NEW ZEALAND TREE-RING SITE REPORT 36

Tree-ring analysis of sub-fossil kauri (*Agathis australis*) from Hal Harding's Farm, Pouto Road, Dargaville, Northland

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Tree-ring analysis of sub-fossil kauri (*Agathis australis*) from Hal Harding's Farm, Pouto Road, Dargaville

This is a technical archive report describing crossdating and chronology development of tree-ring samples from Hal Harding's Farm, Pouto Road, near Dargaville. Please note that although the tree-ring dates presented here will not change, it is possible that interpretation of the results may change as new evidence comes to light.

Summary

Collection of sub-fossil kauri samples from Northland was undertaken for a Foundation for Research, Science and Technology (FRST) funded project on *Sub-fossil Kauri Collection and Analyses*. The project aimed to improve the quality of multi-centennial and multi-millennial tree ring data sets used for palaeoclimate analyses through the addition of new data. Twenty-seven samples were collected from kauri excavated from Hal Harding's Farm (HALH) and tree-ring analysis of the samples was undertaken. There were three significant outcomes from the analysis.

1) Eight samples were dated to between 850 BC and AD 950, providing a modest contribution to the late-Holocene kauri data set.

2) Crossmatching was identified between a floating sequence HAL008 and a 489-year sequence, CHI006, from a sample recovered in the early 2000s from the Chitty's Farm near Dargaville. Ten inner rings from CHI006 had been previously radiocarbon dated to 3933 ± 39 BP (WK15530; 2468-2209 cal BC). The connection raises the potential for extension of the late-Holocene kauri chronology from its current start date of 1724 BC into the 2000s BC; however, further replication is required to link the series together across the entire period of overlap and to resolve problems in CHI006.

3) At least three trees (eight samples) included in a site chronology, HALH03, were growing at the site at ~6000 to 5000 BC. This finding was based on the crossmatching of HALH03 to sequences from two radiocarbon dated trees (CHI015, HAR012) that were growing on, or close to, swamp systems ~2 km to the west (HARD) and ~2.5 km to the north (CHIT). It is supported by additional radiocarbon dates for two HALH samples. These are some of the oldest Holocene-age sub-fossil kauri samples to be recovered from swamps close to Dargaville.

Tree-ring analysis of sub-fossil kauri (*Agathis australis*) timbers from Hal Harding Farm, Pouto Road, Dargaville

Introduction

Long, high-resolution palaeoclimate records from New Zealand, as well as elsewhere in the Southern Hemisphere, are required to assist interpretation of changes in past climate. Since the 1980s, but particularly during the last twelve years, multi-centennial and multi-millennial length tree ring records have been developed from modern, archaeological[1] and, predominantly, sub-fossil (swamp) kauri, the latter dating the late-Holocene (e.g. Boswijk *et al* 2006) and from before the last Glacial Maximum (Palmer *et al* 2006). The climate signal within these records is being investigated to understand, for example, variability of the El Niño-Southern Oscillation during the last millennium (e.g. Fowler *et al* 2008, 2012) whilst the late-Holocene record is also being employed in calibration of the radiocarbon timescale for the Southern Hemisphere (Hogg *et al* 2011). Radiocarbon analyses are also applied to generate high resolution climate data using carbon isotopes. The multi-centennial and multi-millennial kauri records from the Holocene and last Glacial period provide a unique opportunity to reconstruct annual climate change under a range of different boundary conditions; however, often sample depth in the chronologies is low (<10 samples) which may affect reliability of reconstructions derived from tree-ring data. Therefore, additional material is required to improve the quality of the tree ring records. In addition, the analysis of new material may result in an extension of the temporal span of current records, or the development of new records for time periods not currently covered.

In 2008, a two-year FRST funded project – *Sub-fossil Kauri Collection and Analyses* (SFK) – was established at the University of Auckland (UOAX0901). The project aimed to improve regional and local paleoclimate data derived from sub-fossil kauri (*Agathis australis*) tree rings for periods in the last 130,000 years before present (BP). The project encompasses collection, analyses and archiving of sub-fossil kauri, high-resolution radiocarbon analyses of dendrochronologically matched (but not calendar-dated) wood contemporary with the Younger Dryas cooling event (13.0 – 10.5 ka cal BP), and awareness raising amongst local communities so that the scientific value of the sub-fossil kauri is recognised.

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[1] The term 'archaeological' is used to distinguish timbers derived from standing structures and in-ground sites from modern (living tree) or sub-fossil kauri.

This technical report describes the collection of sub-fossil kauri from one site, Hal Harding's Farm (HALH), Pouto Road, near Dargaville, and details chronology development and the calendar dating of material. Other significant outcomes are identified. The intent is to provide an archive document covering details not necessarily included in higher level academic publications, and which can also be used to convey information concerning the swamp kauri to relevant stakeholders, including the landowners, sawmillers and the Kauri Museum, Matakohe which acts as a repository for swamp kauri.

Hal Harding's Farm

Twenty-seven cross-sections (biscuits) were collected from logs excavated from Hal Harding's farm by Nelson Parker of 'Nelson's Kaihu Kauri', a sawmill specialising in swamp kauri. The farm is situated at the northern end of the North Kaipara Peninsula and the extraction site is located west of the Poutu Road and Northern Wairoa River, approximately 6 km south of Dargaville (Figure 1; NZMS260 Sheet P08 873793; 35° 59.5' S 173° 51.1' E; elevation ~18 m above sea level). Other assemblages collected from nearby swamp systems include CHIT (Boswijk 2005a) and HARD (Boswijk 2005b) and DARG from the Oruariki Swamp (D'Costa *et al* 2009).

The site is in a region that is characterised by low hills of Red Hill and Tangikiki Sand and Te Kopuru Sand, interspersed with east-west orientated valleys of Parore Peat and Kaipara peaty clay, and former estuarine flats (Kaipara Clay) adjacent to the Northern Wairoa River (see Sutherland et al 1980, and discussion by D'Costa et al 2009). Pollen analysis indicates kauri has been present in the wider Dargaville region for several thousand years (D'Costa *et al* 2009), whilst dendrochronological analysis and radiocarbon dating indicates preservation of kauri in swamps over a similar time period. No context or environmental information, such specific location and orientation of the logs in the swamp, or depth and composition of the peat, is available from the site. Elsewhere, observation of the distribution of root plates across the Korariwhero Swamp led D'Costa et al (2009) to suggest that, there, kauri grew on the swamp surface. Since human settlement in the region the vegetation cover has undergone considerable change, particularly after European colonisation in the 19th century.

Figure 1: Location of HALH site. (A) The town of Dargaville is located in Northland, north of Auckland City. (B) Hal Harding's farm is ~6km south of Darvgaville. (C) shows the approximate location of the extraction site (white circle) at ~ S 35° 59.5' E 173° 51.1'. The Northern Wairoa River and the Pouto Road are visible in the top right corner. Images: Google Earth, 2011.

The site was 'cleaned-out' during excavation, implying that there are few logs left in the ground to recover. The logs were viewed in the timber yard of Nelson's Kaihu Kauri by one of the authors, after transportation from the farm. Most of the suitable logs were sampled for dendrochronological analysis by cutting 'biscuits', and have since been milled for timber. Four samples had been obtained previously from the site, of which three had been crossdated against the late-Holocene kauri master chronology to the first millennium AD. Therefore, it was anticipated that the assemblage would produce further material of late-Holocene date.

Dendrochronology

Dendrochronology or tree-ring analysis is based on the measurement and comparison of patterns of tree growth. The principles and methodology of tree-ring analysis are described in Baillie (1982), albeit with reference to analysis of Northern Hemisphere oak timbers, and more recently by Speer (2010). In brief, each year during the growing season trees lay down a single growth ring, formed in the cambium directly under the bark. In many species, including kauri, the annual rings are clearly defined by a boundary formed at the end of the growing season, which separates one growth season from the next. The width of the annual ring is limited by climatic conditions, as well as being influenced by local environmental factors, previous growth years and genetic make-up of the tree. Because growth conditions change from year to year, ring width also varies creating a pattern of wide and narrow rings which is unique in time, but common to trees that have grown at the same time under similar conditions. Therefore it is possible to compare the growth patterns of different trees and identify those which are contemporary. Starting with living trees where the calendar date of the outermost ring is known and overlapping series from successively older trees, timbers and/or natural deposits of preserved wood, long absolutely dated tree-ring chronologies can be built. Tree-ring series of unknown age can be compared to these and accurate calendar dates obtained. Comparison of many different living kauri from several sites throughout the upper North Island indicate that the trees have a common signal in their rings (Fowler *et al* 2004) and the suitability of this species for dendrochronology is well established.

