Bell Beaker resilience? The 4.2ka BP event and its implications for environments and societies in Northwest Europe

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Abstract

This paper deals with the Bell Beaker phenomenon in Northwest Europe, and the question of its development around 2200 BC, in relation to the well-known 4.2ka climatic event. The duration of settlement occupation and the subsistence economy are the variables used in this study to address this resilience on a regional scale. Concluding, we state that regional variability exists in the ways in which communities were impacted by the 4.2ka event. In addition to agricultural intensification, the flexibility of subsistence strategies seems to have played an important role.

Keywords

Resilience; Bell Beaker; Northwest Europe; Settlement; Subsistence

Introduction

From 2600 BC onwards, Western and Central Europe are characterised by what archaeologists have historically labelled as “the Bell Beaker phenomenon” (*e.g.* Vander Linden 2013). In various parts of Europe, especially the Iberian Peninsula, the end of this phenomenon is often considered to date around 2200 BC, with the rise of the El Argar civilisation in the Southeast of the Peninsula, associated with significant changes in social organisation, settlement structure and food economy (Lull et al 2015). The role of climate in the demise of the Bell Beaker phenomenon, and the resilience and vulnerability of prehistoric communities, is currently being debated (*e.g.* Blanco-Gonzalez et al 2018; Hinz et al in press). Specifically, an abrupt climatic event around 2200 BC, commonly known as ‘the 4.2ka event’, has a well attested influence on human society in other parts of the world. In the Eastern Mediterranean, Near East and Southeast Asia, this particular climatic event was identified in North Atlantic marine sediments in the 1990s (Bond et al 2001) and has since then also been related to large scale social changes (Walker et al 2019, 217). In these particular regions of the world, this climatic event lasted from 4400 to 3800 BP (c.2300 - 1800 BC) and led to severe droughts in already arid landscapes and the collapse of, amongst others, the Akkadian Empire (Weiss 2015).

Several archaeologists have also tried to find a relationship between cultural change in Central Europe and this climatic event, such as the development of the Southern German Early Bronze Age and the Únětice culture in Central Europe (*e.g.* papers in Meller et al 2015) or the decreasing human activity in Thy, northern Denmark (*e.g.* Andersen 1993). Others have argued against such a view and see a strong regional differentiation with quite different developments. For instance, Müller (2015) conducted a study, comparing between North Jutland, the South Cimbrian Peninsula and the Central German *Mittelelbe-Saale-Gebiet*. He focused primarily on artefacts and burial evidence. Within this north-south transect very different influences of the 4.2ka event were postulated on the societal development (Müller 2015). In order to further this discussion, we will widen the perspective to other areas in Northwest Europe. This paper will review both the climatic evidence and the archaeological evidence from several areas in Northwest Europe in order to provide some clarity and possible answers to the variability in this transition.

As the global environmental phenomenon is recently receiving new attention, aiming at a better understanding of how past societies have coped with adverse climate change in respect to our

present-day challenge (e.g. Weiss 2016), it becomes more and more compelling to study the varied social mechanisms and effects from comparative regional scales. Especially the extensive scale of climatic changes around 2200 BC and the comparability of communities taking part in the Bell Beaker cultural phenomenon, makes this an excellent potential for studying the various responses to abrupt climate change in the past.

The climatic changes around 2200 BC have been the centre of several discussions recently beyond the transformations in prehistoric civilisations. For instance, geologists have proposed the subdivision of the Holocene epoch into three global stages, the Greenlandian, Northgrippian and the Meghalayan stages (Cohen et al 2018). Based on global climatic changes observed, these stages replace the previously informal scheme of Early, Middle and Late Holocene. The change from the Northgrippian to the Meghalayan stage is taking place during 'the 4.2ka BP event', based on particular changes in temperature and precipitation, as observed in a particular Indian stalagmite (Walker et al 2019, 216-8).

Similarly, paleo-ecologists have historically identified this period based on shared changes in vegetation. In Northern Europe, where most of this research has been carried out, this is considered as the Subboreal. This Subboreal period itself is characterised by a steadily decrease in *Ulmus* and *Tilia* pollen visible in many pollen-diagrams, indicating an opening of primary woodland. While this decrease is attributed to a combination of both human impact and a long-term change in climate (Zagwijn 1994, 68), this change often operates on a long time-scale.

