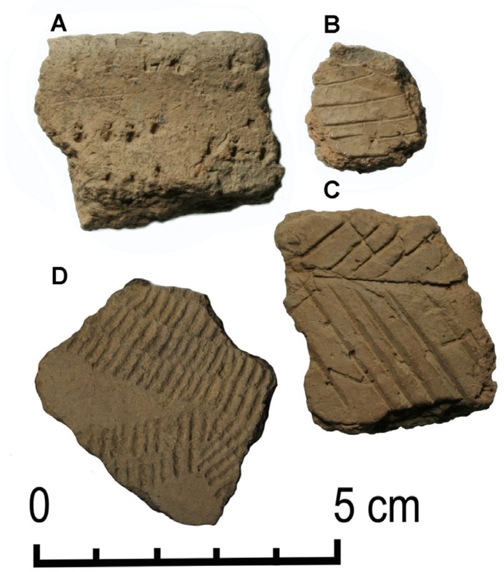

Fig. 4. Ceramic sherds manufactured in coastal Finland and crust-dated to: A) 2880–2600 calBC (KM 15329:132, found in Virolahti Mattila VPK), B) 2900–2680 calBC (KM 22004:6006, Porvoo Böle), C) 2480–2300 calBC (KM 16288:16, Espoo Mäntymäki); and in southern Sweden and dated to: D) 2880–2670 calBC (SHM 22057 1089883, Fjälkestad Rötved). Photos: P. Pesonen, Å. Larsson & E. Holmqvist.

At the Rötved site of Fjälkestad Parish in north-eastern Scania, one of the beakers sampled for foodcrust in this project (Fig. 4), recovered from a CWC grave (Malmer's type B; Hansen 1930; Malmer 1962), was ^{14}C-dated to 2880–2670 calBC. This pot was identified as of southern Swedish origin in our provenance analysis (Holmqvist et al. 2018). The date of this pottery sherd fits well with the Scandinavian chronology of the CWC (Larsson 2009: 338–68).

In sum, the radiocarbon dates mostly support the hypothesis that the CWC was introduced in northern Europe during a fairly short period of time. This supposition appears to apply to different regions, although it should be taken into account that even a short time period like this could still involve several generations, as 100 years sums up to at least five generations. Hence, it is necessary to look into other materials (such as pottery or aDNA) to ascertain the actual events that led to this cultural transformation: mass migration, partial migration of family units or specialists, marriage networks or just a spread of ideas – or a combination of several of these processes (cf. Larsson 2009; Holmqvist et al. 2018). Furthermore, what is valid for one region (Central Poland, Jutland etc.) may not be valid for another, and different patterns of cultural transmission and/or adaptation may apply. In coastal Holland, for instance, there was definitely more of a local adoption of the outer trappings of the CWC (the pottery looks similar, but was made with local craft traditions), whereas in the inland the pottery seems to be made by craftspeople taught in the new technological tradition (Beckerman 2015). These examples underline the need for both regional and inter-regional studies.

Considering the rapid spread of the CWC into eastern Fennoscandia, there are clear similarities to the situation in the rest of Europe. Traditionally, in Finnish archaeological research the arrival of the CWC is usually seen as a result of migration rather than cultural assimilation and transmission via contacts and the diffusion of artefact traditions (e.g. Huurre 2003; Halinen 2015). In the Baltic States, however, it was earlier considered that the CWC arrival involved only limited migration, and that it was primarily based on a gradual local development and intermixing of groups (e.g. Lang 1998). Nowadays, migration is seen as a primary launcher of the CWC also in the Baltic States (Piličiauskas 2018). In the European perspective, aDNA results have finally challenged the views of transmission in the favour of migration (e.g. Allentoft et al. 2015; Haak et al. 2015; Jones et al. 2017; Saag et al. 2017; Mittnik et al. 2018). The new radiocarbon dates cannot offer a major contribution to this debate; nevertheless, this chronological data strengthen the view of rapid expansion, which is difficult to explain by gradual cultural adaptation and development. On the other hand, the discrepancies at the younger end of the radiocarbon dates available for the Finnish CWC can perhaps be seen as an implication of local adaptations and histories between the CWC carriers and the indigenous peoples in this region.