Methods

Twenty-seven cross-sections were cut from the Hal Harding logs by Nelson Parker, Nelson's Kaihu Kauri, and the numbered 'biscuits' were transported to the Kauri Museum, Matakohe for storage. Whilst there, the cross-sections were further reduced in size. In most cases, two radial strips were cut from each biscuit but in some cases, size of the cross-section must have precluded this as only one radial strip per section was present in the assemblage that was subsequently delivered to the Tree-Ring Laboratory at the School of Environment, The University of Auckland. No details were available regarding dimensions of the cross-sections or unusual or notable features, and photographs were not taken prior to the biscuits being reduced to radial strips.

Once at the Tree-Ring Laboratory the site was given a four-letter code, HALH and each sample was relabelled with a unique three-letter three-number code, e.g. HAL001. The samples were further trimmed to a size[2] suitable to fit on a travelling stage beneath a binocular microscope and the cross-sectional surface was sanded to a fine polish so that the ring sequence could be clearly seen. Each sample was assessed for suitability for analysis prior to measurement of the growth rings, based primarily on clarity of the ring pattern and having sufficient rings for crossmatching. The latter was not a significant issue, as most samples clearly had several hundred rings. Total ring width was measured using a set-up comprised of a travelling stage fitted with a linear encoder linked to a computer, and a binocular microscope. Ring widths were recorded in Dendro Input, which is part of the Dendro for Windows (DfW) suite (Tyers, 2004).

Radii from the same tree were measured and the series crossmatched and then averaged to produce a tree-sequence. As the assemblage was measured, single radius series and tree-sequences were compared to each other to identify those that crossmatched. Series or tree-sequences were also compared individually to an unpublished composite kauri master chronology, AGAUc07c_raw, constructed from data derived from modern trees, archaeological wood, and sub-fossil (swamp) kauri, to obtain calendar dates. The computer programs CROS (Baillie and Pilcher, 1973) and Cross84 (Munro, 1984), included in the Dendro for Window (DfW) suite (Tyers, 2004) were used to assist crossmatching. These programs compare pairs of samples and calculate the correlation co-efficient (r) for every position of overlap. Students *t* is calculated to provide a measure of the probability of the r value arising by chance, with a t-value of 3.5 or greater usually indicative of a match (Baillie, 1982). All *t* values reported here are from CROS.

All suggested matches (between series, tree-sequences and against master chronologies) were checked using line plots of the series overlaid on a light-table. Visual inspection of line plots is an important part of the crossmatching process. Kauri can produce false rings (the annual ring is

2 In most cases, the width of the radial strip was reduced by about half. This produced a duplicate sample that can be used for other research purposes.

divided by an apparent boundary) and can also have locally absent rings, where the annual ring is not complete around the entire circumference of the tree. Overlaying line plots enables identification of sections that are in sequence and then which go out of sync. This guides inspection of the sample to locate the problem. False rings can be determined by close inspection of the apparent boundary across the width of the sample and comparison of the same ring on different samples. Observation of many kauri growth rings indicates that the false boundaries become diffuse and usually fade out around the ring. Locally absent rings are identified when a ring is absent from one radius but present on other same-tree samples, and on other samples from different trees. Usually inspection of the sample can locate the ring merging into the boundary with the previous year's growth. This allows for a measured value to be inserted into the series. If a ring is wholly absent from a radius a 'zero' value is inserted. If the location of missing rings cannot be reliably resolved, the series is truncated to cover only the reliable section of tree growth.

All HALH series and tree-sequences that crossmatched to each other were averaged together to form a site chronology, which reduces noise and enhances the common signal on which crossdating is dependant. Where calendar dates were identified by comparison to the late-Holocene kauri master, the position of match was checked against independent site chronologies and tree sequences to verify through replication of results that the dating was correct. In the event that no matches were identified to other series and/or tree-sequences from HALH or to the kauri master, the series or tree-sequences were also compared to undated series/tree-sequences from other site assemblages.

Occasionally, crossmatching may identify tree-ring series (not from the same biscuit) that are very similar, indicated by high *t* and r values between series, and supported by similar characteristics of the samples, such as colour of wood, form of the rings, and events such as suppression episodes. This may indicate that although the samples were cut from different logs, the logs were actually derived from a single parent tree ('same-tree'). As part of the excavation process, kauri trunks are cut into separate (shorter) logs enabling the wood to be transported to the mill on a truck. The logs are then usually stacked in piles, which in the case of the HALH assemblage were sampled for tree-ring analysis. Therefore, there is potential for a sub-fossil kauri assemblage to contain (unrecognised) duplicate samples. In cases where possible 'same-tree' material is identified, the ring width series are averaged together to produce a single tree-sequence for use in chronology development to avoid introducing bias into the site curve (English Heritage 2004).

Preservation conditions will affect the completeness of a ring sequence from a sub-fossil kauri. If the tree trunk was completely buried in an anaerobic environment, the wood and bark will be well preserved and it may be possible to obtain a reliable indication of tree age and to determine the year of tree death. However, if a trunk is partially exposed for some time before burial (or after re-exposure), the wood will start to decay and the outside, and sometimes inner, rings will be lost. In this case, only a minimum estimate for the life span of a tree is obtained.

Results

Details of all samples collected from Hal Harding's Farm, including series length, average growth rate, calendar dates and additional comments are presented in Table 1. Almost all samples were measured. The exceptions were HAL009, which had degraded wood, and HAL021, which on the basis of strong visual similarity was considered to be a duplicate of other samples including HAL016 and HAL018. There was no sample for HAL024.

Series length of the measured assemblage ranged from 154 rings (HAL007a) to 801 rings (HAL027), with an average series length of 480 rings. Several samples had additional rings at the inner or outer end that could not be measured, or which were truncated from the series during the crossmatching process due to concerns about the reliability of the sequence. Taking these rings into account, three samples were from parent trees that were >800 years old when they died.

Duplicate samples

During crossmatching three sets of probable duplicate samples were identified, indicating that that the site assemblage came from fewer than 27 trees. These sets were:

HAL100: HAL001 and HAL028. The ring patterns for these samples covered nearly the same time span (Figure 2), were very similar (t = 20.84, r = 0.72, overlap = 399 years), and the actual wood samples were also visually similar.

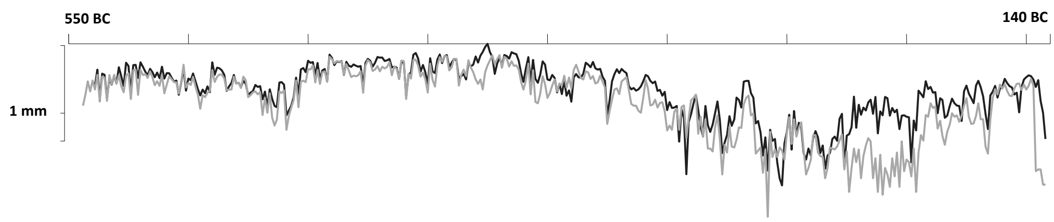

Figure 2: Raw ring width plots for HAL001 (dark) and HAL028 (light)

HAL101: HAL016, HAL018, HAL020, HAL022, HAL027. The ring series of these samples covered a common period. The ring width patterns were near identical (Figure 3; Table 2), displaying common characteristics such as repeated periods of suppression (with locally absent rings). All wood samples had black colouring, which is unusual as kauri is typically a warm golden-honey colour. The black tones in the wood graduated to red-brown in the outer edges of all the samples, and all had bands of lighter coloured wood coincident with the suppression episodes.

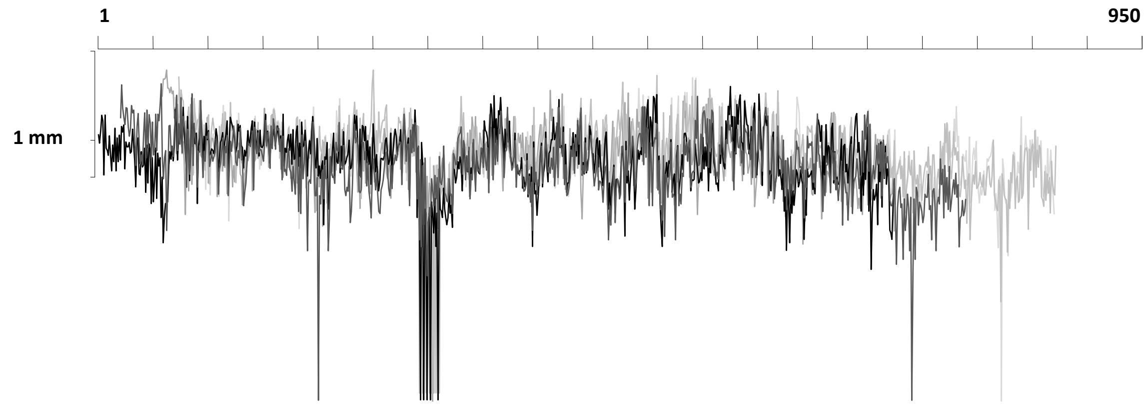

Figure 3: Raw ring width plots for HAL016, HAL018, HAL020, HAL022 and HAL027. Long vertical lines indicate position of locally absent rings, and a significant period of suppression.