It is at the moment however unclear how different regional developments in climatic conditions and vegetation, such as the developing Subboreal vegetation in Northwest and Central Europe, relate to the global climatic 4.2ka event, as Walker et al (2019, 214) also states.

In this paper we will test the hypothesis that the climate change described as the '4.2ka BP event' led to or contributed to the end of Bell Beaker phenomenon between 2200-1800 BC. This hypothesis will be tested by reviewing the climatic evidence from a Northwest European perspective and reviewing the changes taking place around 2200 BC for regional Bell Beaker communities across Northwest Europe. We keep in mind that the Bell Beaker phenomenon is a diversified social construct, which includes dense Bell Beaker style distribution areas as well as areas, in which only a few Bell Beakers are integrated into the local cultural environments. Therefore, an overview of the Bell Beaker phenomenon in the various case studies is given as well.

First, some expectations and basic assumptions will be presented, as to the concepts of resilience and vulnerability and the relationship between climatic and archaeological parameters. After this, an assessment of the existing climatic evidence will be given for changes taking place at the end of the 3rd millennium BC in Northwest Europe, including marine archives from the Northeast Atlantic. Subsequently, archaeological evidence for change and continuity, in particular the occupation period and the abandonment of settlements and changes in subsistence economy, will be discussed.

Methodology and basic assumptions

The study compares archaeological data against a background of regional climate change. By using the concept of resilience we aim to understand the relationship between society and climate. The concept of resilience is often used in relation to climate change and responses in both natural (e.g. Willemse/Groenewoudt 2012) and societal (e.g. Dockrill/Bond 2009; Flohr et al 2016) aspects. Resilience is here defined as the capacity of societies to withdraw adverse climate change and its environmental impacts. Our ability to see resilience is dependant on the way we envisage the relationship between climate and society.

A recent paper by Flohr et al (2016) reviews three different ways environmental crises can impact society: the general collapse of society, the triggering of long-distance migrations combined with the local adaptation towards a new reality, and finally environmental crises can leave no impact on

human societies. Settlement activities, subsistence strategies and demographic change are the main sources for understanding the impact of climatic change and the societal aspects of resilience towards this climatic change. In particular for the early farming communities in Western Asia, changes in agricultural produce and settlement activities can be related to a decrease in precipitation around the 9.2ka, the 8.2ka and 4.2-3.9ka periods (Flohr et al 2016; Weiss 2016).

What we can take from this, is that we can focus our analysis on both settlement activities and subsistence strategies. We must however consider these aspects with a particular regard to our Northwest European case studies and the way these parameters relate to both climate change itself and the resilience of communities in adapting to this climate change during the later 3rd millennium BC.

We study settlement activities by looking at the occupation history of settlements throughout the 3rd millennium BC, noting the start and ending of settlements and the ways in which settlement practices and traditions are continued, changed or halted. If occupation ends or an abrupt halt in settlement practices is visible around 2200 BC, we can argue for a correlation with climatic change. Less dramatic changes, building on traditional practices, can be seen as evidence for resilience. The precise timing of the changes in settlement activities, in order to perfectly correlate with climatic data, will be impossible. The archaeological / socio-environmental methodology uses Bayesian modelled radiocarbon dates (see Bayliss et al 2007 and Bronk Ramsey 2009), pottery typochronology, and direct evidence from, for instance, the changes in sedimentation and soil formation or erosion.

Subsistence strategies are studied by comparing the records for botanical and zoological datasets from archaeological excavations, complemented with evidence such as pottery residues and foodcrusts, cattle hoofprints, ploughmarks, palynological evidence and particular finds associated with subsistence, such as fish traps, flint sickles or storage containers. Particularly important in identifying resilience to climate change are the variability in animal and plant species consumed, and the introduction of new animal and plant species within the human diet. Both will be assessed for their chronological relevance based on the phasing of settlements mentioned above. Not all these types of evidence are present within each study area.

When changes in settlement activities and subsistence strategies are not associated with climate change, or when no changes are observed in settlement activities or subsistence strategies, the hypothesis stated in the previous paragraph ("the climate change described as the 4.2ka BP event led to the end of Bell Beaker associated settlement occupation and subsistence strategies between 2200-1800 BC") must be rejected, and alternatively we can state that communities were resilient in adapting to climate change.