The amount of radiocarbon dates from the CWC contexts in Finland is still fairly limited, preventing detailed interpretations of the internal, domestic development of the culture at this stage with certainty. Nevertheless, it is interesting, for example, that a shift from mineral to organic tempers has been suggested in the ceramic repertoire over the course of the CWC (Nordqvist 2016). This kind of evidence could perhaps be further elaborated with radiocarbon dates, and a growing corpus of reliable dates can aid the examination of, e.g., craft traditions in a more secure chronological context in the future. All of the three crust-dated sherds from the Finnish sites included in the provenance investigation belonged to a fabric group geochemically identified as of coastal Finland origin (Holmqvist et al. 2018), yet the ceramics display stylistic and chronological variation (Fig. 4). Two of these sherds (KM 15329:132 found in Virolahti Mattila VPK, and KM 22004:6006 from Porvoo Böle), together with the pot from Fjälkestad Rötved of southern Swedish origin (SHM 22057 1089883), are broadly from the early centuries of the CWC (dated to 2880–2600 calBC, 2900–2680 calBC, and 2880–2670 calBC, respectively), but appear typologically unrelated. The younger sherd from Espoo Mäntymäki (KM 16288:16, dated to 2480–2300 calBC) bears the so-called herring-bone patterning, possibly also characteristic of the surface treatment of the Porvoo pot, although the state of preservation of the latter prevents a detailed comparison and discussion of the timeframe of this stylistic trait.

To conclude, the beginning of the CWC in Finland seems to be rather established at c 2900 calBC, which is close to the early Fatyanovo dates in the Moscow region. This outcome may imply that the CWC arrived in eastern Fennoscandia c 100 years earlier than in Central Europe, considering the currently accepted start date of the CWC at c 2800 calBC in the European continent. Alternatively, although speculative at the moment, our results may also be indicative of the fact that the start of the CWC in the wider European context dates, in fact, earlier than previously thought (e.g. Brozio 2018), i.e., closer to the 2900 calBC as seen in the region of Finland. The younger end of CWC is placed in Finland to c 2200 calBC, which in turn is rather late in the wider European context. However, this may reflect the late occurrence of the CWC in the southern coast of Finland, parallel to the suggested extension of the late appearance of this cultural phase in the Karelian Isthmus, Ingria, and Estonia (cf. discussion in Nordqvist 2016).

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REFERENCES

Internet sources

CHRONO Marine database. <http://calib.org/marine/>

Literature

Allentoft, M.E., Sikora, M., Sjögren, K.-G., Rasmussen, S., Rasmussen, M., Stenderup, J., Damgaard, P.B., Schroeder, H., Ahlström, T., Vinner, L., Malaspinas, A-S., Margaryan, A., Higham, T., Chivall, D., Lynnerup, N., Harvig, L., Baron, J., Della Casa, P., Dabrowski, P., Duffy, P.R., Ebel, A.V., Epimakhov, A., Frei, K., Furmanek, M., Gralak, T., Gromov, A., Gronkiewicz, S., Grupe, G., Hajdu, T., Jarysz, R., Khartanovich, V., Khokhlov, A., Kiss, V., Kolář, J., Kriiska, A., Lasak, I., Longhi, C., McGlynn, G., Merkevicius, A., Merkyte, I., Metspalu, M., Mkrtchyan, R., Moiseyev, V., Paja, L., Pálfi, G., Pokutta, D., Pospieszny, L., Price, T.D., Saag, L., Sablin, M., Shishlina, N., Smrčka, V., Soenov, V.I., Szeverényi, V., Tóth, G., Trifanova, S.V., Varul, L., Vicze, M., Yepiskoposyan, L., Zhitenev, V., Orlando, L., Sicheritz-Pontén, T., Brunak, S., Nielsen, R., Kristiansen, K. & Willerslev, E.