HAL102: HAL014 and HAL025. As with the groups above, these two series covered a common time period (Figure 4), and the ring patterns were similar (t = 23.18, r = 0.79, overlap = 340 years). The wood samples shared the same visual characteristics, including colour.

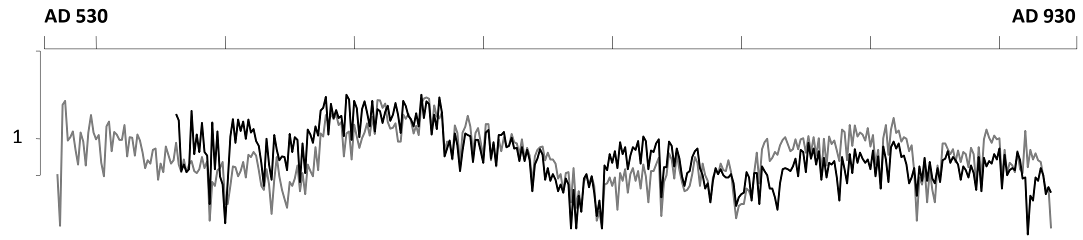

Figure 4: Raw ring width plots for HAL014 (red) and HAL025 (blue).

Site Chronologies

Four site chronologies or two-timber sequences were produced as a result of intra-site comparison of samples. These are HALH01, HALH02, HALH03 and HALH04. Data listings of each chronology are presented in Appendix 1.

1) HALH01

This chronology is comprised of HAL100, HAL011 and HAL017a and spans 603 years (Figure 5; Table 3). The chronology was crossdated to 544 BC – AD 59 by comparison to the late-Holocene kauri master chronology. The position of match was checked against independent site chronologies and each individual series was also compared separately to the kauri master and independent chronologies (Table 4).

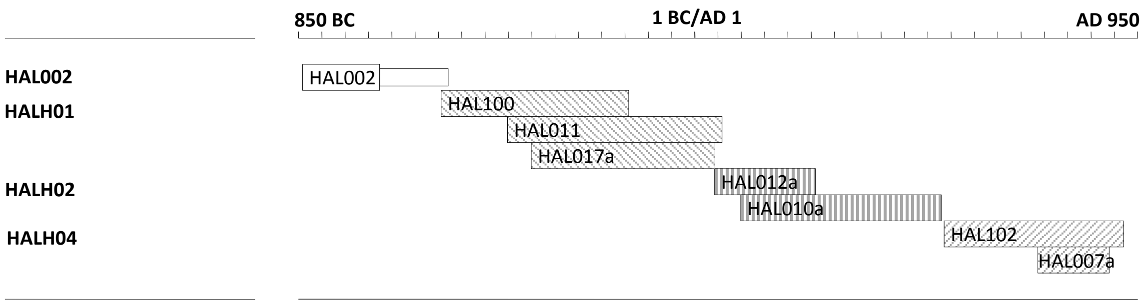

Figure 5: Crossdated position of calendar dated series and tree-sequences included in HALH01, HALH02 and HALH04 and independent series and tree-sequences. Shading indicates groups for HALH01 (left leaning stripes), HALH02 (vertical stripes) and HALH04 (right leaning stripes).

2) HALH02

Technically, HALH02 is a two-timber sequence, constructed from HAL012a and HAL010a (Figure 5; Table 3). The sequence spans 487 years and was calendar dated to AD 43 – AD 529 (Table 4).

3) HALH03

HALH03 includes HAL101, HAL015 and HAL019 (Figure 6; Table 5). The chronology spans 1171 years, but this includes a 150 year section at the start represented by HAL101 only and a ~300 year section at the end which is spanned by HAL019 only.

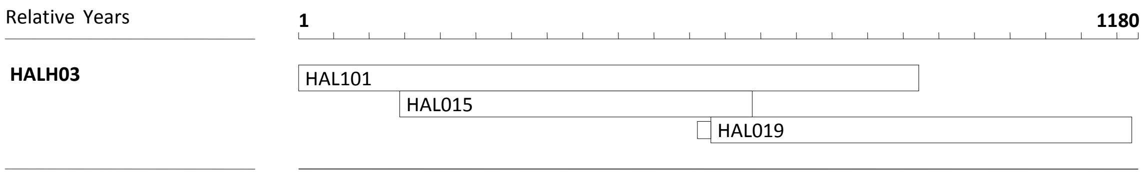

Figure 6: Relative positions of sequences included in HALH03.

No overlap was identified between HALH03 and the late-Holocene kauri master but crossmatching was identified between HALH03 and two floating sequences from other site assemblages: HAR012 and CHI015. These two sequences were from samples collected in the early 2000s from Robert Harding's (HARD) farm and the Chitty (CHIT) farm respectively, also located near Dargaville (Figure 7). Ten rings at relative years 411-420 of CHI015 had been radiocarbon dated to 6369 ±47 BP (WK15532; 5468 – 5306 cal BC; Boswijk, 2005a). HAR012 was not radiocarbon dated but was identified as being from the same log as another HARD sample, HAR009, which was radiocarbon dated to 6286 ± 50 BP (WK15534; 5316-5042 cal BC; (Boswijk, 2005b).

Figure 7: Source location of CHIT, HALH and HARD assemblages.

Despite indications from the radiocarbon dates that CHI015 and HAR012 were likely to be contemporary, no crossmatching between these two sequences had been previously identified and there were doubts about the reliability of both ring sequences due to the occurrence of periods of very narrow and locally absent rings. The identification of a match with HALH03 prompted a review of the sequences, including careful checking of all radii from CHI015, HAR012 and the HALH03 set, and identification of the location of locally absent rings. The HALH03 set were found to be accurate, whilst locally absent rings were identified on CHI015 and HAR012. Revised versions of tree sequences CHI015 and HAR012 were made after the ring series were amended to include missing rings[3]. Where it was not possible to confidently resolve ring problems, such as on the inner sections (closest to pith) of HAR012 and CHI015 the series were truncated.

The position of overlap between HALH03, CHI015 and HAR012 is shown in Figure 8 and crossmatching statistics are presented in Table 6. The sequences were combined to create a new chronology, AGAU_float01. The chronology is 1282 years long.

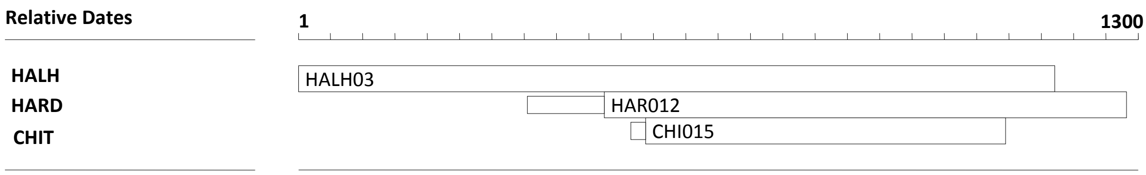

Figure 8: Position of overlap between CHI015, HAR012 and HALH03. Wide bars indicate the span of the chronology/sequence. Narrow bars are unmeasured or excluded rings.

To assist in confirming and refining the dating of AGAU_float01 additional radiocarbon dates were obtained. Thirty rings[4] from the inner section of HAL020b and ten rings from the outer section of HAL019b were submitted to the Radiocarbon Dating Laboratory, University of Waikato. The results (listed below) are in agreement with previous radiocarbon dates for CHI015 and HAR012 (via HAR009). Collectively they indicate that AGAU_float01 dates to ~6000 – 5000 BC.

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[3] HAR012 was remade from HAR012b, HAR012d and HAR012e only. HAR012a and HAR012c were not reliable. CHI015 was remade from CHI015a, CHI015b and CHI015c.

[4] Thirty rings were sampled from HAL020b due to the difficulty in getting enough weight of wood for ^{14}C analysis.

