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Vandenberghe, J.; van der Plicht, J.

Published in:
Quaternary Geochronology

DOI:
[10.1016/j.quageo.2015.12.004](https://doi.org/10.1016/j.quageo.2015.12.004)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2016

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Vandenberghe, J., & van der Plicht, J. (2016). The age of the Hengelo interstadial revisited. *Quaternary Geochronology*, 32, 21-28. <https://doi.org/10.1016/j.quageo.2015.12.004>

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Research paper

The age of the Hengelo interstadial revisited[☆] J. Vandenberghe^{a, *}, J. van der Plicht^{b, c}^a Department of Earth Sciences, VU University Amsterdam, The Netherlands^b Center for Isotope Research, Groningen University, The Netherlands^c Faculty of Archaeology, Leiden University, The Netherlands

ARTICLE INFO

Article history:

Received 5 August 2015

Received in revised form

3 November 2015

Accepted 10 December 2015

Available online 15 December 2015

Keywords:

Hengelo

Interstadial

Radiocarbon

Chronology

Teleconnections

ABSTRACT

Understanding past climate events relies for a large part on correlations between various proxy records. For the last glacial cycle, these are mainly marine and ice core records. However, such tele-connections are often based on weak arguments. For terrestrial data the Hengelo interstadial is a key event, discovered more than 4 decades ago. Here we review the age of this event, in particular by its ¹⁴C dates, their calibration and comparison with other proxy records. We conclude that the Hengelo interstadial, at the type locality and a few nearby comparable sites, dates between 36,000 and 38,600 BP (uncalibrated radiocarbon age), corresponding to 42,350 and 41,380 calBP. Correlation of the Hengelo interstadial with ice-core records remains problematic.

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1. Introduction: the importance of interstadial age determination

Climatic circulation patterns have left their atmospheric signals in terrestrial and aquatic deposits and environments; in particular, in marine, ice, lake, peat and loess deposits. Climatic changes may be recorded in a number of proxies, which ideally should register singular climatic changes in a correlative way. In palaeoclimatology it is an important issue to know the local or global character of a climatic event or evolution. An obvious approach therefore is to investigate the spatial scale at which such an event is occurring. This explains the rationale behind the search for tele-connections. A potentially existing tele-connection assumes that climatic

steering is a global phenomenon that produces palaeoclimatic proxy events at a wide spatial and sedimentary scale that is overprinting local and internal variability (Blaauw, 2012).

Traditionally, high resolution correlations between marine deposits and Greenland ice were made for the last glacial cycle (Bond et al., 1993; Blockley et al., 2012; Elliott et al., 2002; NGRIP Members, 2004; Rasmussen et al., 2014). It became also practice to correlate last-glacial terrestrial palaeoclimatic records with ice-core and marine records. They concern especially the correlations of climatic alternations of stadial-interstadial character. Numerous examples may be found in the correlations of palynological records and in loess and lacustrine records (for references see the next section).

Although climate intervals from the oceans and ice caps generally correspond very well, the correlation of intervals of interstadial signature from marine and ice records with particular intervals in terrestrial records (e.g., speleothems, loess and peat) are more problematic. In many cases they are debated or questioned. There are several reasons for the existence of problematic correlations. Especially terrestrial proxies may suffer from the fact that they are not only dependent on climate but on a wide variety of external and internal conditions while also the risk of erosion should not be underestimated. However, knowing the exact nature and amplitude of climatic intervals in their spatial distribution pattern is necessarily required for recognizing and understanding the palaeoclimatic reconstruction of the intervals concerned.

The best strategy for correlation of climatic events is by

[☆] Radiocarbon dates are reported in BP (or ka BP), i.e. conventional ages using a defined timescale (e.g., van der Plicht and Hogg, 2006); calBP are calendar ages relative to 1950 AD, calibrated using the recommended calibration curve (presently IntCal13; Reimer et al., 2013). In addition, one should be aware of possible confusions concerning timescales. The original GRIP chronology is published in calBP defined as relative to 1990 (Johnsen et al., 1997); recently ice-core chronologies are given relative to 2000 AD and are expressed in b2k. These differences are small and can be neglected (they are within error) for the ages discussed in this paper but even so it is necessary to take notice. Also records dated by OSL and U-series are published in calBP (sometimes called BP), which is again defined differently depending on the dating method.