The methods of this study involve an analysis of settlement occupation patterns and subsistence strategies from three areas of Northern Europe during the period between 2500 and 2000 BC: the Orkney Islands (in the United Kingdom), the Low Countries (comprising of the Netherlands and Flanders) and Schleswig-Holstein (in Germany) in Northwest Europe (fig. 1).

<<Fig 1>>

Figure 1. Study areas within Northwest Europe and climatic archives mentioned in the text.

Climatic changes in NW Europe around 4200 BP

Having explained our premises for this study, and the concept of resilience that relates society and archaeological data to climate change, we will now turn to the climatic change itself. For understanding climate change in Northwest Europe around 4200 BP, the most suitable records are found in the marine archives of the North Atlantic Ocean. Marine archives are well suited to complement continental ones, because they can provide quantitative and continuous reconstructions of temperature and precipitation changes, thus enabling to assess the magnitude and rate of changes as compared to a wider regional setting. Moreover these records help to discriminate the signals of climate change and human impact inherent to Continental lacustrine or peat-derived climate archives.

Jalali et al (2019) provides a recent overview of some of the North Atlantic marine records with the highest temporal resolution and data quality. These records show changes in Sea Surface Temperature, which in turn drive (and can thus be used as records of) two major atmospheric formations in the North Atlantic, the North Atlantic Oscillation (NAO) and the Subpolar Gyre. Due to the mechanism of orbital forcing (Wanner et al 2008), the NAO is already showing a cooling trend from 5300 BP onwards. This also leads to a reduction of activity in the Subpolar Gyre circulation, as Jalali et al (2019) suggest, and a cold and slightly dryer climate in Northwest Europe. Quantitatively, a 2 degrees Celsius decrease in summer-SST and a minor decrease in humidity is argued for, during the period between 4400 and 4100 BP (Jalali et al 2019, 3). Butruille et al (2017) see a similar decrease in both in summer and winter temperature between 4200 and 3500 BP, based on the analysis of two marine sediment corings from the Skagerrak.

On the Continent, some records show evidence for a change in climate, albeit less unequivocal, perhaps reflecting an increased climatic variability. At Lake Bliden in Denmark, Olsen et al (2010) record a humidity shift, within their zone 1 based on their analysis of oxygen, sulphur, carbon and nitrogen isotopes of a sediment core. Between 4300-4050 BP, a decrease in oxygen values points to a wet period. However an increase in nitrogen and sulphur values is indicative of drier and warmer summers, and/or colder winters (Olsen et al 2010, 338). Vorren et al (2007), studying the Sellevollmyra bog in Arctic Norway identified a climatic deterioration with lower temperatures, but moister conditions (a 'wet shift'), between 4220-3810 years BP, primarily based on the study of pollen. And finally, at Engbertsdijkvenen, several cores hint at climatic changes. In cores ENG-I (Van Geel 1978, 18), phase J (48-56 cm) shows the predominance of *Molinia coerulea*, coinciding with a decline in *Ulmus* and *Tilia* and charcoal. This phase J is also found in core ENG-II, and here dated more clearly to around 2200 BC. This particular vegetation change is interpreted as the result of drier conditions and a natural fire around 4200 BP (Van Geel/Dallmeijer 1986, 476-7). Due to the changes in peat ecology as a result of the fire, the particular species *Molinia coerulea* dominates for a few centuries in a seasonal varied wet and dry landscape, until a Sphagnum peat develops around 3900 BP. Core XVI (Blaauw 2003, 58-9) however shows a hiatus between 4200-2500 cal BC, possible as a consequence of this fire, burning away the older peat archive. For Schleswig-Holstein different laminated sediment and pollen records, for example from Lake Belau, indicate long winters and a short vegetation phase between 4050 and 4010 BC, but no major event around 2200 BC (Dreibrodt et al 2012).

An important marker enabling to interconnect terrestrial and marine climate archives, is the Hekla-4 eruption (magnitude of VEI:6). This eruption led to an ash cloud fallout with a global amount of 60×10^6 tons ($H_2SO_4 + HX$), mostly over Northwest Europe during 23rd/22nd century BC (Larsen/Pórarinnsson 1977; Hammer et al 1980; Davies et al 2010, 609, fig. 4). As this kind of eruptions are likely to have acted on much shorter timescales, these would not be recorded in climate curves. No notably effects on climate are reported for the time under consideration (e.g. Caseldine et al 1998).