Sample	Waikato Code	^{14}C Determination	Calibrated BP[5]	Calibrated BC[6]
HAL019b	WK32804	6266±37 BP	7250 – 6999 cal BP	5297 – 5055 cal BC
HAL020b	WK32805	7313±35 BP	8172 – 7996 cal BP	6223 – 6032 cal BC

4) HALH04

HALH04 is a two timber sequence that includes HAL102 and HAL007a (Figure 5; Table 3). The sequence spans 386 years, but HAL007a is only 154 years long, so the bulk of the record is based on data from one tree only. HALH04 was crossdated at AD 535 to AD 920 by comparison to AGAUc07c_raw, and was crosschecked against independent site chronologies (Table 4). The dated positions of HAL102 and HAL007a were also checked independently (Table 4).

Other series

1) HAL002

In addition to the calendar dating of HALH01, HALH02 and HALH04, one sequence, HAL002 was calendar dated to 841 BC – 676 BC (Figure 5; Table 4). The sequence (based on two radii) is 166 years long. The sample had a maximum of 302 rings (HAL002b) but the ring patterns in the outer sections of HAL002a and HAL002b could not be reliably reconciled due to irresolvable ring issues.

2) HAL008

HAL008 did not crossmatch to any other series or sequences from the HALH assemblage, and did not crossdate against the late-Holocene kauri chronology. The series was compared to undated sequences from other sites and a match identified with a series, CHI006, from the CHIT assemblage. CHI006 is an interesting sample because it had at least 1049 rings, but only the inner sections of three radii from the sample could be crossmatched against each other, generating a 489-year tree sequence, CHI006i. Ten rings from inner part of radius CHI006a were radiocarbon dated to 3933 ± 39 BP (WK15530; 2468-2209 cal BC) indicating that, when the total number of rings present is taken into account, the sequence should overlap with the end of the late-Holocene kauri chronology (Boswijk, 2005a).

The inner sections of HAL008 and CHI006i crossmatched (t = 6.91, r = 0.46, overlap = 200 years) but visual comparison indicated that the outer sections were not in sync. Careful review of

[5] Calibrated BP dates supplied by A Hogg from OxCal V4.17 using SHCal04 southern hemisphere calibration curve.
[6] Calibrated BC dates from OxCal V4.1 (online) Bronk Ramsey (2009) using SHCal04.

the ring width series from both samples and further replication by additional material was considered necessary to confidently reconcile ring patterns. Therefore, the suggested match has been noted but has not been advanced further at this stage.

Unmatched series

The inner section of HAL003a overlapped with HAL002 (t = 5.73, r = 0.43, overlap = 149), and the position of match indicated that the series should also overlap with HALH01. However, as with HAL002, there were ring problems in the outer part of the sequence which could not be satisfactorily resolved. There was only one radius from the biscuit and although most of the annual rings were clearly defined, there were some sections with overlapping or lensing rings and locally absent rings. Reconciliation of the complete ring patterns of HAL002 and HAL003 to each other and HALH01 would provide a continuous record of annual tree growth from the HALH site between 841 BC and AD 529. (There is a very short overlap between HALH01 and HALH02.)

HAL004, HAL005, HAL006 and HAL021 could not be matched against other series from the HALH assemblage, or against the late-Holocene master chronology. It is possible that these series have unrecognised ring issues that prevent crossmatching or the sequences date to a time period for which we currently have no other data.

Discussion and Conclusion

Analysis of the swamp kauri assemblage from HALH has been successful in generating new data within an 1800-year period, between 850 BC and 950 AD and, significantly, for the mid-Holocene (~6000 – 5000 BC) as well. The clustering of samples into separate groups which date across a wide time period is similar to patterns observed in other swamp kauri assemblages from the region. For example, the CHIT assemblage produced two site chronologies and a single sequence dated to between 1718 BC and AD 842, and floating sequences radiocarbon dated to before >1724 BC (see Boswijk 2005a for details). Two long calendar-dated chronologies were established for HARD, which also had older material (> 1724 BC) in the assemblage.

The HALH assemblage was also similar to other assemblages from the region in that most samples had 'difficult' rings. This encompasses suppression episodes, where the rings become very narrow and which usually coincide with locally absent rings, lensing rings, overlapping rings (associated with lensing and locally absent rings) and false rings. The series included in HAL101 (those dating to ~6000 – 5000 BC), in particular, had an abrupt and prolonged period of suppression with locally absent rings that affected initial crossmatching between series. Careful checking of the ring patterns was required when reconciling series from radii, and when crossmatching between tree-sequences, to ensure that all rings were accounted for and no errors were inadvertently made when amending sequences. It is possible that unrecognised ring issues may account for series from three trees (HAL004, HAL006 and HAL014) not being crossmatched. Alternatively they could date to time periods for which we currently have no other data.

The purpose of sampling kauri from swamps in the Northland region is to improve the quality of multi-centennial and multi-millennial tree ring data sets that can be used for palaeoclimate analyses by adding new data to the existing records. Additionally, new material may result in an extension of the current temporal span of the calendar dated or floating records, or development of new records for time periods not currently covered. As shown above, all the calendar dated and radiocarbon dated HALH material was of Holocene date. There were three significant outcomes from the analysis.

1) Eight samples were dated to between 850 BC and AD 950, providing a modest contribution to the late-Holocene kauri data set. Across this time period, sample depth in a master chronology would increase by one, and occasionally two, trees. Reconciliation of HAL003 and HAL002 would contribute additional calendar dated series to the set.

2) On the basis of crossmatching to a floating sequence from the CHIT assemblage, one sample (HAL008) likely dates to the early 2000s BC. The connection raises the potential that the late-Holocene kauri chronology could be extended back in time from its current start date of 1724 BC into the 2000s BC, but further replication is required to securely link the series together and to resolve problems in CHI006.

3) At least three trees (eight samples) were growing at the site at ~6000 to 5000 BC and are contemporary with trees that were growing on, or close too, swamp systems ~2km to the west (HARD) and ~2.5 km north (CHIT) (Figure 7). These are some of the oldest Holocene-age swamp kauri samples to be recovered from swamps close to Dargaville, although ‘ancient kauri’ (alive >22 k years BP) has been extracted from swamps near the west coast to the north of the town.

Acknowledgements

We thank Nelson Parker for cutting and supplying samples from the Hal Harding log collection for the dendrochronological analysis, and the team at the Kauri Matakohe Museum for storage of wood and cutting radial strips. Jonathan Palmer arranged the collection and initial preparation of the samples. Further preparation of samples was carried out by Peter Crossley at the School of Environment. Gretel Boswijk undertook the tree-ring analysis and wrote the report, which was reviewed by Jonathan Palmer. This work was funded by the Foundation for Research, Science and Technology UOAX0901.

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Table 1: Details of all samples collected from HALH

Sample = wood; Dimensions = length of sample only; Series = radius; Rings = measured, +*n* indicates unmeasured or excluded heartwood (*h*) or sapwood (*s*) rings; Bark = terminal ring at waney edge present (+B), or possible bark edge (?B); AGR = Average growth rate per annum; Date Span = calendar years (BC/AD) or relative if undated; Comments = additional details about the sample.

Sample	Dimensions (mm)	Series	Rings	Bark edge	Average Growth rate	Dated span	Comments
HAL001			403	+½Bs	1.64	544 BC-142 BC	Same tree as HAL028; Included in HAL100;
	810 x 0	HAL001a	398+*3h*		1.90	544 BC-147 BC	HALH01
	610 x 0	HAL001b	402	+½Bs	1.40	543 BC-142 BC	
HAL002			166+*147h*		2.37	841 BC-676 BC	Truncated as outer section not resolved. Match
	500 x 0	HAL002a	166+*123h*		2.15	841 BC-676 BC	with HAL003
	573 x 0	HAL002b	155+*147h*		2.58	830 BC-676 BC	
HAL003a	832 x 0		456		1.58	1-456	Not dated. Inner matches to HAL002 but outer has unresolved ring issues.
HAL004_a			*20h*+323		0.63	1-323	Not crossmatched
HAL004_b			244		1.43	1-244	
	175 x 0	HAL004aa	240		0.74	22-261	
	403 x 0	HAL004ab	*184h*+244		1.32	1-244	
	208 x 0	HAL004ba	*20h*+323		0.62	1-323	
	545 x 0	HAL004bb	153		1.85	10-162	
HAL005a	560 x 0		646		0.86	1-646	Not crossmatched
HAL006			223	+½Bs	3.50	1-223	Not crossmatched
	725 x 0	HAL006a	209	+½Bs	3.32	15-223	
	845 x 0	HAL006b	223	+½Bs	3.72	1-223	
HAL007a	340 x 0		154		2.16	AD 736-AD 889	Included in HALH04
HAL008			507	+1s+B	1.05	1-507	Match to CHI006i but ring issues to be resolved.
	315 x 0	HAL008a	301		1.02	1-301	
	552 x 0	HAL008b	*1h*+506	+1s+B	1.09	2-507	
HAL010a	432 x 0		431		1.00	AD 99-AD 529	Included in HALH02
HAL011			461	+½Bs	1.74	402 BC-AD 59	Hal011aa = inner section; HAL011ab = outer section;
	223 x 0	HAL011aa	89		2.43	414 BC-326 BC	Included in HALH01
	702 x 0	HAL011ab	382	+½Bs	1.74	323 BC-AD 59	
	785 x 0	HAL011b	461	+½Bs	1.65	402 BC-AD 59	
HAL012a	580 x 0		217		2.66	AD 43-AD 259	Included in HALH02
HAL014			386		0.80	AD 535-AD 920	Same tree as HAL025; included in HAL102;
	290 x 0	HAL014a	371		0.76	AD 535-AD 905	HALH04.
	300 x 0	HAL014b	359		0.84	AD 562-AD 920	
HAL015			496		0.73	143-638	HALH03; ~6000 – 5000 BC
	371 x 0	HAL015a	470		0.71	143-612	
	435 x 0	HAL015b	496+*56h*		0.76	143-638	