2015. Population genomics of Bronze Age Eurasia. *Nature* 522: 167–72.

Bayliss, A. 2009. Rolling out revolution: Using radiocarbon dating in archaeology. *Radiocarbon* 51 (1): 123–47.

Beckerman, S.M. 2015. *Corded Ware Coastal Communities. Using ceramic analysis to reconstruct third millennium BC societies in the Netherlands.* Leiden: Sidestone Press.

Brink, K. 2009. *I palissadernas tid. Om stolphål och skärvor och sociala relationer under yngre mellanneolitikum.* Malmö: Malmö Museer.

Bronk Ramsey, C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51 (1): 337–60.

Brozio, J.P. 2018. Zur absoluten Chronologie der Einzelgrabkultur in Norddeutshland und Nordjütland. *Germania* 96: 45–92.

Buck, C., Kenworthy, J., Litton, C. & Smith, A. 1991. Combining archaeological and radiocarbon information: a Bayesian approach to calibration. *Antiquity* 65 (249): 808–21.

Carpelan, C. 1999. Käännekohtia Suomen esihistoriassa aikavälillä 5100–1000 eKr. In P. Fogelberg (ed.) *Pohjan poluilla. Suomalaisten juuret nykytutkimuksen mukaan*: 249–80. Bidrag till kännedom av Finlands natur och folk 153.

Carpelan, C. 2004. Corded Ware Culture in Northern Finland. In M. Lavento (ed.) *Early in the North, Volume 5*: 47–62. Iskos 13.

Cramp, L.J.E., Evershed, R.P., Lavento, M., Halinen, P., Mannermaa, K., Oinonen, M., Kettunen, J., Perola, M., Onkamo, P. & Heyd, V. 2014. Neolithic dairy farming at the extreme of agriculture in northern Europe. *Proceedings of the Royal Society B* 281: 20140819.

Edgren, T. 1959. Eknäs-graven. Ett bidrag till kännedomen om båtyxkulturen i östra Nyland. *Finskt Museum* 70 (1963): 27–51.

Edgren, T. 1970. *Studier över den snörkeramiska kulturens keramik i Finland*. Suomen Muinaismuistoyhdistyksen Aikakauskirja 72.

Edgren, T. 1992. Den förhistoriska tiden. In M. Norrbäck (ed.) *Finlands historia* 1: 9–270. Esbo: Schildts.

Fischer, A. & Heinemeier, J. 2003. Freshwater reservoir effect in ^{14}C dates of food residue on pottery. *Radiocarbon* 45 (3): 449–86.

Furholt, M. 2003. Absolutchronologie und die Entstehung der Schnurkeramik. *Journal of Neolithic Archaeology*. <http://www.jungsteinSITE.de>

Haak, W., Lazaridis, I., Patterson, N., Rohland, N., Mallick, S., Llamas, B., Brandt, G., Nordenfelt, S., Harney, E., Stewardson, K., Fu, Q., Mittnik, A., Bánffy, E., Economou, C., Francken, M., Friederich, S., Garrido Pena, R., Hallgren, F., Khartanovich, V., Khokhlov, A., Kunst, M., Kuznetsov, P., Meller, H., Mochalov, O., Moiseyev, V., Nicklisch, N., Pichler, S.L., Risch, R., Rojo Guerra, M.A., Roth, C., Szécsényi-Nagy, A., Wahl, J., Meyer, M., Krause, J., Brown, D., Anthony, D., Cooper, A., Werner Alt, K. & Reich, D. 2015. Massive migration from the steppe was a source for Indo-European languages in Europe. *Nature* 522: 207–11.