* Corresponding author.

E-mail address: jef.vandenberghe@vu.nl (J. Vandenberghe).

establishing their absolute age. Nevertheless, sometimes correlations are based on fictive ‘similarity’ of palaeoclimatic signals, doubtful or imprecise absolute datings, poor understanding of processes that govern the generation of the palaeoclimatic signals and different response times of proxies to climatic steering (Singhvi, 2011; Blaauw, 2012; Vandenberghe, 2012). Moreover, the latter authors warn against circular reasoning and a ‘reinforcement syndrome’ as a consequence of non-independent correlations. A firm indication for tele-connections is the synchronicity between the events to be correlated based on absolute dating (Walker et al., 1999; Singhvi, 2011). Furthermore, it is logical that correlations within the last ice age are made with classical interstadials such as the Hengelo, Denekamp and Moershoofd interstadials (Van der Hammen et al., 1967). The use of ‘classical interstadials’, however, requires a reliably determined age in their type locality, apart from a clearly expressed climatic signal.

The goal of this paper is a primordial discussion on the temporal positioning of one of the most traditionally known interstadials from the last ice age, the Hengelo interstadial (Zagwijn, 1974). In addition, potential correspondence is explored with similar, well-dated warm events as recorded in the Greenland ice-core records. Many authors tentatively correlated interstadial records from their terrestrial sites with this interstadial in combination with a link to one or another interstadial in the ice-core records. However, a reliable age control is absolutely needed for such correlation attempts. Since absolute age control for ages older than ca. 15 ka, both in the ice-core records and in radiocarbon dating, has made much progress in the last few years, it is timely now to reconsider the age of this particular classical interstadial starting from the original basic data in its type region and applying the most recent absolute time tables around that interval.

2. Previous recognition of mid-Weichselian interstadial records and their correlation hypotheses with ocean and ice records: a selection of examples

Terrestrial records of mid-Weichselian interstadials which are dated absolutely are still relatively rare. Some interstadials are preserved as singularly occurring events, while others are part of long records (from one site or compiled in a stratigraphic scheme). We discuss here selected examples in the 35–50 ka time range, without the intention to give a complete overview.

Many long records come from lacustrine environments and the involved proxies differ from sedimentary (incl. geochemical) properties (e.g. Schaber and Sirocko, 2005) to palaeobotanical signals (e.g. De Beaulieu and Reille, 1984; Behre and van der Plicht, 1992; Van der Hammen, 1995; Allen et al., 1999; Sanchez-Goni et al., 2002; Harrison and Sanchez-Goni, 2010; Groot et al., 2013). Svensson et al. (2008) claim a good correlation between climatic signals of Greenland ice (observed in NGRIP, 2004) and speleothems such as recorded in the Hulu cave (Wang et al., 2001), although the degree of correlation may be contested (e.g. Blaauw, 2012). Also Genty et al. (2003) claim a good correlation between stalagmites from western Europe and Greenland ice cores. Likewise, Allen et al. (1999) identified generally good correlations of a multi-proxy record of lake sediments with the Greenland ice-core data based on radiocarbon dates and sedimentation rate calculations. Loess deposits have provided similar results. For instance, Haesaerts et al. (2003) compiled a long record of alternating loess and soil layers (corresponding with cold-warm intervals) in the east Carpathian region. Based on many radiocarbon dates, these were correlated (not calibrated) with Dansgaard–Oeschger (D–O) and Heinrich events in Greenland ice (as observed in GISP2). The Nussloch site in Germany, which is considered as a reference site for terrestrial Weichselian palaeoclimatic reconstruction, shows a good

parallel between peaks in the dust record and the ice cores (Antoine et al., 2001; Rousseau et al., 2002). In contrast, Kadereit et al. (2013) contested obvious correlations between specific major pedozones in that loess series and isotopic zones of the marine and ice-core records. The organic material in the palaeosols at Nussloch is radiocarbon-dated at many intervals (Hatté et al., 2001), but these ages are debated by Gocke et al. (2010). Finally, it should be noted that in some cases tuning by using D–O events is already taken into account for obtaining the synchronicity (for a discussion see Blaauw, 2012).