HAL016			770		0.73	21-790	Same tree as HAL018, HAL020, HAL022, HAL027;
	600 x 0	HAL016a	767+*133h*		0.74	1-767	Included in HAL101; HALH03; ~6000 – 5000 BC
	571 x 0	HAL016b	718+*97h*		0.69	53-770	
							-
HAL017a	570 x 0		394		1.43	351 BC-AD 43	-
HAL018			799+*79h*		0.80	74-872	Same tree as HAL016, HAL020, HAL022, HAL027;
	425 x 0	HAL018a	527+*50h*		0.74	346-872	Included in HAL101; HALH03; ~6000 – 5000 BC
	692 x 0	HAL018b	799+*79h*		0.82	74-872	
HAL019			*19h*+592		1.49	580-1171	Included in HALH03. ~6000 –5000 BC.
	790 x 0	HAL019a	*19h*+580		1.24		
	990 x 0	HAL019b	523		1.83		
HAL020	690 x 0		*19h*+725+*129h*		0.83	1-725	Same tree as HAL016, HAL018, HAL022, HAL027;
	325 x 0	HAL020aa	376+*136h*		0.71	350-725	Included in HAL101; HALH03; ~6000 – 5000 BC
	207 x 0	HAL020ab	251		0.83	104-354	
HAL021							Not crossmatched. Sample broken and measured in
	427 x 0	HAL021aa	266		1.59	1-266	two parts.
	495 x 0	HAL021ab	260+*4h*		1.89	1-260	
HAL022			667		0.85	60-726	Same tree as HAL016, HAL018, HAL020, HAL027;
	700 x 0	HAL022a	666+*130h*		0.89	60-725	Included in HAL101; HALH03; ~6000 – 5000 BC
	545 x 0	HAL022b	623+*125h*		0.78	104-726	
HAL023		HAL023a					Not measured. Likely same tree as HAL100 set
HAL024		HAL024					No sample
HAL025			340		0.81	AD 581-AD 920	Same tree as HAL014; Included in HAL102;
	310 x 0	HAL025a	293		0.81	AD 628-AD 920	HALH01
	292 x 0	HAL025b	317		0.82	AD 581-AD 897	
HAL026a	760 x 0		565	+½Bs	1.33	1-565	Not crossmatched.
HAL027			801		0.86	70-870	Same tree as HAL016, HAL018, HAL020, HAL022;
	465 x 0	HAL027a	402+*320h*		0.90	17-418	Included in HAL101; HALH03; ~6000 – 5000 BC
	745 x 0	HAL027b	801+*100h*		0.83	1-801	
HAL028			399	+½Bs	1.81	540 BC-142 BC	Radius c excluded from tree sequence; Same tree as
	745 x 0	HAL028a	399	+½Bs	1.74	540 BC-142 BC	HAL001; Included in HAL100; HALH01.
	730 x 0	HAL028b	384		1.88	526 BC-143 BC	
	860 x 0	HAL028c	554	+½Bs	1.51	1-554	

Table 2: Crossmatching between HAL101 sequences
t-value/r value; * = empty triangle

Filenames	-	-	HAL016	HAL018	HAL020	HAL022	HAL027
-	start	dates	21	74	1	60	70
-	dates	end	790	872	725	726	870
HAL016	21	790	*	15.09/0.49	20.59/0.61	26.09/0.71	27.84/0.72
HAL018	74	872	*	*	14.02/0.48	18.98/0.60	22.29/0.62
HAL020	1	725	*	*	*	19.07/0.60	18.70/0.59
HAL022	60	726	*	*	*	*	35.32/0.81
HAL027	70	870	*	*	*	*	*

n = 10 min t = 14.02 max t = 35.32 mean t = 21.80 s.d. = 6.08

Table 3: Crossmatching between HALH series and tree sequences included in HALH01, HALH02 and HALH04
t-value/r value; \ = overlap < 25 years or no overlap;- = t-values less than 3.00;* = empty triangle

			HALH01			HALH02		HALH04	
Filenames	-	-	HAL011	HAL017a	HAL100	HAL010a	HAL012a	HAL007a	HAL102
-	*start*	*dates*	*402 BC*	*351 BC*	*544 BC*	*AD 99*	*AD 43*	*AD 736*	*AD 535*
-	*dates*	*end*	*AD 59*	*AD 44*	*142 BC*	*AD 529*	*AD 259*	*AD 889*	*AD 920*
HAL011	*402 BC*	*AD 59*	*	8.81/0.41	10.52/0.55	\	-	\	\
HAL017a	*351 BC*	*AD 44*	*	*	8.14/0.49	\	\	\	\
HAL100	*544 BC*	*142 BC*	*	*	*	\	\	\	\
HAL010a	*AD 99*	*AD 529*	*	*	*	*	10.54/0.65	\	\
HAL012a	*AD 43*	*AD 259*	*	*	*	*	*	\	\
HAL007a	*AD 736*	*AD 889*	*	*	*	*	*	*	6.98/0.50
HAL102	*AD 535*	*AD 920*	*	*	*	*	*	*	*

n = 6 min t = 0.81 max t = 10.54 mean t = 7.63 s.d. = 3.30

Table 4: Crossmatching of HALH01, HALH02, HALH04 and HAL002 to AGAUc07c_raw and independent site chronologies and tree sequences. Individual series and tree sequences included in the site chronologies are also included for comparative purposes. Reference chronologies arranged by start date. *t*-values only. \ = overlap < 25 years; - = *t*-values less than 3.00

			Site chronologies			Independent series and tree sequences							
							HALH01			HALH02		HALH04	
			HALH01	**HALH02**	**HALH04**	**HAL002**	**HAL011**	**HAL017a**	**HAL100**	**HAL010a**	**HAL012a**	**HAL007a**	**HAL102**
	start	*dates*	*544 BC*	*AD 43*	*AD 535*	*841 BC*	*402 BC*	*351 BC*	*544 BC*	*AD 99*	*AD 43*	*AD 736*	*AD 535*
	dates	*end*	*AD 59*	*AD 529*	*AD 920*	*676 BC*	*AD 59*	*AD 44*	*142 BC*	*AD 529*	*AD 259*	*AD 889*	*AD 920*
AGAUc07c_raw *(TRL, unpubl)*	*1724 BC*	*AD 2002*	14.53	18.73	12.02	7.59	9.47	11.08	9.14	18.61	11.12	6.99	14.29
Northland													
DARGVL01 *(TRL, unpubl)*	*1589 BC*	*AD 120*	13.09	-	\	9.10	6.90	9.30	12.51	\	-	\	\
HARDING2 *(Boswijk, 2005b)*	*1466 BC*	*437 BC*	5.56	\	\	13.60	\	\	5.57	\	\	\	\
CHITTY2 *(Boswijk, 2005a)*	*1257 BC*	*676 BC*	\	\	\	6.65	\	\	\	\	\	\	\
MAITAHI *(Boswijk, 2005c)*	*576 BC*	*AD 370*	15.30	8.93	\	\	8.42	9.81	10.46	9.63	7.82	\	\
CHITTY1 *(Boswijk, 2005a)*	*477 BC*	*AD 842*	16.16	14.24	7.22	\	10.02	11.68	9.58	14.95	7.27	3.71	7.86
TIK401A *(TRL, unpubl)*	*38 BC*	*AD 489*	7.76	16.19	\	\	4.54	4.97	\	15.46	9.05	\	\
TIK001 *(Boswijk, 2004)*	*AD 67*	*AD 730*	\	11.02	4.73	\	\	\	\	12.52	6.48	\	4.73
HARDING1 *(Boswijk, 2005b)*	*AD 124*	*AD 1152*	\	11.78	10.83	\	\	\	\	12.31	7.02	8.11	12.52
YAKAS1 *(Boswijk & Palmer, 2004)*	*AD 304*	*AD 1273*	\	7.64	11.59	\	\	\	\	7.64	\	6.13	14.73
Waikato													
WHANGAPE *(Boswijk & Palmer, 2003)*	*1180 BC*	*131 BC*	4.97	\	\	5.63	3.95	3.50	4.12	\	\	\	\
FURNISS1 *(Boswijk et al 2001)*	*315 BC*	*AD 769*	6.20	7.50	4.28	\	4.61	5.18	-	7.11	5.74	-	4.56

n = 76 min t = 0.80 max t = 18.73 mean t = 8.81 s.d. = 4.09

Table 5: Crossmatching between HALH03 series (HAL101, HAL015 and HAL019)
t-values/r values; * empty field.