Halinen, P. 2015. Kivikausi. In G. Haggrén, P. Halinen, M. Lavento, S. Raninen & A. Wessman *Muinaisuutemme jäljet. Suomen esi- ja varhaishistoria kivikaudelta keskiajalle:* 2–121. Helsinki: Gaudeamus.

Hansen, F. 1930. En nyfunnen skånsk markgrav från stenåldern. *Fornvännen* 25: 129–35.

Helama, S. & Oinonen, M. 2019. Exact dating of the Meghalayan lower boundary based on high-latitude tree-ring isotope chronology. *Quaternary Science Reviews* 214: 178–84.

Holmqvist, E., Larsson, Å.M., Kriiska, A., Palonen, V., Pesonen, P., Mizohata, K., Kouki, M. & Räisänen, J. 2018. Tracing grog and pots to reveal Neolithic Corded Ware Culture contacts in the Baltic Sea region (SEM-EDS, PIXE). *Journal of Archaeological Science* 91: 77–91.

Hüls, C.M., Nadeau, M.J., Grootes, P.M., Erlenkeuser, H. & Andersen, N. 2010. Experimental study on the origin of cremated bone apatite carbon. *Radiocarbon* 52 (2): 587–99.

Huurre, M. 2003. Viipurin läänin kivikausi. In M. Saarnisto (ed.) *Karjalan synty. Viipurin läänin historia* I: 151–244. Joensuu: Karjalan kirjapaino.

Jones, E.R., Zarina, G., Moiseyev, V., Lightfoot, E., Nigst, P.R., Manica, A., Pinhasi, R. & Bradley, D.G. 2017. The Neolithic transition in the Baltic was not driven by admixture with early European farmers. *Current Biology* 27 (4): 576–582.

Jungner, H. & Sonninen, E. 1983. *Radiocarbon Dates II*. Radiocarbon Dating Laboratory: University of Helsinki: Report 2.

Koivisto, S. 2010. Vantaa Hommas. Myöhäismesoliittinen asuinpaikka Kehäratalinjalla. In H. Ranta (ed.) *Kentältä poimittua 7. Kirjoitelmia arkeologian alalta*: 5–18. Museoviraston arkeologian osaston julkaisuja 12.

Krenke, N., Erschov, I., Erschova, E. & Lazukin, A. 2013. Corded Ware, Fatyanovo and Abashevo Culture sites on the flood-plain of the Moskva River. *Sprawozdania Archeologiczne* 65: 413–24.

Lang, V. 1998. Some aspects of the Corded Ware Culture east of the Baltic Sea. In K. Julku & K. Wiik (eds.) *The Roots of Peoples and Languages of Northern Eurasia*: 84–104. Historica Fenno-ugrica I.

Larsson, Å.M. 2009. *Making and Breaking Bodies and Pots. Material and ritual practices in Sweden in the third millennium BC*. Uppsala: Uppsala University.

Leskinen, S. & Pesonen, P. 2008. *Vantaan esihistoria*. Vantaa: Vantaan kaupunki.

Lõugas, L., Kriiska, A. & Maldre, L. 2007. New dates for the Late Neolithic Corded Ware Culture burials and early husbandry in the East Baltic region. *Archaeofauna* 16: 21–31.

Malmer, M.P. 1962. *Jungneolithische Studien*. Lund: Lund University.

Mittnik, A., Wang, C.-C., Pfrengle, S., Daubaras, M., Zarina, G., Hallgren, F., Allmäe, R., Khartanovich, V., Moiseyev, V., Tõrv, M., Furtwängler, A., Andrades Valtueña, A., Feldman, M., Economou, C., Oinonen, M., Vasks, A., Balanovska, E., Reich, D., Jankauskas, R., Haak, W., Schiffels, S. & Krause, J. 2018. The genetic prehistory of the Baltic Sea region. *Nature Communications* 9: 442.