In addition, we mention a few selected examples of correlation attempts from specific intervals. Bos et al. (2001) reconstructed interstadial conditions by pollen evidence and frozen-soil degradation around 40–42 ka BP that they correlated with the Upton Warren interstadial (Coope, 1977) and the Glinde interstadial (Behre and van der Plicht, 1992) and suggested correspondence with D–O event 14. It is followed by permafrost conditions, probably corresponding with the Hasselo stadial (see below). Thermo-karst activity in eastern Germany was also potentially correlated with D–O event 14 by Bohncke et al. (2008) but dated at c. 46 ka BP. Vaquero et al. (2013) described a warm interval, represented in pollen assemblages under a rock shelter in NE Spain, spanning the period between 45 and 40 ka (age mainly based on a series of U/Th datings on calcareous tufas and confirmed by a few radiocarbon and TL-datings). They correlated this interval with the interstadial complex of D–O events 12 to 9.

Distinctly older, consistently radiocarbon dated but very near to the limits of radiocarbon dating, are interstadials reported by Vandenberghe (1985: the Riel interstadial, end of interstadial at 48,480 (+3200, –2300) BP, subarctic open forest), and by Behre and Lade (1986): the Oerel interstadial (peat) with less open vegetation cover than the younger interstadials, reviewed by Behre and van der Plicht (1992) between 53,500 and 57,700 BP, and the Glinde interstadial (peat indicative for shrub tundra, also dated by the latter authors between 48,700 and 51,550 BP). The latter two interstadials were correlated by Behre (1989) with the two first maxima in MIS-3 in marine records and plausibly also with oscillations in other terrestrial sequences, for instance in Grande Pile (Woillard and Mook, 1982). The ages from Oerel were obtained by the enrichment method applied at that time (Groote, 1977). Van Geel et al. (2010) found a clearly expressed warming event dated between 46.6 and 54.6 ka calBP (by a combination of OSL and radiocarbon dating, the latter around the limit of the method) in a peat deposit from the central Netherlands and, based on those datings, correlated it with D–O event 12 or 14. Vaquero et al. (2013) in their Spanish rock shelter (see above) identified also a warm interval between 46 and 52 ka BP that they correlated with D–O oscillations 14 to 17. Otherwise, Helmens et al. (2007) and Helmens and Engels (2010) suggested correlation of a warm interval, OSL-dated at 55–62 ka BP, in eastern Scandinavia tentatively with IS14.

Engels et al. (2008) distinguished 3 interstadial phases in the early part of OIS 3 in a maar in the German Eifel corresponding with IS 14 to IS16 (correlation based on tuning with the NGRIP $\delta^{18}\text{O}$ record –also in Schaber and Sirocko, 2005). A good overview of inter-correlations of climatic cycles as observed in terrestrial records from the last glacial is given by Guiter et al. (2003).

It is striking from all these examples that in many cases it seems possible to link long terrestrial records, even when compiled from different sources, with the ice-core stratigraphy. However, the above-mentioned examples of singular mid-Weichselian interstadial phases illustrate that there is no general agreement at all on how to correlate such individual phases recorded at specific terrestrial sites with the North-Atlantic stratigraphy. Therefore, a reappraisal of the positioning of the Hengelo interstadial in a chronological and chronostratigraphical framework appears very

useful and timely.