Other effects of this volcanic eruption might have played a more significant role however, for the prehistoric communities of Northwest Europe. Volcanic ash rains consist mainly of the acidic element of sulphur. As Iceland was uninhabited during prehistory, and separated from the Continent by a large mass of water, most of this acidic sulphur would have ended up here. Acidity might have influenced the natural acidity threshold of already sensitive soils, such as the mountainous soils in Scotland. When critical sulphur loads in soils exceed the natural threshold, this hampers the growing of vegetation (Grattan/Gilbertson 2000). This might have indirectly influenced the possibilities of growing crops, in particular on acidic soils, and have led to harvest failures or induced changing crop cultivation regimes.

Concluding, we have shown that climate change commonly described as 'the 4.2ka BP event' also took place in the Northern latitudes around the Atlantic. The effects were a mean 2 degrees Celsius drop in both summer and winter temperatures and a possible decrease in humidity on the Continent, between 2200 and 1800 BC.

The Bell Beaker phenomenon in Northwest Europe

Here, a short overview of the Bell Beaker phenomenon as a cultural entity in these three case studies is given. In all these study areas, the Bell Beaker phenomenon shows very particular regional traits, that have often been dismissed as either 'no Bell Beaker presence' or 'local imitation' (see Vander Linden 2006). In the subsequent paragraphs the specific archaeological evidence for settlement activity and subsistence economy will be reviewed for the period under consideration here. Subsequently the review will move from West to East: the Orkney Islands, the Low Countries and Schleswig-Holstein.

On the Orkney Islands, the Bell Beaker phenomenon, as it is known from other parts of Europe, is almost non-existent. The ubiquitous and well-known large stone settlements and megalithic funerary monuments such as chambered cairns and stone circles all predate 2400 BC. No funerary monuments are known from the time period dating between 2400 and 2000 BC, and the material culture that can be determined as “Bell Beaker” has been found only in limited quantities. Additionally, these sherds and vessels have been centre of debate, because of their lack of distinct Bell Beaker characteristics. Instead these vessels, although having spatula impressed geometric decoration, are more thick-walled, barrel-shaped and decorated in a less strict fashion (see Clarke et al 2016, 61, Illus. 3). Similarly, Gibson (1984, 80) sees a particular vessel as having a ‘degenerate’ shape. Several metal and flint objects and graves can be dated between 2100-1700 BC, such as the famous Knowes of Trotty burial (Sheridan et al 2003), a flint dagger (Frieman 2014) and two specific bronze daggers (Gerloff 1975:77 and 120), indicating the existence of exchange networks, but restricted to the British Isles.

In the Low Countries, the Bell Beaker phenomenon is primarily known from the funerary record (*e.g.* Lanting/Van Der Waals 1976), with the typical “Bell Beaker graves”, occurring under barrows in the sandy landscapes of Central and Eastern Netherlands, equipped with typical Bell Beaker style artefacts such as wristguards, copper daggers, flint arrowheads and pottery. This particular distribution corresponds to the preceding Corded Ware phenomenon (Fokkens 2012). These kinds of graves are common, especially in Central Europe (see for instance Grossmann 2016). Specifically Bell Beaker pottery shows a continuous development into the regional Veluwe-style and the heavily decorated Potbeker vessels, concurring with the development of thick-walled and loosely decorated Common Ware (Kleijne 2019). From c. 2100 BC onwards, developments in metallurgy (both in artefacts produced and their composition) and pottery show a change in exchange networks taking place. In the Western Netherlands likewise a continuation of Vlaardingen and Corded Ware settlements and more abnormal funerary practices can be seen.

In Schleswig-Holstein, the Bell Beaker phenomenon also follows on the Corded Ware phenomenon. This preceding phenomenon is clearly present here in single grave burials (Hübner 2005), particular stone axe hammers (Schultrich 2019) and several settlements (Brozio et al 2019). However, only several graves are known containing Bell Beaker artefacts (mainly pottery, wristguards and arrowheads). The pottery is well-produced, having thin walls, S-shapes and well-executed spatula impressed decoration, primarily in zoned motifs or bands (Struve 1955). A large number of burials, known as ‘dagger graves’, is associated with flint daggers and sometimes undecorated pottery. These graves are tentatively dated between 2350 and 1900 BC (Kuhn 1979; Vandkilde 1996) and occur throughout Schleswig-Holstein, and into Denmark (Sarauw 2007) and Mecklenburg-Vorpommern (*e.g.* Forler 2006). The daggers accompanying these graves are exchanged all across Northern (Apel 2001), Central (Siemann 2003) and Western Europe, between the Low Countries (Drenth 2015) and Belarus (Czebreszuk/Kryvaltsevich 2003), however they are found here in low quantities and primarily not in burial contexts.