Mökkönen, T. 2008. A review of Neolithic multiroom housepits as seen from the Meskäärtty site in Virolahti parish, extreme south-eastern Finland. *Estonian Journal of Archaeology* 12 (2): 114–51.

Mökkönen, T. 2011. *Studies on Stone Age Housepits in Fennoscandia (4000-2000 calBC). Changes in ground plan, site location, and degree of sedentism*. Helsinki.

Mökkönen, T. & Nordqvist, K. 2014. Vuoksen synty ja kulttuurikehitys. *Muinaistutkija* 2014 (4): 47–56.

Nordqvist, K. 2016. From separation to interaction. Corded Ware in the eastern Gulf of Finland. *Acta Archaeologica* 87 (1): 49–84.

Nordqvist, K. & Häkälä, P. 2014. Distribution of the Corded Ware in the areas north of the Gulf of Finland – an update. *Estonian Journal of Archaeology* 18 (1): 3–29.

Nordqvist, K. & Mökkönen, T. 2016. Periodisation of the Neolithic and radiocarbon chronology of the Early Neolithic and the beginning of the Middle Neolithic in Finland. *Documenta Praehistorica* 44: 78–86.

Oinonen, M., Pesonen, P., Alenius, T., Heyd, V., Holmqvist-Saukkonen, E., Kivimäki, S., Nygrén, T., Sundell, T. & Onkamo, P. 2014. Event reconstruction through Bayesian chronology: Massive mid-Holocene lake-burst triggered large-scale ecological and cultural change. *The Holocene* 24 (11): 1419–27.

Ojonen, S. 1983. Vantaan Myyrmäen Jönsaksen radiohiiliajoitukset v. 1975–77. *Karhunhammas* 7: 14–20.

Olalde, I., Brace, S., Allentoft, M.E., Armit, I., Kristiansen, K., Booth, T., Rohland, N., Mallick, S., Szécsényi-Nagy, A., Mittnik, A., Altena, E., Lipsøn, M., Lazaridis, I., Harper, T.K., Patterson, N., Broomandkhoshbacht, N., Diekmann, Y., Faltyskova, Z., Fernandes, D., Ferry, M., Harney, E., de Knijff, P., Michel, M., Oppenheimer, J., Stewardson, K., Barclay, A., Werner Alt, K., Liesau, C., Riós, P, Blasco, C., Vega Miguel, J., Menduiña García, R., Avilés Fernández, A., Bánffy, E., Bernabò-Brea, M., Billoin, D., Bonsall, C., Bonsall, L., Allen, T., Büster, L., Carver, S., Castells Navarro, L., Craig, O.E., Cook, G.T., Cunliffe, B., Denaire, A., Egging Dinwiddy, K., Dodwell, N., Ernée, M., Evans, C., Kuchařík, M., Francès Farré, J., Fowler, C., Gazenbeek, M., Garrido Pena, R., Haber-Uriarte, M., Haduch, E., Hey, G., Jowett, N., Knowles, T., Massy, K., Pfrengle, S., Lefranc, P., Lemercier, O., Lefebvre, A., Heras Martínez, C., Galera Olmo, V., Bastida Ramírez, A., Lomba Maurandi, J., Majó, T., McKinley, J.I., McSweeney, K., Mende B.G., Modi, A., Kulcsár, G., Kiss, V., Czene, A., Patay, R., Endródi, A., Köhler, K., Hajdu, T., Szeniczey, T., Dani, J., Bernert, Z., Hoole, M., Cheronet, O., Keating, D., Velemínský, P., Dobeš, M., Candilio, F., Brown, F., Flores Fernández, R., Herrero-Corral, A.-M., Tusa, S., Carnieri, E., Lentini, L., Valenti, A., Zanini, A., Waddington, C., Delibes, G., Guerra-Doce, E., Neil, B., Brittain, M., Luke, M., Mortimer, R., Desideri, J., Besse, M., Brücken, G., Furmanek, M., Hałuszko, A., Mackiewicz, M., Rapínski, A., Leach, S., Soriano, I., Lillios, K.T., Cardoso, J.L., Parker Pearson, M., Włodarczak, P., Price, T.D., Prieto, P., Rey, P.-J., Risch, R., Rojo Guerra, M.A., Schmitt, A., Serralongue, J., Silva, A.M., Smrčka, V., Vergnaud, L., Zilhão, J., Caramelli, D., Higham, T., Thomas, M.G., Kennett, D.J., Fokkens, H., Heyd, V., Sheridan, A., Sjögren, K.-G., Stockhammer, P.W., Krause, J., Pinhasi, R., Haak, W., Barnes, I., Lalueza-Fox, C. & Reich, D. 2018. The Beaker phenomenon and the genomic transformation of northwest Europe. *Nature* 555: 190–6.