Filenames	-	-	HAL101	HAL015	HAL019
-	*start*	*dates*	*1*	*143*	*580*
-	*dates*	*end*	*872*	*638*	*1171*
HAL101	*1*	*872*	*	18.92/0.65	12.06/0.58
HAL015	*143*	*638*	*	*	5.36/0.59
HAL019	*580*	*1171*	*	*	*

n = 3 min t = 5.36 max t = 18.92 mean t = 12.11 s.d. = 5.54

Table 6: Crossmatching between CHI015, HAR012 and HALH03
t-values/r values; * empty field.

Filenames				CHI015	HAR012	HALH03
	start	*dates*		*538*	*474*	*1*
	dates	*end*		*1095*	*1282*	*1171*
CHI015	*538*	*1095*	*		18.30/0.61	17.86/0.61
HAR012	*474*	*1282*	*		*	17.40/0.55
HALH03	*1*	*1171*	*		*	*

n = 3 min t = 17.40 max t = 18.30 mean t = 17.85 s.d. = 0.37

Appendix 1:
Raw data listings for dated and floating site chronologies.

HALH01

Ring-width AGAU data of 603 years length, dated 544 BC to AD 59
3 timbers raw data mean
Average ring width 175.83   Sensitivity 0.27

544 BC							119	153	210	166							*1*	*1*	*1*	*1*
-	205	174	246	130	232	227	131	231	189	235	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	192	250	197	166	267	263	144	275	278	180	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	286	256	244	225	260	235	201	223	197	257	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	181	213	233	215	198	200	149	195	283	168	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
500 BC	204	195	231	189	157	125	155	145	166	159	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	285	215	248	253	246	224	162	171	179	228	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	190	194	173	214	198	143	149	158	171	161	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	167	111	147	104	159	108	92	95	176	174	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	173	77	95	111	134	211	128	231	237	222	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
450 BC	294	285	302	212	283	200	253	260	200	364	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	341	299	321	316	319	233	307	273	250	262	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	255	256	269	166	298	334	318	268	286	319	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	298	314	295	302	325	253	283	272	212	322	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	314	137	237	230	352	359	313	237	263	224	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*2*	*2*
400 BC	194	352	230	281	338	362	288	339	356	239	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	259	280	269	135	191	179	182	289	206	218	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	252	250	327	350	390	367	350	320	225	251	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	262	261	356	293	303	337	323	360	341	231	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	155	205	263	159	271	166	141	158	194	192	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*3*
350 BC	146	138	172	178	124	203	169	217	139	183	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	143	239	272	217	229	196	206	234	191	220	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	165	183	185	162	128	67	91	184	187	206	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	198	210	199	241	207	172	184	151	135	157	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	196	208	210	196	175	190	138	219	189	148	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
300 BC	120	130	138	168	183	95	132	121	81	97	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	95	125	181	107	108	77	120	92	81	84	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	116	179	164	106	127	116	133	111	93	124	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	140	110	203	213	224	172	192	128	131	127	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	80	92	47	102	69	106	88	89	103	102	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
250 BC	90	156	99	193	155	128	179	101	91	94	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	123	174	147	129	94	82	53	54	66	81	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	69	95	112	126	38	88	95	104	125	68	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	127	103	129	95	135	153	82	89	43	118	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	109	139	131	119	142	92	83	83	121	56	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
200 BC	81	68	45	79	48	115	89	100	111	112	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	125	95	124	79	104	62	66	80	70	132	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	150	121	151	74	141	179	116	137	112	150	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	150	115	136	82	94	152	171	184	130	190	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	204	213	210	163	170	136	152	139	216	246	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
150 BC	184	191	184	195	120	142	131	152	130	175	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*2*
-	102	97	86	131	63	146	83	183	122	153	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*

-	152	133	165	114	156	102	126	84	128	185	2	2	2	2	2	2	2	2	2	2
-	216	179	175	142	167	197	222	97	151	147	2	2	2	2	2	2	2	2	2	2
-	160	58	137	77	143	150	72	140	123	106	2	2	2	2	2	2	2	2	2	2
100 BC	142	124	108	115	74	64	80	106	80	130	2	2	2	2	2	2	2	2	2	2
-	62	96	157	131	175	138	98	83	172	167	2	2	2	2	2	2	2	2	2	2
-	141	121	160	205	120	183	117	204	285	335	2	2	2	2	2	2	2	2	2	2
-	320	307	276	248	210	264	178	206	97	201	2	2	2	2	2	2	2	2	2	2
-	125	130	115	202	207	229	239	235	233	226	2	2	2	2	2	2	2	2	2	2
50 BC	151	144	112	114	164	85	132	207	264	331	2	2	2	2	2	2	2	2	2	2
-	191	207	131	161	138	150	173	70	143	56	2	2	2	2	2	2	2	2	2	2
-	108	148	105	156	161	89	125	45	99	122	2	2	2	2	2	2	2	2	2	2
-	132	147	113	87	182	270	216	182	47	289	2	2	2	2	2	2	2	2	2	2
-	197	282	242	297	283	174	211	128	139	230	2	2	2	2	2	2	2	2	2	2
AD 1	229	248	201	133	99	25	124	148	60	115	2	2	2	2	2	2	2	2	2	2
-	98	155	135	174	53	144	48	214	273	227	2	2	2	2	2	2	2	2	2	2
-	239	111	165	92	187	167	182	170	254	258	2	2	2	2	2	2	2	2	2	2
-	221	152	121	96	131	108	143	201	70	121	2	2	2	2	2	2	2	2	2	2
-	153	207	174	198	265	293	229	305	241	296	2	2	2	2	1	1	1	1	1	1
AD 51	184	219	251	305	202	288	223	164	222		1	1	1	1	1	1	1	1	1	

HALH02

Ring-width AGAU data of 487 years length, dated AD 43 to AD 529
2 timbers raw data mean
Average ring width 145.27   Sensitivity 0.36

AD 43			407	402	407	394	385	267	222	315			1	1	1	1	1	1	1	1
AD 51	81	213	192	250	246	133	155	187	206	216	1	1	1	1	1	1	1	1	1	1
-	150	272	51	46	87	88	149	113	217	153	1	1	1	1	1	1	1	1	1	1
-	137	162	267	76	167	76	169	298	228	224	1	1	1	1	1	1	1	1	1	1
-	211	188	296	312	209	234	396	388	460	454	1	1	1	1	1	1	1	1	1	1
-	218	335	208	411	205	294	318	355	77	139	1	1	1	1	1	1	1	1	2	2
AD 101	162	103	220	164	164	235	225	142	177	154	2	2	2	2	2	2	2	2	2	2
-	213	148	254	234	113	167	116	157	111	209	2	2	2	2	2	2	2	2	2	2
-	243	193	164	197	206	175	228	125	169	126	2	2	2	2	2	2	2	2	2	2
-	140	223	201	239	175	220	228	210	162	208	2	2	2	2	2	2	2	2	2	2
-	155	119	216	157	125	184	186	175	148	160	2	2	2	2	2	2	2	2	2	2
AD 151	165	168	131	163	138	174	147	74	101	158	2	2	2	2	2	2	2	2	2	2
-	129	189	163	203	127	148	86	146	149	116	2	2	2	2	2	2	2	2	2	2
-	156	86	156	157	176	103	187	214	213	199	2	2	2	2	2	2	2	2	2	2
-	235	156	215	271	135	188	168	198	265	157	2	2	2	2	2	2	2	2	2	2
-	203	157	177	198	167	195	95	135	150	246	2	2	2	2	2	2	2	2	2	2
AD 201	194	177	218	168	171	196	131	291	211	270	2	2	2	2	2	2	2	2	2	2
-	237	281	262	240	117	247	241	244	174	216	2	2	2	2	2	2	2	2	2	2
-	217	218	225	206	290	113	199	197	278	279	2	2	2	2	2	2	2	2	2	2
-	249	267	254	70	173	229	231	189	149	180	2	2	2	2	2	2	2	2	2	2
-	189	157	220	131	234	261	248	274	66	236	2	2	2	2	2	2	2	2	2	2