Prior to this analysis, some general comments have to be given concerning the above mentioned radiocarbon dating. It is important to first dealing with the analytical preparation and methodology. Before the actual ^{14}C measurement, the sample materials have to be chemically pretreated in order to isolate the datable fraction, and to remove contaminants (Mook and Streurman, 1983). The routine treatment of samples consists of the following steps: (i) with Acid (HCl) in order to remove soil carbonate and possibly infiltrated humic acids; (ii) with Alkali (NaOH) to remove e.g. soil humates; (iii) with Acid (HCl) to remove any CO_2 absorbed during step (ii). This treatment is referred to as the “AAA” treatment. After the chemical pretreatment, the samples are combusted and turned into purified CO_2 . All radiocarbon analyses from before ca. 1990 were carried out on large bulk samples (often hundreds of grams). For these, radiocarbon dating was done by the conventional method (radiometry). Later, selected macro-remains from peat deposits were dated by AMS as a common practice (e.g., Blaauw, 2003). Contamination by younger humic acids can strongly influence dates in the older part of the ^{14}C dating range (e.g., van der Plicht, 2012). This can be investigated by dating different chemical fractions. When the residue and extract dates yield the same result, the dates are considered reliable. In addition, quality control by ^{13}C -measurement and dating of the extract fraction (to check sample homogeneity) was often missing. Finally, correlations with ice-core ages during the 1990's were biased to some extent by existing discrepancies between the main chronologies, GISP2 and GRIP before an integrate timescale (GICC05) was constructed for Greenland ice (Rasmussen et al., 2014).

3. The Hengelo interstadial in its type region and locality

In the classical palaeoclimatic evolution of the last ice age in western Europe, the Hengelo interstadial is by far the most prominent signal of a temperature rise of interstadial character (Van der Hammen et al., 1967; Zagwijn, 1974). The Hengelo interstadial is first described by Zagwijn (1974) in its type locality Hengelo KNZ. According to the latter author, the pollen assemblages suggest the initiation of a shrub tundra following a pure treeless tundra (rise of aquatics and *Salix* followed by expansion of *Betula nana*) as reaction to a rise in temperature (Fig. 1- for further details see Zagwijn, 1974).

The Hengelo signal has been incorporated in several palaeoclimatic evolution tables where it has been correlated with D–O events from the Greenland ice cores. For instance, Bos et al. (2001) correlated it with D–O event 12, while Van der Hammen (1995) suggested previously a correlation with D–O event 11, following the NGRIP stratigraphy by Johnsen et al. (1992).

A main obstacle for a firm position in such a stratigraphical sequence of global significance has been the fact that its absolute age was based on bulk radiocarbon dates not so far from the upper limit of the method and the lack of calibration of ^{14}C dates into absolute ages in the recent past. Since its first descriptions, considerable progress has been made by accurate documentation of newly discovered organic deposits in the type region undoubtedly originating from the Hengelo interstadial (Kasse et al., 1995). In addition, and very significantly, much progress has been made recently in the calibration of radiocarbon ages. The calibration curve now covers the complete dating range of the ^{14}C method (Reimer et al., 2013). This makes it possible to reconsider the significance of the Hengelo interstadial, as one of the marker stones in the classical last ice-age stratigraphy, and its position in the last ice-age climatic evolution and possible correlation with the new ice-core record.

In addition to its age, the lithostratigraphic position is of great

importance for the correlation of the Hengelo interstadial with other occurrences. At the KNZ site it is represented by a peat layer that is overlying a well-developed cryoturbation level. A ^{14}C sample consisting of *Batrachium* seeds, with certainty taken within the interstadial peat, resulted in an age of $36,600 \pm 600$ BP. However, it cannot be excluded that this date is too young because of the limited preparation technique applied to that particular sample (it could only be treated with diluted acid). The Hypnaceae peat layer that is occurring within the underlying cryoturbated level is dated at $38,350 \pm 550$ BP. That level without doubt shows the existence of permafrost prior to the Hengelo interstadial and corresponds with the Hasselo stadial (Van Huissteden, 1990).

4. The radiocarbon age of the Hengelo interstadial in its type region

Apart from the type locality at Hengelo described above, several other localities in The Netherlands have been identified with stratigraphically equivalent deposits containing the Hengelo interstadial and with relevant radiocarbon dates. This concerns the sites Breda and Grouw; their locations and that of the type site Hengelo are shown in Fig. 2.