Olsen, J., Heinemeier, J., Horsnstrup, K.M., Bennike, P. & Thrane, H. 2012. 'Old wood' effect in radiocarbon dating of prehistoric cremated bones? *Journal of Archaeological Science* 40: 30–4.

Pääkkönen, M., Holmqvist, E., Bläuer, A., Evershed, R. & Asplund, H. 2019. Diverse economic patterns in the north Baltic Sea region in the Late Neolithic and in the Early Metal Periods. *European Journal of Archaeology* 23*:* 1–18. <10.1017/eaa.2019.39>

Pesonen, P., & Leskinen, S. 2011. Pottery of the Stone Age hunter-gatherers in Finland. In P. Jordan & M. Zvelebil (eds.) *Ceramics before Farming: The dispersal of pottery among prehistoric Eurasian hunter-gatherers*: 299–318. Walnut Creek: Left Coast Press.

Pesonen, P. & Oinonen, M. in press. The chronology of Jäkärlä Ware – Bayesian interpretation of the old and new radiocarbon dates from Early and Middle Neolithic Southwest Finland. *Documenta Praehistorica* 46.

Pesonen, P., Oinonen, M., Carpelan, C. & Onkamo, P. 2012. Early Subneolithic ceramic sequences in Eastern Fennoscandia – a Bayesian approach. *Radiocarbon* 54 (3–4): 661–76.

Piličiauskas, G. 2018. *Virvelinės keramikos kultūra Lietuvoje 2800–2400 cal BC.* Vilnius: Lietuvos istorijos institutas.

Purhonen, P. 1986. Vantaan Jönsaksen nuorakeraamiset haudat. In T. Edgren (ed.) *Studia præhistorica Fennica C.F. Meinander septuagenario dedicata*: 113–25. Iskos 6.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Hoffmann, D.L., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Staff, R.A., Turney, C.S.M. & van der Plicht, J. 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon* 55 (4): 1869–87.

Saag, L., Varul, L., Scheib, C.L., Stenderup, J., Allentoft, M.E., Saag, L., Pagani, L., Reidla, M., Tambets, K., Metspalu, E., Kriiska, A., Willerslev, E., Kivisild, T. & Metspalu, M. 2017. Extensive farming in Estonia started through a sex-biased migration from the Steppe. *Current Biology* 27 (14): 2185–93.

Sjögren, K-G., Price, T.D. & Kristiansen, K. 2016. Diet and mobility in the Corded Ware of Central Europe. *PLoS ONE* 11 (5): e0155083.

Torvinen, M. 1979. Liedon Kukkarkosken kivikautinen kalmisto. *Suomen Museo* 85 (1978): 37–80.

Van Strydonck, M., Boudin, M. & De Mulder, G. 2010. The carbon origin of structural carbonate in bone apatite of cremated bones. *Radiocarbon* 52 (2): 578–86.

Włodarczak, P. 2009. Radiocarbon and dendrochronological dates of the Corded Ware culture. *Radiocarbon* 51 (2): 737–49.