Analysis: Settlement and subsistence activities in NW Europe around 4200 BP

The Orkney Islands

<<Fig 2>>

Figure 2. All the mentioned sites on the Orkney Islands

Situated in the far North of the British Isles, human occupation on the Orkney Islands shows important developments during the 3rd millennium BC. During the earlier 3rd millennium BC, large stone walled nucleated settlements such as Skara Brae, Ness of Brodgar and Barnhouse (associated with Grooved Ware pottery), are being occupied intermittently during the first half of this millennium, until c. 2400 BC (cf. Bayliss et al 2017, 1182, fig. 5). At Late Neolithic sites in the Orkney Islands, various sources of evidence points that “...there was economic stability between the early and late Neolithic in this area, with no significant exploitation of wild terrestrial or marine fauna in either period...” (Bishop 2015, 844).

Only for two of these stone walled settlements, occupation lasts beyond the middle of the 3rd millennium BC: at Tofts Ness on Sanday and at Links of Noltland on Westray. At the latter, large stone houses are abandoned with a spectacular deer heap deposition, but some evidence for occupation exists. In trench C, a cultivation soil developed on top of a stone wall, producing some Bell Beaker pottery (Clarke et al 2016, 60-61). Trench D also uncovered a wall in a phase postdating the spectacular Late Neolithic settlement abandonment, preceded with evidence for ard and spade cultivation and the removal of wall stones (phase VII and VIII; Clarke et al 2016, illus. 5), signalling a renewed activity in this landscape during the Bell Beaker phase. Plant remains and animal bones have not been published yet.

At Tofts Ness, on mound 11, settlement evidence consists of a stone roundhouse structure, covered by a settlement mound and various cultural layers. Late Neolithic occupation is present in the form of a midden sequence, covered by windblown sand. Habitation on this site continues into the Early Bronze Age. The Late Neolithic midden sequence, phase 2 of the site, produced cultural remains of both stone tools and pottery. The absence of Grooved Ware, so common on other settlements on the Orkney’s, is remarkable. Instead, pottery decoration points towards maritime exchange networks with communities on Shetland (Dockrill 2007, 381). Plant remains here show a predominance of naked barley (*Hordeum vulgare* var. *Nudum*), cultivated in a garden-like fashion,

using manuring (Dockrill/Bond 2009, 35). The animal remains from Tofts Ness show that subsistence economy was not solely based on cereal cultivation and animal husbandry however. While domestic cattle and sheep predominate the spectrum of land-based animals, the number of bird and fish remains indicate an important role for the fowling of various species of birds and marine fishing, primarily on large cod and ling (Dockrill/Bond 2009). It is clear that this settlement can be characterised by a flexible subsistence economy.

Palynological evidence on the Orkney Islands generally shows a predominantly open and treeless landscape, dominated by herbaceous vegetation. This landscape has developed since the first opening of the woodland during the earlier Neolithic and continues throughout the 3rd millennium BC. This is apparent from both on-site investigations (see Davidson/Jones 1985, 26-27) and from several recent peat cores (e.g. Farrell 2015). At the peat bog of Glims Moss however (Keatinge/Dickinson 1979, fig. 2-3), a minor spike in tree-pollen is visible around 420-445cm depth. Six radiocarbon dates were taken from bulk peat samples at this site. When we remodel the radiocarbon chronology for this core, this particular minor spike can be dated around 2200 BC.¹ This spike is associated with a rise in woodland taxa (*Betula*, *Pinus*, *Quercus*, *Alnus*, *Fraxinus* and *Corylus*) and a presence of plantain (*Plantago lanceolata*). This can tentatively be seen as a minor woodland regeneration, alongside the continued indications for human disturbance and open grazing pastures. This provides a good indication of the changing landscape around 2200 BC, with a decrease in human activity and a change in subsistence economy. This decrease in human activity was previously dated from 2000 BC onwards (Davidson/Jones 1985) When quantifying the monument building and its special distribution, domestic patterns and comparing these results to palaeoecological evidence, Müller (1990) already stated that around 2300 BCE a steep decrease in economic and cultural activities took place. Bunting et al (2018) recently modelled the vegetation development during the Neolithic on the Orkney Islands, and they state that no changes in land-cover are visible that might be explained by climate change or abandonment associated with the final occupation of the stone walled settlements around 2300 BC. They suggest a continuity of land-use instead (Bunting et al 2018, 11). What is however visible in their curves around the end of the 3rd millennium BC is a minor increase in the proportion of land area covered by pine-oak trees, both in lowland and upland landscapes (Bunting et al 2018, figure 4B and 4C) and some regional varying developments (Bunting et al 2018, figure 3) that might be more indicative of a decrease in human activity or changing land-use practices.