A site at Breda (southern Netherlands) was described even before Zagwijn discussed the type locality (Van der Hammen et al., 1967). At that site, an early phase of the Hengelo interstadial was dated at $37,000 \pm 600$ BP (sieved plant material from a coarse detritus gyttja). Similar to the KNZ-site the concerned lake clay bed at Breda is overlying and thus postdating a distinct cryoturbation level. At very short distance (within a few hundred metres) from the original type locality at Hengelo, Van Huissteden (1990) introduced the Hasselo stadial appearing from underlying permafrost-indicating sedimentary deformations (ice-wedge casts) (Hengelo A1). A peat bed associated to that stadial was dated at $39,640 \pm 370$ BP. The warming subsequent to this stadial is represented by the cryoturbation of that layer due to the degradation of the previous permafrost as is also the case at Breda and KNZ (e.g. Vandenberghe and Van den Broek, 1982). At the A1 section no datable peat layer from the Hengelo interstadial has been observed, but a younger peat layer was found with an age of $33,100 \pm 600$ C 14 BP. In addition, near to the type section Zagwijn (1974) identified interstadial deposits of the same age (brickyard Rientjes, $37,500 \pm 650$ BP, obtained on samples of leaves and twigs of tundra plants).

More recently, a well-documented and radiocarbon dated sediment series around the concerned time interval was described from Grouw (northern Netherlands) by Kasse et al. (1995). The Hengelo interstadial is documented by detailed palaeobotanical analysis of a gyttja bed that has been dated at $37,750 + 900/-800$ BP. This was confirmed by additional dating the extract fraction to $38,800 + 1000/-900$ BP. The transition from the Hengelo interstadial to the next cold period (according to the pollen analysis) has been dated at $36,850 + 800/-750$ C 14 BP (also gyttja). It should be noted that this site provides the most reliable radiocarbon dates as all analyses were based on rigorous criteria of dated material, AMS dating and control by extract dates (for preparation and other analytical details see Kasse et al., 1995). Identical to the situation at Breda and Hengelo KNZ and A1, another heavily cryoturbated, organic layer occurs below the organic bed of Hengelo age. Thus, that latter bed dates from the Hasselo stadial while the subsequent cryoturbation took place during the warming at the beginning of the Hengelo interstadial. The age of the organic layer is $38,700 + 1100/-1000$ BP (humic silt).

The relevant ^{14}C dates are shown in Table 1. They are all measured at the Groningen conventional laboratory (code GrN). From this set of radiocarbon dates we may deduce the age of the

Fig. 1. Pollen diagram Hengelo KNZ from the type locality as published by Zagwijn in 1974 (Vegetation, climate and radiocarbon datings in the Late Pleistocene of the Netherlands: Part II Middle Weichselian. Mededelingen Rijks Geologische Dienst 25-3, 101–110, enclosure 1); reproduced with permission.

Hengelo interstadial according to the uncalibrated radiocarbon ages from the type locality region.

Excluding the date GrN-15123, which obviously postdates the Hengelo interstadial, an average age of 37.0 ± 0.3 ka BP can be calculated for the Hengelo interstadial (4 datings at 1 σ confidence level) and 39.0 ± 0.3 ka BP for the Hasselo stadial. However, the precision (1-sigma confidence level) seems unrealistic. Alternatively, the Hengelo interstadial may be bracketed between 36.0 ka BP (=36,600–600 as the ‘youngest Hengelo age’) and 38.6 ka BP (=37,750 + 900 as the ‘oldest Hengelo age’) – see Table 1. The latter age is in accordance with the ‘oldest minimum age’ of the preceding Hasselo stadial (=38.9 ka BP at Hengelo KNZ – see Table 1). The ‘youngest Hengelo age’ is derived from the site Hengelo KNZ (sample possibly ‘too young’ as mentioned above), but a highly reliable date from Grouw is available, taken exactly at the pollen-based transition from the end of the Hengelo interstadial to the next stadial: $36,850 \pm 800/-750$ BP (Kasse et al., 1995) which gives an almost identical ‘youngest age’ of 36.1 ka. Summarizing, we derive for the Hengelo interstadial a ^{14}C age interval of 36,000–38,600 BP, and for the Hasselo stadial 37,700–39,900 BP.