AD 251	254	268	153	190	229	298	180	262	169	95	2	2	2	2	2	2	2	2	2	1
-	103	127	136	114	111	103	114	65	76	58	1	1	1	1	1	1	1	1	1	1
-	103	64	50	61	91	97	83	94	53	88	1	1	1	1	1	1	1	1	1	1
-	138	131	161	127	67	80	131	68	155	94	1	1	1	1	1	1	1	1	1	1
-	143	76	127	70	114	131	95	152	106	126	1	1	1	1	1	1	1	1	1	1
AD 301	112	82	122	145	41	137	89	120	93	138	1	1	1	1	1	1	1	1	1	1
-	106	133	138	102	83	136	75	137	169	128	1	1	1	1	1	1	1	1	1	1
-	161	137	169	109	115	75	108	140	154	136	1	1	1	1	1	1	1	1	1	1
-	138	133	95	126	63	132	158	100	154	115	1	1	1	1	1	1	1	1	1	1
-	164	132	164	135	127	82	111	65	100	132	1	1	1	1	1	1	1	1	1	1
AD 351	127	44	88	172	113	150	96	98	136	210	1	1	1	1	1	1	1	1	1	1
-	123	134	189	115	174	122	124	39	106	143	1	1	1	1	1	1	1	1	1	1
-	73	132	121	99	117	108	93	114	28	100	1	1	1	1	1	1	1	1	1	1
-	95	110	111	91	140	136	126	89	154	59	1	1	1	1	1	1	1	1	1	1
-	109	123	121	133	140	97	95	136	80	144	1	1	1	1	1	1	1	1	1	1
AD 401	99	136	92	22	85	159	27	135	130	151	1	1	1	1	1	1	1	1	1	1
-	147	103	123	92	73	129	36	110	104	149	1	1	1	1	1	1	1	1	1	1
-	138	145	150	127	154	78	126	137	150	41	1	1	1	1	1	1	1	1	1	1
-	113	160	92	135	103	135	106	44	49	49	1	1	1	1	1	1	1	1	1	1
-	63	22	38	33	1	47	82	54	100	68	1	1	1	1	1	1	1	1	1	1
AD 451	96	42	72	111	37	119	96	105	93	83	1	1	1	1	1	1	1	1	1	1
-	103	64	52	79	93	16	91	145	102	131	1	1	1	1	1	1	1	1	1	1
-	106	84	71	67	64	72	14	58	67	17	1	1	1	1	1	1	1	1	1	1
-	66	94	94	67	56	46	63	20	92	56	1	1	1	1	1	1	1	1	1	1
-	105	129	90	129	116	49	94	91	89	56	1	1	1	1	1	1	1	1	1	1
AD 501	77	123	108	43	90	86	93	83	89	73	1	1	1	1	1	1	1	1	1	1
-	108	86	132	149	160	138	72	111	94	94	1	1	1	1	1	1	1	1	1	1
-	40	100	82	115	115	64	93	62	110		1	1	1	1	1	1	1	1	1	

HALH03

Ring-width AGAU data of 1171 years length, undated; relative dates - 1 to 1171
3 timbers raw data mean
Average ring width 105.06   Sensitivity 0.36

1	109	93	116	152	138	53	153	85	82	75	1	1	1	1	1	1	1	1	1	1
-	106	74	57	90	67	121	57	102	67	107	1	1	1	1	1	1	1	1	1	1
-	107	193	143	137	94	135	130	105	100	99	1	1	1	1	1	1	1	1	1	1
-	131	139	129	82	53	112	130	72	59	78	1	1	1	1	1	1	1	1	1	1
-	62	87	122	55	129	66	123	107	51	104	1	1	1	1	1	1	1	1	1	1
51	54	66	120	58	117	100	128	146	62	94	1	1	1	1	1	1	1	1	1	1
-	131	136	117	141	147	152	128	144	123	165	1	1	1	1	1	1	1	1	1	1
-	158	174	109	188	109	155	117	138	109	105	1	1	1	1	1	1	1	1	1	1
-	67	121	122	65	121	196	59	149	116	102	1	1	1	1	1	1	1	1	1	1
-	74	104	101	175	88	69	99	62	111	107	1	1	1	1	1	1	1	1	1	1
101	129	52	86	92	98	89	86	103	95	42	1	1	1	1	1	1	1	1	1	1
-	82	68	90	134	66	119	85	115	37	71	1	1	1	1	1	1	1	1	1	1

-	133	97	105	90	86	59	81	121	99	108	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	68	63	46	54	55	76	92	86	90	104	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	121	45	134	79	106	135	86	117	102	118	*1*	*1*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
151	91	120	153	93	123	118	69	131	101	144	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	143	96	117	116	135	118	152	61	117	65	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	88	88	127	142	91	85	64	97	75	80	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	108	119	62	86	48	104	76	84	127	84	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	54	75	81	75	114	155	100	80	41	87	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
201	62	80	69	74	102	49	94	94	89	39	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	42	94	71	93	80	74	124	104	108	163	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	104	80	93	127	70	85	97	105	131	85	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	84	90	127	145	100	117	72	58	90	65	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	109	134	114	150	74	90	76	74	75	86	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
251	142	93	85	86	64	70	69	82	102	109	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	99	127	123	79	69	72	101	54	81	75	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	84	88	67	84	94	98	51	93	123	108	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	84	96	119	44	125	78	103	72	119	98	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	55	106	37	59	61	65	47	112	45	38	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
301	50	62	61	62	43	30	65	37	53	32	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	69	55	46	53	91	71	41	36	45	66	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	50	44	36	76	83	67	72	86	84	84	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	104	74	79	72	51	58	51	73	43	55	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	60	94	76	52	80	62	47	46	56	62	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
351	53	84	71	60	73	36	87	108	100	51	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	107	68	81	62	100	104	146	86	82	47	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	70	73	127	91	77	65	60	65	70	95	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	42	77	69	75	73	81	50	56	61	64	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	84	48	72	67	100	49	145	64	64	53	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
401	77	69	94	124	65	80	91	128	112	89	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	73	82	84	94	91	56	72	109	50	110	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	83	105	111	133	66	73	42	35	40	61	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	92	66	75	46	79	65	97	63	104	124	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	39	37	50	87	49	50	59	92	95	65	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
451	60	39	75	82	81	42	60	54	42	50	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	56	78	96	56	28	41	34	45	54	68	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	31	45	62	65	52	41	112	123	80	37	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	107	71	57	77	58	58	87	69	40	47	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	66	111	90	91	69	113	56	125	71	122	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
501	123	51	87	82	44	82	96	86	125	44	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	74	47	36	34	78	44	61	56	47	52	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	62	101	40	39	43	38	82	110	51	41	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	37	60	53	123	108	122	71	77	102	51	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	88	65	64	136	77	79	37	41	63	53	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
551	105	100	85	74	118	60	111	60	113	101	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	53	51	45	47	33	71	61	89	65	49	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	44	62	65	104	84	73	63	66	33	92	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*3*
-	64	121	80	91	84	56	73	54	105	82	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	86	96	75	80	89	35	108	122	38	89	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
601	89	143	77	75	58	106	108	96	97	88	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
-	40	48	55	90	91	35	48	68	122	57	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*