<<Fig 3>>

Figure 3. Remodelling of 14C data for the Glims Moss peat sequence, with highlighted the given depth of the palynological remains dating to 2200 BC.

¹ Thanks to Dr. M. Dal Corso for assisting in interpreting this pollen profile after remodelling the radiocarbon dates.

<<Fig 4>>

Figure 4. Pollen diagram from Glims Moss, with highlighted the given depth that was modelled for 2200 BC (after Keatinge/Dickinson 1979, fig. 2-3).

The Low Countries

<<Fig 5>>

Figure 5. All the mentioned sites in the Low Countries

Bell Beaker settlements in the Low Countries are known primarily from the Western Netherlands (see Kleijne/Drenth 2019, fig. 1). Houses consist of rectangular wooden structures, with central posts and wall posts often preserved. These house plans show a continuous development from the earlier 3rd millennium BC onwards. Two-aisled plans, such as at Vlaardingen (phase 2) date between c. 2600-2200 BC. Such simple types of houses continue to be built at Carnisselande (phase 3), between c. 2200-2000 BC, and change only slightly with the addition of an extra internal structure (possibly connected to storage facilities) and double wall-posts at for instance Molenaarsgraaf (phase 1) and a move towards a (wider) three-aisled ground plan at Heiloo (phase 1) and Noordwijk (phase 1);

Kleijne/Drenth 2019). Excavations often only reveal a single house plan or two house plans that are not contemporaneous but probably subsequent. Settlements themselves seem to have been occupied for only one generation making any assessment of increasing or decreasing settlement intensity difficult. The ceramics found on these settlements show a similar continuity with the development of Common Ware vessel types such as potbekers and *Riesenbecher* and the slow introduction of Barbed Wire decorated vessels (Kleijne 2019). These various kinds of pottery are both known from settlements, as sherds, or as complete vessels from carefully placed deposits. In the Low Countries, the number of potbeker and *Riesenbecher* vessels from funerary contexts is relatively low (Kleijne 2019, 158-161).

<<Fig 6>>

Figure 6. Duration of occupation at several archaeological sites with remains of houses, and the arable lands of Oostwoud (Bayesian models are published in Kleijne/Drenth 2019, for Oostwoud see Fokkens et al 2017)

The subsistence economy of Late Neolithic communities in the Low Countries is primarily based on arable farming and animal husbandry, based on cattle and sheep (Clason 1999), but gathering and fishing, and the hunting and fowling of wild animals continues to be of importance (see also Fokkens et al 2016). At the site of J97, a large number of fish weirs and fish traps were found dating to the later 3rd millennium BC (Bulten et al 2009) and at Molenaarsgraaf a burial contained both a Bell Beaker vessel and a number of fish remains, fish hooks and possibly an antler-shaped fishing rod (Louwe Kooijmans 1974). Fish remains at settlements such as for instance Carnisselande show that it formed an integral part of the subsistence economy (Moree et al 2010), continuing well into the Bronze Age (Van Amerongen 2015).

A review and aoristic analysis of all the arable fields during the 4th and 3rd millennium BC throughout Northwest Europe, shows an increase in frequency after 2200 BC after a decrease during the preceding centuries for the Low Countries, Denmark and Northern Germany (see fig. 7). Examples of this in the Low Countries are the large plots of arable land at Velsen Westlaan 2 (Therkorn 2008; Kleijne 2015), Oostwoud (Fokkens et al 2017, see fig. 4) and Noorderboekert (Knippenberg 2018). At these locations extensive tracts of arable land often consist of multiple phased criss-crossed ploughmarks. These sites are often situated in dynamic coastal landscapes, well-suited for cereal cultivation. On the less fertile sandy soils, a more pastoral economy is envisaged based on the continued openness of cultural landscapes and the maintenance of heathland, as visible in pollen-diagrams (Doorenbosch 2013, 233-234).