5. Calibration of the Hengelo interstadial and possible correlation with ice-core stratigraphy

As radiocarbon dating plays a crucial role in establishing the exact position of the Hengelo interstadial in the chronostratigraphy of the last glacial, it is important to note that the samples discussed here are all analysed before the AMS era. They are bulk samples,

measured by the conventional method using gas proportional counters (Mook and Streuerman, 1983). The two dates from Grouw have been tested most extensively for their reliability.

A first attempt to ‘calibrate’ the radiocarbon dates to ‘absolute’ or ‘ice-core ages’ was made according to the tables provided by Shackleton et al. (2004). Applying his table 1 for the beginning and end of the Hengelo interstadial results in c. 43.8 and 42.6 ka calBP, respectively. According to table 2 in the same publication this period then might be correlated with the interglacial GIS-11 which starts at 43.87 ka.

When using GRIPs09sea ages (Johnsen et al., 2001), the result is a bit less clear. In that case, again according to table 1 of Shackleton et al. (2004) beginning and end of the Hengelo interstadial should have an age of c. 42.2 and 41.4 ka, respectively. Applying again table 2 of the latter authors would lead to a correspondence of the Hengelo interstadial with the final part of IS-11 and the first part of the next stadial.

The presently recommended calibration curve for the radiocarbon timescale is IntCal13 (Reimer et al., 2013). For the first time, reliable calibration of terrestrial samples of the oldest part of the ^{14}C method is possible. Among others, a main reason is the integration of the varved sediment from Lake Suigetsu (Bronk Ramsey et al., 2012). This produces a curve based on hundreds of ^{14}C dates from terrestrial samples whereas the previous curve IntCal09 relied on marine records for this time range (Reimer et al., 2009). One should note that IntCal13, while being the “state of the art”, is a construction based on underlying records, each of which can be used as a “comparison tool” depending on the research objectives.

Fig. 2. The location of the 'Hengelo' sites Breda, Grouw and Hengelo in The Netherlands.

This is in detail discussed by [Bronk Ramsey et al. \(2013\)](#).

Simply calibrating the ^{14}C dates we derived using IntCal13 leads to calibrated age results of 40,600–42,800 calBP for the Hengelo interstadial, and 42,000–43,700 calBP for the Hasselo stadial ([Fig. 3](#)). However, we can also consider the Hengelo and Hasselo periods as two separate phases in a sequence, using a Bayesian model in the computer program OxCal ([Bronk Ramsey, 2009](#)). This constraint results in a more precise result, which is shown in [Fig. 4](#). Numerically, the resulting calibrated dates are 42,350–41,380 calBP for Hengelo, and 43,220–42,290 calBP for Hasselo. It should be noted that all ^{14}C dates (BP and calBP) in this paper are discussed here at 1-sigma confidence level; all numerical values are rounded to the nearest 10.

For Greenland ice, a high precision chronology for the last 60 ka is available ([Svensson et al., 2008](#); [Rasmussen et al., 2014](#)). The maximum counting error in absolute age for the relevant date range is about 1700 years ([Rasmussen et al., 2014](#), table 2). The relevant part of this ice chronology is shown in [Fig. 3](#). We added the calibrated ^{14}C dating ranges of Hengelo and Hasselo in that figure.

This analysis shows, unexpectedly, that the Hengelo interstadial centres almost exactly around a stadial (GS-11) and the Hasselo stadial around an interstadial phase (GI-11). However, from a palaeoclimatological point of view it is more probable that the

Fig. 3. Relevant part of the Greenland ice chronology, with stadials and interstadials indicated (taken from [Rasmussen et al., 2014](#); blue: NGRIP, red: GRIP, green: GISP2; ages in thousands of years ago b2k). Our derived calibrated ^{14}C age ranges for the Hengelo (HE) interstadial and the preceding Hasselo (HA) stadial are also shown. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Hengelo interstadial should correspond to GI-10 or GI-11, and the preceding Hasselo stadial likewise to the preceding GS-11 or GS-12. Assigning Hengelo to GI-12 seems unlikely, but can theoretically not be excluded given the maximum counting error of the ice record which is of the same order of magnitude as the periodicity of the D–O events. Our analysis excludes assigning Hengelo to even older interstadials, in particular GI-14 which has been suggested before.