-	78	61	59	87	49	44	27	64	43	75	3	3	3	3	3	3	3	3	3	3
-	114	66	72	41	76	81	99	66	90	123	3	3	3	3	3	3	3	3	2	2
-	88	116	35	133	88	111	69	91	100	84	2	2	2	2	2	2	2	2	2	2
651	47	94	78	151	179	97	121	105	117	57	2	2	2	2	2	2	2	2	2	2
-	106	89	87	91	108	76	72	177	151	100	2	2	2	2	2	2	2	2	2	2
-	161	83	127	79	68	115	128	45	119	115	2	2	2	2	2	2	2	2	2	2
-	85	114	56	98	126	146	53	110	75	127	2	2	2	2	2	2	2	2	2	2
-	95	117	75	157	96	154	90	131	106	106	2	2	2	2	2	2	2	2	2	2
701	176	72	187	94	96	122	83	133	139	71	2	2	2	2	2	2	2	2	2	2
-	123	81	152	74	175	94	154	101	176	181	2	2	2	2	2	2	2	2	2	2
-	131	168	148	146	197	121	172	121	134	148	2	2	2	2	2	2	2	2	2	2
-	90	145	53	173	72	135	133	140	85	133	2	2	2	2	2	2	2	2	2	2
-	135	47	157	138	109	148	86	116	130	66	2	2	2	2	2	2	2	2	2	2
751	72	105	92	98	81	129	130	124	59	120	2	2	2	2	2	2	2	2	2	2
-	155	79	74	82	99	56	151	129	133	60	2	2	2	2	2	2	2	2	2	2
-	121	92	138	55	142	89	99	109	137	95	2	2	2	2	2	2	2	2	2	2
-	125	101	125	43	78	84	135	98	97	87	2	2	2	2	2	2	2	2	2	2
-	53	98	113	56	95	128	175	127	159	124	2	2	2	2	2	2	2	2	2	2
801	108	99	123	98	80	115	119	88	135	99	2	2	2	2	2	2	2	2	2	2
-	148	122	99	121	126	102	112	85	70	116	2	2	2	2	2	2	2	2	2	2
-	118	36	141	132	140	101	89	94	137	49	2	2	2	2	2	2	2	2	2	2
-	127	72	149	155	112	107	151	72	88	174	2	2	2	2	2	2	2	2	2	2
-	109	93	142	144	107	132	74	106	110	118	2	2	2	2	2	2	2	2	2	2
851	148	77	154	95	158	74	167	167	70	100	2	2	2	2	2	2	2	2	2	2
-	94	142	61	124	103	133	90	175	114	154	2	2	2	2	2	2	2	2	2	2
-	140	176	263	166	122	139	145	45	128	49	2	2	1	1	1	1	1	1	1	1
-	121	72	79	144	88	158	57	146	163	147	1	1	1	1	1	1	1	1	1	1
-	268	234	146	248	164	173	125	191	138	167	1	1	1	1	1	1	1	1	1	1
901	175	80	207	160	211	223	94	217	149	194	1	1	1	1	1	1	1	1	1	1
-	181	127	195	66	161	146	116	137	72	124	1	1	1	1	1	1	1	1	1	1
-	101	137	86	148	56	120	136	56	139	155	1	1	1	1	1	1	1	1	1	1
-	141	102	160	94	168	207	115	219	216	114	1	1	1	1	1	1	1	1	1	1
-	241	239	180	159	228	163	216	244	77	264	1	1	1	1	1	1	1	1	1	1
951	293	157	234	226	211	213	140	126	173	172	1	1	1	1	1	1	1	1	1	1
-	251	130	152	85	188	192	77	253	179	133	1	1	1	1	1	1	1	1	1	1
-	258	155	199	181	204	178	157	212	149	224	1	1	1	1	1	1	1	1	1	1
-	138	158	183	107	183	237	163	202	218	96	1	1	1	1	1	1	1	1	1	1
-	199	157	193	156	195	100	231	153	214	250	1	1	1	1	1	1	1	1	1	1
1001	228	264	239	175	207	102	119	180	103	137	1	1	1	1	1	1	1	1	1	1
-	159	116	143	177	189	162	185	159	119	218	1	1	1	1	1	1	1	1	1	1
-	105	170	100	207	184	240	136	194	218	200	1	1	1	1	1	1	1	1	1	1
-	190	135	134	233	112	167	166	58	85	102	1	1	1	1	1	1	1	1	1	1
-	112	180	51	189	139	114	176	75	119	131	1	1	1	1	1	1	1	1	1	1
1051	96	108	90	45	156	69	134	160	120	66	1	1	1	1	1	1	1	1	1	1
-	154	114	185	125	203	68	164	157	98	125	1	1	1	1	1	1	1	1	1	1
-	181	85	143	195	97	158	145	110	168	173	1	1	1	1	1	1	1	1	1	1
-	173	88	123	115	160	138	112	103	155	122	1	1	1	1	1	1	1	1	1	1
-	76	151	200	78	202	72	138	119	94	123	1	1	1	1	1	1	1	1	1	1
1101	68	102	49	97	180	135	51	120	134	117	1	1	1	1	1	1	1	1	1	1
-	148	60	146	177	120	120	89	47	149	139	1	1	1	1	1	1	1	1	1	1

-	72	108	154	116	41	134	127	60	153	56	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	159	121	129	139	155	108	129	64	126	100	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	103	48	153	138	84	159	115	43	126	108	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
1151	122	94	116	133	86	120	142	145	138	84	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	190	95	176	145	101	175	151	136	173	167	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	224																			

HALH04

Ring-width AGAU data of 386 years length, dated AD 535 to AD 920
2 timbers raw data mean
Average ring width 111.07   Sensitivity 0.25

AD 535					53	21	184	197	97	103					*1*	*1*	*1*	*1*	*1*	*1*
-	114	82	63	112	95	62	112	153	112	99	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
AD 551	107	65	51	125	136	80	113	108	98	98	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	128	73	103	102	74	108	97	78	59	68	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	64	82	84	48	64	55	87	75	64	68	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	124	101	55	66	55	60	116	66	81	68	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	102	69	70	27	90	50	85	55	55	26	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
AD 601	38	73	101	76	96	85	101	75	108	92	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	99	85	72	54	41	79	53	37	77	77	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	59	56	53	43	77	61	76	80	42	73	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	45	90	82	72	105	81	138	139	182	118	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	172	143	161	136	143	89	165	158	83	163	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
AD 651	138	94	135	154	146	115	172	111	185	181	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	153	175	158	129	138	161	124	103	175	161	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	153	140	117	142	116	204	175	203	195	109	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	168	134	177	160	76	89	95	69	118	100	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	60	96	117	129	115	72	104	109	87	69	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
AD 701	121	123	69	93	61	103	93	108	86	88	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	105	89	88	71	92	68	83	71	42	68	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	76	84	81	58	68	58	61	56	44	48	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	38	51	49	26	49	102	112	96	107	167	*1*	*1*	*1*	*1*	*1*	*2*	*2*	*2*	*2*	*2*
-	118	137	144	101	96	86	116	108	124	101	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
AD 751	103	58	132	119	160	91	152	146	179	192	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	147	156	152	124	128	111	138	153	51	148	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	131	190	176	148	153	162	125	166	160	127	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	134	156	178	172	153	152	146	162	143	162	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	153	172	164	169	141	152	148	127	139	147	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
AD 801	126	152	137	126	145	128	101	119	143	150	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	134	123	126	133	134	140	149	111	131	106	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	131	111	157	168	151	166	136	136	130	134	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	106	132	104	137	115	136	143	135	146	168	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	157	201	173	192	170	164	144	173	163	167	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
AD 851	176	146	168	125	204	214	165	159	193	186	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*

-	193	131	189	205	148	148	161	49	139	126	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	162	136	144	138	127	171	78	164	187	122	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*
-	101	104	87	106	68	84	95	73	107	65	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*1*
-	42	79	44	85	89	84	78	91	84	92	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
AD 901	44	78	53	61	60	56	79	63	51	82	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-	39	59	51	63	57	62	51	38	42	29	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
-																				

HAL002

Raw Ring-width AGAU data of 166 years length, dated 841 BC to 676 BC
0 sapwood rings and no bark surface
Average ring width 237.28   Sensitivity 0.34

841 BC										235
-	222	318	94	248	402	281	388	149	324	418
-	320	421	301	488	312	432	135	371	260	255
-	272	321	168	316	245	288	200	246	116	190
-	152	314	314	357	207	269	377	357	444	366
800 BC	308	340	392	271	367	169	365	284	315	294
-	325	150	262	171	279	391	398	157	274	300
-	305	327	157	280	265	251	299	225	334	208
-	193	256	226	169	340	343	222	322	295	345
-	224	350	197	373	204	249	240	388	391	197
750 BC	300	245	373	165	306	280	262	252	283	322
-	191	303	111	242	291	249	294	134	218	216
-	147	315	326	232	233	106	169	196	254	231
-	240	139	184	85	133	74	150	165	174	148
-	159	209	132	194	99	160	160	220	243	172
700 BC	177	197	124	160	67	111	79	127	142	86
-	144	133	176	183	117	90	119	86	83	92
-	99	106	85	151	89					