<<Fig 7>>

Figure 7. Frequency of arable fields in Northwest Europe (based on aoristic analysis)

Schleswig Holstein

<<Fig 8>>

Figure 8. All the mentioned sites in Schleswig-Holstein.

Settlement activity in Schleswig-Holstein during the later 3rd millennium BC is characterised by small scale single farmsteads. Early Corded Ware settlements, where occupation ends around 2600 BC, have been found for instance at Oldenburg LA 232 (Brozio et al 2018), but only settlement scatters are known from between 2600 and 2200 BC. Also, total quantities of material culture shows a 'bust' during this period, followed by a 'boom' around 2200 BC (Müller 2015; Feeser et al 2019). Around

2000 BC new indications for permanent occupation are known from Flintbek LA20, Archsum LA65 Melenknop (Wirth 1994; Zich 2000), Schoolbek and Harrislee. In many instances, material culture or other kinds of dating evidence are lacking however (Ethelberg et al 2000, 165-172). These houses continue to show a simple two-aisled plan throughout the 3rd millennium BC, just as the earlier house plans in Oldenburg LA 232, without any modifications or internal structuring. Similarly to many regions of the North Central European Plain, a particular type of large storage vessel, the *Riesenbecher*, develops around 2200 BC (Hartz/Müller 2018), here however more often found in structured depositions and in graves.

Between 2600 and 2200 BC, a decrease in settlements and subsistence intensity is also visible from palynological evidence for human impact (Feeser et al 2012). From c. 2200 BC onwards, subsistence activities can be characterised as an intensified mixed farming economy (Brozio et al 2019; Kirleis 2019). This is similarly visible in the weighted aoristic analysis carried out (see fig x). At both Flintbek LA20 and Archsum LA65 Melenknop, a cultivation soil with ploughmarks developed during the occupation between 2200-2000 BC. More ploughmarks in Schleswig-Holstein are known from the period between 2000-1700 BC, often found below Early Bronze Age burial monuments (e.g. Tegtmeier 1993). Mixed cereal cultivation on these arable fields was practiced of both *Hordeum vulgare* and *Triticum dicoccum*. Large quantities of both cereals and chaff remains were found in a pit at Bosau (Kroll 1980; Kirleis et al 2012), and also the human impact seems to have increased (Feeser et al 2019). This economic intensification and population increase can be associated with the development of new exchange networks, investing in the highly skilled production and the exchange of flint daggers (Brozio et al 2019).

An important exception to this model of intensification of the agricultural economy, is the settlement site of Quern-Neukirchen “Tegelbarg”. This settlement developed between 2200 and 1900 BC, and is characterised as a shell-midden (Arnold 1981; Hartz/Müller 2018). This site is characterised by an up to 40 cm thick layer of occupation debris, flint artefact production waste, hearths and mussel shells. Found within this midden are the remains of gathered wild plants and fruits (Schaller/Kirleis 2018), both wild and domestic animals and a large number of thrown away shells of mussel (*Mytilus edulis*) and cockle (*Cerastoderma edule*). Fish remains are notably absent (although no sieving was carried out; Höfgen 2018). It is unclear if the shell-midden was a seasonal camp or continuously occupied and how these activities relate to the late Neolithic arable farming and husbandry economy. Similar shell middens dating to the 3rd millennium BC are known from Denmark (Andersen 2007) and the Netherlands (e.g. Kleijne et al 2013) and might fit into a broader pattern of continued reliance on wild and marine food sources.

Discussion

At the start of this paper the question was posed regarding the resilience and vulnerability of Bell Beaker communities in Northwest Europe around the 4.2ka BP climatic event. In the above we have reviewed both the climatic data specifically for Northwest Europe and the archaeological data concerning occupation patterns and subsistence economy of Bell Beaker communities in the Orkney Islands, the Low Countries and Schleswig-Holstein.