In addition, one should consider that the Hengelo interstadial seems to represent (one of) the warmest interval(s) within the terrestrial Weichselian Pleniglacial (corresponding with OIS 2–3–4) in contrast to GI-10 and GI-11 which are certainly not the warmest oscillations within the last ice age according to the ice-core proxies. Obviously, correlation of the climatic oscillations Hengelo/Hasselo with those in Greenland ice still poses real problems, as based on existing chronologies which today are more precise than decades ago at the time of the discovery of the Hengelo type site.

One could hypothesize about the cause for this discrepancy. For the time being, it seems improbable that the ice-core chronology or the radiocarbon calibration curve or the ^{14}C datings would be wrong for more than one millennium. Similarly, the hypothesis that the Hengelo interstadial would correspond with a minor warm oscillation within GS-11 does not seem to be realistic. An ultimate, but controversial, reason for the discrepancy would be to accept a real disconnection between land and ice climatic proxies (e.g.

Table 1

Overview of radiocarbon dates (in BP) of the Hengelo interstadial and Hasselo stadial. The samples Hengelo KBZ, Rientjes and Breda are described in detail in a datelist by [Vogel and Zagwijn \(1967\)](#), the Grouw samples in [Kasse et al. \(1995\)](#) and the Hengelo A1 samples in [Van Huissteden \(1990\)](#).

	Hengelo KNZ	Hengelo Rientjes	Hengelo A1	Breda	Grouw
Hengelo interstadial	36,600 ± 600 [GrN-2685]	37,500 ± 650 [GrN-1763]	33,100 ± 600 [GrN-15123]	37,000 ± 600 [GrN-2515]	37,750 + 900/–800 [GrN-16200]
Hasselo stadial	38,350 ± 550 [GrN-4828]		39,640 ± 370 [GrN-14215]		38,700 + 1100/–1000 [GrN-16202]

Fig. 4. Bayesian calibration analysis results of the ¹⁴C dates of the Hasselo/Hengelo phases.

Blaauw, 2012; Singhvi, 2011; Vandenberghe, 2012). But also such a far-reaching deduction is highly questionable.

Anchor points provide more crucial information concerning chronologies. A case in point is the Laschamp geomagnetic excursion. This is dated by Ar/Ar to ca. 40 ka, and it shows up at 41 ka in Greenland ice (Svensson et al., 2008). This is a strong indication for the reliability of the present Greenland ice chronology, within the error bars of the existing methodologies.

Finally, it is interesting to make a historical note here. About 50 years ago, the Hengelo date GrN-1763, 37,500 ± 650 BP, was reported as 35,550 BC, obviously by subtracting 1950 from the BP date (Vogel and Zagwijn, 1967). Indeed, radiocarbon dating has come a long way. So did modern ice-core chronologies, but apparently not all puzzles are solved thus far. However, the chronological position of the Hengelo interstadial is now (re-)established according to the most recent advancements in dating

methodology.

6. Conclusions

We have re-investigated the ¹⁴C dates of the classic Hengelo interstadial obtained for the typesite, and conclude that it dates in the range 36,000–38,600 BP. Using the calibration curve IntCal13, which now covers this age range, the absolute date for Hengelo is derived as 42,350–41,380 calBP (at 1-sigma confidence). This corresponds best with the interstadials GI-10 or 11 on the Greenland ice core timescale. This correlation is anyway not representing the longest warmest interstadial as appears from the ice-core and marine records, as widely assumed in the literature.

The correlation of long records of terrestrial, ice and oceanic series seems easier than the correlation of single interstadial events, which apparently is not yet understood. It follows that the

correlation of marine and ice records with the classical terrestrial record is not evident.

Acknowledgements

We thank the Geological Survey of The Netherlands for the permission to reproduce the original pollen diagram of the Hengelo interstadial as published by W.H. Zagwijn in 1974.

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