With regard to occupation patterns, the Orkney Islands shows a clear decrease in settlement activity after 2300 BC. No complete abandonment seems to have taken place, but a decrease in settlement intensity is likely. A shift from stone house agglomerations towards a less intensive settlement system, represented only by the accumulation of household waste in cultural layers, is recognisable. Continuity in occupation is attested for the settlement of Tofts Ness, north in the Orkney's, which is also showing exchange networks with the continuous habitation on Shetland (Sheridan 2013). We argue that this decrease in settlement intensity is not merely a product of archaeological visibility but also a decrease in population numbers. This population decrease did not lead to a total abandonment, but a reorganisation in terms of subsistence, a decrease in strength of exchange

networks and a more flexible economical system for the remaining inhabitants. Subsistence economy on the Orkney Islands changed from a strong focus on cereal cultivation and animal husbandry, towards a more flexible economy including the hunting of wild and marine animals and possibly pastoralism. Dockrill and Bond (2009) demonstrate that for the Tofts Ness settlement, resilience played a role in the Late Neolithic subsistence activities, with the flexibility of resources and the continued existence of exchange networks after 2200 BC.

In the Low Countries, settlement activity shows a continuity in terms of practices and the built structures (see also Kleijne/Drenth 2019). The two-aisled house plan is continuously built throughout the 3rd millennium BC, with double wall posts and inner compartments added after 2200 BC. Subsistence economy is primarily agricultural, as indicated by numerous arable fields with ploughmarks known from coastal wetland landscapes, but fishing and hunting still played an important role (see also Fokkens et al 2016).

Settlement activity in Schleswig-Holstein increased around 2200 BC (after a long period of decline during the after 2600 BC, during the late Corded Ware and early Bell Beaker period) with several house plans known. Also, the agricultural economy intensified after 2200 BC, as demonstrated by the numerous plough-marks below round barrow mounds. A new regional exchange network, based on flint daggers, linked these communities to the wider world. The flexibility of the subsistence economy can be demonstrated by the shell midden of Tegelbarg, dating between 2100-1900 BC.

The presence of ard marks in large numbers in both Schleswig-Holstein and the Low Countries after 2200 BC might indicate that cereal cultivation was not negatively affected by the climatic changes. Maybe even the 4.2ka event, and the associated 2C drop in temperature, had a positive effect on the possibility of agriculture in these areas. A similar pattern, of Bell Beaker occupation and arable fields primarily dating after 2200 BC, can be seen in the Scottish Western Isles (Sharples 2009, 2015). We can thus agree to Müller (2015)'s arguments for regional variability in the changes occurring around 2200 BC.

While the decrease in temperature is minor in absolute terms, its relative impact can only be assessed when compared to the preceding climatic conditions. The period preceding the 4.2ka event, is generally considered to be final part of the so-called Holocene Climatic Optimum, during which temperatures were several degrees warmer than present day. Exemplary are also the finds of, for instance, a pond tortoise (*Emys orbicularis* L.) nowadays only encountered in the Mediterranean, at the Dutch Late Neolithic settlement of Vlaardingien (Van Wijngaarden-Bakker 1996), or of a greater flamingo (*Phoenicopterus ruber*) at the Late Neolithic site of Kolhorn (Zeiler/Clason 1993, 69), both predating the 4.2ka event and the Bell Beaker phenomenon.

It is not known how much the large variety of agricultural activities (clearance, ploughing/tilling, manuring, sowing, harvesting, fallow and crop rotation; see Lewis 2012) changed during this time as an (indirect) consequence of the climatic deterioration after the mid-Holocene optimum and the 4.2ka event.

Conclusion

The 4.2ka event, generally dated between 2200 and 1800 BC, appears to have had a different impact on the regional climate in Northwest Europe, compared to for instance the Iberian Peninsula or the Near East. In terms of both temperature and humidity, and in terms of the effects on vegetation, a regional variability is visible. This regional variability indicates that no widespread collapse of settlement and subsistence economies associated with the Bell Beaker phenomenon is visible. Especially for communities in Continental Northwest Europe, settlement activity continued, agricultural practices developed and new exchange networks were initiated. Economic

diversification, by hunting and fishing and the gathering of shellfish, provided the necessary flexibility of possibly more variable weather conditions.

The changes around 2200 BC in Continental Northwest Europe are thus mainly cultural, related to new exchange networks, the introduction of new materials such as bronze and objects such as *Riesenbecher* (perhaps to facilitate storage and the accumulation of prestige, see Hartz/Müller 2017).

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